IRS-1D HANDBOOK

National Remote Sensing Agency
Department of Space
Government of India
Hyderabad, India.

IRS-1D/NRSA/NDC/HB-12/97

IRS-1D DATA USERS' HANDBOOK

NATIONAL REMOTE SENSING AGENCY
(DEPARTMENT OF SPACE, GOVERNMENT OF INDIA)
BALANAGAR, HYDERABAD-500037, A.P. INDIA

DOCUMENT CONTROL AND DATA SHEET

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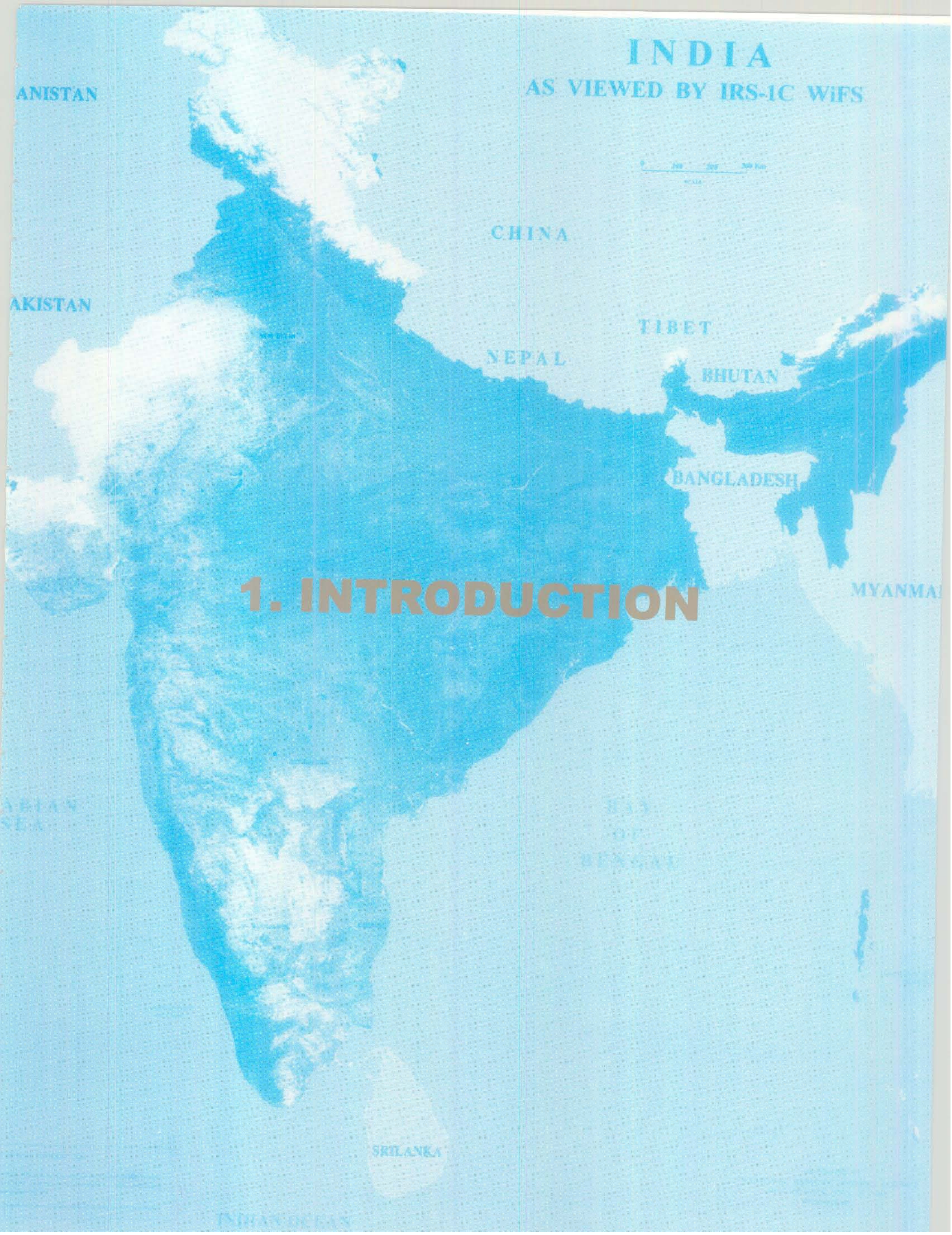
1. INTRODUCTION



1.1 INDIAN SPACE PROGRAMME

1.1.1 GOAL

The goal of the Indian Space Programme is to harness space technology for applications in the areas of communications, broadcasting, meteorology, disaster warning, search and rescue operations and remote sensing. Operational systems have been realised in all the above areas during the past decade and a half. The remote sensing component of the programme, in particular, has successfully achieved global acceptance.

1.1.2 INDIAN REMOTE SENSING PROGRAMME

1.1.2.1 Scope

Remote sensing is an important part of the Indian Space Programme and the Department Of Space (DOS), Government of India, is the nodal agency for the realisation of the National Natural Resources Management System (NNRMS), the National Resources Information System (NRIS) and the Integrated Mission for Sustainable Development (IMSD), besides several other national level application projects in close collobaration wih the user agencies.

As part of this programme, it has acquired the capability to design, develop and operate state-of-the-art multi-sensor satellite based systems comprising of space, ground and application segments to meet domestic and international requirements.

1.1.2.2 Indian Remote Sensing Satellite Missions

The following satellite missions are the important milestones, which have been crossed, in the realisation of indigenous end-to-end capabilities.

Bhaskara-1 & 2 : These were experimental remote sensing satellites launched in June 1979 and November 1981 respectively. Their payload consisted of TV cameras and radiometers.

IRS-1A/1B : These were operational first generation remote sensing satellites with two Linear Imaging Self Scanning sensors (LISS-I & LISS-II) for providing data in four spectral bands (in visible and near infra-red regions) with a resolution of 72.5m and 36.25m, with a repetivity of 22 days. These satellites were launched in March 1988 and August 1991 respectively. Even though the design life was three years, IRS-1A was in service till October 1992 and IRS-1B is still in service, providing good quality data.

IRS-P2 : The satellite was launched in October 1994 on the indigenously developed Polar Satellite Launch Vehicle (PSLV-D2). IRS-P2 carries a modified LISS camera.

IRS-1C : This was the first of the second generation, operational, multi-sensor satellite mission with improved sensor and coverage characteristics, besides having an On Board Tape Recorder (OBTR) for obtaining data outside the visibility of ground stations. IRS-1C was launched successfully on December 26, 1995 and the data is being received , processed and disseminated from ground stations in India, USA, Germany, Taiwan and Thailand.

The three sensors on-board IRS-1C satellite are :

* PAN sensor with a resolution of 5.8m (at nadir) single band in the visible region, with a swath of 70km (at nadir) and ± 26 deg. across track tilt capability
* LISS-III multi-spectral sensor with a resolution of 23.5m in three visible/ near infra-red and 70.5m in Shortwave Infra-Red (SWIR) band and a swath of 141km

* Wide Field Sensor (WiFS) sensor with a resolution of 188m, two bands in the visible/ near infra-red region and a swath of 810km.

Several types of data products on different digital and photographic media with different enlargements are being supplied by NRSA Data Centre (NDC) to users who are migrating towards IRS-1C/1D data products for their studies. Many new applications to exploit the improved capabilities of IRS-1C have been attempted.

IRS-P3 : This satellite was launched in April 1996, on PSLV-D3 and has two imaging sensors and one non-imaging sensor viz., Wide Field Sensor (WiFS), with a resolution of 188m and swath of 810km, similar to IRS-1C WiFS, but having an additional SWIR band ; Modular Opto-electronic Scanner (MOS) mainly for oceanography applications and an X-ray astronomy payload. WiFS and MOS data products are being disseminated to users.

1.1.2.3 FUTURE IRS SATELLITE MISSIONS

Encouraged by the successful operation of the IRS missions, many more missions have been planned for realisation in the next few years. These missions will have suitable sensors for applications in cartography, crop and vegetation monitoring, oceanography and atmospheric studies.

IRS-P4 (OCEANSAT-1) : This mission will have payload, tailored for making measurements of the physical and biological oceanographic parameters. An Ocean Colour Monitor (OCM) with eight spectral bands and a Multi-frequency Scaning Microwave Radiometer (MSMR), operating in four frequencies will provide valuable ocean-surface related observation capability. OCEANSAT is slated for launch by PSLV during 1998.

IRS-P5 (CARTOSAT-1) : This mission will have a PAN sensor with 2.5m resolution with fore-aft stereo capability to cater for applications in cartography, terrain modelling, cadastral mapping etc. CARTOSAT-1 is slated for launch during end 1999 by PSLV.

IRS-P6 : This mission will mainly cater to applications in agriculture and will have a multispectral LISS-IV sensor with a resolution better than 6 m and a swath of 25 km with across track steerability, an improved LISS-III sensor with 23 m resolution and 140 km swath and an advanced WiFS sensor with 80 m resolution and 1400km swath. IRS-P6 is slated for launch during end 2000 by PSLV.

1.2 IRS-1D MISSION OVERVIEW

1.2.1 BACKGROUND

IRS-1C is the first of the second generation operational Indian Remote Sensing satellite missions with better resolution, coverage and revisit. IRS-1D is the follow-on, second generation mission. IRS-1D was launched by the indegenously developed Polar Satellite Launch Vehicle (PSLV) from Sriharikota, India on 29th September, 1997. The satellite is placed in a near circular, sun-synchronous, near polar orbit with a nominal inclination of 98.53 deg., at a mean altitude of 780 Km.

The principal components of the mission are:

* three axes stabilised polar sun synchronous satellite with three sensors.
* a ground based data reception, recording and processing system
* ground system for in-orbit satellite control
* hardware/software elements for the generation of user oriented data products , analysis and archival.

1.2.2 MISSION OBJECTIVES

The objectives of the mission are :

* launch and operate the follow on, state-of-the-art second generation, three axes body stabilised satellite, for providing continious space based remote sensing services to user community
* augment and operate the improved ground based systems for data reception, recording, processing, generation of data products, analysis, archival and mission control facilities
* develop new areas of user applications to take full advantage of the enhanced capabilities of IRS-1C/1D.

1.3 ORGANISATION OF THE HANDBOOK

The IRS-1D Data Users' Handbook is published, to provide esssential information to the users of IRS-1D satellite data.

The main part of the handbook covers the chain of activities involved in data acquisition, generation and distribution of data products, alongwith a chapter on various applications.

Chapter 2 describes the IRS-1D system overview, data handling system and space segment which includes payload, orbit and coverage.

Chapter 3 covers various aspects of IRS-1D ground segment such as mission operations and control centre, data acquisition and archival system and data products generation system.

Chapter 4 deals with the path/row referencing scheme and the various types of data products that are made available to the users.

Chapter 5 provides information on data dissemination, ordering procedures, terms and conditions of data supply, payload programming and digital browse facility.

Chapter 6 contains information about potential applications of IRS-1C/1D data. A number of demonstrated application studies have been included.

Appendix - I gives the list of product codes.
Appendix-II gives the list of acronyms.
Appendix -III gives the Product Supply Agreement.

2.1 SYSTEM OVERVIEW

The IRS-1D is a three axes body stabilised satellite, similar to IRS-1C. It will have an operational life of three years in a near polar, sun synchronous orbit at a mean altitude of 780 Km.

The payload consists of three sensors.

(1) Panchromatic camera (PAN)

The Panchromatic camera provides data with a spatial resolution of 5.2-5.8m (at nadir) and a ground swath between 63 Km - 70 Km (at nadir). It operates in the 0.50-0.75 microns spectral band. This camera can be steered upto ± 26deg (steerable upto ± 398 Km across the track from nadir), which in turn increases the revisit capability to 3 days for most part of the cycle and 7 days in some extreme cases.

(2) Linear Imaging and Self Scanning Sensor (LISS-III)

The LISS-III sensor provides multispectral data collected in four bands of the visible, near infra-red (V,NIR) and short wave infra-red (SWIR) regions. While the spectral resolution and swath in the case of visible (two bands) and NIR (one band) regions are between 21.2m to 23.5m and 127 Km - 141 Km. respectively, they are between 63.6m to 70.5m and 133 Km to 148 Km. for the data collected in SWIR region.

(3) Wide Field Sensor (WiFS)

WiFS sensor collects data in two spectral bands and has a ground swath between 728 Km to 812 Km with a spatial resolution of 169m to 188m.

The satellite is equipped with an On-Board Tape Recorder, capable of recording limited amount of specified sensor data. Operation of each of the sensors can be programmed. The payload operation sequence for the whole day can be loaded daily onto the on-board command memory when the satellite is within the visibility range.

The ground segment consists of :

1. A Telemetry Tracking and Command (TTC) segment comprising of a TTC network to provide optimum satellite operations and a Mission control centre for mission management, spacecraft operations and scheduling
2. An Image segment comprising of data acquisition, data processing and product generation system along with data dissemination centre. The over view of IRS-1D mission is shown in Figure 2.1.1.

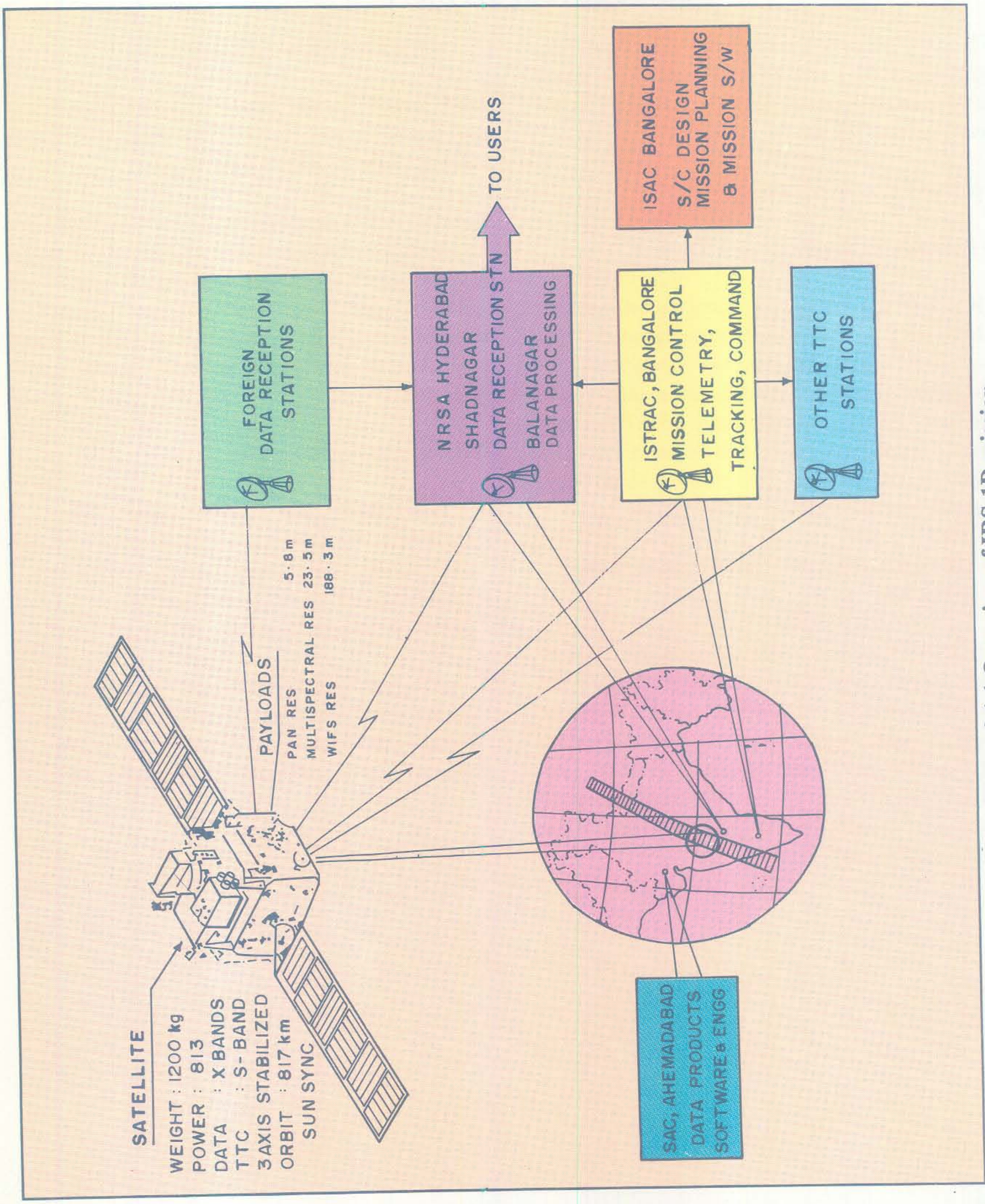
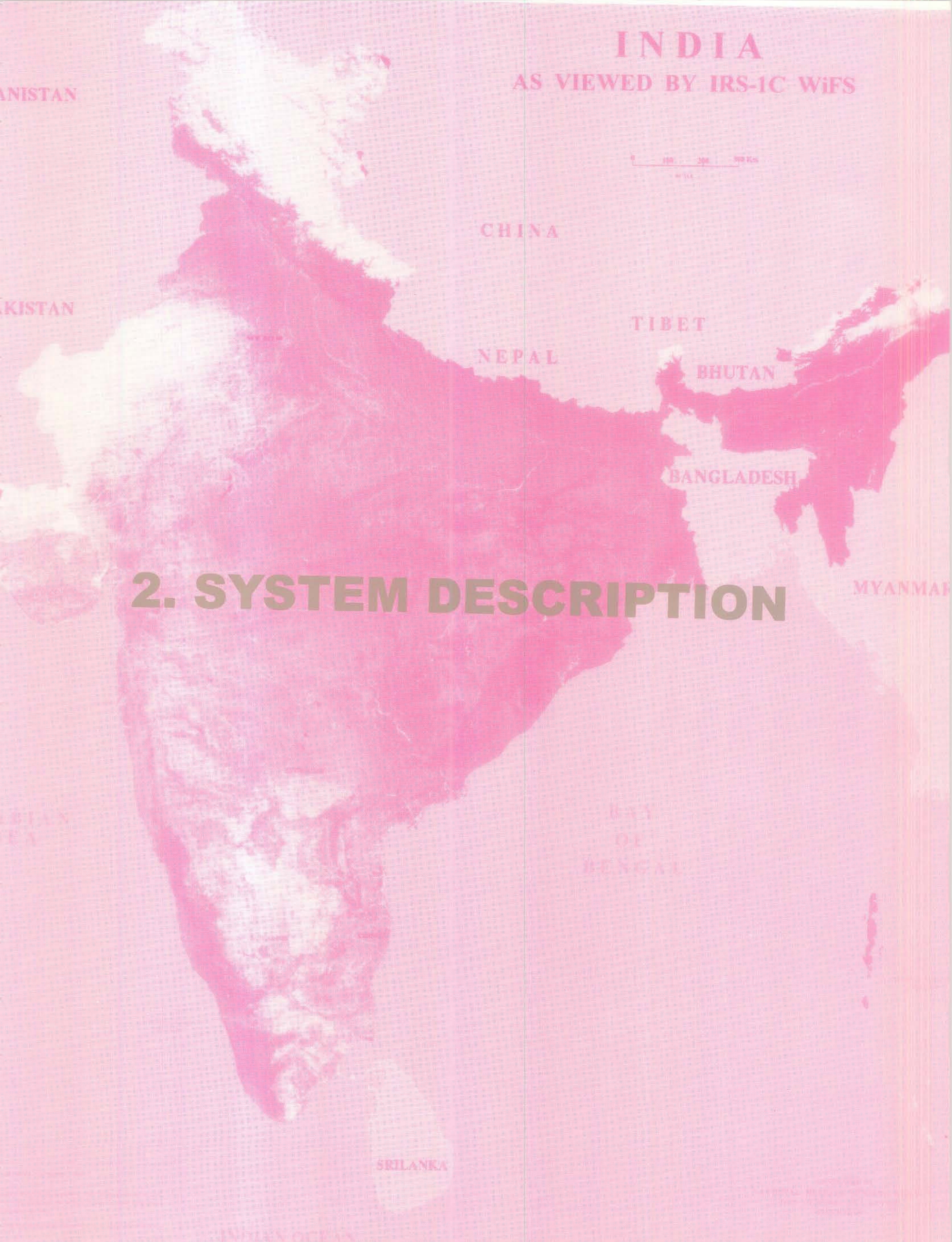


Figure 2.1.1 Overview of IRS-1D mission

2. SYSTEM DESCRIPTION



2.2 SPACE SEGMENT

The space segment carries out the following functions :

- Images the earth in all the required spectral bands.
- Formats the payload sensor data and transmits to ground stations in X-band and also records the video data for later transmission.
- Provides necessary power (with a margin) for mainframe and payload subsystems, in all operating conditions.
- Provides attitude stability required for imaging
- Provides housekeeping information for monitoring the satellite health and accepts telecommands to control the spacecraft.

The structure of the spacecraft consists of :

* Main platform
* Payload platform

The main platform consists of four vertical panels and two horizontal decks, supported on a central load bearing cylindrical shell of 930 mm diameter and 1123 mm height. The bottom of the cylinder is attached to an interface ring, which interfaces with the launch vehicle. The vertical panels and horizontal decks, carry the major mainframe subsystem packages. The Sunside and anti-Sunside panels, additionally support solar arrays and the power transfer assemblies. The earth viewing panel carries the payload data transmission antenna, the TTC antenna and Sun sensors.

The payload platform accommodates the PAN, LISS-III and WiFS cameras. In addition, it accommodates Earth sensors and Star sensors. A Carbon Fibre Reinforced Plastic (CFRP) monocoque cylinder, of 930 mm diameter and 370 mm height separates these two platforms and provides thermal isolation to minimise thermal distortion effects on imaging.

The PAN payload has a capability to tilt upto an angle of ± 26 deg in the direction of pitch. A Payload Steering Mechanism (PSM) supporting the PAN camera enables this rotation. The PSM is initially held by a hold down mechanism during launch. Later, it is released by activating a pyrocutter by a command from the ground.

Four Reaction Control System (RCS) propellant tanks made of titanium of 390 mm diameter are mounted on either side of a 30.7 mm thick stiffened honeycomb deck of 875 mm diameter, which is fixed inside the main cylinder.

The thermal control system maintains the temperature of different subsystems within the specified limits. It employs semi-active and active elements like heaters and temperature controllers, in addition to passive elements like paints, multi layer insulation blankets and optical solar reflectors.

The power requirements of IRS-1D are met by six deployable solar panels (size 1.1 m x 1.46 m each). Three panels are mounted on the Sun side and three are mounted on the anti Sun side. The panels have a capacity to generate 813 W of power at EOL (End Of Life), at normal incidence. Besides the Sun tracking panels, two batteries of twenty eight cells, with a capacity of 21 AH (Ampere Hours) are provided to support peak power requirements and power during eclipse.

The TTC system is configured to work in S-band. It comprises of telemetry and telecommand subsystems and a transponder.

The telemetry system collects the house keeping data from each subsystem and then formats and modulates it on the subcarrier. There are two formats, viz., dwell and normal. Dwell mode and normal mode formats, can be simultaneously received. An on-board storage facility of 2.75 million bits exists for recording the house keeping data of one orbit period or sampled data in 1:5 ratio in sampled mode, for four orbits period. The normal telemetry rate is 512 bits per second (bps), while the playback data from storage is at 6.4 Kbps. Telemetry system, except for storage, has full redundancy.

The telemetry data is transmitted on two Phase Shift Key (PSK) subcarriers, of 25.6 KHz and 128 KHz. The normal telemetry is modulated on 25.6 KHz subcarrier, while the 128 KHz subcarrier is used for playback data or dwell data.

The telecommand system employs a shortened B-C-H code, for command reception. It provides time tag command execution facility with edit, block execution and memory error detection features. The time tag facility permits execution of 255 commands per decoder. TC supports auto commanding, for autodeployment and safemode operations. It also houses programmable and fixed duration timers to control the operation of payload and data handling system. It provides special logics to configure the payload and data handling system for various operational modes.

The transponder serves to transmit housekeeping data, receive telecommand signals, demodulate ranging tones and retransmit it to ground, with a fixed turn around ratio of 240/221.

The Attitude and Orbit Control System (AOCS) for IRS-1D, is configured to achieve three axes body stabilisation of the spacecraft in Sun synchronous orbit. The AOCS system is configured around a processor based system with redundency. The AOCS system is associated with necessary sensors and actuators to carry out the control functions. All the three axes are controlled using actuators, reaction wheels, magnetic torquers and thrusters. The attitude control electronics package, generates control signals for these actuators depending upon the attitude errors, sensed by Earth sensors, Gyros and Sun sensors. The system provides initial three axes acquisition, in-orbit three axes control and orbit control. The overall specifications of the Observatory are given in Table 2.2.1.

The IRS-1D satellite and the isometric view of the spacecraft (Stowed mode) are shown in Figures 2.2.1 and 2.2.2 respectively. The disassemled configuration view of IRS-1D spacecraft is shown in Figure 2.2.3.

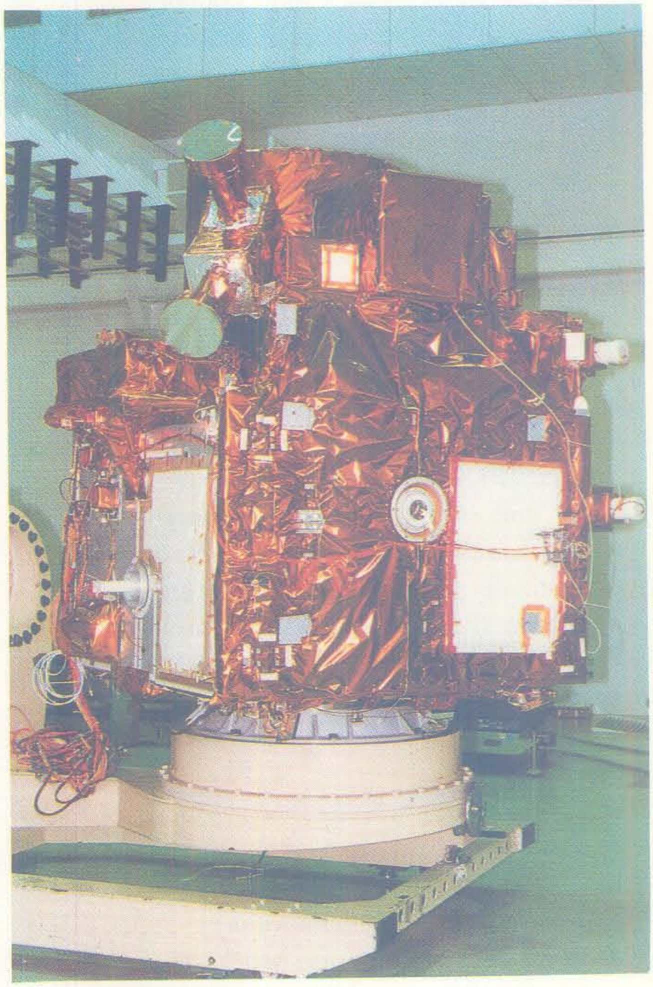


Figure 2.2.1 IRS-1D Satellite

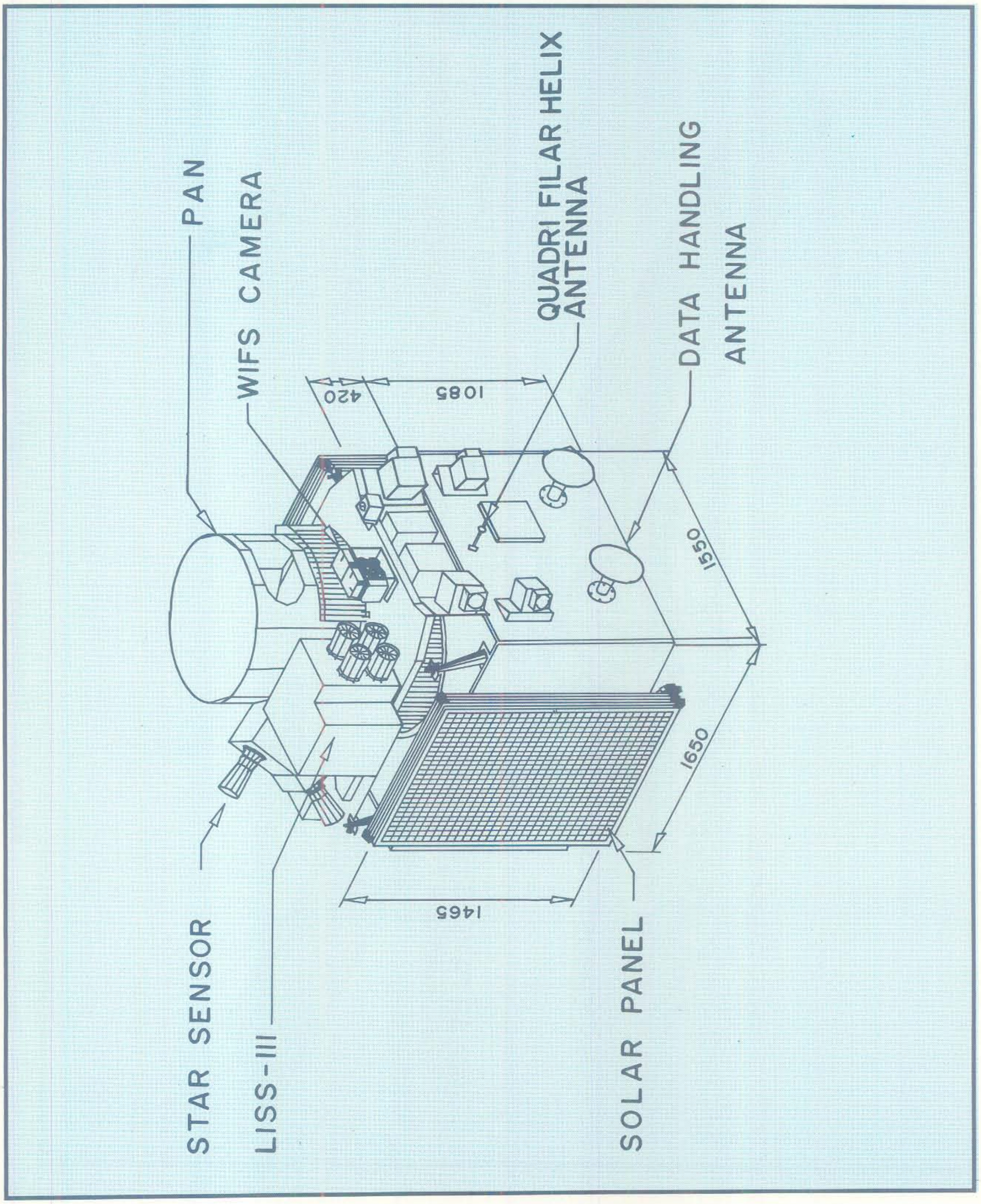


Figure 2.2.2 Isometric view of IRS-1D spacecraft (Stowed mode)

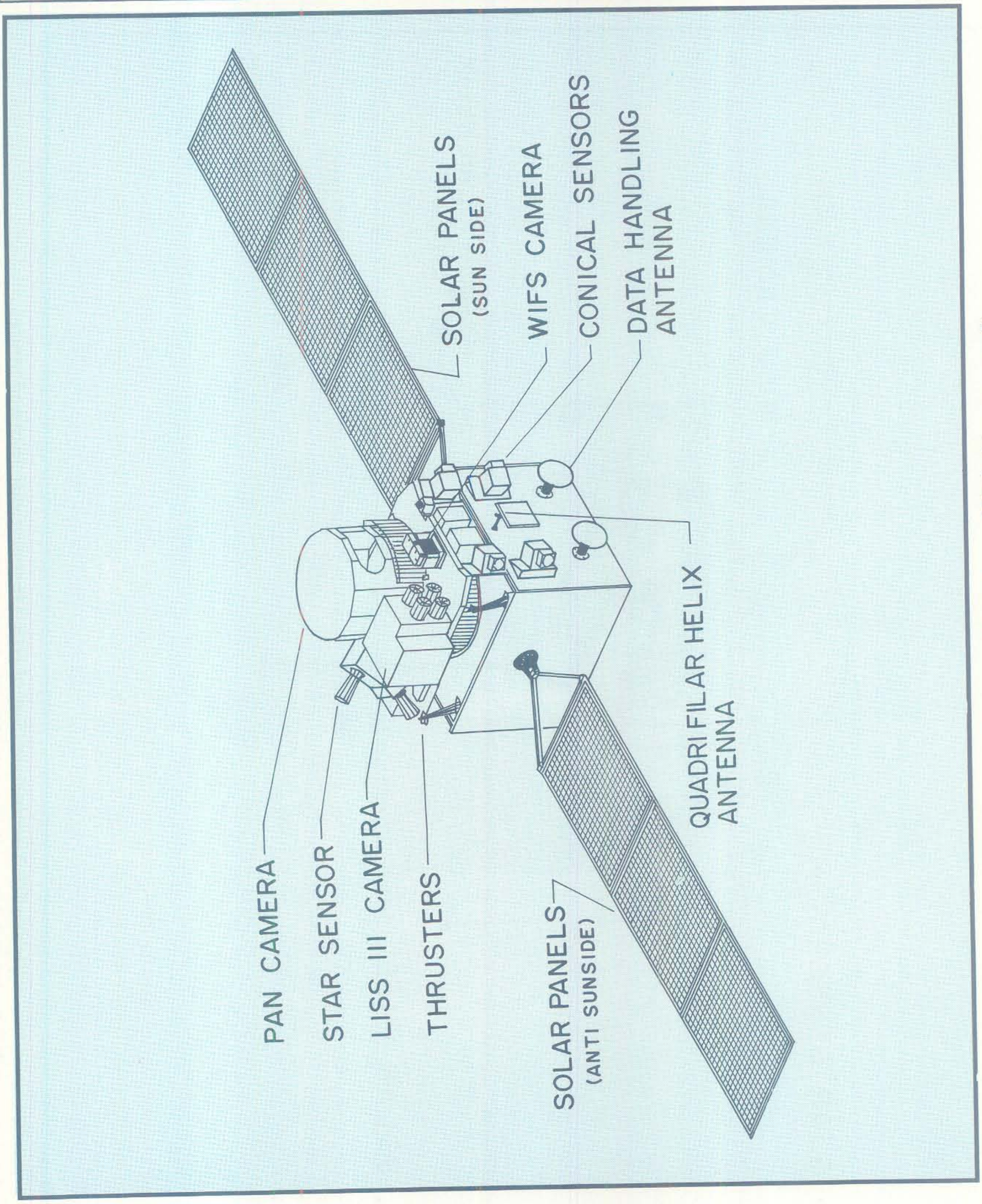


Figure 2.2.3 Disassembled view of IRS-1D spacecraft

Table 2.2.1 Specifications of Space Segment

TYPE	:	Three axes, body stabilised Remote Sensing Satellite
ORBIT	:	Near Polar, Sun synchronous, mean altitude of 780 Km with equatorial crossing time of 10.30 A.M. to 10.47 A.M. (over a period of 4.8 years), in descending node
REPETIVITY	:	358 orbits / 25 days
REVISIT CAPABILITY	:	3 Days for WiFS and PAN (with steering), 25 days for LISS-III
MISSION LIFE	:	Three years
<u>MECHANICAL CONFIGURATION</u>		
STRUCTURE	:	Aluminium and Aluminium Honeycomb
WEIGHT	:	1200 Kg
<u>THERMAL CONTROL</u>		
COMPONENTS	:	Passive control using tapes, paint, Optical Solar Reflectors (OSR), Multi Layer Insulation (MLI) blankets and semi-active, active control using proportionate temperature controllers and heaters
TEMPERATURE	:	20 ± 3 deg Centigrade for payload ; 2 ± 2deg Centigrade for batteries, 0 to 40 deg Centigrade for electronic packages
<u>PAYLOADS</u>		
TYPE	:	Optical sensors (Charged Coupled Devices (CCD) linear arrays)
NO. OF SENSORS	:	Three - i) PAN ii) LISS-III iii) WiFS
SPECTRAL BANDS	:	PAN 0.50 -0.75 μ LISS-III Band 2 0.52 - 0.59 μ Band 3 0.62 - 0.68 μ Band 4 0.77 - 0.86 μ Band 5 1.55 - 1.70 μ

SPECTRAL BANDS	:	WiFS	Band 3	0.62 - 0.68 µ
			Band 4	0.77 - 0.86 µ
SPATIAL RESOLUTION	:	PAN	5.2-5.8m (at nadir)	
		LISS-III	21.2m to 23.5m for B2, B3, B4 ; 63.6m to 70.5m for B5	
		WiFS	169m to 188m	
SWATH	:	PAN	63 Km - 70 Km (at nadir) ; 90 Km. (at maximum look angle)	
		LISS-III	127 Km to 141 Km for B2, B3, B4 ; 133 Km to 148 Km for B5	
		WiFS	728 Km to 812 Km	
ENCODING	:	PAN - 6 Bits ; LISS-III - 7 Bits ; WiFS - 7 Bits		

DATA HANDLING :

		PAN	LISS-III
DATA RATE	:	84.903 Mbps	42.4515 Mbps
MODULATION	:	QPSK	QPSK
FREQUENCY	:	8150 MHz	8350 MHz
POWER	:	40 Watts	40 Watts
BEACON FREQUENCY	:	8255 MHz	
POWER	:	100 milliWatts	

ON-BOARD TAPE RECORDER

NUMBER OF STREAMS	:	One
INPUT/OUTPUT DATA RATE	:	42.4515 Mbps
RECORDING CAPACITY	:	62 GB (24 minutes)
TRANSMISSION	:	Through LISS-III chain

POWER

SOLAR ARRAY POWER

GENERATION CAPACITY AT EOL : 813 Watts
BATTERY : 2 batteries of 21 AH each

ATTITUDE AND ORBIT CONTROL

ATTITUDE SENSORS	:	Four PI sun sensors, five sun sensors, analog yaw sensor, precision yaw sensor, conical scanner earth sensors, digital yaw sensor, star sensor, solar panel sun sensor, magnetometers, pressure sensors, temperature sensors, dynamically tuned gyros
ACTUATORS	:	Four Reaction wheels; Two Magnetic torquers; Sixteen One Newton Hydrazine thrusters, One Eleven Newton Hydrazine thruster
POINTING ACCURACY	:	ROLL ± 0.15 Deg ; PITCH ± 0.15 Deg ; YAW ± 0.2 Deg
DRIFT	:	3×10^{-4} deg/sec

TELEMETRY, TRACKING AND COMMAND

A.	TELEMETRY DATA	:	Realtime	512 bps
		:	Dwell	512 bps
		:	Playback (Storage)	6.4 Kbps
	SUBCARRIER	:	Realtime	25.6 KHz
		:	Dwell/Playback/SPS RT/PB	128 KHz
	MODULATION	:	Pulse Code Modulation/ Phase Shift Keying/	
		:	Phase Modulation (PCM/PSK/PM)	
	STORAGE (HK)	:	Capacity	2.75 Mb
	(HOUSE KEEPING)	:	Data type	Sampled (1:5) or continuous
B.	TELECOMMAND	:	No. of ON/OFF commands	704
			No. of Data commands	46
			Command Bit rate	100 bps

MODULATION	:	Pulse Code Modulation/ Frequency Shift Keying/ Frequency Modulation/Pulse Modulation (PCM/FSK/FM/PM)	
FSK SUB-CARRIER FOR ONE	:	5.555 KHz	
FSK SUB-CARRIER FOR ZERO	:	3.125 KHz	
NO. OF TIME TAG COMMANDS	:	255 per Decoder	
PROBABILITY OF ERRONEOUS COMMAND EXECUTION	:	$1.8X10^{-42}$	
PROBABILITY OF COMMAND REJECTION	:	0.98×10^{-13}	
TRANSPONDER	:	Uplink frequency	2028.78 MHz
		Down frequency	2203.2 MHz
		Turn Around Ratio	240/221
		S-Band tone ranging	Max Tone 100KHz two way Doppler

2.3 PAYLOAD SYSTEM

2.3.1 PAN Camera

Optics and electronics

The Panchromatic camera uses reflective optics along with 4096 element CCD linear array (7 micron x 7 micron) for imaging. A special arrangement comprising of an isoceles prism reflector, is used for covering the full swath. Each detector has separate interference filters and 4 Light Emitting Diodes (LEDs), alongwith a cylindrical lens. Two LEDs are for optical biasing and two are for inflight calibration of the sensor. Four selectable gains are provided for PAN camera. The payload performance specifications are given in Table 2.3.1.

S.No.	PARAMETER	SPECIFICATION
1.	Spatial resolution (m)(at Nadir)	5.2 to 5.8
2.	A. Swath (Km) at Nadir	63 to 70
	B. Swath Steering Range (Deg)	± 26
	C. Step size (Deg)	± 0.09
	D. Repeatability (Deg)	± 0.1
3.	Spectral band (micron)	0.50 - 0.75
4.	Camera Square Wave Response (SWR) (at Nyquist frequency)	> 0.20
5.	Quantisation (Bits)	6
6.	Signal to Noise Ratio (SNR) (at saturation radiance)	> 64
7.	Saturation radiance (Gain 1) (mw/cm^2-str-micron)	35 - 40
8.	Integration time (ms)	0.873
9.	Data rate (Mbps)	84.903

Table 2.3.1 Specifications of PAN camera

Inflight calibration

The detector characteristics that are evaluated on the ground are Light Transfer Characteristics (LTC), spectral responsivity, dark current, dynamic range and shading characteristics. Besides the main detectors, optical components like lenses and filters are thoroughly performance tested on ground and extensive calibration data are generated on ground for radiometric correction. Regular inflight calibration helps to study the degradation in response of the CCD output. The inflight calibration of the camera will be carried out using LEDs. LEDs have the advantage of low power consumption, low thermal dissipation and fast response time. The scheme envisages the calibration of CCDs excluding optics. LEDs are operated in pulse mode at higher currents, resulting in higher intensities.

A calibration cycle comprises of 2048 lines. The time taken for one calibration cycle, for PAN camera is approximately 1.64 seconds. The LEDs are operated at pulsed mode and the duration for which the LEDs are 'ON' is varied, in specific steps. The CCD detector integrates the light falling on it during one readout period. Six non-zero exposure levels spanning the full dynamic range, are provided for each detector.

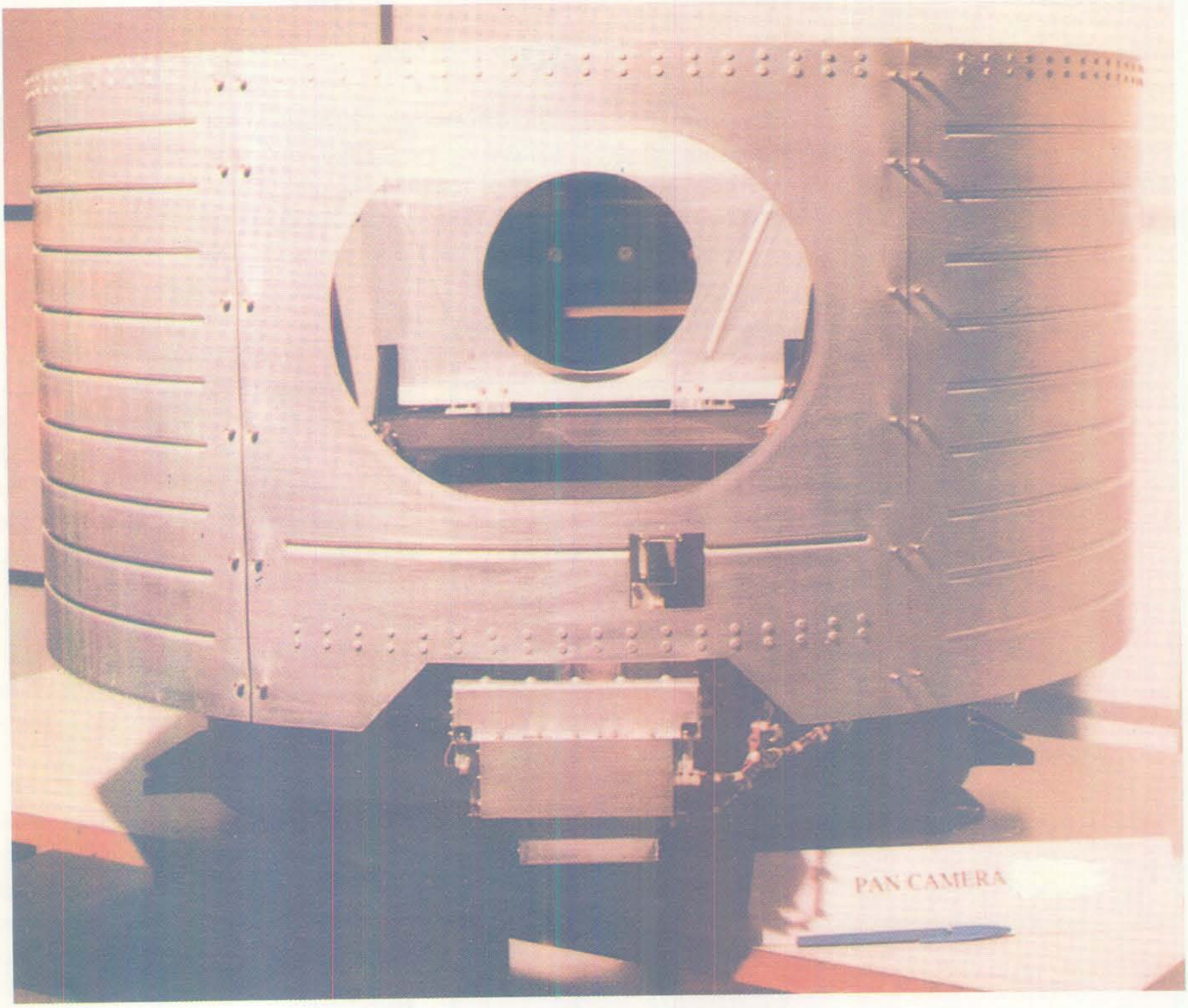


Figure 2.3.1.1 IRS-1D PAN Camera

Figure 2.3.1.2 PAN image showing parts of Mumbai city

2.3.2 LISS-III Camera

Optics and electronics

LISS-III sensor operates in four spectral bands. There are separate optics and detector arrays for each band. Three bands (B2, B3 and B4) are in the visible and near infrared region. B5 is in short wave infrared region. Since the first three bands of LISS III are in the same spectral region as IRS-1A/1B/P2 sensors, the same nomenclature is continued. Bands B2, B3 and B4 of IRS-1D are therefore identical to that of IRS-1A/1B/P2/1C.

The camera uses refractive optics. The collecting optics consists of eight refractive lens elements with interference filter in front. A linear array of 6000 elements of CCDs is used for visible and infrared bands. It has a pixel size of 10 micron by 7 micron. It has separate readouts for odd and even pixels on two channels. Each detector has its own detector drive electronics. Band 2, 3 and 4 have separate video chains.

Band 5 consists of a 2100 element linear CCD array (7 modules of 300 pixels) arranged in staggered way, with a pixel size of 26 micron by 26 micron. The device will be operated between 5-15°C with a temperature stability of ±0.1 deg C.

Four independently selectable gains are provided for each band of LISS III. The payload performance specifications are given in Table 2.3.2.

Inflight calibration

The inflight calibration of the camera is carried out using LEDs. Six Non zero exposure levels, spanning the dynamic range are provided for each detector. Four LEDs per CCD, for B2, B3 and B4 and 2 IR LEDs for B5 are used for illumination. Two LEDs operate at a time to cover half the length of CCD. The LEDs are operated in pulsed mode and the duration during which the LEDs are 'ON', is varied in

Sl. No.	PARAMETER	SPECIFICATION	
1.	Spatial resolution (m)	B2,B3,B4	21.2 to 23.5
		B5	63.6 to 70.5
2.	Swath (Km)	B2,B3,B4	127 to 141
		B5	133 to 148
3.	Spectral band (microns)	B2	0.52 - .059
		B3	0.62 - 0.68
		B4	0.77 - 0.86
		B5	1.55 - 1.70
4.	Camera Square Wave Response (SWR)	B2	>40
		B3	>40
		B4	>35
		B5	>30
5.	Quantisation (bits)	7	
6.	Signal to Noise Ratio (SNR) (at saturation)	>128	
7.	Saturation Radiance (Gain 1) (mw/cm^2-str-micron)	B2	29 ± 1.5
		B3	28 ± 1.5
		B4	28 ± 1.5
		B5	3.25 ± 25
8.	Integration time (ms)	B2,3 and 4	3.6
		B5	10.8
9.	Data rate (Mbps)	B2,3 and 4	35.7904
		B5	1.3906
10.	Band to Band registration (pixels)		± 0.25

Table 2.3.2 Specifications of LISS-III Camera

specific steps. Each LED has a cylindrical lens to maximise the intensity. For Band-5, the LEDs have very small angular divergence. The CCD detector integrates the light falling on it, during one readout period. A calibration cycle comprises of 2048 lines.

The time taken for one calibratio III is 7.3 seconds. The Band-5 c multiplexed with data of other ban

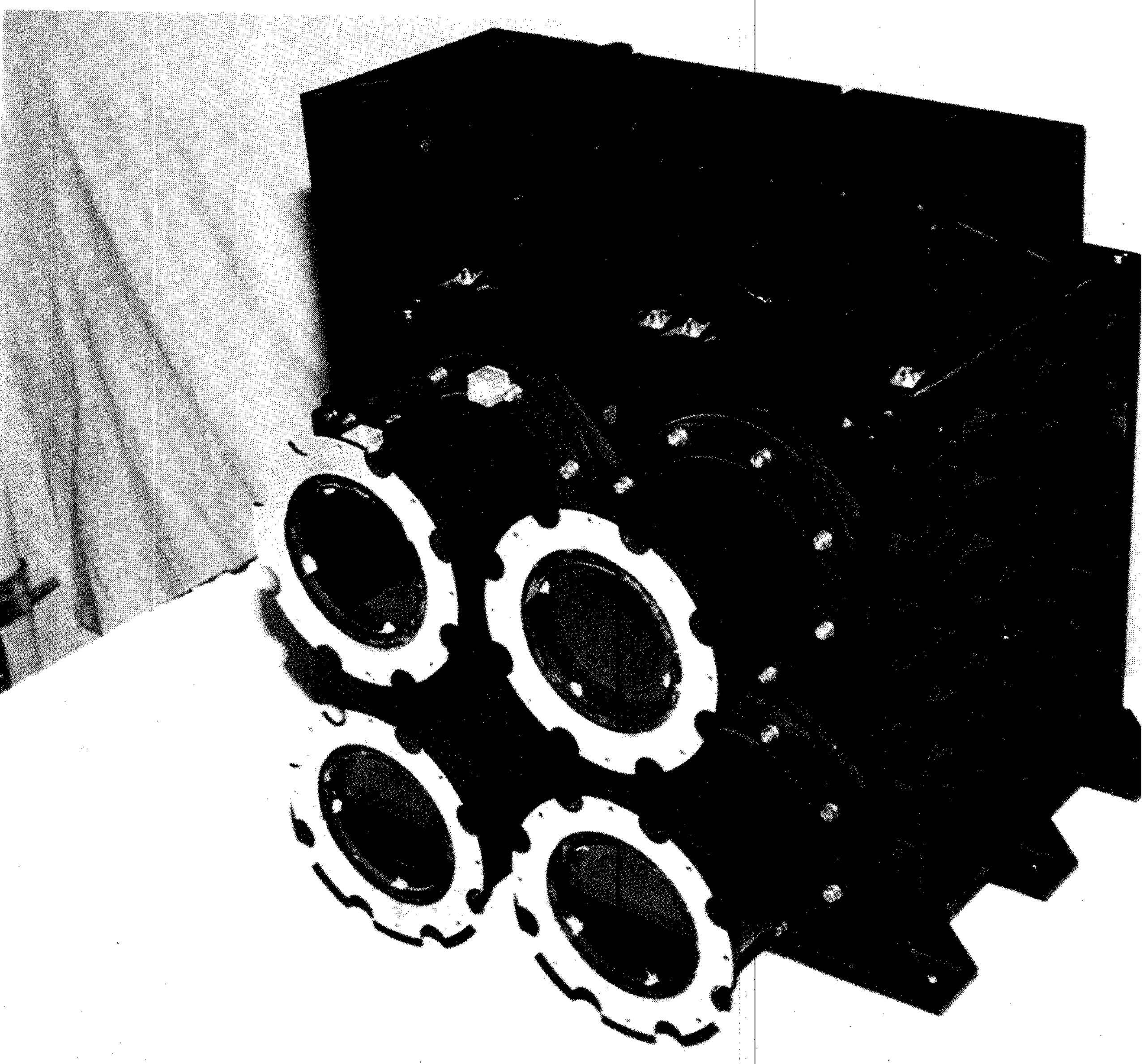


Figure 2.3.2.1 IRS-1D LISS-III Camera

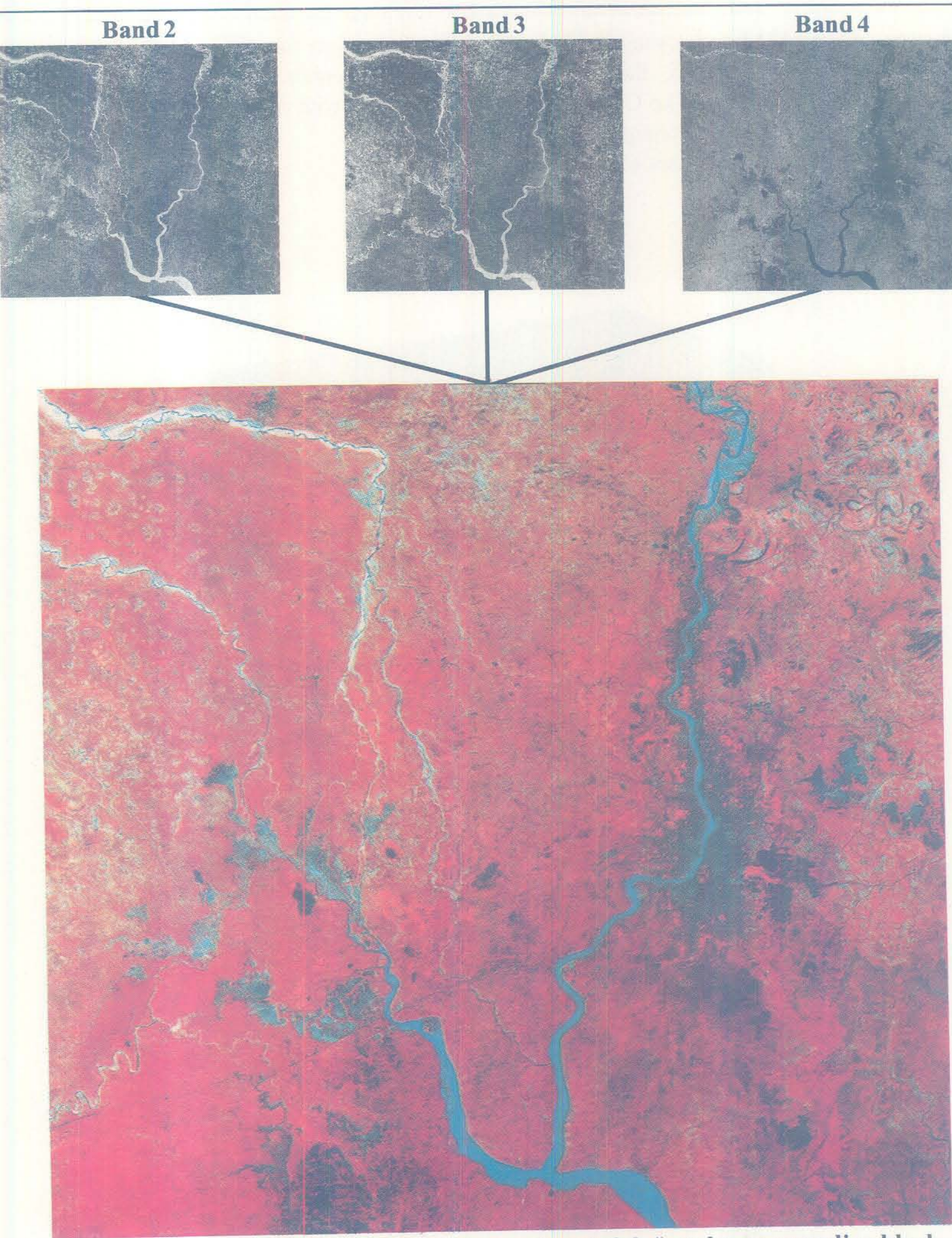


Figure 2.3.2.2 IRS-1D LISS-III FCC image (bands 2,3,4) and corresponding black and white images of band 2 , band 3 and band 4 data of path 108, row 56 showing Calcutta and surrounding areas

2.3.3 WiFS Camera

Optics and electronics

WiFS camera collects data in two bands. These are named as B3 and B4, because they are similar to Band-3 and Band-4 of LISS camera of IRS-1A/1B/P2. The total swath is covered using two optical heads i.e., two lenses and two CCDs are used per band. They are mounted at an angular separation of 26 deg generated by a single Electro Optic Module (EOM). WiFS camera uses refractive collecting optics, consisting of eight refractive lens elements with interference filter and neutral density (ND) filter in the front. A 2048 element linear array CCD with a pixel size of 13 micron by 13 micron is used. It has separate readouts for even and odd pixels on two channels.

The data from each device is readout four times during the line scan time period. Only one out of every four readouts is transmitted.

The payload performance specifications are given in Table 2.3.3. Four independently selectable gains are provided for each band/CCD.

Sl .No.	PARAMETER	SPECIFICATION
1.	Spatial resolution (m)	169 to 188
2.	Swath(Km)	728 to 812
3.	Spectral band (micron)	B3 0.62-0.68 B4 0.77-0.86
4.	Square Wave Response	B3 >0.34 B4 >0.20
5.	Quantisation (bits)	7
6.	Signal to Noise Ratio (at saturation)	>128
7.	Saturation radiance (mw/cm^2-str-micron)	B3 28 ± 1.5 B4 31 ± 1.5
8.	Integration time (ms)	28.8
9.	Data rate (Mbps)	2.0616

Table 2.3.3 Specifications of WiFS camera

Figure 2.3.3.1 IRS-1D WiFS Camera

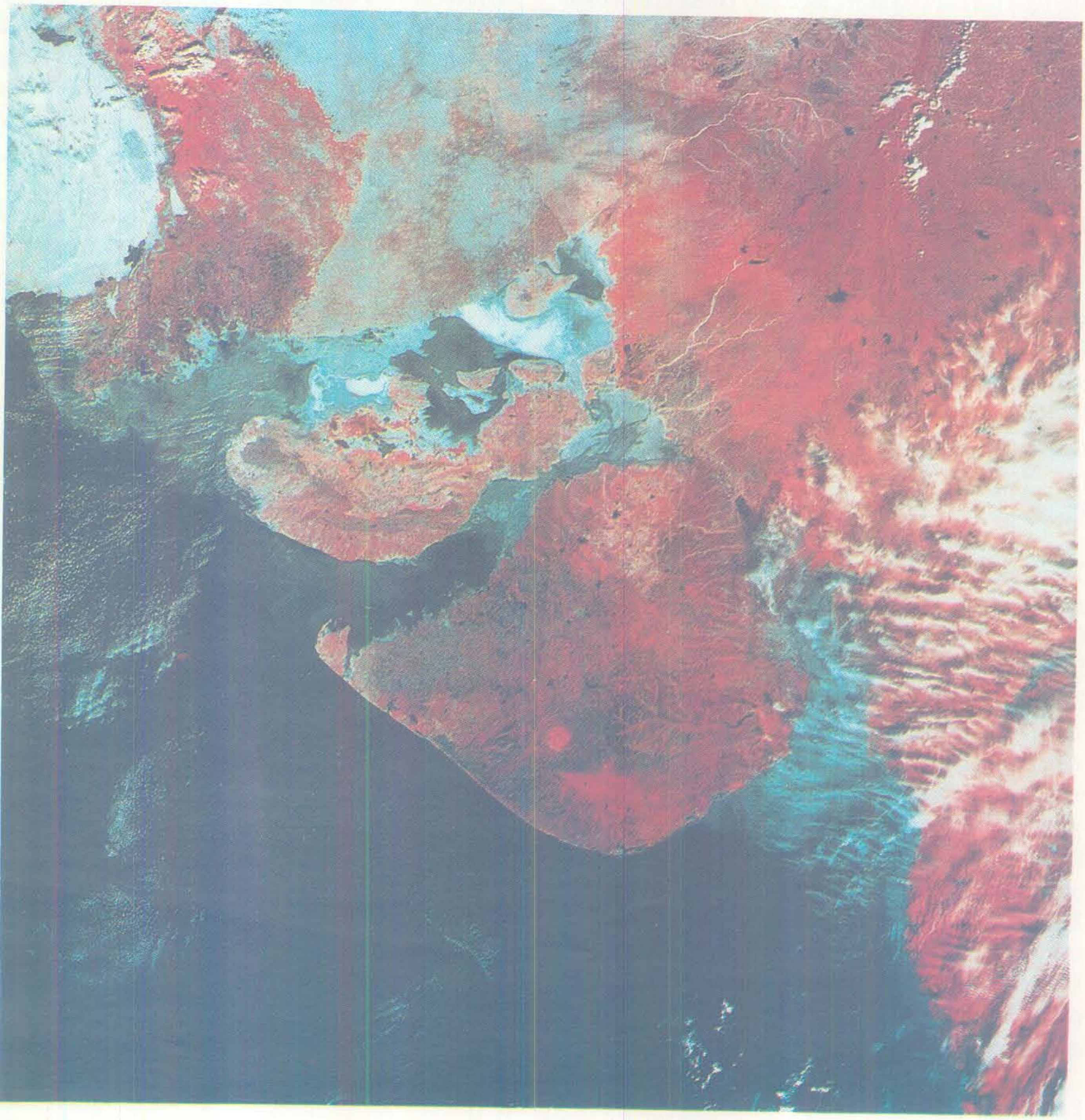


Figure 2.3.3.2 IRS-1D WiFS FCC image (bands 3,3,4) data showing parts of Western India

2.4 PAYLOAD DATA HANDLING SYSTEM

The data handling system, basically consists of a base band system and a Radio Frequency (RF) system. The base band system consists of control circuits, oscillators, formatters, randomiser and modulation interfaces. The RF system contains the local oscillators, modulators, power amplifiers and antenna systems.

2.4.1 BASE BAND DATA HANDLING SYSTEM

The base band data handling system caters to different functions. It formats PAN data and LISS-III data. It provides selection for the half swath data of PAN camera or full swath data of LISS-III, for recording OBTR data.

PAN

The parallel digital data from payload is formatted into two serial PCM streams, viz.,PAN -I and PAN-Q, each with a data rate of 42.4515 Mbps. The PAN camera consists of three CCD arrays. Each CCD array has 4 ports. From each port, data is shifted out to base band data handling system. The data from all the four ports of first CCD and port 1 and 2 of second CCD are multiplexed and formatted to stream "I".The data from all four ports of third CCD and port 3 and 4 of second CCD are multiplexed and formatted into the second stream "Q". Each formatted data viz., PAN-I and PAN-Q is merged with low bit rate house keeping data, Gyro fine rate information, channel ID, cal status and line count information. All these data are inserted in appropriate slots.

LISS-III

The LISS formatter accepts digital data from LISS-III payload in three bands and SWIR payload in one band and WiFS data in two bands and then multiplexes them and formats them into a single PCM stream of 42.4515 Mbps. To this serial stream, auxillary data such as frame sync code, camera ID, house keeping data, Gyro fine rate information and cal status are also inserted.

The data from Band-5 (SWIR), which has seven modules of 300 elements, is multiplexed into even and odd channels and output in two ports. The data is shifted in a manner similar to Band 2, 3 and 4.

WiFS

WiFS consists of four CCDs each, with two ports. The data is shifted in the same way as LISS-III Bands. The data from WiFS and Band-5 are multiplexed with Band 2, 3 and 4 data. Pre mux are employed for WiFS and Band 5 data. Along with valid video pixels, some blank pixels are added to match the data format.

On-Board Tape Recorder interface

The data handling system also provides the selected data of either PAN-I (M/R) or PAN-Q (M/R) or LISS-III (M/R) to the OBTR for recording. The data during playback is received from tape recorder and after splitting the data, it is differentially encoded and fed to QPSK modulator.

2.4.2 DATA HANDLING (RF) SYSTEM

The serial data from the base band system, is fed to RF system to modulate and transmit the data to ground. The PAN data is QPSK modulated and transmitted by 8150 MHz carrier in X-Band. The LISS-III data is also QPSK modulated and transmitted through 8350 MHz carrier in X-Band.

This facilitates transmission of both PAN and LISS-III data simultaneously. Each stream has a power output of 40 Watts. Travelling Wave Tube Amplifiers (TWTA), are employed to achieve this power. Three TWTAs are provided with 2 by 3 redundancy. Two TWTAs are exclusively channelised and meant for PAN and LISS-III, while the third one is selectable for either PAN or LISS-III channel. The playback data from OBTR is transmitted through LISS-III chain.

A Beacon system with a power output of about + 20 dBM is being provided and it operates at 8255 MHz frequency in X-Band. The Beacon signal is combined with LISS-III signal at the antenna, for transmission. The Beacon has the capability to switch ON/OFF independently.

Figure 2.4.1 shows the schematic diagram of Data Handling system (RF).

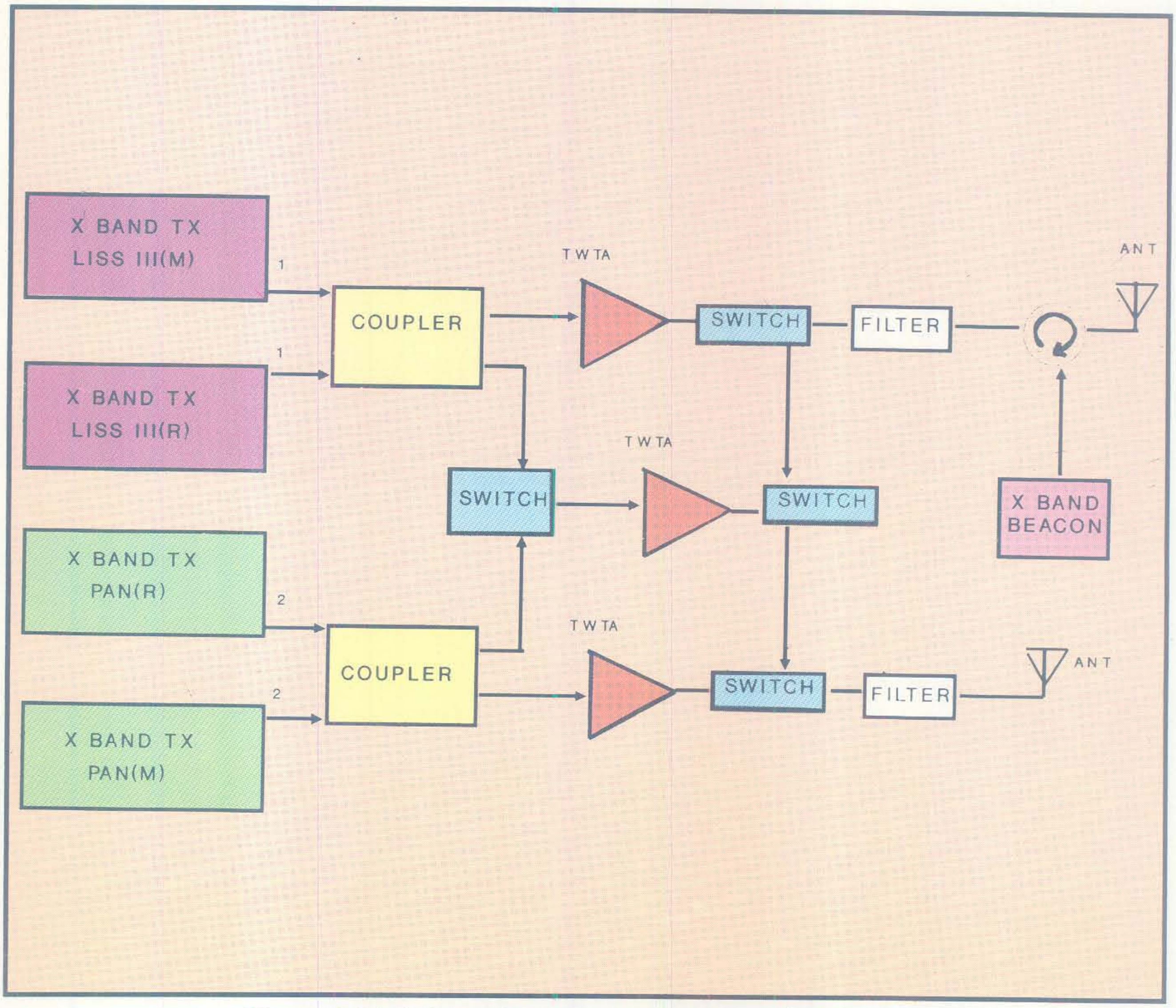


Figure 2.4.1 Schematic diagram of RF data handling system

2.4.3 ON-BOARD TAPE RECORDER

It is possible to acquire data outside the visibility region of any ground station, through an On-Board Tape Recorder (OBTR). The OBTR can record and store data, collected in two segments of 8 minutes each. Data recorded on the OBTR, is downlinked to the Indian ground station during night passes and products are supplied as per user's requirements. OBTR has capability to receive and record a single stream of 42.4515 Mbps data. Hence, either PAN-I or PAN-Q or LISS-III (with or without WiFS) data can be recorded. The PAN-I or PAN-Q data corresponds to half a swath while LISS-III data corresponds to full swath. The reproduced data is configured to be transmitted through LISS-III chain. Table 2.4.3 gives the major specifications and features of OBTR.

SPECIFICATION	PARAMETER
Data capacity (User)	54 Gb
No. of tracks	16
User data rate	42.4515 Mbps
Tape speed	94.7 IPS
Bit Error Rate	1 in 10^{-7} excluding bursts 1 in 10^{-6} including bursts
Operating modes	Stand by, Reproduce, Record, Rewind, Wind, Power on/off
Start/stop times	135secs/100secs +/-10secs

Table 2.4.3 Major Specifications and features of OBTR

2.5 ORBIT AND COVERAGE

The primary objective is to provide systematic and repetitive acquisition of data of the earth's surface, under nearly constant illumination conditions. The satellite operates in a near circular, sun-synchronous, near polar orbit with a nominal inclination of 98.53 degrees, at a mean altitude of 780 Kms. The satellite takes 100.55866 minutes to complete one revolution around the earth and completes about 14 orbits per day. The entire earth is covered by 358 orbits during a 25 day cycle. The orbital parameters are summarised in Table 2.5.1.

Orbits/cycle	358
Cycle duration	25 days
No. of orbits per day	14
Inner cycle	3 days (West)
Mean perigee altitude	737 Kms.
Mean apogee altitude	821 Kms.
Semi-major axis	7,157.578 Kms.
Nominal inclination	98.53 degrees
Mean eccentricity (e)	0.0059
Nodal period	100.55866 minutes
Distance between adjacent traces	111.94 Kms.
Distance between successive ground tracks	2,798.5 Kms.
Ground track velocity (P)	6.729 Kms./sec.
(A)	6.572 Kms./sec.

Table 2.5.1. IRS-1D Orbit

The mean equatorial crossing time in the descending node will be between 10:30 and 10:47 a. m. over a time duration of 4.8 years. The orbit adjust system is used to attain the required orbit initially and it is maintained throughout the mission period. The ground trace pattern is controlled within ± 8 Kms., of the reference ground trace pattern.

The mean eccentricity of IRS-1D orbit achieved at the end of orbit acquisition phase is 0.0059.

Asphericity of earth causes long periodic perturbation in the eccentricity which varies in a sinusoidal fashion as shown in Figure 2.5.1. The Apsidal line i.e., the line joining the perigee and apogee points in the orbit, rotates in the orbital plane. The period of this rotation is about 122 days. The eccentricity vector plot over the cycle is shown in Figure 2.5.2. As seen from Figure 2.5.1. the mean eccentricity reaches a maximum value of about 0.0074 and a minimum value of about 0.0050 over one cycle. The actual altitude as a function of latitude varies with date depending on the mean eccentricity and argument of perigee on that date. Figures 2.5.3. to 2.5.5. show the altitutde profile with respect to latitude when eccentricity is maximum (e vector over north pole), minimum (e vector over south pole) and when e vector is over equator. As can be seen from these figures the minimum altutude can be around 740 Kms. and maximum altitude around 824 Kms. over 0 degree to 50 degrees latitutde region during a cycle of 122 days.

The sensors collect data with different swaths. Furthermore, the swaths for a given sensor depend on the actual altitude. Over the latitude region of zero to fifty degrees, the altitude varies between 740 Kms. to 824 Kms. Hence, the swath of LISS-III sensor in the visible and NIR bands varies between 127 Kms. and 141 Kms., while in SWIR band the swath varies between 133 Kms. and 148 Kms. The swath of PAN (nadir) sensor varies between 63 Kms. and 70 Kms., while the swath of WiFS sensor varies between 728 Kms. and 812 Kms. Details of overlaps and sidelaps between scenes of a sensor are given in Table 2.5.2. The successive orbits are shifted westward by 2,798.5 Kms. at the equator. Figure 2.5.6. shows a typical ground trace of the orbits. The entire globe is covered in 358 orbits, between 81 degrees North and 81 degrees South latitudes during the 25 day cycle.

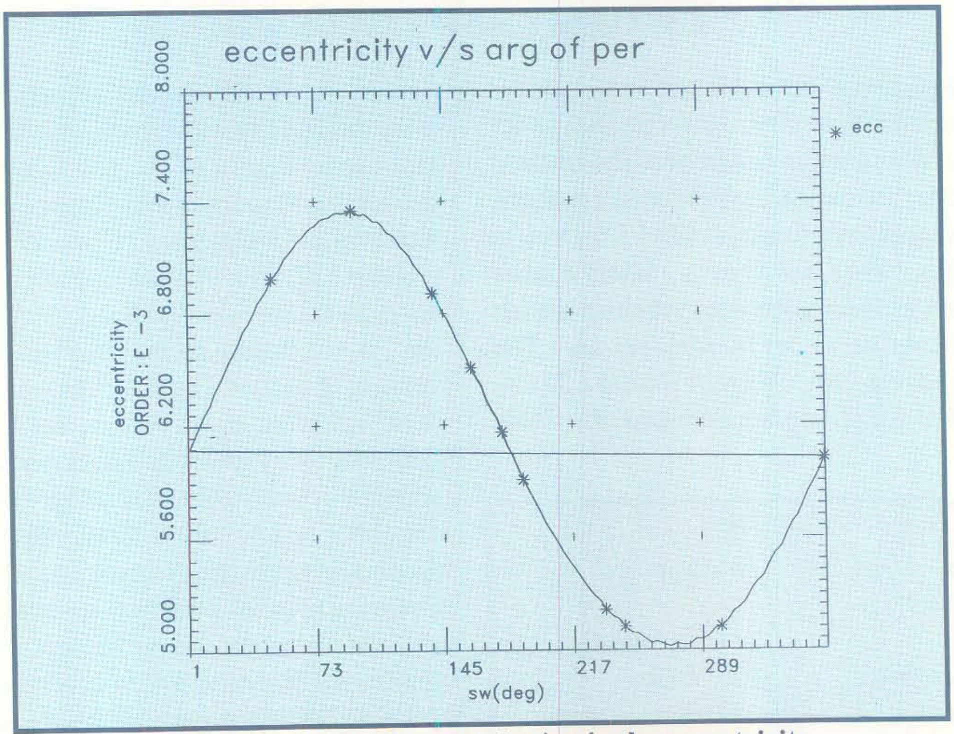


Figure 2.5.1. Periodic perturbation in the eccentricity

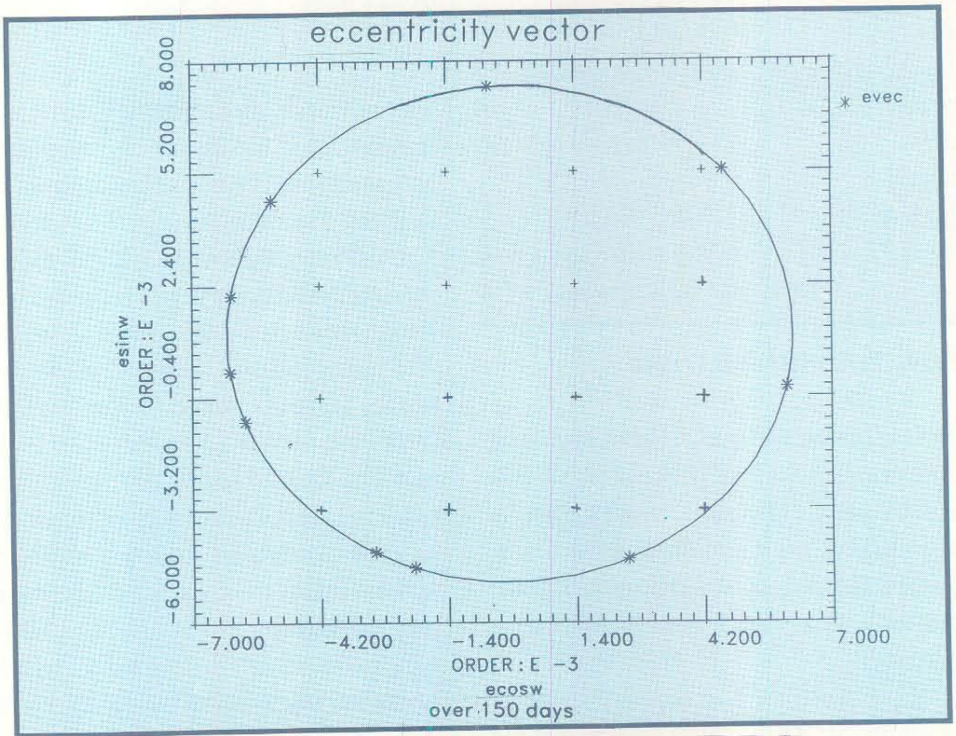
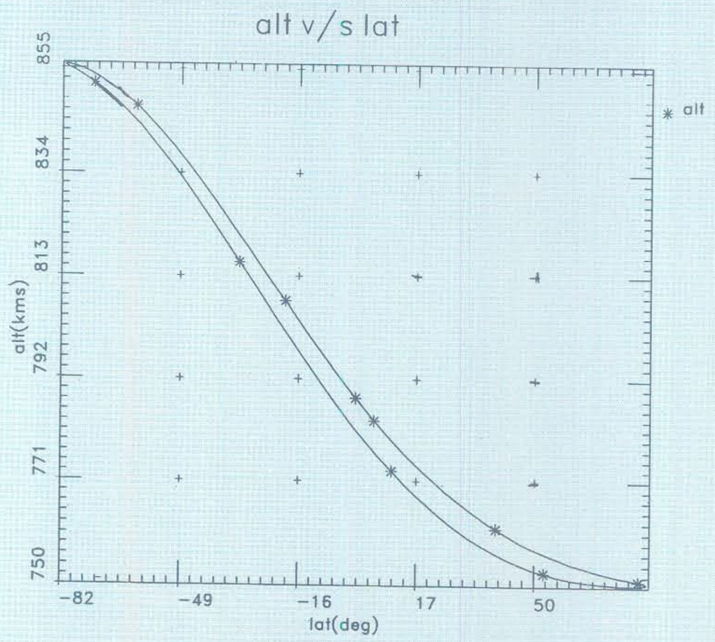
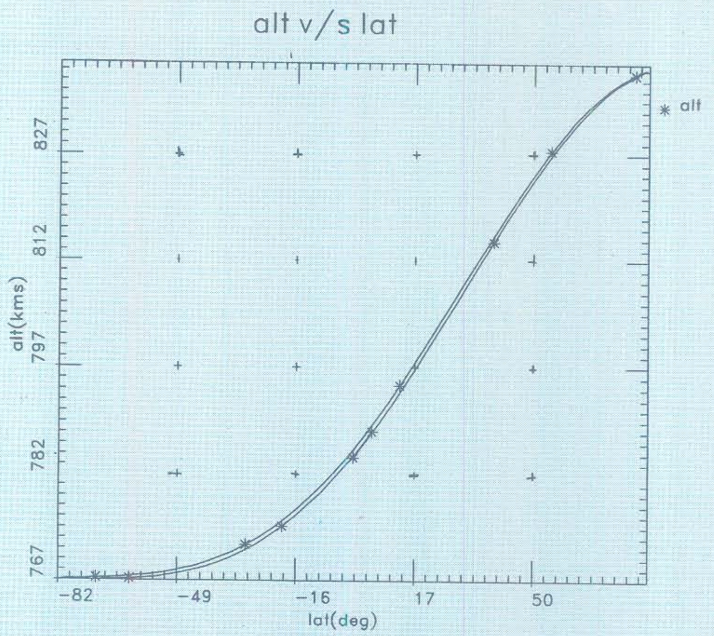


Figure 2.5.2. Eccentricity vector plot over the cycle



(emax. = 0.0074, Perigee over north pole)

Figure 2.5.3. Altitutde profile with respect to latitude when eccentricity is maximum



(emin. = 0.005, Perigee over south pole)

Figure 2.5.4. Altitutde profile with respect to latitude when eccentricity is minimum

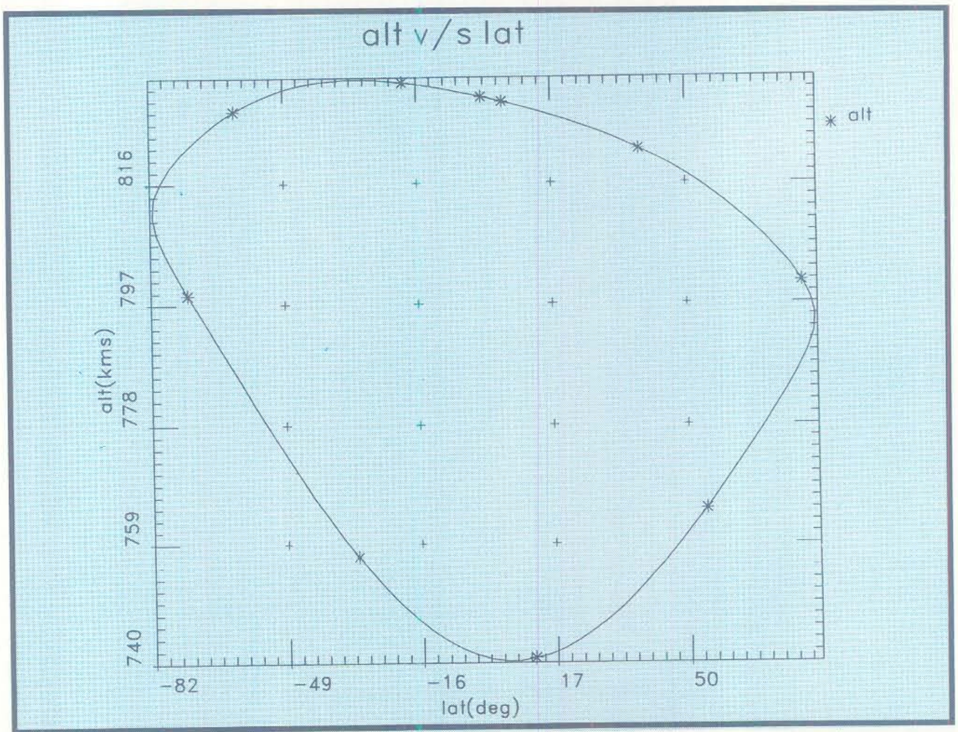


Figure 2.5.5. Altitutde profile with respect to latitude when e vector is over equator

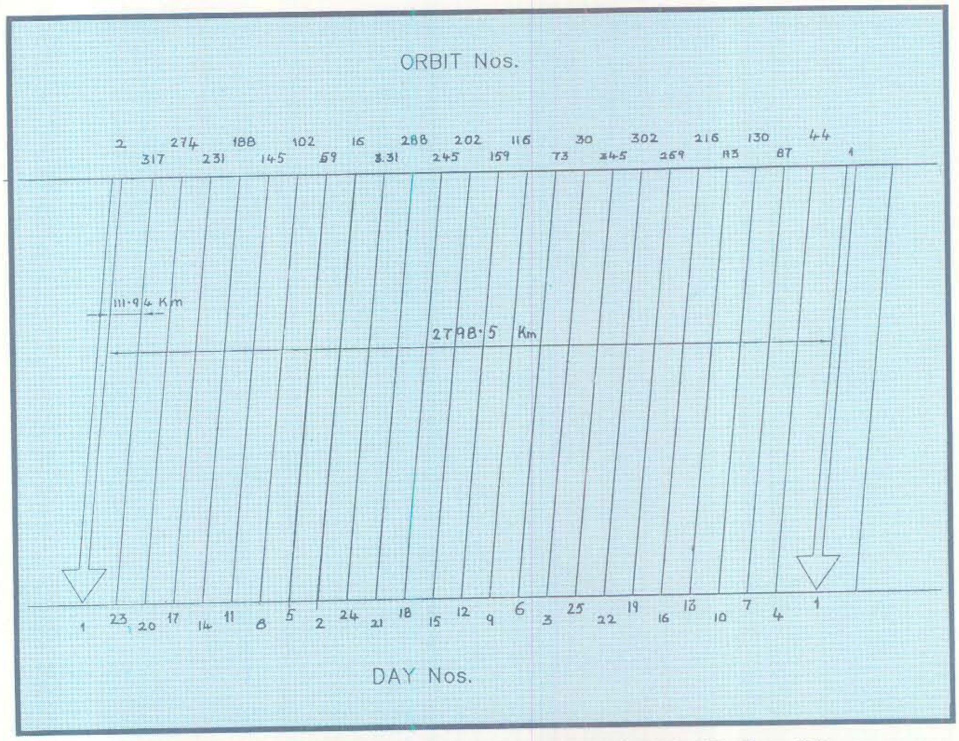


Figure 2.5.6. Ground trace pattern of IRS-1D Satellite

Payload	Resolution (metres) P/A	Ground swath (Km) P/A	Image size Km x Km P/A	Overlap (Km) P/A	Sidelap at equator (Km) P/A
LISS-III					
Visible	21.2 23.5	127 141	127 X 145.5 141 X 142.1	10 6	15.1 29.5
SWIR	63.6 70.5	133 148	133 X 153 148 X 149	17 13	21.1 36.1
PAN	5.2 5.8 (nadir)	63 70	63 X 71.8 70 x 70	4 2	1 8
WiFS	169 188	728 810	720 X 795 810 X 776	82.8% 82.4%	84.6% 86.2%

Table 2.5.2. Overlap and sidelap between the scenes

Scene layout : Figure 2.5.7. shows the scene layout of LISS-III (visible and NIR bands), LISS-III SWIR band and PAN scenes, within one WiFS scene. The corners are numbered as shown in the figure. Same pattern of marking the corners is followed for other images also. The LISS-III (SWIR) scenes are framed in such a way that their length is same as LISS-III (V, NIR) scene though its breadth is 7 Kms. more than a LISS-III (V, NIR) scene.

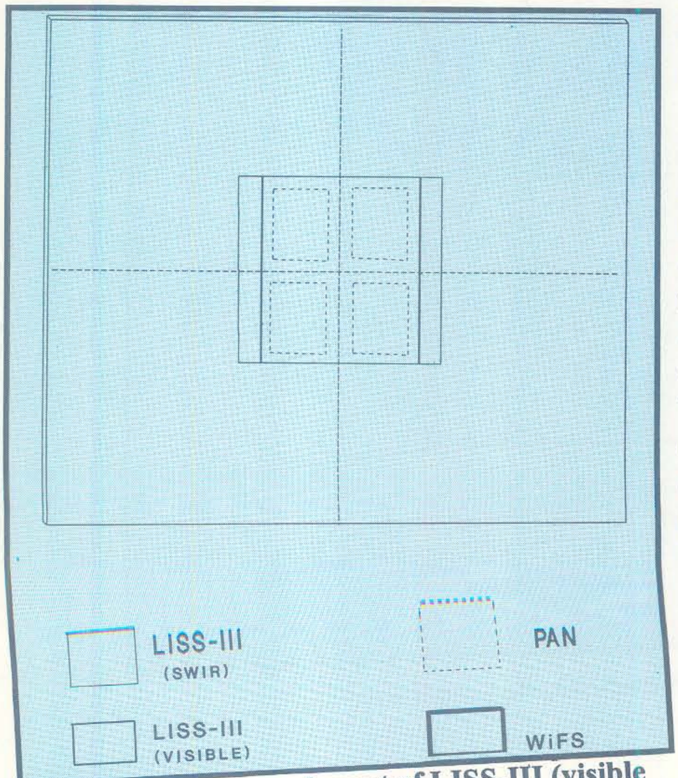


Figure 2.5.7. Scene layout of LISS-III (visible and NIR bands), LISS-III SWIR band and PAN scenes, within one WiFS scene

There is an overlap of 6 Kms. to 10 Kms. between adjacent scenes of LISS-III along a path. Also there is a sidelap of 15 Kms. to 29 Kms. between scenes of adjacent paths at equator. The sidelap is minimum at equator. As we go away from the equator, the sidelap increases because the paths come closer to each other, as we move towards the pole. Table 2.5.2 depicts the sidelap and overlap in case of LISS-III scenes. The sidelap is more in the case of LISS-III (SWIR) as the swath is also more when compared to LISS-III (V, NIR).

As the swath of WiFS is very large, there is a sidelap of about 85 % between WiFS scenes of adjacent paths at equator. But, between the nth and n+6th path, the sidelap varies between 56 Kms. and 140 Kms. at equator. Hence, for data products generation the scenes on nth and n+6th path (which occurs after 7 days) can be selected. Beyond 40 degrees latitude, overlap exists between nth and n+8th path which occurs next day itself. Hence, scenes on nth and n+8th path at the same row can be selected for data product generation. Also there is an overlap of around 80 % between adjacent scenes in a path. But the overlap between mth and m+5th scenes along a path varies between 96 and 115. Hence, one out of every five consecutive scenes can be selected for data products generation.

Revisit capability of PAN : Because of PAN's tilting capability, a given area can be viewed more than once within one cycle. This is known as revisit, due to PAN's steerability. Figure 2.5.8. shows a path with three adjacent paths on either side from equator, the tilt angle with which the central path can be viewed from adjacent paths and also the day number on which the adjacent paths can be viewed relative to the central path. From the figure, it can also be seen that the maximum wait period to view an area is only 3 days. The maximum tilt angle being ± 26 degrees, PAN camera can see only three paths on either side at equator. As we go away from equator, paths become closer to each other. Hence, more number of paths can be viewed by PAN at high latitudes.

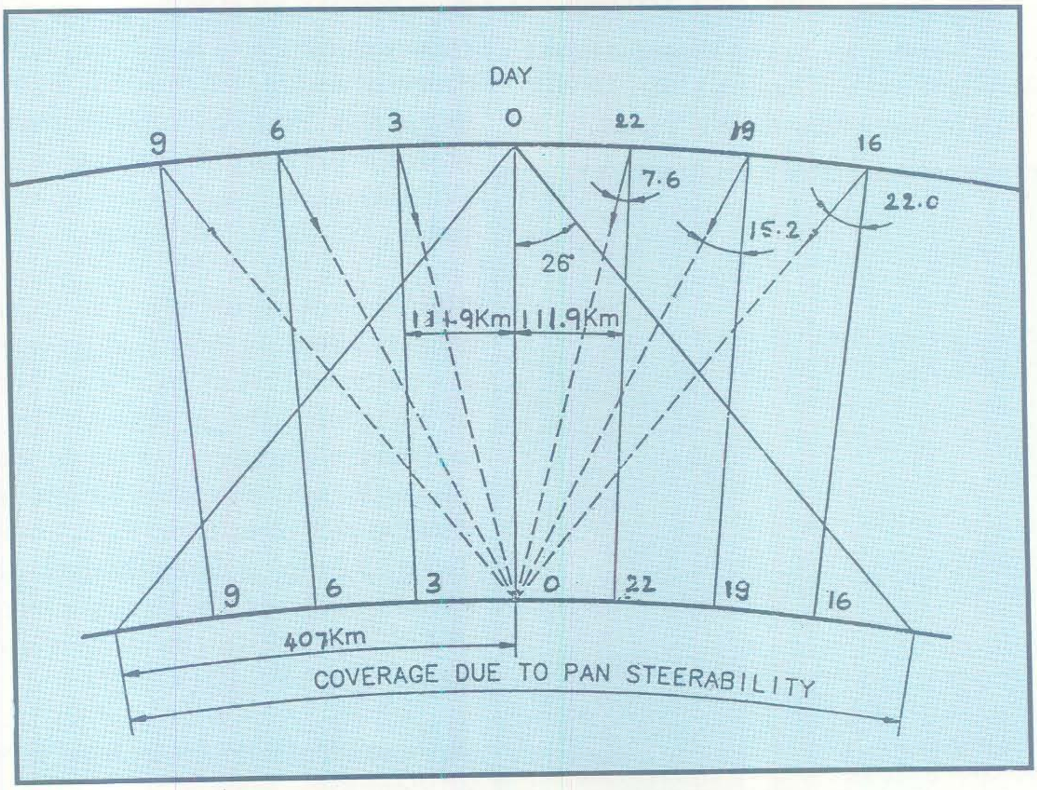


Figure 2.5.8. PAN off-nadir viewing capability

3. GROUND SEGMENT

3.1 GROUND SEGMENT OVERVIEW

The main functions of the Ground Segment are:

- Telemetry Tracking and Command
- Mission Control
- Data Reception
- Data Products Generation and Dissemination

Telemetry Tracking and Command (TTC) functions are carried out by ISRO Telemetry Tracking and Command Centre (ISTRAC) with its Ground Stations located at Bangalore, Lucknow and Mauritius, with the selective support from space agencies of Europe, Russia and America. The reception and recording of payload data, is done at the earth station of the National Remote Sensing Agency (NRSA), located at Shadnagar, near Hyderabad. Processing and distribution of all the products are carried out from NRSA, Balanagar, Hyderabad. Mission control support is provided from ISTRAC, Bangalore. Data is also transmitted to different International Ground Stations (IGSs). The various elements of the IRS-1D Ground Segment are given in Table 3.1.1 and the Ground Segment Organisation is shown in Figure 3.1.1

ELEMENT	LOCATION	FUNCTIONS
TTC	ISTRAC Ground station at Bangalore, Lucknow and Mauritius	1. Satellite house keeping, data reception and recording 2. Spacecraft commanding and tracking
Mission Control	ISTRAC, Bangalore	1. Network coordination and control 2. Scheduling spacecraft operations 3. Spacecraft HK data logging 4. Orbit, attitude determination and control 5. Communication links between concerned Ground Segment elements
Data Reception	NRSA, Shadnagar	1. Reception and recording of payload and OBTR data 2. Generation and display of browse imagery 3. Generation of ancillary data for product generation 4. Transfer of all data
Data Products Generation and dissemination	NRSA, Balanagar	1. Generation and distribution of different types of data products 2. Data quality evaluation, archival and management 3. Payload programming and request processing 4. Transcribing the data from HDT to DLT

Table 3.1.1 Ground segment elements and functions

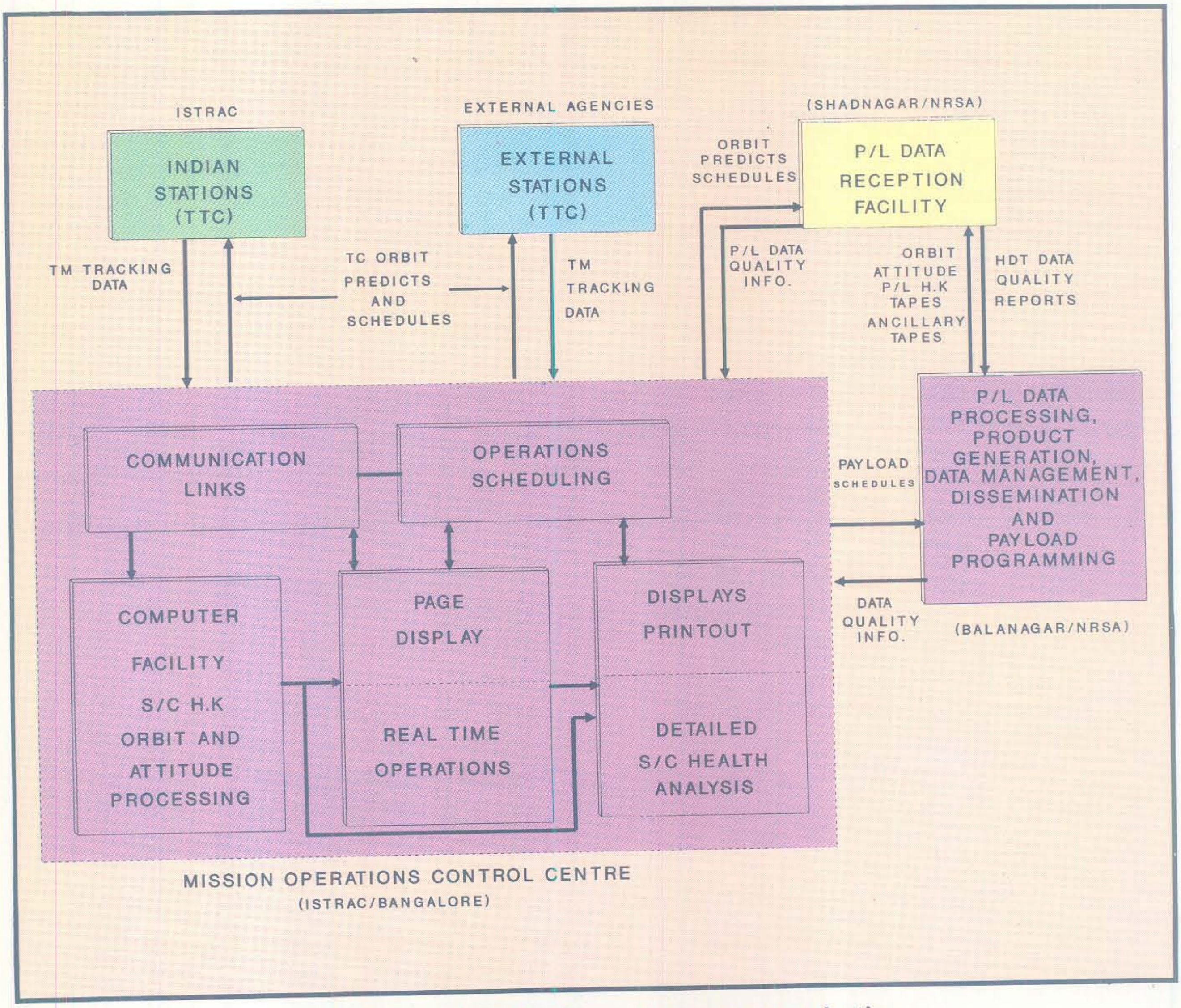


Figure 3.1.1 IRS-1D Ground segment organisation

3.2. TTC AND SPACECRAFT CONTROL CENTRE

3.2.1. INTRODUCTION

ISTRAC provides telemetry, tracking, telecommand, spacecraft operations and control support for IRS-1D mission through its network of ground stations, and Spacecraft Control Centre (SCC). SCC consists of mission control room, mission analysis room, simulation and training facilities, dedicated mision control room, computer facilities, flight dynamic operations and skylink communication facilities etc. TTC network comprises of a network of ground stations located at Bangalore (BLR), Lucknow (LCK), Mauritius (MAU), Bearslake (BRK), Sriharikota (SHAR), Weilheim (WHM), Pokerflat (PKF). A description of various facilities of ISTRAC and their functional responsibilities with specific reference to IRS-1D are provided in the following sections.

3.2.2. SPACECRAFT OPERATIONS

The TTC network, Spacecraft Control Centre, data links and the operations team, form essential elements of mission control. In order to fulfil IRS-1D mission goals, SCC with TTC network support, conducts a variety of operations on the spacecraft. Among other things, these include operation of mission payloads, OBTR record/dump operations, PSM camera rotation, SPS data collection, near continous health monitoring and control.

Spacecraft controllers on the ground rely on House keeping telemetry to monitor the health of a satellite. Telecommands provide the means to reconfigure, reorient and reposition the satellite by remote control. Tracking involves, measurement of range and range rate of satellite, with reference to a ground station, from which the position and velocity of the spacecraft are determined.

The spacecraft controllers at SCC interact through voice communication channels with the TTC stations and co-ordinate in uplinking the commands, scheduled during the radio visible segments of every orbit. SCC is equipped with the requisite mission software and display terminals to ensure error-free operations. These operations are carried out on a routine basis to keep the spacecraft in the intended health, orbit and orientation. Anomalies in spacecraft health and deviation in spacecraft attitude, are tackled by spacecraft controllers, by swift action with the help of mission specific contingency operations management procedures.

ISRO ground stations at Bangalore (BLR), Lucknow (LCK), Mauritius (MAU) and Bearslake (BRK), provide the network support during initial and normal phases.Initial phase TTC support is augmented with external agency support from Pokerflat (PKF) and Weilheim (WHM).

The ISTRAC functional organisation for IRS-1D mission support is shown in Figure 3.2.2.1.

3.2.3. TTC NETWORK

TTC is a combination of two or more ground stations spread geographically. Spacecraft mission operations and control, require a suitable network of ground stations to plan and execute appropriate telecommand operations on the spacecraft, as per pre-determined time-line. Ground station locations for IRS-1D have been chosen on the basis of mission's sequence of events, mission strategies and sufficient radio visibility requirements, of important arcs of the orbit.

Support from external agencies, PKF, WHM is mainly to meet the following requirements :

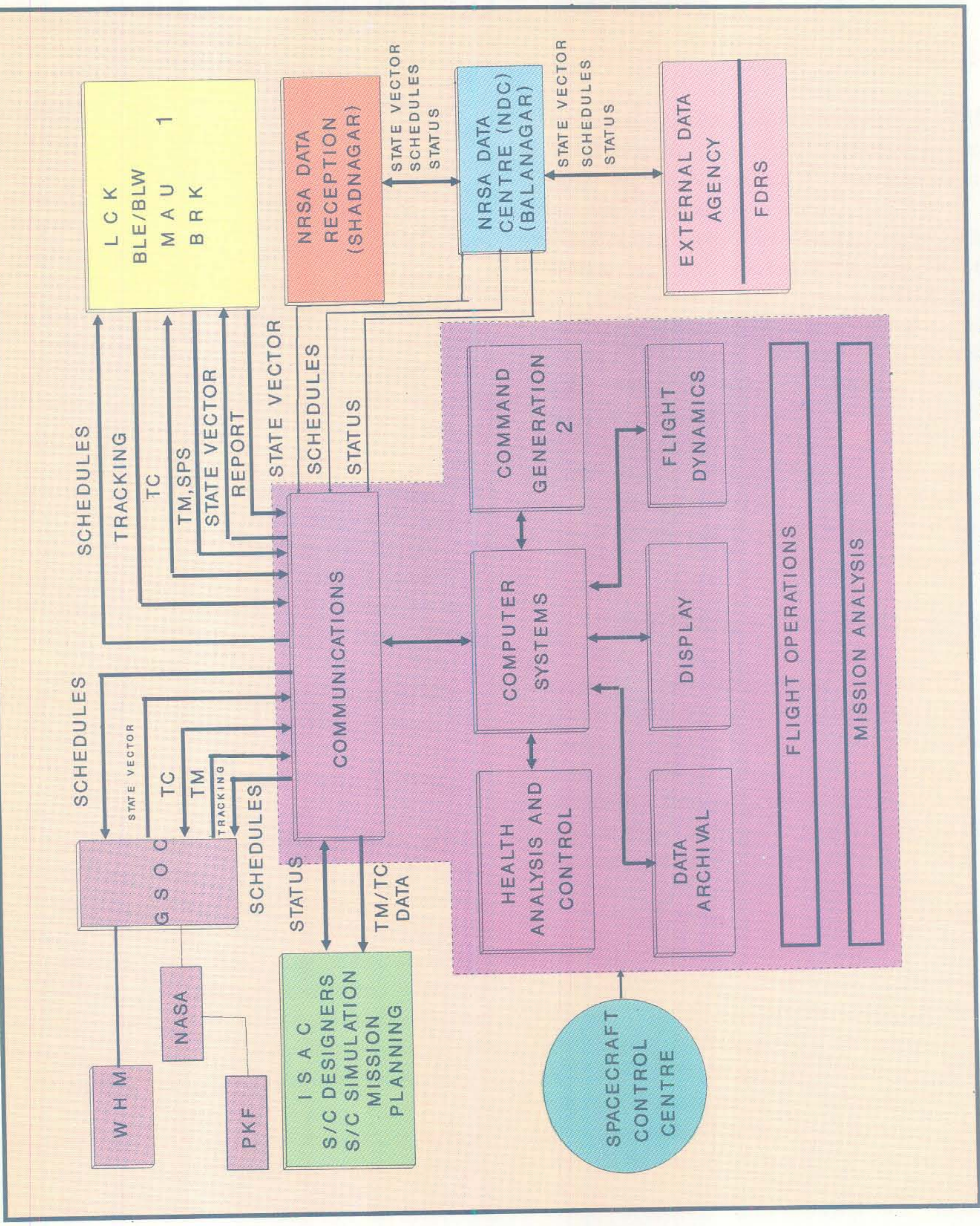


Figure. 3.2.2.1 ISTRAC functional organisation for IRS-1D mission support

- Spacecraft operations through near continuous health monitoring of spacecraft, during the early phase.
- For uplinking time critical commands during launch phase.
- Collection of tracking data for definitive orbit determination, during initial phase operations.

1.	Operating frequency	Receive 2200 to 2300 MHz Transmit 2025 to 2120 MHz
2.	Antenna	
	Size	10 m (1 m acq.)
	Gain/Temp	19.5 dB/deg K
	Velocity	9.0 deg/s
	Acceleration	9.0 deg/s²
	Tracking mode	Auto/Program/CDM/ Manual
	Effective Isotropic Radiative Power	> 70.0 dBw
3.	Modulation	Downlink PCM/PSK/PM Uplink PCM/FSK/FM/PM
4.	Timing Accuracy	100 micro seconds
5.	Transmitter Power	2 KW
6.	Tracking	
	Angles	0.1 deg
	Range	10.0 m
	Range rate	0.1 m/s
7.	Data transfer	x.25 Level-2

Table 3.2.4.1 Characteristics of ISTRAC network stations

The external agency support will be required only during the initial phase of IRS-1D.

3.2.4 TTC GROUND STATIONS

ISTRAC TTC stations are equipped with almost identical systems for Telemetry (TM) reception, tracking and telecommanding. All ground stations are installed with 10m diameter antenna with a G/T of 19.5 dB. An acquisition antenna of equivalent 1m diameter, mounted on the main antenna system, facilitates initial acquisition of the satellite. Capability to receive up to 3/4 TM carriers, with necessary recording, PCM decommutation and quick look facilities, exist in all the stations. Each station is provided with a complete telecommand system of 2 KW RF power and high precision range and range rate systems. Each station has almost complete redundancy at all levels. Ground station computers send the data to mission computers at SCC for data processing. Important characteristics of ISTRAC network stations are given in Table 3.2.4.1.

3.2.5. FUNCTIONAL REQUIREMENTS OF TTC NETWORK

The TTC ground station functions are:

* Housekeeping data reception in real time, dwell and play modes.
* SPS data reception and transmission to SCC computers.
* Conditioning and transmitting the data to SCC computers.
* Transmission of commands generated at SCC to IRS-1C/1D.
* Tracking IRS-1C/1D and collecting range, doppler and angle data and transmitting to SCC for flight dynamics operations.

The details of various support functions, are given in the following sub-sections.

3.2.5.1 Telemetry

ISTRAC ground station(s) receives the down-link signals from IRS-1C/1D spacecraft in real-time and carry out the following activities:

* Demodulate the signal
* Bit and Frame synchronize
* Time tag
* Format into standard blocks for transmission
* Record analog data for recall

3.2.5.2 Telecommand

Telecommand supports remote commanding, in real-time during ground station visibility. Commands can also be sent in local mode by entering directly at the encoder at the ground stations and transmitted to the spacecraft.

3.2.5.3 Tracking

Tracking support is provided during any segment of the orbit subject to radio visibility. Tracking support is provided simultaneously with telecommanding. The ground stations measure range, range-rate and antenna angles with respect to the spacecraft. This is very essential for spacecraft orbit determination and ephemeris generation.

3.2.5.4 Data Communication

Data communication links at ISTRAC establishes the required communication lines, in co-ordination with the national and international agencies, to ensure transfer of telemetry, tracking and telecommand data using standard protocols. The TTC ground stations supporting IRS-1C/1D and SCC systems, are interlinked continuously through dedicated sky links using INSAT and INTELSAT satellites and backup land links.

3.2.6 SPACECRAFT CONTROL CENTRE

The Spacecraft Control Centre (SCC) located at Bangalore is the nerve centre of all TTC and spacecraft control operations.

IRS-1D Mission operations are conducted from SCC which is fully geared up with necessary technical facilities for carrying out and coordinating IRS-1D spacecraft health monitoring, analysis and control.

Mission Analysis Room (MAR), Mission Control Room (MCR) of SCC comprise of several observation consoles and command terminals connected to the computer facility, for providing spacecraft health data to mission experts and mission operations team from pre-launch till end of initial phase. MAR during IRS-1D launch phase was large enough to accommodate around twenty work stations with improved facilities. All mission activities are carried out from Dedicated Mission Control Room (DMCR) of IRS-1D, in normal phase. SCC has several DMCRs, which are restructured to handle many spacecraft missions simultaneously.

The major tasks of the Spacecraft Control Centre are :

* Scheduling and execution of IRS-1C/1D mission operations.
* Planning and execution of orbit and AD manoeuvers as per mission requirements.
* Orbit and attitude determination
* Scheduling of command operations as part of payload programming
* House keeping data monitoring in realtime.
* Spacecraft health data archival and database management
* Spacecraft health analysis and performance evaluation and reporting.
* Co-ordination with various network stations, IGS, NDC and other related agencies to realise above tasks.
* Anomaly identification and recovery action initiation in case of spacecraft emergencies along with mission experts.

3.2.6.1 Computer Configuration for IRS-1D :

A distributed computer system architecture is implemented at SCC, ISTRAC to support IRS-1D mission during launch and normal phase operations. This new computer system supports IRS-1D in the multi-mission environment along with IRS-1C, IRS-P3, IRS-P4, IRS-P5 Missions.

The computer configuration for IRS-1D comprises of:

* Work stations for all processing and display of IRS-1D spacecraft data.
* File servers/Database servers for data management.
* Bridge/Routers for interconnecting SCC to ISTRAC ground stations.
* Gateway systems for interconnecting SCC to external agencies.
* Virtual LANS for LAN connectivity of all the work stations, communication processors, file servers. bridge/routers, etc.,.

These systems operate continuously and concurrently, with the existing computer systems which support ongoing IRS-1B, IRS-P3 and IRS-1C missions. On these systems, a unified software system runs, consisting of a set of layered software products catering to the functions of data communication, data management, data flow monitoring and intersystem time synchronisation.

Figure 3.2.5.1 shows the computer configuration for IRS-1D mission operations support.

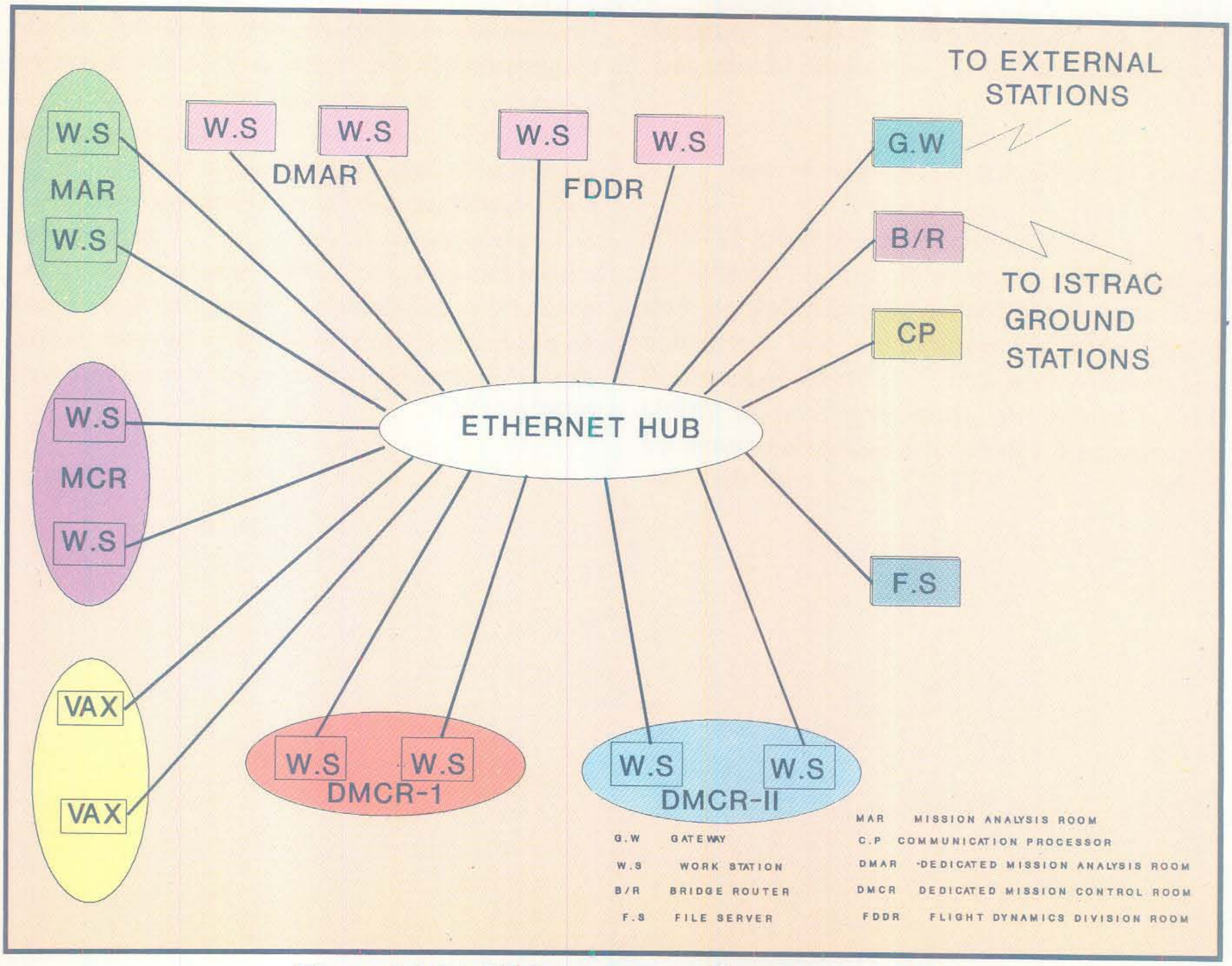


Figure. 3.2.5.1 SCC computer configuration for IRS-1D

3.2.6.2 Flight Dynamics Operations:

Flight dynamics operations at SCC consist of:

* Processing the tracking the data from ground stations and determining the orbit.
* Generation of the orbital events, for scheduling and spacecraft operations.
* Look angle generation for ground station.
* Transmission of state vector to the users.
* Attitude determination using various sensors.
* Orbit maintenance planning for stringent orbit control.

Figure 3.2.6.2 provides the flight dynamics operations support configuration in the multi-mission environment at SCC.

3.2.6.3 Multi-Satellite Scheduling System :

Effective TTC support is channelised to IRS-1C/1D in the multi-mission environment by ISTRAC multimission scheduling software. Multi-Satellite Scheduling System (MSS) software programme was developed and operationalised at SCC. This MSS interfaces with Payload Programming System (PPS) in generating the operation schedules and command schedules for IRS-1D along with the other on-orbiting operational spacecrafts, controlled from SCC. MSS generates IRS-1D schedules optimally, by taking into account the following factors in the multi-mission operations environment at SCC.

* Spacecraft specific requirements.
* Spacecraft constraints.
* Special operations requirements.
* Network ground stations.
* Ground stations configurations.
* Visibility clashes.

3.2.7 PAYLOAD PROGRAMMING :

Payload programming is a payload operation scheduling process which involves translation of the prioritised payload operational requirements from NRSA Data Centre (NDC) into a set of sequential command operations. These commands are merged into the multi-satellite general operations schedule of ISTRAC. SCC plans spacecraft command operations to enable data access by IGSs. Assuming atleast one payload operation per pass, the total commanding load for payload operations itself will be considerable for IRS-1D and this involves close co-ordination between NDC and SCC.

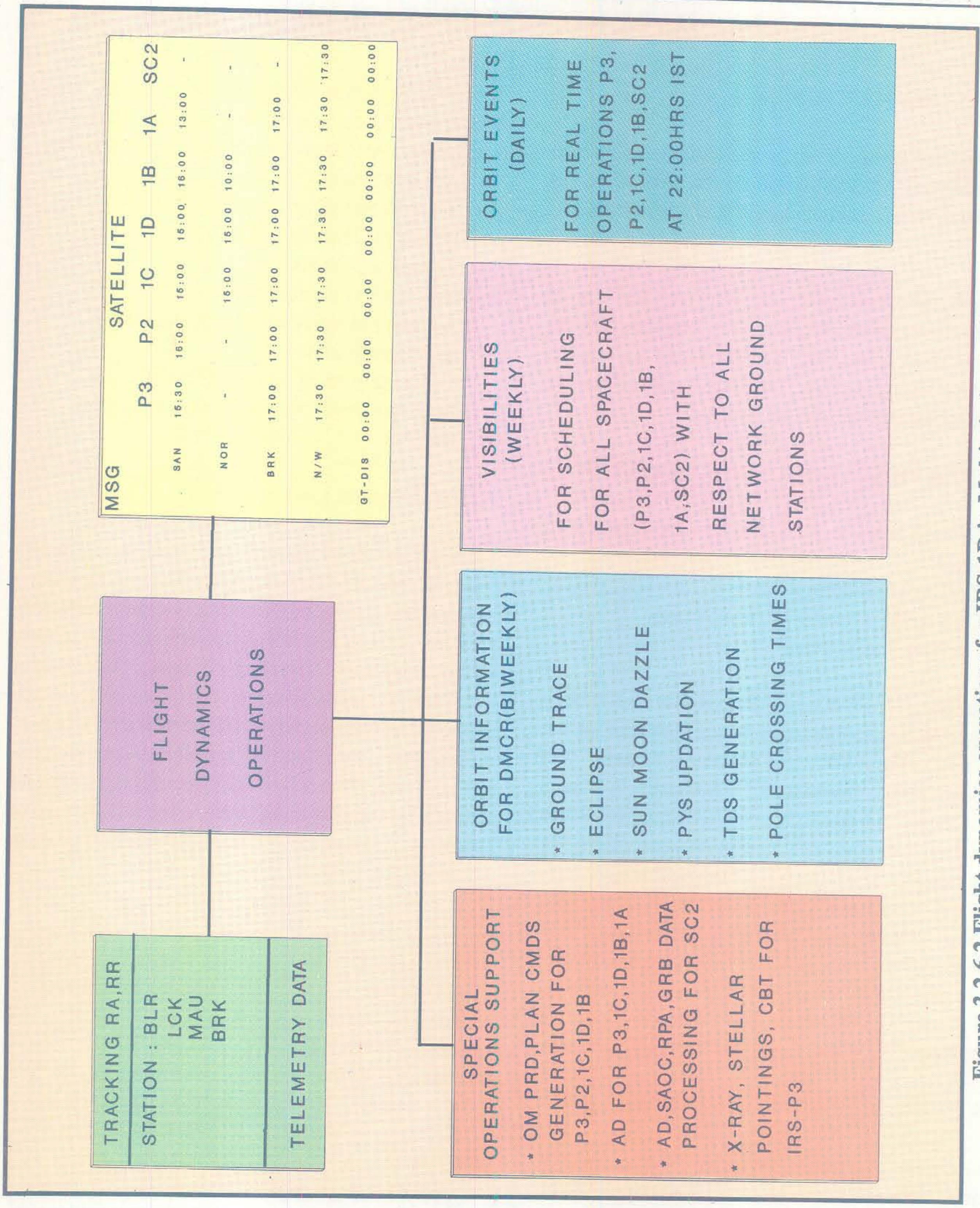


Figure 3.2.6.2 Flight dynamics operations for IRS-1D in Multimission environment at SCC

3.3 DATA RECEPTION STATION

3.3.1 INTRODUCTION

The Data Reception Station at Shadnagar receives payload data (PAN, LISS-III and WiFS) and Beacon in X-Band and house keeping and telemetry data in S-Band.

The earth station has the capability to track and receive data from any satellite operating in frequency bands 2200-2300 MHz and 8025-8400 MHz (allocated for Remote Sensing). The Shadnagar ground station configuration is given in Figure 3.3.1.1.

3.3.2 EARTH STATION CONFIGURATION

The Ground Station at Shadnagar near Hyderabad consists of:

- Data Acquisition System
- Data Archival and Real Time System
- Communication Links

The existing Servo Control Systems have been replaced with microprocessor based servo controller, which, in conjunction with the above system, will provide reception capability for IRS Mission in X and S Band. A set of two High Density Tape Recorders (HDTR) provide the raw data archiving capability for the payload (PAN and LISS-III) as well as telemetry data with one to one back up capability. The third HDTR is available as back-up for recording either LISS-III or PAN data. A VAX 3400 based computer system provides capability for Quick Look and Real Time System telemetry data reproduction and processing of the same, to generate level '0' products.

3.3.3 DATA ACQUISITION SYSTEM

Data Acquisition System at Earth Station Complex in Shadnagar receives and records video data of PAN, LISS-III and WiFS cameras, on High Density Digital Tape (HDT). Simultaneously, both camera data are displayed on Quick Look displays. The Data Acquisition System comprises of four constituent elements:

- Antenna System
- Servo Control System
- Receiving/Tracking System
- Recording System

Essentially, the system provides for:

- Acquisition and recording of payload and telemetry data
- Tracking of satellite in both X and S Bands
- Back-up operations through Landsat/ERS terminal.

3.3.3.1 Antenna system

This consists of a 10m diameter antenna on a compact tracking pedestal. The components of the antenna are of segmental configuration and low weight, bolted construction enabling quick dismantling and assembly without elaborate alignment process. The reflector consists of a machined reinforced circular hub, which supports twenty four radial truss-ribs, twenty four panels and other circumferential bracings. All the interconnecting parts of the reflector are machined, so that no optical alignment techniques are required at the time of assembly. Antenna system characteristics are given in Table 3.3.3.1.

Main reflector	:	10 metre diameter
Subreflector	:	1.5 metre diameter
Focal length over diameter ratio (F/D)	:	0.39
Surface accuracy	:	0.8 mm RMS static 1.25 mm RMS at 96 Kmph wind
Weight	:	1.6 tonnes
Survival wind velocity	:	200 Kmph

Table 3.3.3.1 Antenna system characteristics

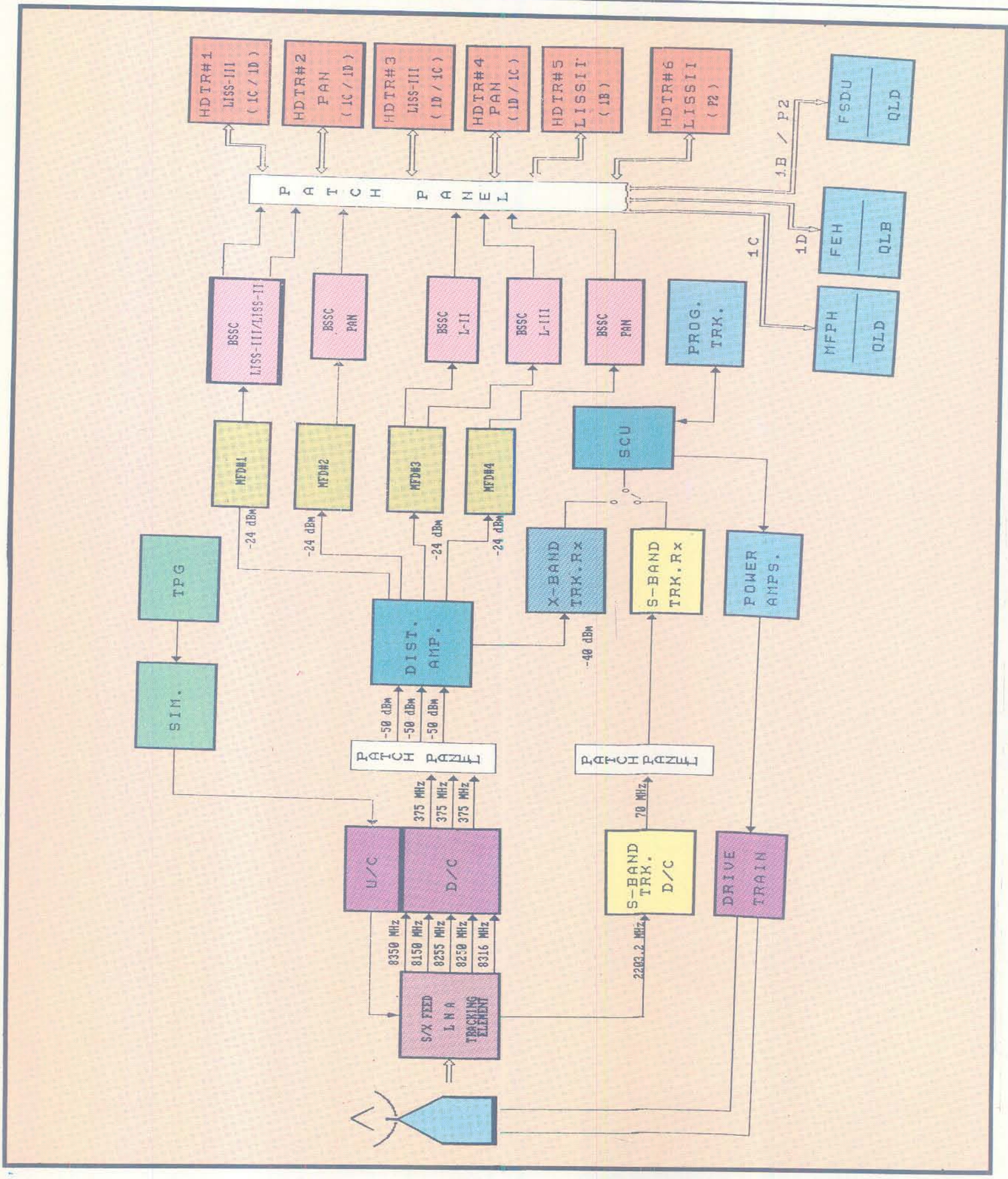


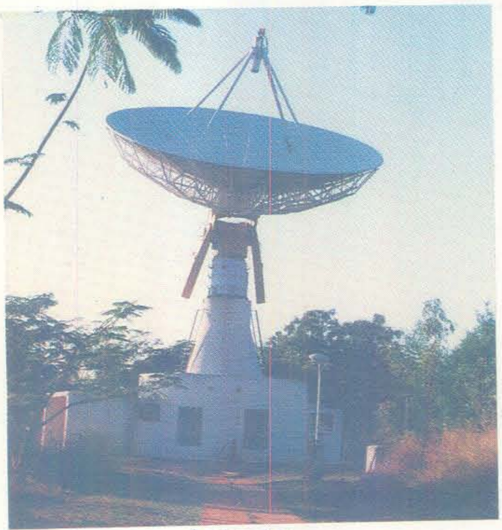
Figure 3.3.1.1 Shadnagar Ground Station configuration

3.3.3.2 Tracking Pedestal

The compact tracking pedestal is a steel structure housing drive trains, synchro and limit switch packages and interlocks for both azimuth and elevation axes. Tracking pedestal characteristics are given in Table 3.3.3.2.

Type	: Elevation over Azimuth mount
Input power required	: 415/240 V, 50 Hz, 4 wire 3 phase
Delivered torque at each axis	: 81345 Newton meter
Orthogonality tolerance	: 0.02 deg
Gear type	: Precision spur gear
Gear ratio	: AZ 1026:1 EL 1700:1
EL travel limits	: Primary (Electrical) -2 deg., ±182 deg. Secondary (Mech) -5 deg., ±185 deg.
AZ travel limits	: ±360 deg
Stowing	: Hand crank
Weight	: 5.5 tonnes

Table 3.3.3.2 Tracking pedestal characteristics



Antenna

3.3.3.3 Servo Control System

The system can be broadly classified into three parts, based on digital elements (for mode selection, backup and switching signal routes), analog signal (position and rate compensation, feed-back networks) and power electronics (employing fully reversible Silicon Controlled Rectifier (SCR) bridge, controlling DC motors driving the antenna). Servo Control system consists of microprocessor based Servo Controller, a PC, Power amplifiers and other interfaces, to work as a torque biased dual drive closed loop control system. The characteristics of Servo control system are given in Table 3.3.3.3.

Operating modes	: Ready, manual rate, manual position, Command angle program track, auto track, position memory, rate memory, auto track and auto acquisition.
Motors	: Permanent magnet, shunt wound DC motor, 7.5 HP, two per axis, short time rating upto 15 HP, rated speed 5000 RPM.
Drive type	: Dual motor drive for each axis with torque bias arrangement to eliminate back-lash.
Max velocity	: AZ 22 deg/s EL 10deg/s
Max acceleration	: AZ 5 deg/sec^2. EL 1 deg/sec^2
Bandwidth	: NB II-0.5 Hz WB II-0.85 Hz
Overshoot	: 30 percent maximum
Locked rotor freq	: 4.2 Hz
Dynamic RMS accuracy per axis	: ±0.08 deg

Table 3.3.3.3 Characteristics of Servo Control System

3.3.3.4 Receiving System

The PAN data at 8150 MHz and LISS-III data at 8350 MHz and beacon in X-Band(8255 MHz) are received by composite X and S-Band feed for single channel monopulse configuration in cassegranian arrangement and amplified using preamplifiers. The X-Band signals are down converted to an IF of 375 MHz and the S-Band signals are down converted to an IF of 70 MHz. The X Band down-converter has 3 channels for down conversion and two channels for up conversion. Up-Conversion mode is used for RF loop checks. These UP/DN convertors can be used for any frequency in X-Band. The down converted signals are QPSK demodulated. The final extracted data and clocks from Demod/BSSC are recorded on HDTRs. The telemetry data received for house-keeping, includes PM Demodulator, sub-carrier PSK demodulators and bit synchronizers. Receiving system specifications are given in Table 3.3.3.4.

	X-BAND	S-BAND
Polarisation	RHC	RHC
Axial Ratio (dB)	2	1.5
Sum Channel Gain at preamp input (dBi)	54.0	43
Frequency Band (MHz)	8025-8400	2200-2300
IF Frequency (MHz)	375	70
System G/T (dB/degK)	31.0	19.5
Bit rates	PAN 84.903 Mbps LISS-III 42.4515 Mbps	Telemetry 512 bps

Table 3.3.3.4 Receiving system specifications

3.3.4 DATA ARCHIVAL AND LEVEL-0 SYSTEM

The functions of Data Archival and Level-0 System at Shadnagar are as follows :

* Reception and recording of Payload and OBTR data daily and CAL data on scheduled days.
* Quick look display for LISS-III and PAN
* Sub-sampled browse data archival in real time for both LISS-III (multiple band) and PAN.
* Sub-sampled WiFS browse data generation in playback mode.
* Generation of ancillary data for LISS-III and PAN.
* Generation of ancillary and raw WiFS data on DATs.
* Browse scene framing and compressed browse data transfer on network, to browse archival system at NDC.
* All the above functions are performed for OBTR passes also.
* Interaction with SCC for state vectors, attitude biases, schedules, processed satellite positioning system data and other payload programming requests.
* Interaction with IMS for the transfer of ADIF on network.
* For scheduled CAL pass, generation of DAT for multiple cycle CAL disk load for CALANAL at DQE.
* Act as router for messages between SCC and NDC for payload programming

3.3.4.1 Data Archival System

As per the IRS-1D mission plan, it is decided that in the initial phase, data will be recorded on HDTs till the Advanced Front End Hardware (AFEH) is operational. Subsequently, in real time, the data is to be stored on Redundant Array of Inexpensive Disks (RAIDS). Storage of data for permanent archival is planned to be on Digital Linear Tape (DLT) as this is a low cost alternative to HDTs. The archival system plan after the development of AFEH is the normal phase of operation.

Initial phase of operation :

Payload

The data from LISS-III and PAN at 42.45 Mbps and 84.903 Mbps respectively is recorded on two different HDTRs along with IRIG-A time code. Recording densities are kept at 33.33 Kbps. Data of two passes of LISS-III or one pass of PAN, can be recorded on each tape. These recorders have the facility to read after write for verification of the data recording in real-time.

On Board Tape Recorder (OBTR)

PAN-I / PAN-Q / LISS-III data from OBTR is recorded on one HDTR at 42.45 Mbps. Data from two passes can be recorded on one tape. This data is played back in reverse mode, for the generation of forward tape for further processing at Balanagar.

Calibration

CAL data for LISS-III and PAN is recorded on single HDTR on scheduled days. LISS-III Cal data is recorded at 42.45 Mbps and PAN cal is recorded at 84.903 Mbps. Table 3.3.4.1 gives the specifications of HDTR.

Normal Phase (with the AFEH system)

With the availability of AFEH system at Level-0 systems, the real time data is planned to be stored directly on RAID storage disks. Later, the data will be transferred on to DLTs for permanent archival. It will therefore be possible to dispense with the very expensive HDTRs and HDTs.

Description	**LISS-III & OBTR**	**PAN**
Model	: HD-96e	HD-96e
No. of Tracks	: 28	28
No. of HDT Tracks for Payload	: 24	24
No. of Direct Tracks	: 2	2
Recording Speed (IPS)	: 63.5	127
Packing Density (Kbps)	: 33.33	33.33
Bit Error Rate (BER)	: $1X10^{-8}$	$1X10^{-8}$
Input Data and Clock Level	: ECL(SE)	ECL(SE)
Output Data and Clock Level	: ECL(SE)	ECL(SE)

Table 3.3.4.1 Specifications of HDTR

Payload, OBTR and Calibration passes :

The Level-0 system is configured as two chains for Data Archival and Quick Look Browse based on high-speed UNIX workstation. The data from LISS-III/PAN-I/PAN-Q will be directly stored in real time on RAID storage disks. This will be archived by a UNIX work station, which supports the RAID storage disks.

RAID :

For PAN, 24 GB and for LISS-III, 12 GB for one day payload operations.

Sustained transfer rate is 18 MB/Sec.

DLT specifications:

Data rate	:	5 MB/Sec
Capacity	:	35 GB
Media type	:	MP-2
Interface	:	SCSI-2/Fast/Wide

3.3.4.2 Timing Systems

The timing accuracy at Level-0 System affects the along track location accuracy. Therefore time is maintained precisely with respect to Universal Time (UT). This is achieved by means of Time Code Generator (TCG) which is driven by a highly stable oscillator. The TCG provides the required IRIG-A time code and is synchronized with respect to a Global Positioning System (GPS) receiver. The accuracy achieved is better than 5 Microseconds. Two Time Code Translators (TCTs) are used with the two FEH systems for time. Timing system is shown in Figure 3.3.4.2 and specifications of GPS receiver and Time Code Generator/Translator are given in Table 3.3.4.2.

GPS Receiver		
Time Accuracy	:	100 nano seconds
Location Accuracy	:	about 100 mts
GPS Code	:	Coarse Acquisition Code (C/A)
Time Code Generator/ Translator (TCG/TCT)		
Output Time Code	:	IRIG-A/ IRIG -B (selectable)
Control	:	GPIB
Output	:	48-bit Parallel BCD
Precision Oscillator		
Model	:	ODETICS
Power	:	230V AC/24V DC ±10% with Battery backup for 2 Hrs.
Stability	:	Better than 1x10e-10
Output	:	1, 5 , 10 MHZ Sine wave signal

Table 3.3.4.2 Specifications of timing system

3.3.5 QUICK LOOK AND REAL TIME SYSTEMS

3.3.5.1 Payload operations (day pass)

The Level-0 system as shown in Figure 3.3.5.1 provides a real time quick look display and browse archival of PAN and LISS-III data. This system generates pass predictions, antenna pointing angles and start of scene framing information based on input from SCC. This system caters to the browse archival of both LISS-III and PAN in real time and WiFS in playback during initial phase of operation and LISS-III, PAN and WiFS in real time during the normal phase of operation.

The Level-0 computer system consists of two chains for Data Archival and Quick Look Browse (DAQLB) system based on high speed UNIX workstation with RAID storage. The two chains are configured for the two sensors i.e., LISS-III and PAN in real time for quick look and subsampled browse data archival functions. These units are interfaced through a general purpose SCSI interface board. The FEH units are modified to cater to OBTR and CAL operations of Level-0 systems. The FEH unit gives subsampled video data along with ancillary data in real time to support quick look and browse functions. The ancillary data created in real time is validated for the purpose of quality evaluation of the data that is archived.

In the initial phase of DAQLB implementation, payload data is recorded on HDTRs and HDTs are sent to transcribing system at Balanagar for the generation of browse data on DATs by playing the HDTs at reduced speed.

In the normal phase, data from both the sensors will be archived on RAID storage disks in real time and later on will be copied on DLTs at Shadnagar.

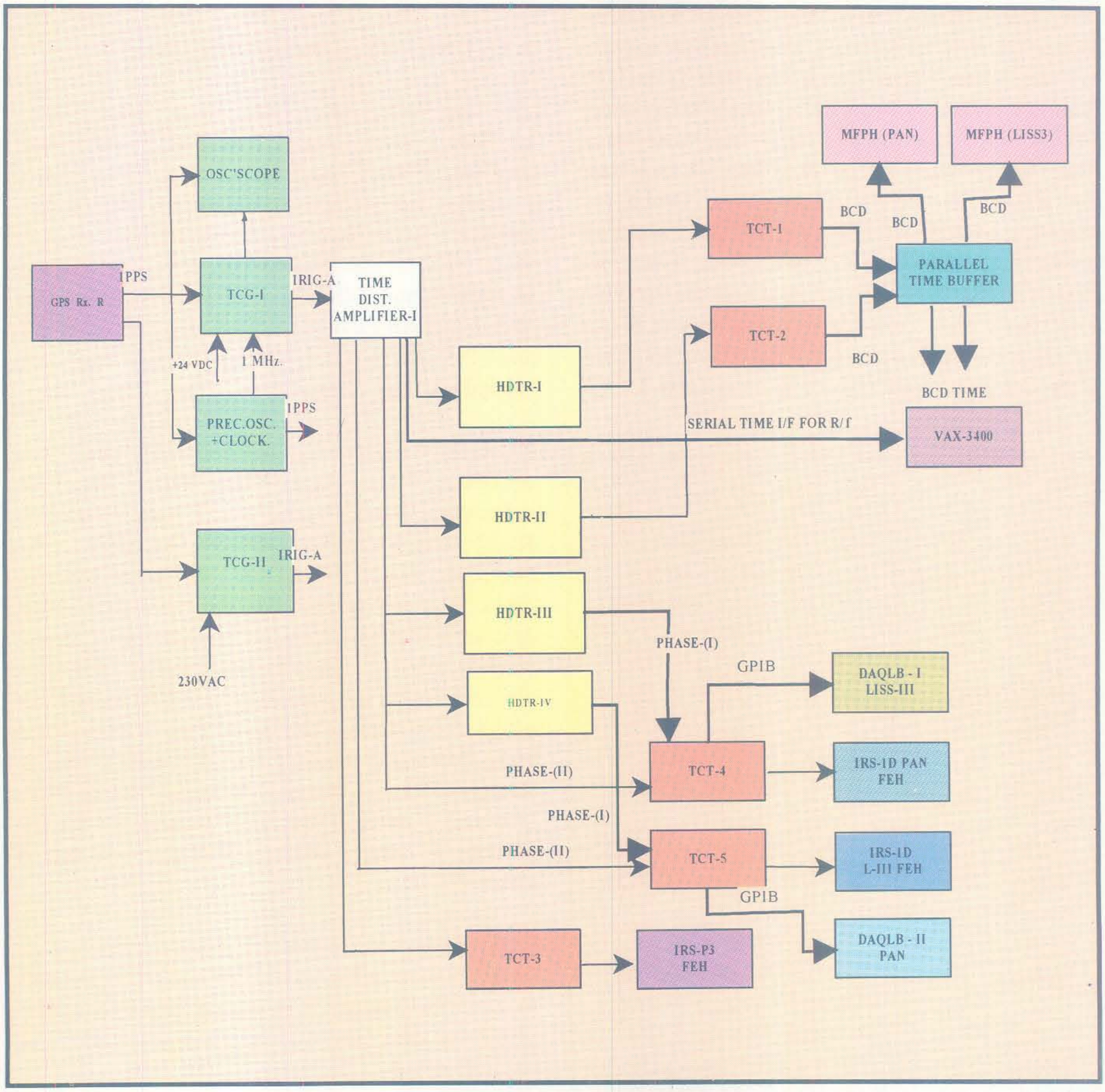


Figure 3.3.4.2 Block diagram of timing system

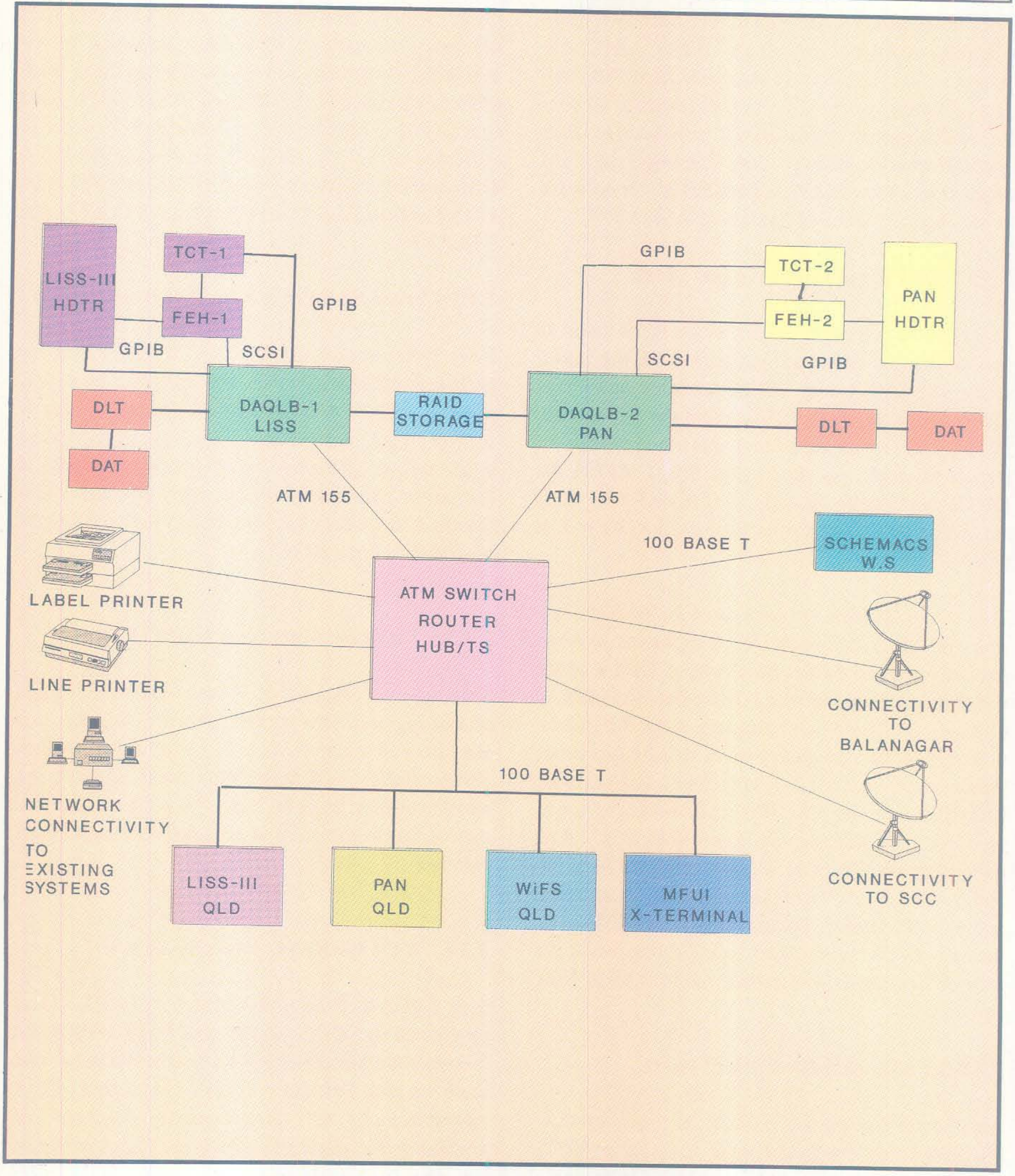


Figure 3.3.5.1 Block diagram of Level-0 system

Satellite ephemeris are generated, based on state vectors information from SCC. Attitude determination is carried out using validated Auxillary data and ephemeris. ADIF is generated for all sensors and validated, before being populated in IIMS over the network. Browse scene framing is done and compressed browse data is transferred via network to the Browse Archival System (BAS) at NDC.

3.3.5.2 OBTR operations (night pass)

The Level-0 computer system chain is the same as that of the day time payload passes. In the initial phase, the OBTR data will be recorded on HDTR for all segments, with GRT in real time and another HDT containing forward data is generated off-line. In the normal phase, with the availability of AFEH, the OBTR data will be directly logged on RAID storage disks, for all segments alongwith GRT in real time.

Two DAQLB chains are configured for the identification of LISS-III and PAN OBTR segments and Aux data is extracted during playback of HDTR in the initial phase. Sub-sampled browse data for LISS-III (3 band)/WiFS/ PAN is extracted. After the generation of Aux files, the quality of the data logged in and the on-board time to GRT correlation is done using MOVIES software. Satelllite ephemeris are generated based on state vectors input from SCC. Attitude determination is done using validated Aux data and ephemeris. ADIF is generated, for all segments and validated before being populated in IIMS, over the network. Browse scene framing is done and compressed browse data is transferred to BAS at NDC via network.

3.3.5.3 CAL operations (night pass)

The Level-0 computer system is used for CAL operations also. The CAL data is recorded on HDTR for all segments, with GRT in real time in the initial phase. With the availability of AFEH, CAL data will be directly logged on RAID storage disks for all segments, alongwith GRT in real time, in the normal phase. Aux data of LISS-III and PAN data is logged in real time. CAL files are generated and Aux data is validated using MOVIES software. Multiple CAL cycle data is disk loaded and transferred onto a DAT. The CAL DAT is despatched to DQE for CALANAL.

3.3.5.4 Front-End Processing Hardware (FEH)

FEH will receive data either from HDTR or built-in simulator. FEH is intended for front-end preprocessing of data from IRS series of satellites. It receives data and clock, conditions them, frame synchronizes and does word synchronization. It formats and buffers the data suitably for display and transfer it to the computer. It is connected to an Octane workstation through SCSI.

3.3.5.5 Telemetry Interface Unit (TIU)

This is a programmable frame synchronizer and processing unit. This is used for processing the Low Bit rate Telemetry (LBT - 512 bps) and Raw Star Sensor (RST- 6.4K bps) data, received from the satellite or from an in-built simulator. The processed data is fed to the computer system through DMA interface.

3.3.6 NETWORKING INTERFACES

The Level-0 Computer System of IRS-1D is connected to SCC Systems and IIMS systems on Network for the transfer of various messages like state vectors, attitude bias, raw star sensor Data, schedules, payload programming requests and confirmations and ADIF Transfer. These systems on the network will be operated under

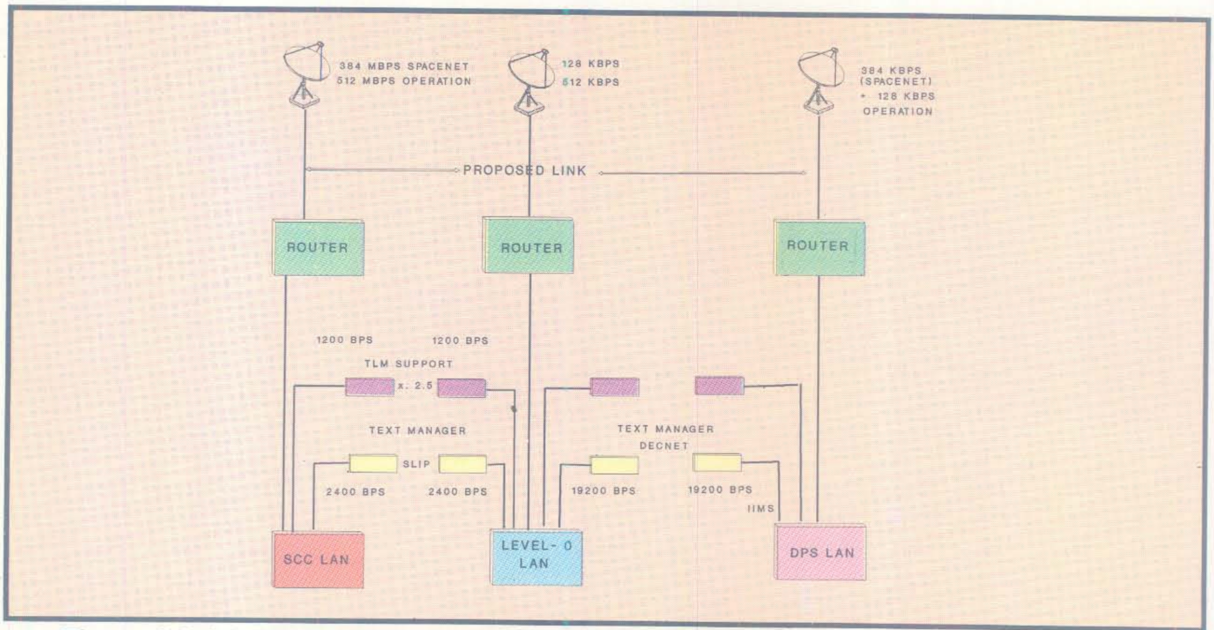


Figure 3.3.6.1 Block diagram of SCC-Shadnagar-Balanagar Networking interfaces

heterogeneous networking environment like DECnet and TCP/IP on the available communication links. The networking interfaces are shown in Figure 3.3.6.1.

Communication Links

The communication links established through Department of Telecommunication (DoT) lines during IRS-1A/1B, are now operated through INSAT satellite in the extended C-band. One 3.8m antenna with the associated transreceive equipment, is installed at Shadnagar to link with ISTRAC, Bangalore. This 64kbps link can support multiple voice and data channels.

Three V-Sat terminals are to be installed at NRSA Balanagar, Shadnagar and at SAC, Ahmedabad for voice/data networking amongst these centres. Figure 3.3.6.2 gives the block diagram of the SAT terminal at Shadnagar.

However, the existing DoT links will be in operation for some duration as a back-up. NRSA communication links are shown in Figure 3.3.6.3.

3.3.7 SCC INTERFACE HARDWARE UNIT

In order to enable data transfers related to station status and also the HK telemetry data collected in real time, a hardware interface unit has been envisaged, which is designed and developed by ISTRAC. The status of various equipments at the data reception station, is made available on a panel by NRSA, which will be accessed by the ISTRAC hardware unit.

The HK telemetry data from the frame synchronizer and the time information from the time distribution unit, is fed to the interface unit. All the data is formatted and multiplexed by the unit, before transmitting to SCC. Regular ADIF data transfer is done through data link from DRS Shadnagar to DPS Balanagar. The data transmission is in the form of blocks with X.25 level 2 protocol.

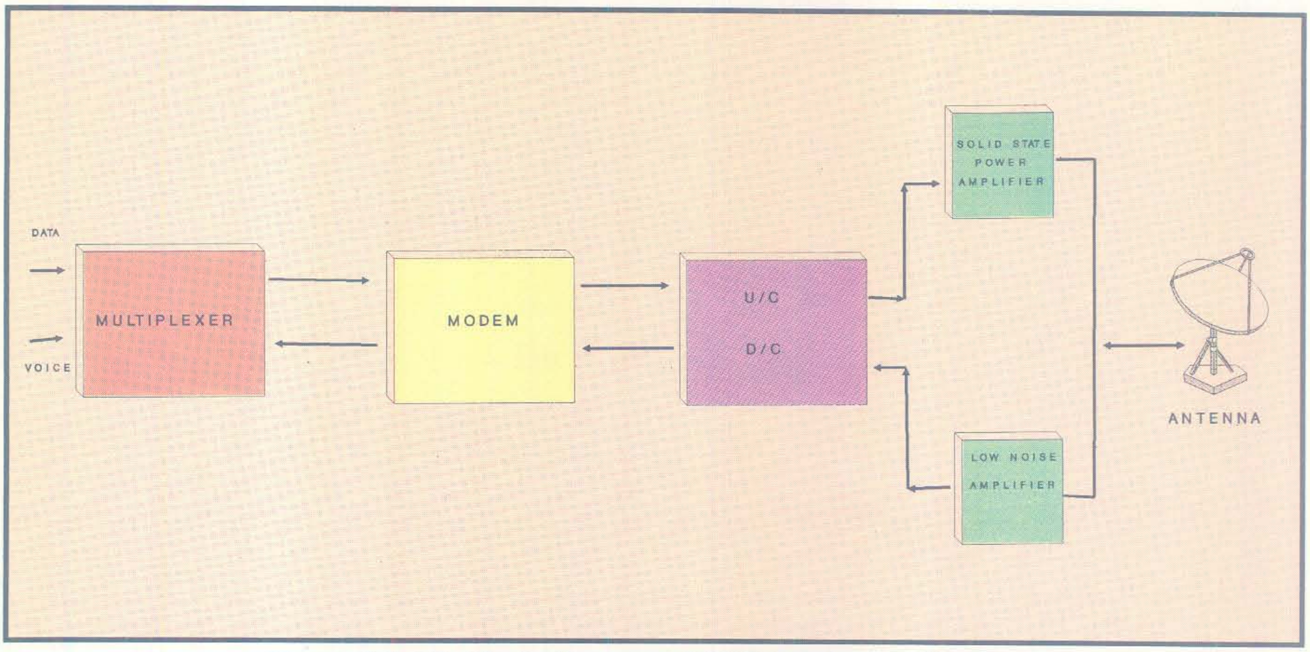


Figure 3.3.6.2 Block diagram of SAT terminal at Shadnagar

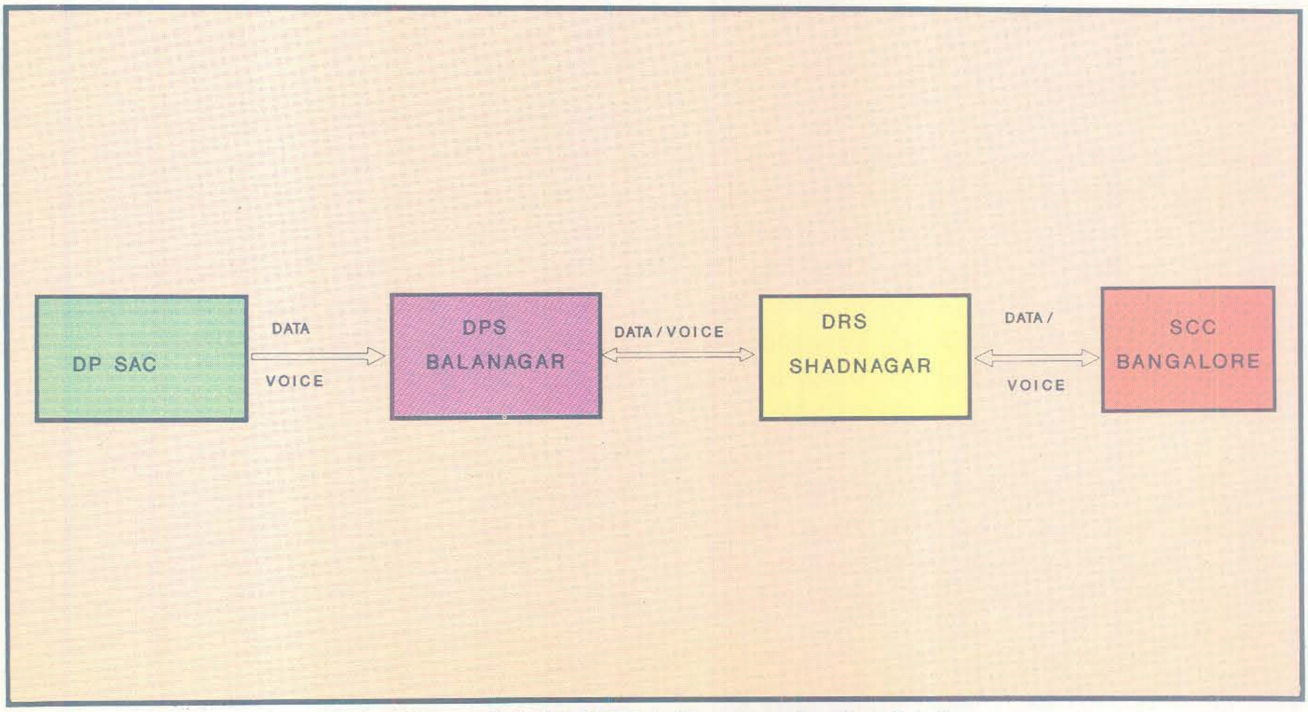


Figure 3.3.6.3 NRSA Communication Links

3.4 DATA PRODUCTS GENERATION FACILITY

3.4.1 INTRODUCTION

The IRS-1C/1D Data Products Generation Facility (DPGF) is designed to establish facilities for generation of various data products, both photographic and digital, as per users requirements. A catalogue of all acquired data, alongwith cloud cover and quality information is generated routinely and maintained in the Integrated Information Management System (IIMS) for easy retrieval as and when required. A catalogue of all the photographic masters is also maintained.

In order to meet the increasing demand for IRS-1C/1D data products, the existing facilities have been augmented to achieve improved throughput and better reliability. Some of the benefits of augmentation are :

* Near real time browse generation at Shadnagar using QLB system,ensuring browse availability on the day of acquisition.
* Browse data access to users through LAN, INTERNET, Web Browsers and Dial-up-lines.
* Archival of raw data on Digital Linear Tapes (DLT), tor better storage.
* Modular Data Processing Units with built-in quality checks, for reliable and quality outputs with improved throughput.
* Faster network for data transfers, to avoid physical media transfer wherever possible.
* Creation of GCPs in various resolutions for improving geometric quality of the data products.

The major functions of IRS-1C/1D Data Products Generation Facility are :

* Archival of raw data on Digital Linear Tapes (DLT) for better storage.
* Archival of all payload data, alongwith their corresponding ancillary information.
* Browse data archival with access to users through LAN, INTERNET, Web Browsers and Dial-up-lines.
* Data processing and data product generation which comprise of data ingest, data correction, transfer to required media and data product quality checking.
* Data processing for generation of stereo pairs and derived stereo products like orthophotos.
* Photo product generation, which includes photo writing from digital media to photographic media.
* Quality checking of master films and photo products.
* Data Quality Evaluation (DQE), for monitoring the sensor and platform behaviour.
* Integrated Information Management System (IIMS) for management of products generation and dissemination activities.

The flow diagram for data products generation is given in Figure 3.4.1.1.

NRSA Data Centre (NDC) interacts with users, processes user indents, monitors and distributes the data products. All the user requests are processed and monitored using IIMS, which connects all production centres. All the user accounts and data supply information, are maintained in IIMS.

3.4.2 BROWSE ARCHIVAL & LAN ACCESS

A Browsing facility is a pre-requisite for the generation of data products. It enables a user to select his/her area of interest for product generation, based on factors such as distribution of cloud cover over the scene, percentage of cloud cover and data quality.

Browsing facility archives sub-sampled and compressed browse images, alongwith corresponding catalogue information on mass data storage devices.

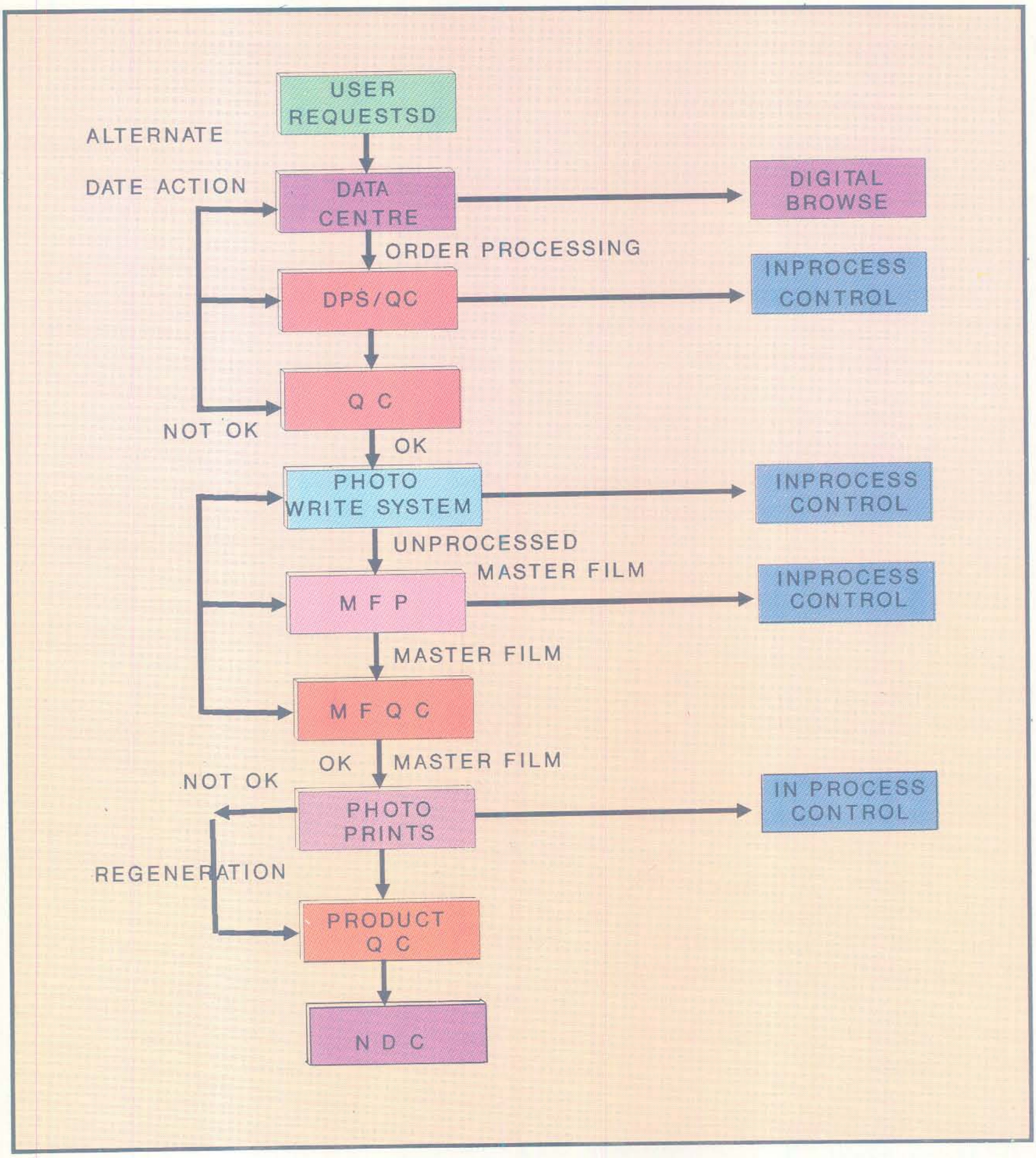


Figure. 3.4.1.1 Data products generation flow

It also houses a suitable server for making the browse data available to the users through queries.

At present, NRSA has different PC-based systems for the archival and browsing of images of the IRS series and foreign satellites.

The existing system is being augmented and data of both IRS series and foreign satellites will soon be made available to users at their work place, through Internet/ LAN network/Dial-up-lines.

The two main functions of the browse facility are :
* Data Archival.
* Browsing.

Browse image and catalogue generation are planned on DAQLB system in Shadnagar, for IRS-1C/1D. The sub-sampled, compressed image data (JPEG standards) and the meta data, will be sent to NRSA either on media or via link.

This meta data i.e., data describing the browse image for all the acquired passes, will be stored on disk and will always be available on the system.

The following is the plan for archival of browse data:

Current Archives

Due to the large volume of data, 6 months/1 year data will be made available to the users. International users and users in Indian Metros will be able to access the Browse archives on Internet or through a Dial-up network. Due to the bandwidth limitations of these networks, it is planned to maintain two types of current archives.

* An archive with browse images of 1K X 1K resolution. This is maintained for LAN users of NRSA and also for the browse data exchange with International Ground Stations (on media).

* A second archive with browse images of 256 X 256 size resolution. This is maintained for the remote user, accessing through Internet or Dial-up connection. This lower resolution is achieved by decompressing, sub-sampling and recompressing the 1K X 1K browse images.

Backup Archives

As the size of the current archives will be limited, the back dated data will be moved to a back-up media like Digital Linear Tapes or Digital Audio Tapes. The structure will be designed such that the accessing method is simple. Data from current archives will be moved to backup archives periodically.

The fields in meta data file(s), indicate whether the image is in current or backup archive. The Archives Manager performs the archival and retrieval of data from archives.

Browse Server

With the evolution of Internet and World Wide Web, dissemination and browsing of different forms of data has become easy. It is planned to set up a web server, so that the user can access browse archives through Internet or dial-up network. While making the browse data available to the user across the globe, it is necessary to ensure that no format dependent software is necessary at the user's site. Hence, it is proposed to develop the interfaces, with commercially available Java enabled web browsers.

The browse server is described below :

Two servers will be available, one for LAN users and the other for Remote users. Users asking for browse data will have to choose the options provided in the Query form and submit it to the server. The server responds by placing the data and annotations at the user's end.

The Browse System will consist of:

1. Query Handling System (QHS).
2. Intelligent Search Engine.
3. Output Handler.

QHS

QHS accepts the user's inputs through a query form and converts to Path/Row details. This output is passed onto the Intelligent Search Engine, for fetching the data. The user can specify his area of interest in terms of path-row, latitude-longitude, SOI mapsheet or name of the location.

When the user submits the query form with the above inputs, a list of all the available images will be displayed. The user can browse through the images.

QHS will also have the following information as HTML documents :

* About NRSA : This document will have all the information about the organisation and also the facilities available at NRSA.
* IRS series of satellites : This document contains information about the IRS constellation, launch details, sensors and their spectral resolution, etc.,.
* Products and Services : This document contains details about the available products, media on which those products can be obtained and the services offered at NDC, etc.,.
* Latest Interface, ISRO/DOS Newsletters, information about the user interaction workshops and other remote sensing related news are planned to be put on the Web as HTML documents.
* Information about different satellite referencing schemes.
* Accession catalogue.

Intelligent Search Engine

* It accepts the Path/Row information from QHS.
* It searches the requested browse image in the static database, for the availability of the browse image.
* It gets the FILEID, DISKID from the meta data base.
* It Passes its output to Output Handler.

Output Handler

* It Accepts the messages, FILE ID, DISKID from the intelligent search engine.
* It acts as an interface to DATA ARCHIVAL system, it passes FILEID, DISKID to the Archives Manager and it receives the extracted images from the Archives Manager.
* It finally annotates the received Browse images and transfers it to the user's site.

3.4.3 DATA PROCESSING SYSTEM

All types of standard/special products from the different sensors of IRS-1C/1D are processed at the Data Processing System (DPS). The identified DPSs to process these products are :

* Data Processing System Chain - 1 (DPS C-1)
* Data Processing System Chain - 2 (DPS C-2)
* Data transcribing System
* Image Analysis System (IAS)
* Stereo and Orthophoto Generation System

3.4.3.1 Data Processing System Chain - 1 & 2

The block diagram of the data processing system chain 1 & 2 is given in figure 3.4.3.1. Each chain consists of :

* Data ingest system
* Data processing system
* Data outputting and Data Quality Control system (DQC).

The data ingest system extracts/ingests the data required from HDTs/DLTs, for any sensor. This system is also used for swath modelling.

The transcribing system transcribes the data from the HDTs onto DLTs.

The data processing work station performs all radiometric and geometric corrections on the ingested data.

The output and quality control work station checks all the generated products and then the data is transferred onto desired output media for digital products and to the Photo Compatible Tapes (PCTs) to be sent to filming work centre, for generation of photographic products.

Scheduling strategy for DPS chain - 1 & 2

Request queing by IIMS to DPS chain 1 and 2 is done through IIMS work order file whenever DPS chain scheduler is initiated.

Functions of scheduler :
* Normal request queueing :
- system capability to generate specific product.
- HDT dependancy.
- Priority.
- Merging of multiple products of same scene.
- Batching of multiple media products for same scene.

* Priority request queueing :
- Out-of-turn assignment for urgent products.
- Queing based on completion or operator request.
- Swath model on DPS chain 1 and 2 and GCP updation on DQE system.

3.4.3.2 Special Products Generation System

In order to meet the demand from users for the supply of non-standard/special products, a dedicated system with image analysis software is established. This system will be used to generate mosaic products, PAN +LISS-III merged products, portion extractions and enhanced products.

3.4.3.3 STEREO AND ORTHO PRODUCTS GENERATION FACILITY

The following products will be generated at this facility :

1. Orthoimages

   i. PAN Orthoimages on 1:25,000 scale for an area corresponding to 7.5' X 7.5', for which stereo data and corresponding scanned map or atleast four GCPs are available.

   ii. LISS-III Orthoimages on 1:50,000 scale for mapsheet area of 15' X 15' for which DEM is made available by the user.

2. Basic stereo pairs

The functional diagram of the system is shown in Figure 3.4.3.3.

3.4.3.4 Ground Control Points Library

Ground Control Points (GCPs), are points which are precisely identifiable in the geometrically uncorrected image data as well as on ground, or equivalently, on a large scale topographic map. GCPs are used for performing or evaluating the geometric corrections applied to the data.

To facilitate operational generation of highly precise geometrically corrected data products for IRS-1C/1D, a digital library of Ground Control Points is being built. The GCP library mainly consists of the following two data sets:

i. Ground co-ordinates of GCPs and

ii. Space images for digital GCP chip extraction and digital/manual GCP identification.

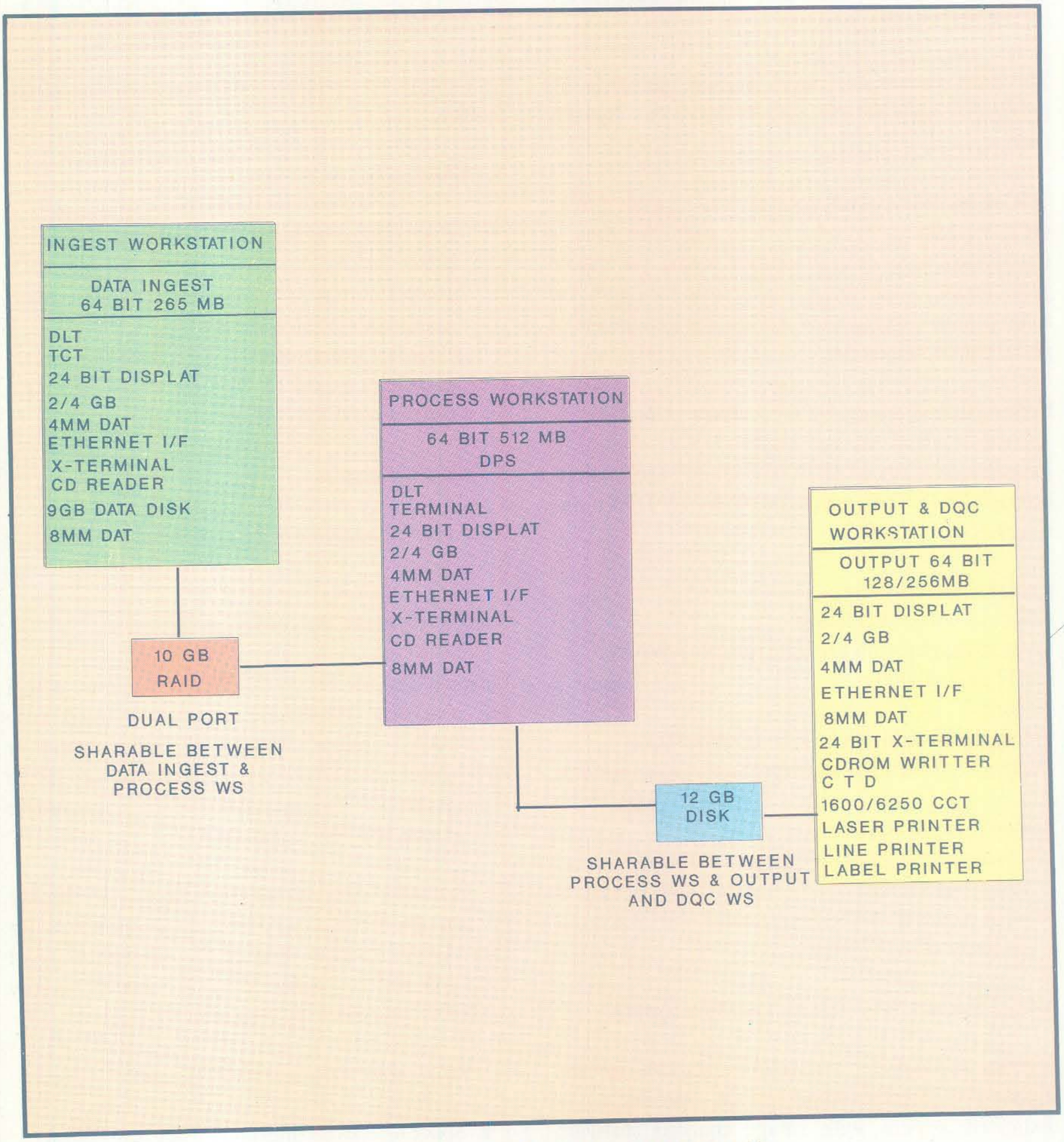


Figure 3.4.3.1 Configuration of DPS chain

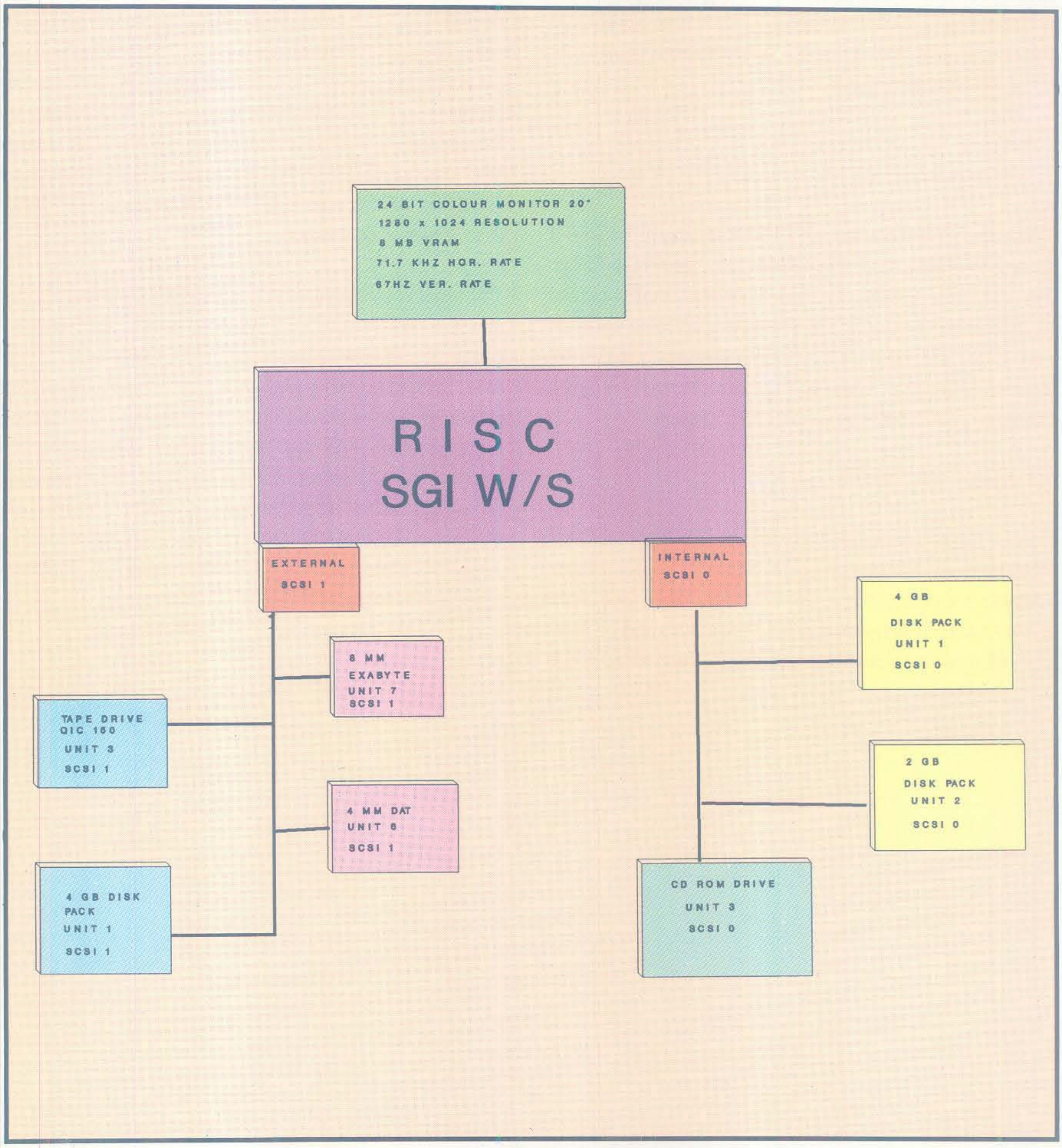


Figure 3.4.3.3 Functional diagram of Stereo and Ortho products generation system

The basic library generation is done at SAC, in collaboration with Survey of India, for finding GCP ground co-ordinates, and then installed at NRSA for operational use. The ground co-ordinates are found using any one of the following methods.

* From 1:25,000 toposheets,
* using GPS receivers.

The library contains around 1500 GCPs for LISS-III sensor covering the Indian landmass, generated from IRS-1B LISS-II data. In order to operationally use the GCP library, the digital GCP chips need to be updated with IRS-1C LISS-III/PAN data, covering different seasons of the year. This GCP updation activity is being carried out at NRSA at GCP/DQE system.

3.4.3.5 Swath Model

Conventional geometric correction methods model only the systematic errors, giving ground location accuracies of data products of the order of kilometer or two, for a scene. For the correction of random errors and generation of highly precise data products, individual scene based GCPs are traditionally used.

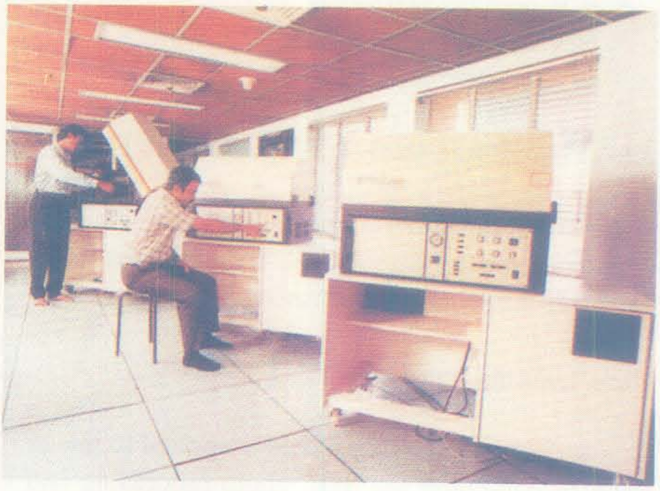
For IRS-1C/1D, to operationally realise a highly precise geometric correction, a pass processing method, called 'Swath Model', is adopted which uses only a few precise GCPs spread over each pass. Modelling the pseudo-navigational or platform parameters, using a few precise GCPs over the entire pass (or multiple scene segments), will result in location accuracies better than 200m in any scene.

The basic requirement for swath modelling is the availability of a GCP library, with accuracies commensurate with the resolution of IRS-1C/1D sensors. Swath modelling is a direct extension of precision processing scheme over multiple scenes. The knowledge of precise image and ground positions, of a number of well distributed GCPs over a payload pass, is being used as observations to model the low and middle order frequency components of orbit and attitude errors respectively, over a time period of interest (approximately 15 minutes).

3.5 FILMING SYSTEM

The filming system is a centralised facility for generating B/W and color master film products for all satellites/sensors. The Filming system is equipped with B/W and Color FIRE-240 recorders for exposing 10" X 10" films. A Large Format Film Recorder is also available for exposing B/W films, B/W photographic paper and Color films of 40" X 40" size. These systems use Photo Compatible Tapes (PCT) generated by Data Processing Systems, for master film/paper product generation.

At filming system, film CCTs alongwith the IIMS work order for film/photographic paper products, are received from DPS. A test target is filmed in each batch of the film, to verify the performance of the Film Recorder. Films are generated as per priority in IIMS work order. After updating IIMS work order, the exposed film is sent to photolab for processing. Before filming, the image is seen on the display. This operation considerably reduces the chances of rejection of the film. The films rejected by Quality Control, due to filming reasons are refilmed in subsequent batches and sent for photo processing.



Film Recorder

Configuration of the Filming System is given in Figure 3.5.1.

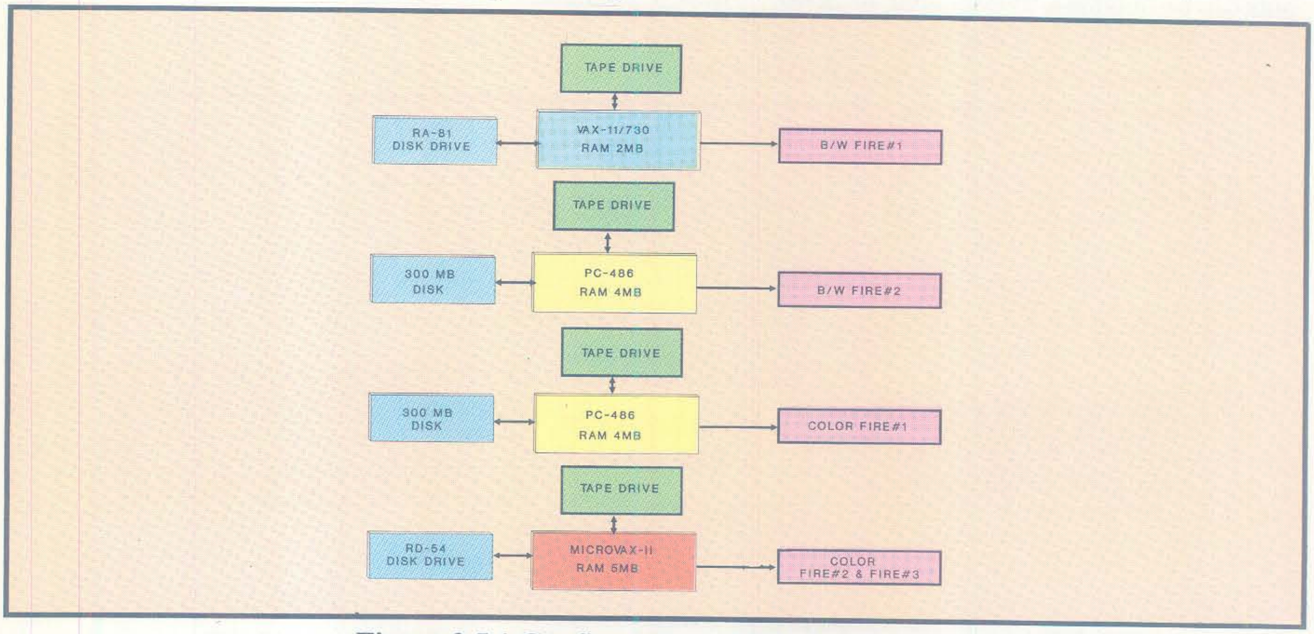


Figure 3.5.1 Configuration of Filming System

The various types of films/prints generated at the Filming System are :

* B/W negative film (10" X 10")
* FCC negative film (10" X 10")
* B/W negative film (40" X 40")
* FCC negative film.(40" X 40")
* B/W positive paper (40" X 40")

3.5.1 FILMING LOOK-UP-TABLE (LUT)

A LUT is applied to the image data to correct film, photo processing and photowrite non-linearities. Look Up Table is also used for enhancement of image data.

Film Gamma correction LUT

Linear Gamma Look Up Table is applied to image data for correcting the film, photo processing and Photowrite non-linearities (Figure 3.5.1.1).

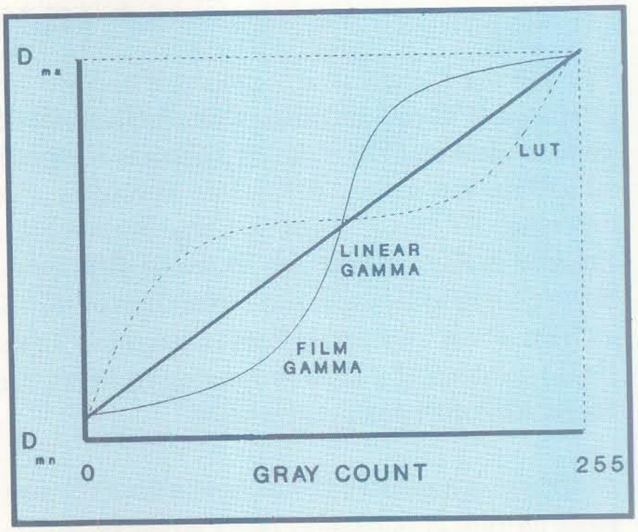


Figure 3.5.1.1 Film gamma correction

3.5.2 LARGE FORMAT PHOTOWRITE SYSTEM

In Large Format Photowrite System, large scale outputs can be obtained, by exposing 40" x 40" B/W film or B/W paper or Color negative films. In conventional reproductions, due to the diffusion effect, the minor details are lost giving a rise to poor Moduler Transfer Function. In digital photowrite systems, higher MTF is obtained, due to the inherent features built in the system. In digital image generation, as each pixel is exposed separately, higher MTF is achieved. Look-Up Tables are used for correcting film and processing characteristics and photowrite non-linearities. The configuration of the system is given in Figure 3.5.2.1.

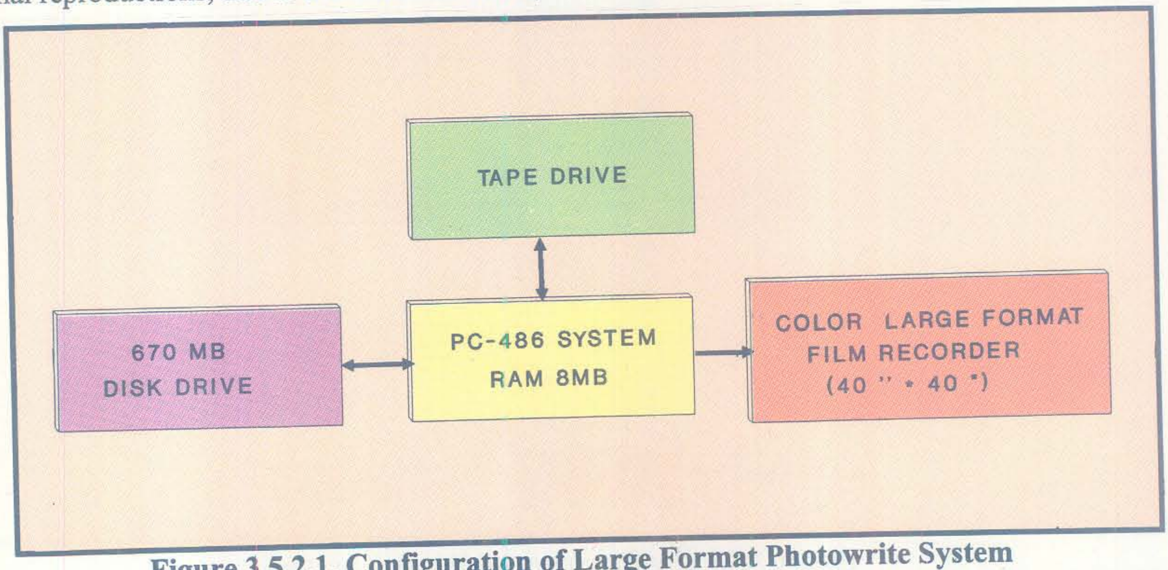


Figure 3.5.2.1. Configuration of Large Format Photowrite System

The various types of films/prints generated at the Filming System are :

* B/W negative film (10" X 10")
* FCC negative film (10" X 10")
* B/W negative film (40" X 40")
* FCC negative film (40" X 40")
* B/W positive paper (40" X 40")

3.5.1 FILMING LOOK-UP-TABLE (LUT)

A LUT is applied to the image data to correct film, photo processing and photowrite non-linearities. Look Up Table is also used for enhancement of image data.

Film Gamma correction LUT

Linear Gamma Look Up Table is applied to image data for correcting the film, photo processing and Photowrite non-linearities (Figure 3.5.1.1).

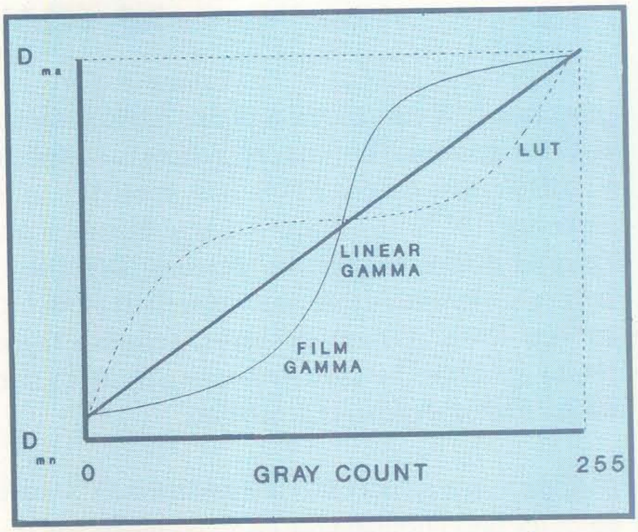


Figure 3.5.1.1 Film gamma correction

3.5.2 LARGE FORMAT PHOTOWRITE SYSTEM

In Large Format Photowrite System, large scale outputs can be obtained, by exposing 40" x 40" B/W film or B/W paper or Color negative films. In conventional reproductions, due to the diffusion effect, the minor details are lost giving a rise to poor Moduler Transfer Function. In digital photowrite systems, higher MTF is obtained, due to the inherent features built in the system. In digital image generation, as each pixel is exposed separately, higher MTF is achieved. Look-Up Tables are used for correcting film and processing characteristics and photowrite non-linearities. The configuration of the system is given in Figure 3.5.2.1.

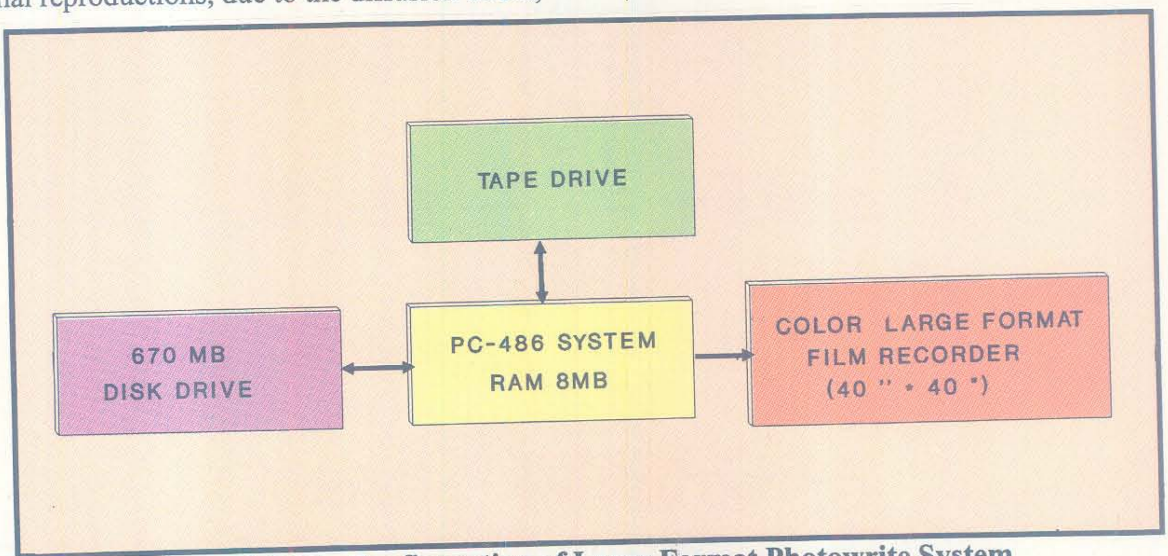


Figure 3.5.2.1. Configuration of Large Format Photowrite System

3.6 PHOTO PRODUCTS GENERATION SYSTEM

Photo Processing Laboratory is responsible for master film processing and generation of all B/W and Color photo products, in the form of film transparencies and paper prints. It is equipped with modern photo processing and duplicating systems. The facility is tailor made to meet the stringent quality requirements of photoproducts, as required by users. It consists of:

* Master film processing systems
* Photo Printers and Enlargers
* Duplicate products processing systems

In the photo processing system, the exposed film is processed and the master image is sent for quality check, at quality control. The products which qualify the quality criteria are routed to Photolab. Photolab takes the work order from IIMS, draws the required master from film archives and returns the same after the product is generated. The final products are sent for quality check, to quality control work centre. Photo Processing system has a number of "In-Process Control" checks, to ensure quality of outputs. For this purpose, sophisticated Sensitometric and Analytical tools are available. The functions of various photographic systems are given in Table 3.6.1.

Figure.3.6.1 and 3.6.2 show the Photo Processing work flow of various data products.

Name of the System	Functions
Versamat film processor-I	240mm B/W master film processing
Hostert C-41 film processor	240mm Colour master film processing
LF Colenta C-41 film processor	Large format Colour film processing
LF Colex B/W film processor	Large format B/W film processing
HK contact printer-I/II	B/W and Colour duplicate film generation
HK contact printer - III/I	B/W 1X print generation
HK 677/877 AF enlarger	B/W 2X,3X,3.6X,4X,5X enlargement
Hostert/Colenta B/W paper processor	B/W 1X, 2X, 3X, 3.6X, 4X & 5X print processing
HK Contact printer - II/III	Colour 1X print and duplicate film generation
Durst 2000/2501 AF enlarger	Colour 2X,3.6X,4X,5X enlargement
Kreonite RA-4 color paper processor	Colour 1X, 2X,, 3.6X, 4X & 5X print processing
LF Contact printer/LFColex B/W film Processor	Large format B/W duplicate film generation
LF Contact printer/Hostert B/W paper processor	Large format B/W contact print generation
LF Contact printer/Colenta C-41 film processor	Large format colour duplicate film generation
LF Contact printer/Colour paper processor	Large format colour contact print generation

Table-3.6.1 Functions of various photographic processors

Photographic products processing systems

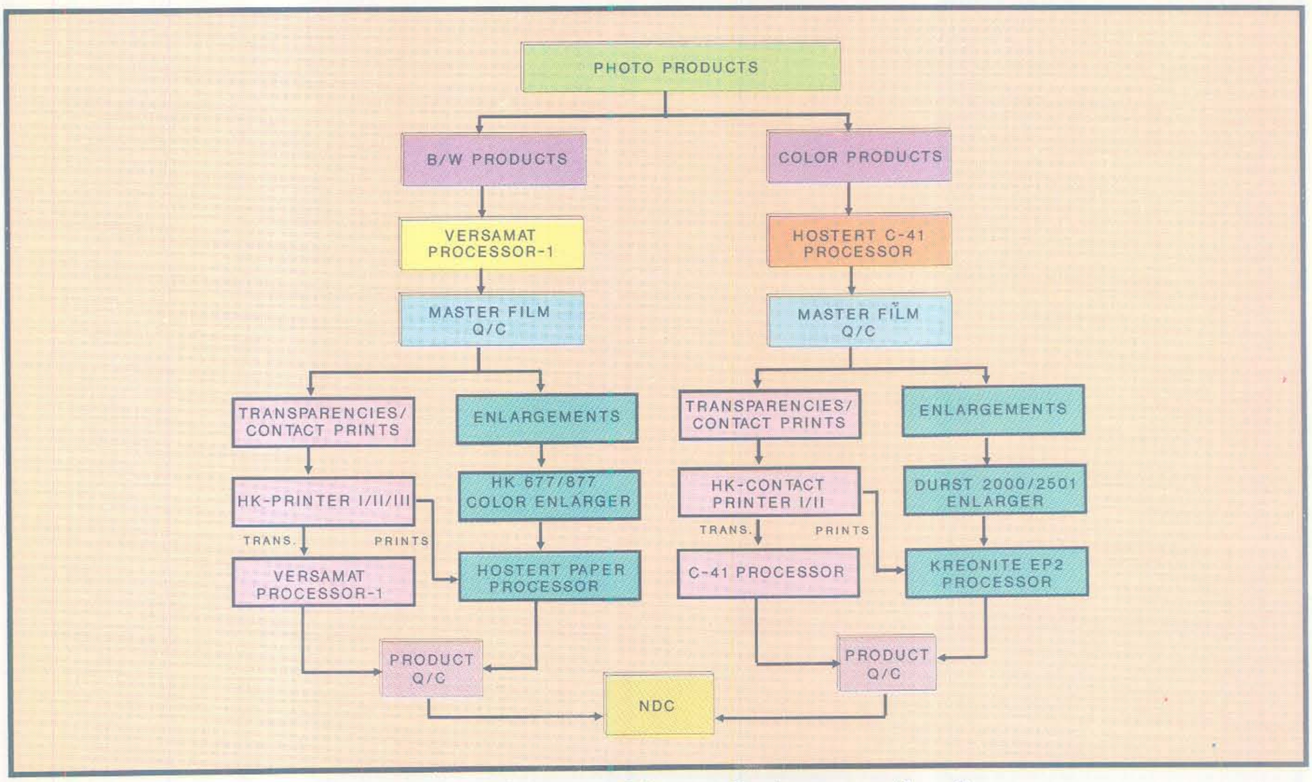


Figure 3.6.1 Photographic products generation flow

Photographic products processing systems

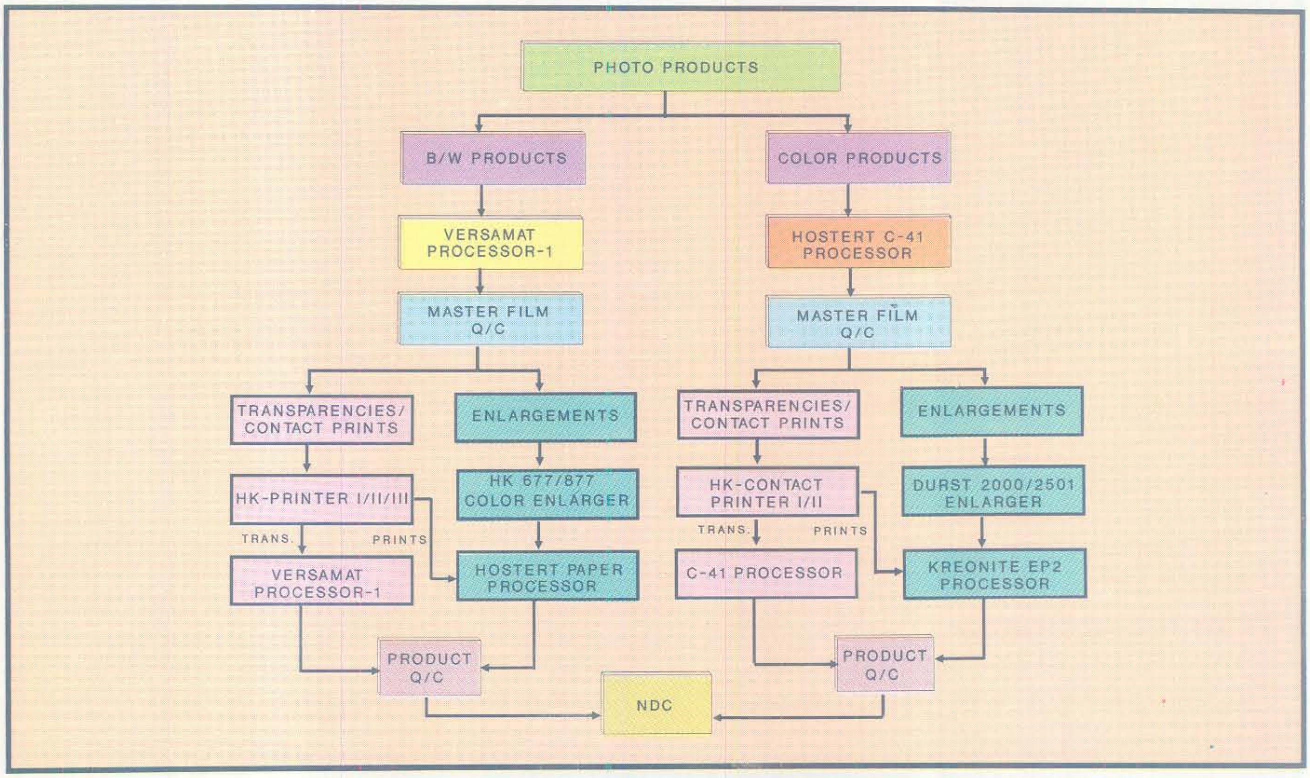


Figure 3.6.1 Photographic products generation flow

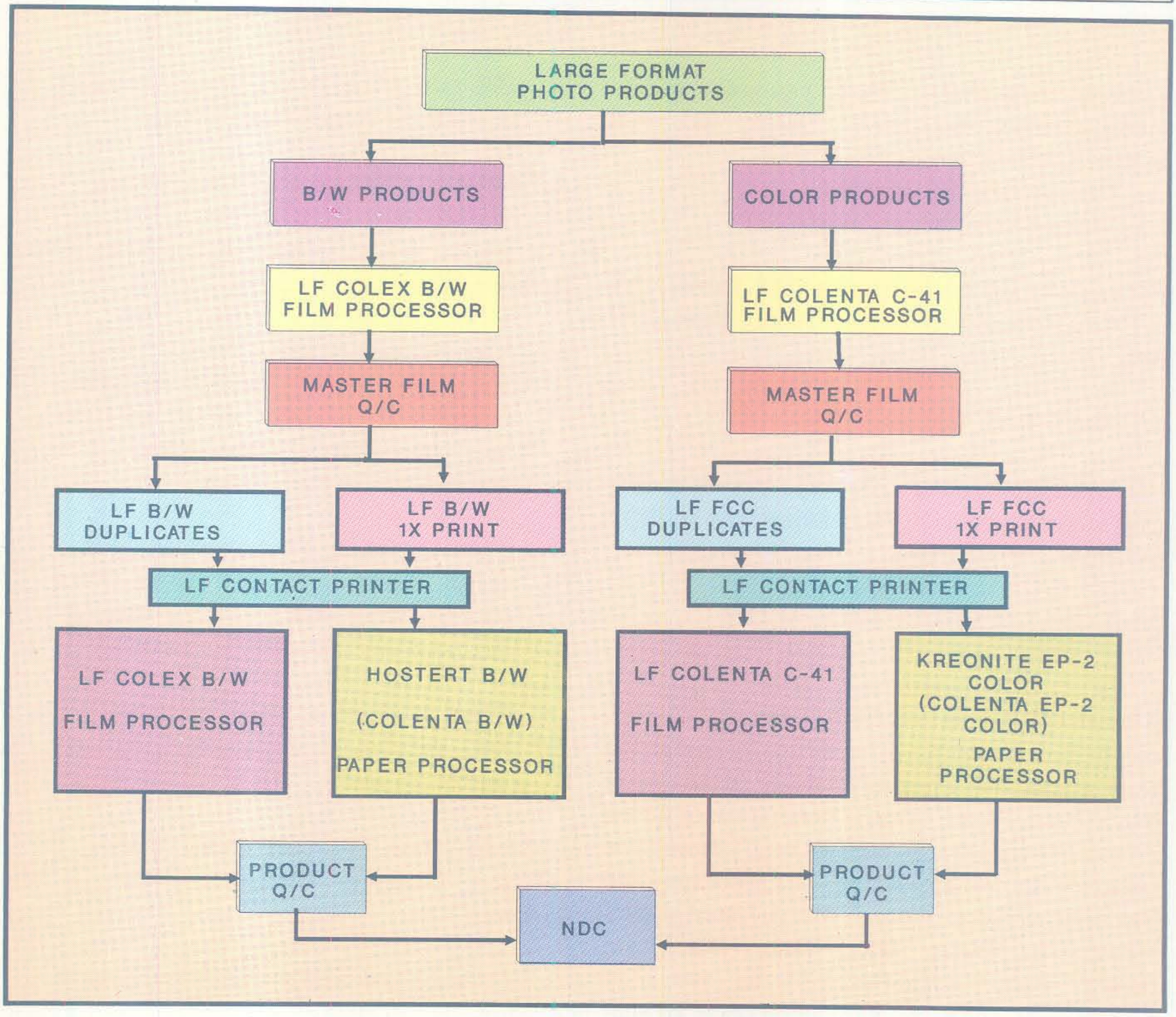


Figure 3.6.2 Large format photographic products generation flow

3.7 QUALITY ASSURANCE

Efforts are made to ensure that only good quality data products are sent to the users. The Quality Assurance System (QAS) consists of :

i. Raw data quality verification
ii. Data product Quality Control (QC)

Figures 3.7.1 and 3.7.2 depict the QAS. Tables 3.7.1 to 3.7.3 give the specifications of various photo products.

3.7.1 RAW DATA QUALITY

All the acquired data are checked for scene quality using automatic methods. This information is available in the accession catalouge.

3.7.2 DATA PRODUCTS QUALITY CONTROL

All production centres have inbuilt In Process Control, by which all the equipment identified for production work are certified for quality outputs. In the case of digital products, PC based systems are used for the inspection of data. For photoproducts, the masters are inspected for data acquisition, data processing and filming/photoprocessing problems. Accepted masters are kept in Master Film Archives (MFA) for further photo reproductions as per user requirements. The duplicate photoproducts, are subjected to final QC inspection for photo duplication quality. The masters will be checked against the specifications (Table 3.7.2), and certified accordingly.

.3.7.3 GENERAL CRITERIA

i. Product should be free from severe vertical striping.
ii. Data loss should not exceed one scan line
iii. Scattered Pixel dropouts should not affect more than 5% of the total image area.
iv. There should not be any image distortions affecting the continuity of data.

3.7.4 PHOTO PRODUCTS CRITERIA

All photo products should conform to the following criteria :

i. Film Recorder problems such as microbanding, seating problem, recorder lines, fog, scratches etc., should not affect the interpretability of the image and aesthetic quality of the image.

ii. Photo Processing defects such as roller marks, scratches, fog, dust, finger prints, inks etc., should not affect the interpretability and aesthetic quality of the image.

iii. There should be sufficient image contrast so that the photographic duplicate can be interpreted easily.

3.7.5 DIGITAL PRODUCT CRITERIA

Digital products should conform to the following :

i. Should be free from severe vertical striping.

ii. Data loss should not exceed one scan line.

iii. Scatterred pixel dropouts should not affect more than 5% of the total image area

iv. Digital products should be free from physical damages and be readable in a system other than the one available in production unit.

v. Digital product should conform to NRSA digital product format document.

Quality control facility

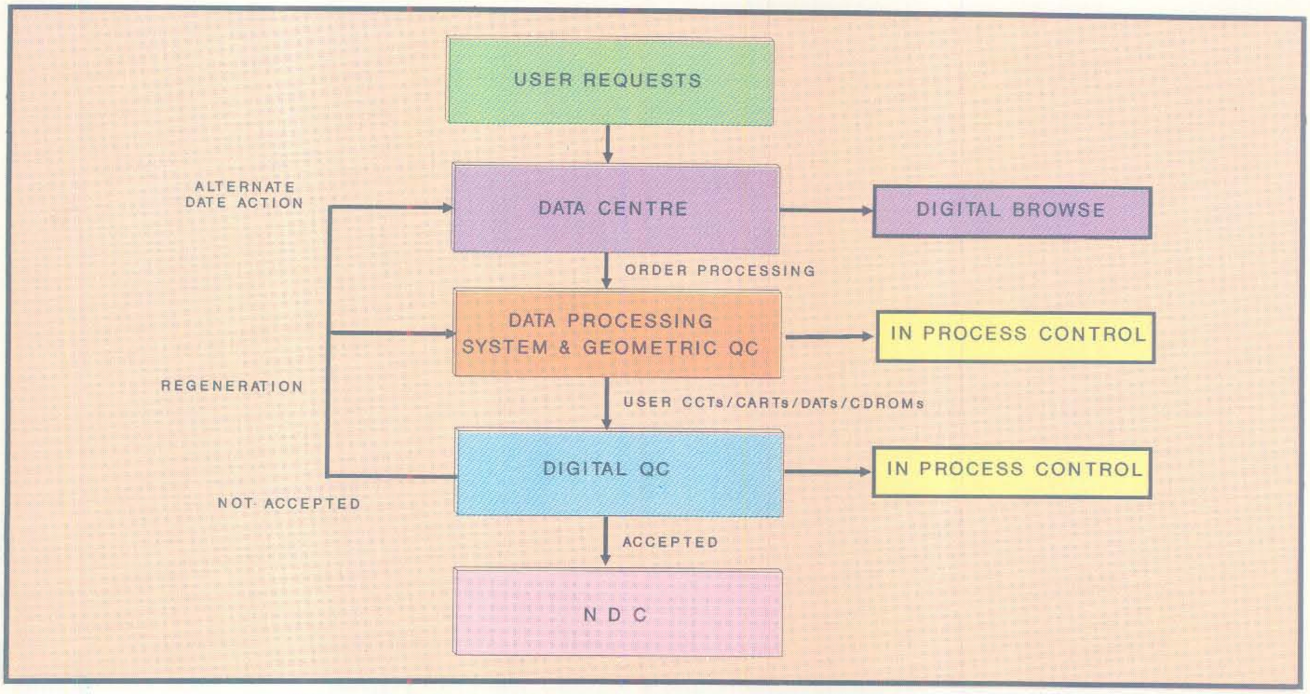


Figure 3.7.1 Quality control scheme for digital products

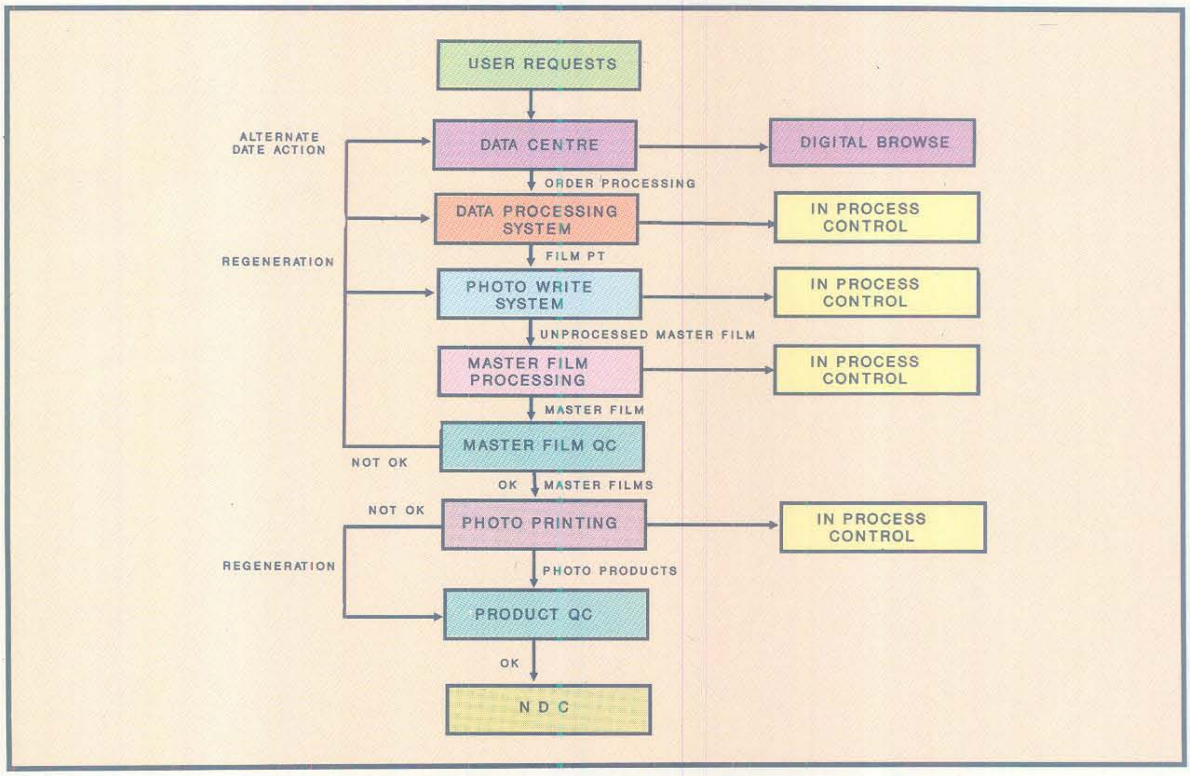


Figure 3.7.2 Quality control scheme for photoproducts

PARAMETER	B/W	FCC
Dmax (without Base+Fog)	1.75 ± 0.10	0.90 ± 0.10
Dmin	≤ 0.15	0.25 R 0.65 G 0.85 B
Colour balance (without Base+Fog)	—	≤ 0.07D at 0.60D above B + F
Linearity at G scale	≤ 6% at Dmax	≤ 8% at Dmax
Density Uniformity (with Base+Fog)	≤ 0.1D at around 1.0	≤ 0.10 at 0.6D
Modular Transfer Function	≥ 60% for 17 cycles/mm	≥ 40% at 17 cycles/mm
Physical dimension	≤ 0.1%	≤ 0.1%
Registration	—	half pixel

Table 3.7.1 Specifications of Photomaster

PARAMETER	B/W	FCC
Dmax	1.75 ± 0.10	≥ 2.65
Dmin	≤ 0.15	≤ 0.20
Colour balance	---	≤ 0.1D at 1.0D above B + F
Denisty uniformity	≤ 0.08 at 0.8D above B + F	≤ 0.05 at 0.6D above Dmin
Modular Transfer Function	≥ 60% for 17 cycles/mm	≥ 65% at 17 cycles/mm
Physical dimension	≤ 0.1%	≤ 0.1%
Registration	—	half pixel

Table 3.7.2 Specifications of phototransparencies

PARAMETER	B/W	FCC
Dynamic Range	1.60 ± 0.10	2.5 ± 0.2
Dmin.	≤ 0.15	≤ 0.20
Colour balance	—	≤ 0.1D at 1.0D above B + F
Density uniformity	≤ 0.15 at 0.8D above B + F	—
Physical Dimension	≤ 0.15%	≤ 0.15%

Table 3.7.3 Specifications of photoprints

However, considering the volume of data products generated, it is possible that a defective product may be supplied to the user. In such cases, the products may be returned to NDC for replacement, free of cost. It should however be noted, that, the quality of reproduced product, can never exceed the quality of the master reproducible in the archives.

3.7.6 DATA QUALITY EVALUATION (DQE)

The primary function of DQE is to monitor the performance of the sensors and the stability of the platform. DQE can be broadly classified into

i. Radiometric DQE
ii. Geometric DQE

3.7.6.1 Radiometric DQE

The performance of the sensors are continuously monitored by Radiometric Data Quality Evaluation (RDQE). RDQE can be evaluated in two ways. i.e.,

i. Calibration Analysis
ii. Scene Related Analysis

Calibration Analysis

The facility for inflight calibration is available for PAN and LISS-III as described in section 2.3.3.

The calibration data is obtained from the satellite during night pass, once in each cycle. This on-board calibration data will be compared with ground reference data. The parameters used in evaluation are:

i. Standard error between the on-board calibration data and ground reference data
ii. Temporal error between two successive on-board calibration data
iii. Dark current levels
iv. LED status

Scene Related Analysis

Spectral response of the sensor is evaluated by comparing spectral signature of various known terrains viz., desert sand, river sand, vegetation, water, barren land, urban area and snow at different sun elevation angles. Scene related evaluation is carried out once in each cycle using browse level digital data.

3.7.6.2 Geometric DQE

Geometric Data Quality Evaluation (GDQE) is done to know the following :

- Location accuracy of data products
- Band to band misregistration
- Internal distortions in a scene

These will be done using, ADIF information and GDQE of acquired scenes.

3.8 ARCHIVES

The Archives work centre is responsible for receiving and archiving HDTs/DLTs and Photographic master films. The HDTs/DLTs and master films are issued to a work centre on request and are replaced on completion of the job.

In the initial phase of IRS-1D operations, both HDTs/DLTs are planned to be archived. After stabilisation of transition from HDTs to DLTs, only DLTs will be archived.

The functions of HDTs/DLTs and Photo master archives are described below:

HDT/DLT Archives

- Receipt of HDTs/DLTs from Shadnagar
- Archival of HDTs/DLTs in sequential order, maintaining proper environment
- Issuing the required HDTs/DLTs to DPS
- Replacing HDTs/DLTs received back from DPS
- Cleaning the HDTs periodically
- Periodic cleaning and evaluation of CCTs.

Photo Master Archives

- Archival of photo master films of different satellites
- Maintenance of proper environment
- Issuing the masters on Photolab request
- Replacing masters received back from Photolab
- Deletion of degraded masters.

3.9 INTEGRATED INFORMATION MANAGEMENT SYSTEM (IIMS)

IIMS is an endeavour in the direction of automation when manual methods are highly difficult to handle large amount of acquired data, different types of data products from various satellites and stringent turn-around-time requirements.

IIMS is a co-ordinated system, that handles the entire sequence of operations, right from the moment an order is received, till the product is despatched. IIMS manages the accession information of various satellites, automates all the functions of user order/request processing, user accounting, monitoring, archival, costing and billing of the data products.

IIMS system is built around DEC-Alpha 3000 model 600S, having 2MB Cache and 96MB main memory with 5GB disk space. The operating system is VMS-AXP and the data base software is DEC RDB. Configuration of the IIMS system is given in Figure 3.9.1

The main functions of IIMS are :

* Management of the acquired data
* Generation of accession catalogue
* Proforma processing
* User order/Request processing
* Priority of data products generation
* User Account/Billing management
* Various reports for monitoring the production status of the products
* Dynamic scheduling of data requests to a system
* Work-orders for various work center
* Updation functions for each work center
* HDT/CCT/Film Archives Management
* Production Management
* Accounting in Indian and Foreign currency
* Statistics on data usage by users etc.,.

In addition to the above functions, the following functions are included for IRS-1C/1D :

* Interfacing with Swath Modelling operations
* Pass Programming operations

The system handles different products like

* CCT (6250 bpi)
* 8mm Exabyte tape
* CD-ROM
* Cartridge (525 MB)
* Transparency (Black and White, FCC)
* Paper Print (Black and White, FCC)

The various work centers involved in the production chain are :

* NRSA Data Centre
* Data Processing System Chain(s)
* Filming System
* Photo Processing Facility
* Photo Lab
* Quality Control
* Archives

The work centers involved in the production of different products are different. The data product generation involves several complex sequence of operations and the data product flow is based on the satellite, sensor, product type, format and media. All this is achieved through the efficient computerised IIMS.

Various queries regarding data availability, quality of the data available and area coverage for the user specified requests, are handled by NDC using the utilities provided by IIMS.

Integrated Information Management System facility

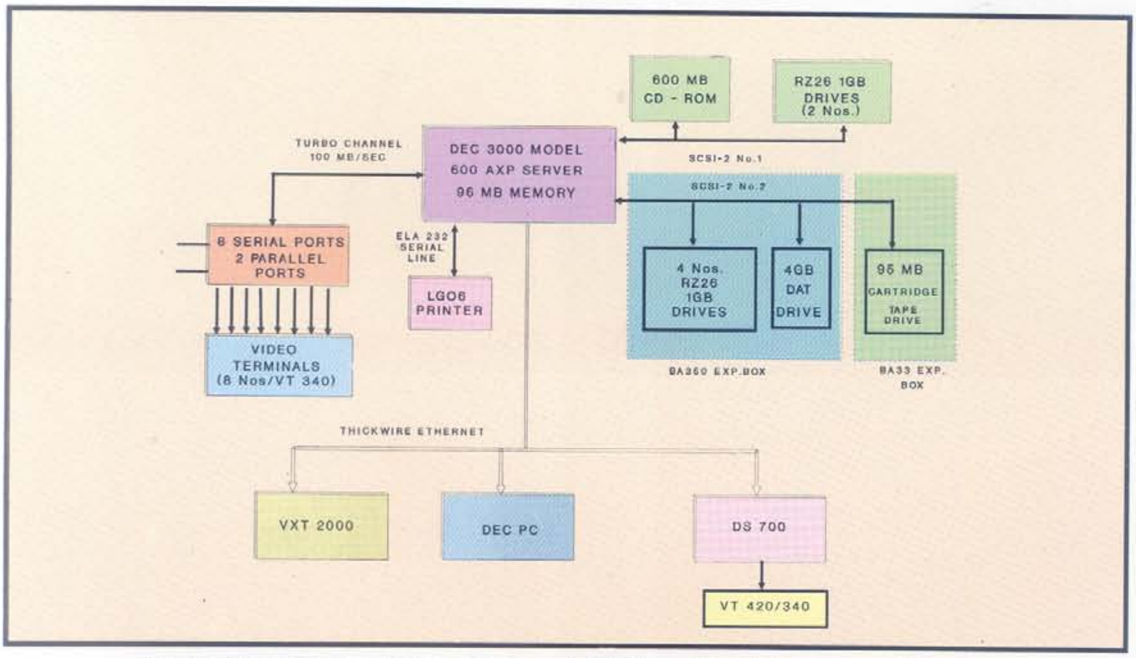


Figure 3.9.1 Configuration of Integrated Information Management System

4. DATA PRODUCTS

4.1 REFERENCING SCHEME AND DATA PRODUCTS

This Chapter describes the IRS-1D referencing scheme and the various types of data products, that will be made available to the users. The referencing scheme is discussed in Section 4.2. The various types of products that are generated at the DPS, are described in Section 4.3. These include the path-row based, shift-along-track, quadrant, geocoded and special products. The path-row based products are generated on the basis of the IRS-1D image referencing scheme and are available on both films/paper and digital media. The shift-along-track products are generated by sliding the standard scene along the track.

4.2. REFERENCING SCHEME

4.2.1. DEFINITION

Referencing scheme, which is unique for each satellite mission, is a means of conveniently identifying the geographic location of areas on the earth. This scheme is designated by Path and Rows. The Path-Row concept is based on the nominal orbital characteristics. This section describes the referencing scheme and related information.

4.2.2. PATH

An orbit is the course of motion taken by the satellite in space and the descending ground trace of the orbit is called a 'Path'. In a 25 day cycle, the satellite completes 358 orbis with an orbital period of 100.559 minutes. This way, the satellite completes approximately 14 orbits per day.

Though the number of orbits and paths are the same, the designated path number in the referencing scheme and the orbit number are not the same. On day one (D1), the satellite covers orbit numbers 1 to 15, which as per the referencing scheme will be path numbers 176, 151, 126, 101, 76, 51, 26, 1, 334, 309, 284, 259, 234, 209 and 184, assuming that the cycle day one has Path 1. So orbit 1 corresponds to path 176, orbit 2 to path 159, orbit 3 to path 126, etc. The sixteenth orbit or first orbit of day two (D2), is path 159 which will be to the east of path 151 and is separated from path 151 by 8 paths.

4.2.3. ROW

Along a path, the continuous stream of data is segmented into a number of scenes of convenient size. While framing the scenes, the equator is taken as the reference line for segmentation. The scenes are framed in such a manner, that one of the scene's centre lies on the equator. For example, a LISS-III scene, consisting of 6,000 lines, is framed such that, the centre of the scene lies on the equator. The IRS-1D scene centre latitudes for LISS-III will be same as that of IRS-1C and each scene consists of 6,000 lines.

The lines joining the corresponding scene centres of different paths are parallel to the equator and are called Rows. The uniformly separated scene centres are, such that, same rows of different paths fall at the same latitude. The row number 1 falls around 81 degrees North latitude, row number 41 will be near 40 degrees North and row number of the scene lying on the equator is 75. The Indian station coverage extends from row numbers 40 to 82 and path numbers 70 to 126.

4.2.4. SCENE DEFINITION

The camera scans the ground track, line by line continuously. The satellite motion along the track provides continuous imaging of the ground. This continuous stream of data is segmented into convenient sizes. These segments are called scenes.

The camera system takes certain amount of time to read and register the CCD array data. This integration time is chosen prior to launch and is fixed throughout the mission. The integration time for each camera is so chosen, that, it is equivalent to the time taken by the satellite in nominal orbit, to traverse the scan line distance of the respective cameras. The across track width is limited by the swath of the respective cameras. Due to the line-by-line mode of scanning, the along track scan is a continuous strip and is divided into a number of uniform scenes.

Each line of the camera consists of fixed number of CCD elements, in the form of an array. The image obtained by one CCD element is a pixel. The pixel size on ground is equal to the resolution of the respective cameras. The across track length of the scan (swath) is determined by the pixel size and number of elements in a line. Each imaging sensor scans line by line during its integration time, which is fixed for each camera. Thus, each camera scans a fixed number of lines in fixed intervals of time. Therefore, the along track length of a scene is based on the number of lines in that scene.

4.2.5. USE OF REFERENCING SCHEME

The Path-Row referencing scheme eliminates the usage of latitude and longitudes and facilitates convenient and unique identification of a geographic location.

It is useful in preparing accession and product catalogues and reduces the complexity of data products generation.

Using the referencing scheme, the user can arrive at the number of scenes that covers his area of interest.

Due to orbit and attitude variations during operation, the actual scene may be displaced slightly from the nominal scene defined in the referencing scheme. Hence, if the user's area of interest lies in border region of any scene, the user may have to order the overlapping scenes in addition to the nominal scene.

4.2.6. IRS-1D REFERENCING SCHEME

The Referencing Scheme of IRS-1D is similar to IRS-1C, where LISS-III scene is taken as the reference.

The PAN scenes acquired with near nadir tilt, can be fitted into the LISS-III scene.

For identifying continious WiFS scenes, every fifth LISS-III scene can be chosen.

4.2.7. LISS-III REFERENCING SCHEME AND SCENE COVERAGE

The minimum swath of LISS-III is about 127 Kms. in visible and near infrared bands and 133 Kms. in Short Wave Infra-Red (SWIR) band. Since the swath of LISS-III in all the four bands is greater than the inter-orbit distance (111.94 Kms.), the sensor scans the entire globe once in every cycle, without gaps.

The referencing scheme of LISS-III consists of 358 paths numbered from West to East. Each path consists of 149 rows. Consecutive paths are covered with a separation of three days. If Path 2 is covered on day one, Path 1 will be covered on day four (Figure 4.2.7.1.).

Each LISS-III scene of visible and near infra-red bands covers a minimum area of 127 Kms. x 145 Kms. In the case of LISS-III SWIR band, the minimum area covered is about 133 Kms. x 145 Kms. The minimum side lap between two LISS-III (V, NIR) scenes is about 15.1 Kms. at the equator and for SWIR band it is about 21 Kms. The minimum overlap between successive scenes in a path is about 6 Kms. The SWIR band coverage in a LISS-III (V, NIR) scene is shown in Figure 4.2.7.2.

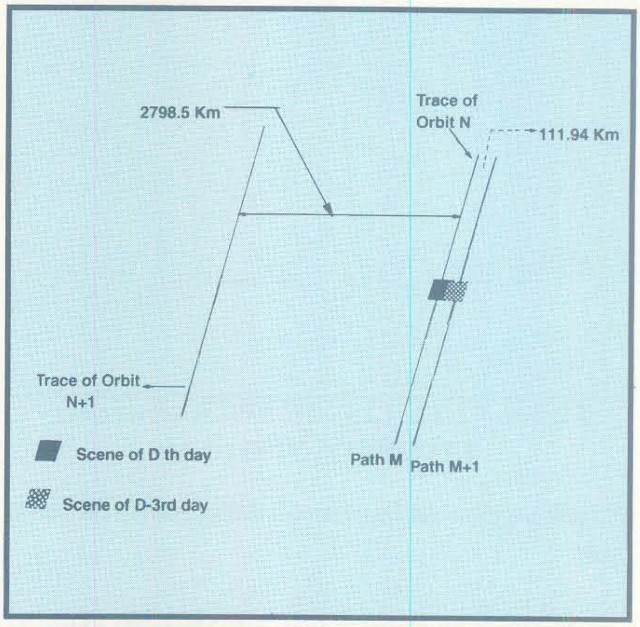


Figure 4.2.7.1. LISS-III coverage pattern

4.2.8. PAN REFERENCING SCHEME AND SCENE COVERAGE

As already mentioned in Chapter 3, the PAN camera consists of three CCD arrays. Each array in turn consists of four ports. The data from the sensor is formatted into two serial PCM streams, called I and Q. The data from the four ports of first CCD array and ports one and two of the second CCD array are multiplexed and formatted to form stream I. The data from the four ports of the third CCD array and ports three and four of the second array are multiplexed and formatted into the 'Q' stream. So I + Q streams put together form the PAN full scene. The minimum total swath of the three arrays of detectors put together is about 63 Kms., when viewed in the nadir mode. This leads to gaps because the distance between any two orbits (paths) is 111.94 Kms. Provision has been made to steer the camera ± 26 degrees. By tilting the camera, entire globe can be covered, though not in the same cycle.

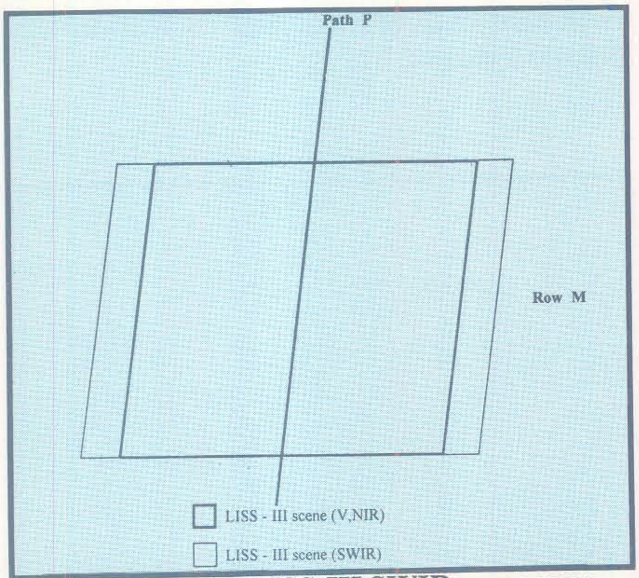


Figure 4.2.7.2. LISS-III SWIR scene over LISS-III (V, NIR) scene

The referencing scheme of PAN has been evolved around the LISS-III scene centre. Further, each LISS-III scene can accommodate four PAN full scenes designated as A, B, C and D. The PAN scenes will be referred to by the same path and row numbers as that of LISS-III along with the suffixes A, B, C and D (Figure 4.2.8.1.). It is to be noted that this layout for PAN is chosen for referencing scheme only. The side lap between A & B and C & D is assumed to be 1 Km. It is possible to process the data CCD array wise.

This has lead to the concept of PAN subscenes as in the case of IRS-1A/1B LISS-II. A PAN scene consists of nine subscenes and each is of minimum dimension of 21Km x 23Km.

The configuration of PAN camera is such that, inthe nadir view, the PAN scene center will fall in the ground trace of LISS-III as shown in Figure 4.2.8.2. It is evident that scene A & B are partially covered in the nadir, hence, in actual practice, because of the steerability, the data corresponding to scene A & C (or) B & D are acquired fully, by tilting the camera at an angle of ± 2.4 degrees approximately from nadir.

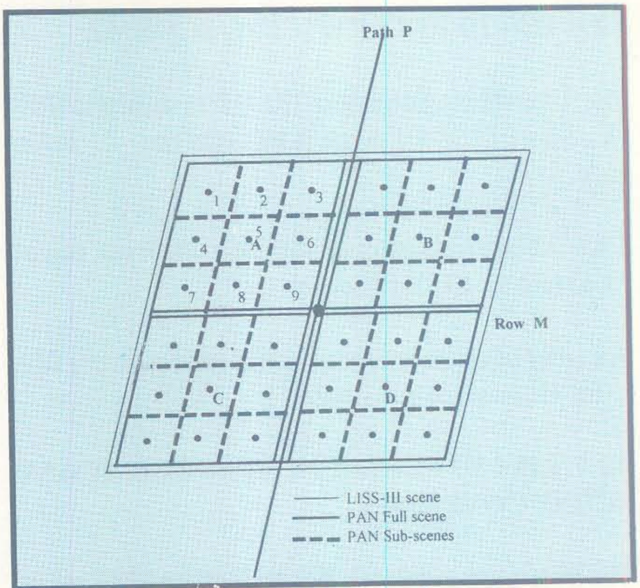


Figure 4.2.8.1. PAN subscenes

4.2.9. WiFS REFERENCING SCHEME AND SCENE COVERAGE

The WiFS referencing scheme is also based on LISS-III scene centre. Due to eccentricity of IRS-1D orbit the WiFS swath varies between 728 Kms. and 812 Kms. depending on the apsidal location at imaging time. However, due to large coverage of each WiFS scene (minimum 728 Kms. x 795 Kms.), there is an overlap of 83 % i. e., 620 Kms. between adjacent paths. Similarly, the overlap between adjacent rows is about 620 Kms. So, if a user requires continuous area, say, 1,200 Kms. x 1,200 Kms., it is enough if he orders for four WiFS scenes. The point to be noted here, is that, that user should order data pertaining to path P and path P $\pm$ 6 (which is covered with a gap of one week) and rows R and R + 5 of paths P and P $\pm$ 6,

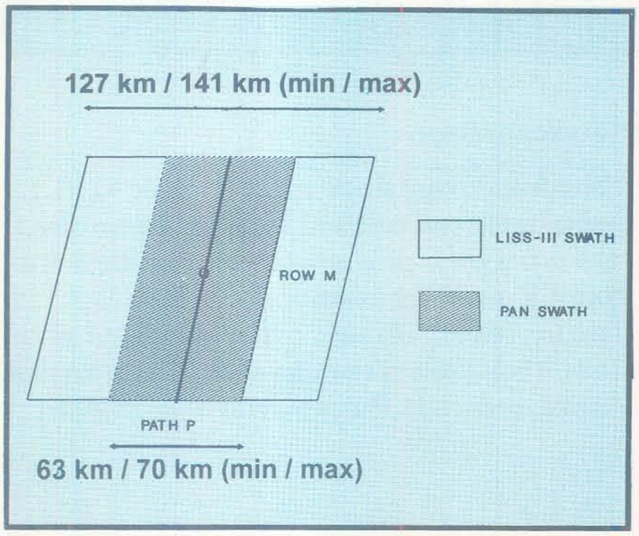


Figure 4.2.8.2. PAN scene (NADIR)

to cover his entire area. This way user gets data pertaining to his area within a week (Figure 4.2.9.1.).

The huge overlaps between the WiFS scenes of adjacent paths, results in repeated coverage of the same area in a given cycle.

A given scene can be covered completely on its day of pass and also by a combination of two scenes, acquired on different days, during the cycle.

Take again path P1 which is covered on day D1. The area pertaining to Path P1 can also be covered by the following combinations of paths, acquired on various days during the cycle.

Combination of Paths	Day of the cycle
P2-P354	23rd and 16th
P2-P355	23rd and 13th
P2-P356	23rd and 10th
P2-P357	23rd and 7th
P2-P358	23rd and 4th
P3-P355	20th and 13th
P3-P356	20th and 10th
P3-P357	20th and 7th
P3-P358	20th and 4th
P4-P356	17th and 10th
P4-P357	17th and 7th
P4-P358	17th and 4th

This is the case at the equator. Since at higher latitudes the overlap is more, the coverage is more frequent.

4.2.10. REFERENCING SCHEME MAPS

The reference map of IRS-1D is similar to IRS-1C. In addition to the reference maps, a software package called Integrated Digital Referencing Scheme (IDRS) is available with NDC which has a number of utilities like converting the path-rows of one satellite in terms of other, identifying the scene based on latitude/longitudes or mapsheet number, etc. This software can work on any PC, with Windows 3.1. The software can be provided to users, on a floppy, on request.

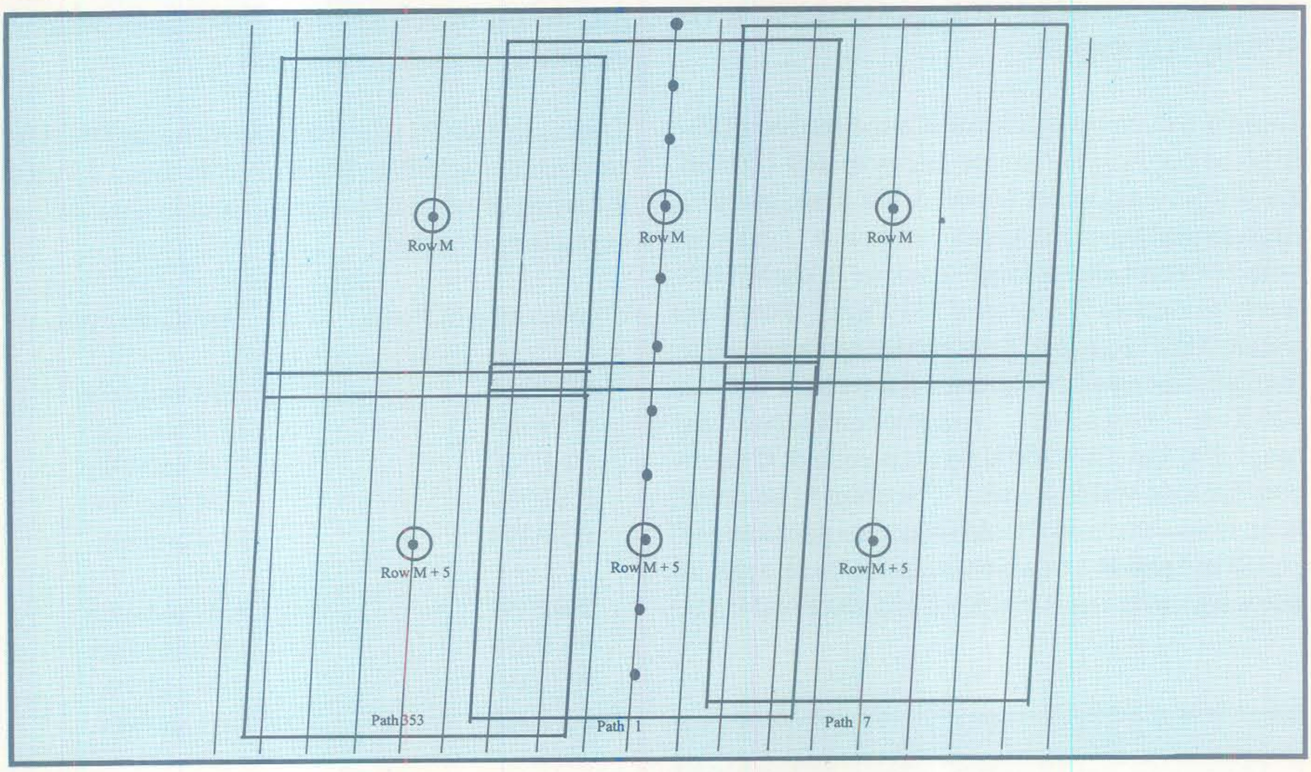


Figure 4.2.9.1. WiFS scene coverage

4.2.11. DETERMINATION OF OBSERVATION DATES

For the chosen path, the ground track repeats every 25 days, after 358 orbits. Therefore, the coverage pattern is almost constant.

The deviations of orbit and attitude parameters are controlled within limits such that the coverage pattern remains almost constant through out the mission. Therefore, on any given day, it is possible to determine the orbit which will trace a designated path. Once the path is known, with the help of referencing scheme, it is possible to find out the region covered by that path. Therefore, an orbital calendar, giving the details of paths, covered on different days, is helpful to users to plan their procurement of satellite data products.

Considering a typical path calendar (Table 4.2.11.1.), assuming that path number 23 starts on January first, if data over a geographic area covered by path 60 is required, it is seen that this path is covered on days, 15th January, 9th of February, 6th of March and so on. Thus, it is possible to know on which day the required data has been collected, or is going to be collected.

PATHS																									
	173	181	189	197	180	188	196	179	187	195	178	186	194	177	185	193	176	184	192	175	183	191	174	182	190
	148	156	164	172	155	163	171	154	162	170	153	161	169	152	160	168	151	159	167	150	158	166	149	157	165
	123	131	139	147	130	138	146	129	137	145	128	136	144	127	135	143	126	134	142	125	133	141	124	132	140
	98	106	114	122	105	113	121	104	112	120	103	111	119	102	110	118	101	109	117	100	108	116	99	107	115
	73	81	89	97	80	88	96	79	87	95	78	86	94	77	85	93	76	84	92	75	83	91	74	82	90
	48	56	64	72	55	63	71	54	62	70	53	61	69	52	60	68	51	59	67	50	58	66	49	57	65
	23	31	39	47	30	38	46	29	37	45	28	36	44	27	35	43	26	34	42	25	33	41	24	32	40
	356	6	14	22	5	13	21	4	12	20	3	11	19	2	10	18	1	9	17	358	8	16	357	7	15
	331	339	347	355	338	346	354	337	345	353	336	344	352	335	343	351	334	342	350	333	341	349	332	340	348
	306	314	322	330	313	321	329	312	320	328	311	319	327	310	318	326	309	317	325	308	316	324	307	315	323
	281	289	297	305	288	296	304	287	295	303	286	294	302	285	293	301	284	292	300	283	291	299	282	290	298
	256	264	272	280	263	271	279	262	270	278	261	269	277	260	268	276	259	267	275	258	266	274	257	265	273
	231	239	247	255	238	246	254	237	245	253	236	244	252	235	243	251	234	242	250	233	241	249	232	240	248
	206	214	222	230	213	221	229	212	220	228	211	219	227	210	218	226	209	217	225	208	216	224	207	215	223
				205			204			203			202			201			200			199			198
JAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	26	27	28	29	30	31																			
FEB							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	20	21	22	23	24	25	26	27	28																
MAR										1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31										
APR																1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30					
MAY																					1	2	3	4	5
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	31																								
JUN		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	25	26	27	28	29	30																			
JUL							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	20	21	22	23	24	25	26	27	28	29	30	31													
AUG													1	2	3	4	5	6	7	8	9	10	11	12	13
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31							
SEP																			1	2	3	4	5	6	7
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
OCT																								1	2
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	28	29	30	31																					
NOV					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	22	23	24	25	26	27	28	29	30																
DEC										1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31										

Table 4.2.11.1 IRS-1D Orbital calendar

4.2.12. ESTIMATION OF PATH AND ROW, LOCAL CLOCK TIME AND OTHER DETAILS FOR ANY POINT ON INDIAN SUB-CONTINENT

The procedure outlined below may be used to determine the path and row, Greenwich Meridian Time (GMT) and the local clock time when the satellite passes over any point in the Indian sub-continent.

i. Define the latitude and longitude of the point of interest over Indian region.

ii. Determine the approximate descending node as follows :

1. Locate the latitude of the point of interest in Table 4.2.12.1. Table 4.2.12.1. gives the longitudinal difference from the given longitude to the descending node longitude, as a function of latitude.

2. Read the value of longitude from this table. If the latitude falls within two values, then, interpolate and get required longitude.

3. Add this value to the longitude of the point of interest, to get rough estimate of descending node longitude.

iii. The actual descending node details are obtained as follows :

1. Table 4.2.12.2. gives the descending node longitude of all paths over Indian region. Find the path, nearest to the longitude computed in step ii. This gives the path number and descending node longitude of the path.

2. Table 4.2.12.3. gives the descending node time (GMT), expected for each path over Indian sub-continent.

iv. GMT at the point of interest is found as follows :

1. Given a latitude, using the nominal inclination of the orbit, the time from descending node can be calculated.

2. Add the time to the GMT of the descending node as obtained in step iii, by carefully noting the algebraic sign.

v. The Indian Standard Time (IST) is obtained by adding five and a half hours to the time (GMT) obtained in step iv.

vi. Table 4.2.12.1. gives the row numbers versus latitude. Find the nearest row latitude from this table and assign the same row number.

Thus, with the above procedure, the path and row numbers and other details of the point of interest can be obtained. The details presented in Tables 4.2.12.1. to 4.2.12.3. are typical.

4.2.13. FRAMING PROCEDURE AND SCENE CENTRE AND CORNER COORDINATES EVALUATION FOR THE REFERENCING SCHEME

Based on the reference orbit, ephemeris are generated for all the 358 orbits of one coverage cycle. From the ephemeris, all the details about the paths over the Indian sub-continent are extracted. These details are path number, descending node details etc. Descending nodal points of all the paths are the scene centres. The row numbers and corresponding latitudes are same as that of IRS-1C. The scene centres times are computed using ephemeris and row centre latitudes. Therefore, all the details of LISS-III scenes along the paths are obtained, taking descending nodal points as reference. While assigning thee row numbers, counting is done from

LATITUDE	ROW NO.	LONGITUDE	LATITUDE	ROW NO.	LONGITUDE
81.30	1	-84.54	42.79	39	-10.99
81.06	2	-78.59	41.61	40	-10.58
80.68	3	-72.11	40.43	41	-10.19
80.18	4	-65.92	39.25	42	-9.80
79.56	5	-60.28	38.07	43	-9.42
78.84	6	-55.28	36.89	44	-9.06
78.05	7	-50.80	35.71	45	-8.70
77.20	8	-46.90	34.53	46	-8.35
76.30	9	-43.47	33.34	47	-8.01
75.36	10	-40.45	32.16	48	-7.67
74.38	11	-37.78	30.97	49	-7.34
73.37	12	-35.40	29.79	50	-7.02
72.35	13	-33.29	28.60	51	-6.70
71.30	14	-31.39	27.41	52	-6.39
70.23	15	-29.67	26.22	53	-6.08
69.16	16	-28.12	25.04	54	-5.78
68.07	17	-26.71	23.85	55	-5.48
66.97	18	-25.41	22.66	56	-5.18
65.86	19	-24.23	21.47	57	-4.89
64.74	20	-23.13	20.28	58	-4.60
63.62	21	-22.11	19.09	59	-4.31
62.49	22	-21.16	17.89	60	-4.03
61.36	23	-20.28	16.70	61	-3.75
60.22	24	-19.45	15.51	62	-3.47
59.07	25	-18.67	14.32	63	-3.20
57.93	26	-17.94	13.13	64	-2.93
56.78	27	-17.25	11.93	65	-2.65
55.62	28	-16.59	10.74	66	-2.38
54.47	29	-15.97	9.55	67	-2.12
53.31	30	-15.37	8.35	68	-1.85
52.15	31	-14.80	7.16	69	-1.58
50.98	32	-14.26	5.97	70	-1.32
49.82	33	-13.74	4.77	71	-1.05
48.65	34	-13.24	3.58	72	-0.79
47.48	35	-12.76	2.39	73	-0.53
46.31	36	-12.29	1.19	74	-0.26
45.13	37	-11.84	0.00	75	0.00
43.96	38	-11.41			

Table 4.2.12.1 The difference in longitude of a given row latitude and descending time

Path	Longitude	Path	Longitude
65	39.621	101	75.822
66	40.626	102	76.827
67	41.632	103	77.833
68	42.637	104	78.838
69	43.643	105	79.844
70	44.649	106	80.850
71	45.654	107	81.855
72	46.660	108	82.861
73	47.665	109	83.866
74	48.671	110	84.872
75	49.676	111	85.878
76	50.682	112	86.883
77	51.688	113	87.889
78	52.693	114	88.894
79	53.699	115	89.900
80	54.704	116	90.906
81	55.710	117	91.911
82	56.716	118	92.917
83	57.721	119	93.922
84	58.727	120	94.928
85	59.732	121	95.933
86	60.738	122	96.939
87	61.744	123	97.945
88	62.749	124	98.950
89	63.755	125	99.956
90	64.760	126	100.961
91	65.766	127	101.967
92	66.771	128	102.973
93	67.777	129	103.978
94	68.783	130	104.984
95	69.788	131	105.989
96	70.794	132	106.995
97	71.799	133	108.000
98	72.805	134	109.006
99	73.811	135	110.012
100	74.816		

Table 4.2.12.2 Equatorial crossing longitude for various paths

Path	GMT	Path	GMT
65	7:52	100	5:31
66	7:47	101	5:27
67	7:43	102	5:23
68	7:39	103	5:19
69	7:35	104	5:15
70	7:31	105	5:11
71	7:27	106	5:07
72	7:23	107	5:03
73	7:19	108	4:59
74	7.15	109	4:55
75	7:11	110	4:51
76	7:07	111	4:46
77	7:03	112	4:42
78	6:59	113	4:38
79	6:55	114	4:34
80	6:51	115	4:30
81	6:47	116	4:26
82	6:43	117	4:22
83	6:39	118	4:18
84	6:27	119	4:14
85	6:23	120	4:10
86	6:19	121	4:06
87	6:15	122	4:02
88	6:11	123	3:58
89	6:07	124	3:54
90	6:03	125	3:50
91	5:59	126	3:46
92	5:55	127	3:42
93	5:51	128	3:38
94	5:47	129	3:34
95	5:43	130	3:30
96	5:39	131	3:26
97	5:35	132	3:22
98	5:31	133	3:18
99	5:27	134	3:14

Table 4.2.12.3 Equatorial crossing time (GMT) for various paths (descending node)
(Local time at node 10:30 hrs.)

northern most scene centre, on a path. The size of LISS-III scene is 6,000 pixels X 6,000 lines. Once scene cnetre time is known, by taking 3,000 lines above and below that point, the scene start and end timings can be obtained.

In this process, the along track overlap is automatically taken care and sidelap is given by ground track placings. Similarly, all the LISS-III scenes are sized along the track. By evaluating corner coordinates of each scene, the framing is completed. The details are provided in the next section.

Each LISS-III scene can contain four PAN scenes. From the scene definitions, it is possible to obtain the start and end timings of PAN scenes by knowing the LISS-III scene centre time. With respect to LISS-III scene centre, scene centres and corner points of other payloads in terms of lines and pixels can be established. Therefore, other payload scenes are easily framed. The layout of scenes are such that, the requirements of overlap and sidelap are taken care of.

PAN scenes will be in the A, B, C or D segments of a LISS-III scene, only when the tilt is about 2.4 degrees. However, whenever PAN is tilted by a large angle, the corresponding PAN scene centre times are computed using ephemeris and the actual PAN scene centre latitude obtained for the tilt.

4.2.14 ESTIMATION OF THE CENTRE AND CORNER COORDINATES OF LISS-III AND PAN SCENES :

From the ephemeris information, it is possible to compute geographical coordinates of the LISS-III scene centres which lie on the ground track. However, this is not the case with PAN scene centers as they lie on either side of the ground track. The time of occurence of any PAN scene center or any corner coordinate, is obtained by using the information, that the scanning is done line by line at an interval of integration time of the respective cameras. Taking LISS-III scene center as the origin, the coordinates of any point is established in terms of lines and pixels.

In figure 4.2.14.1, let a1 be a point on the ground track with coordinates (ϕ_1, λ_1). Let P be a corner point of a

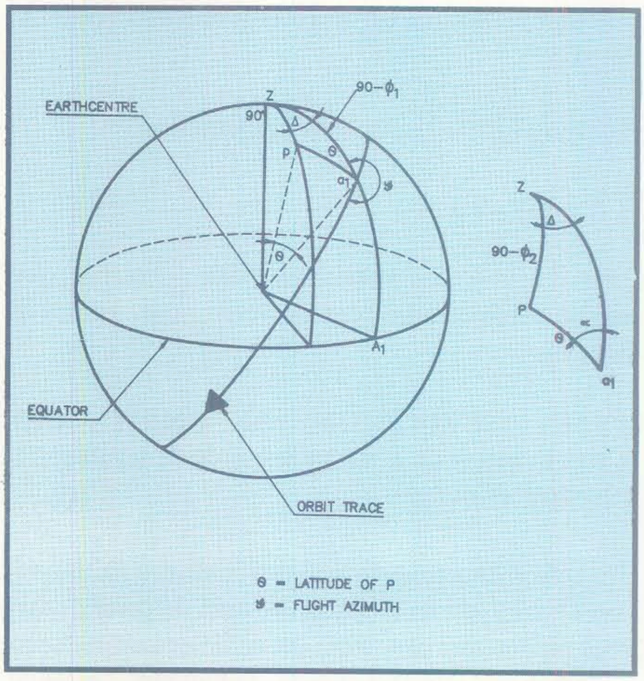


Figure 4.2.14.1 Calculations of co-ordinates of point P on the earth surface

scene. The coordinates of P, say, (ϕ_2, λ_2) can be calculated as follows.

$$\sin\phi_2 = \cos\theta \sin\phi_2 \pm \sin\theta \cos\phi_1 \cos\alpha \quad -(1)$$

Where $\alpha = 2\pi - \zeta \pm \pi/2$
and θ, ϕ_1, ϕ_2 and ζ are the angles as shown in Figure 4.2.14.1.

$$\cos\theta = \sin\phi_1 \sin\phi_2 \pm \cos\phi_1 \cos\phi_2 \cos\Delta \quad -(2)$$

Where Δ is longitudinal difference of λ_2 from λ_1 is the angle subtended by arc a1P (Fig. 4.2.6) at the centre of the Earth.

Using equation (2), the expression for 'Cos Δ' can be derived as

$$\mathrm{Cos}\Delta = \frac{\mathrm{Cos}\,\theta - \mathrm{Sin}\phi_1 \mathrm{Sin}\phi}{\mathrm{Cos}\phi_1 \ \mathrm{Cos}\phi_2} \qquad (3)$$

Appropriate sign is used to denote ' Δ ' depending on whether the point P (ϕ_2, λ_2) is east or west of point a_1 (ϕ_1, λ_1)

The longitude λ_2 is, therefore obtained as

$$\lambda_2 = \lambda_1 \pm \Delta \qquad (4)$$

Thus, the geographical coordinates of any required point can be obtained either for a corner or the centre of the scene.

4.2.15. DEVIATIONS OF ORBIT AND ATTITUDE PARAMETERS AND ITS EFFECT ON THE IMAGE

The referencing scheme has been generated for the reference orbit, under ideal conditions. In practice, orbital parameters vary from the reference orbit due to perturbations. Similarly, due to internal and external torques acting on the satellite, its attitude slowly drifts. Both orbit and attitude parameters are controlled within certain limits, by the attitude and orbit control system.

These perturbations cause the scenes to slightly deviate from the nominally predicted locations. It is, therefore, necessary for users to understand the deviations, to see how best they can use the successive images of a specific scene, for registering, overlaying and for comparison. In this section, a brief summary of the image deviations is given.

Orbit Perturbations :

In order to maintain the required coverage pattern and local time, it is essential that the defined sun-synchronous orbit be maintained throughout the operational life time of the satellite. Even after the launch vehicle injection errors are removed, the perturbations to the orbit, orbit determination and orbit adjust system uncertainties, cause deviations from the ideal sun-synchronous orbit. Hence, orbital parameters have to be controlled near to the ideal orbit within the tolerance specified. The main perturbations are due to atmospheric drag, asphericity of the Earth and to some extent by lunisolar gravitational attraction. Deviations caused by these are corrected by periodic orbit adjust operations. The effect of the deviations within the limits of these corrections are discussed in subsequent sections.

Atmospheric Drag :

Though the atmospheric density is small at an altitude of about 800 Kms., the effect of atmospheric drag cannot be neglected, as it causes gradual loss of altitude continuously, if the orbit decay is not controlled. Due to altitude decay, the time period of the orbit changes which affects the ground track pattern and therefore, coverage pattern. It is planned to control the ground track pattern within ± 8 Kms. w. r. t. the nominal pattern. This would be achieved by suitably controlling the altitude, within appropriate limits. Periodicity of altitude corrections depends on the decay rate.

Asphericity of the Earth :

Asphericity of the earth has two major effects, namely ;

i. Eccentricity varies in a sinusoidal fashion.

ii. Apsidal line, that is the line joining the perigee and apogee points in the orbit, rotates in the orbital plane. The period of this rotation for IRS-1D orbit is estimated to be around 122 days. The mean eccentricity of IRS-1D orbit over 150 days cycle is shown in figure 2.5.1. Due to the apsidal rotation the imaging from IRS-1D will be realised at different altitudes depending on the actual altitude at imaging time. Variation of altitude directly affects the swath resolution scene size, sidelap, overlap and also causes scale variations of the image (Figure 4.2.15.1.) for a given camera system.

Due to the eccentricity altitude variations over the Indian region would be within about 90 Kms. Equator is taken as the reference for framing the scenes, while

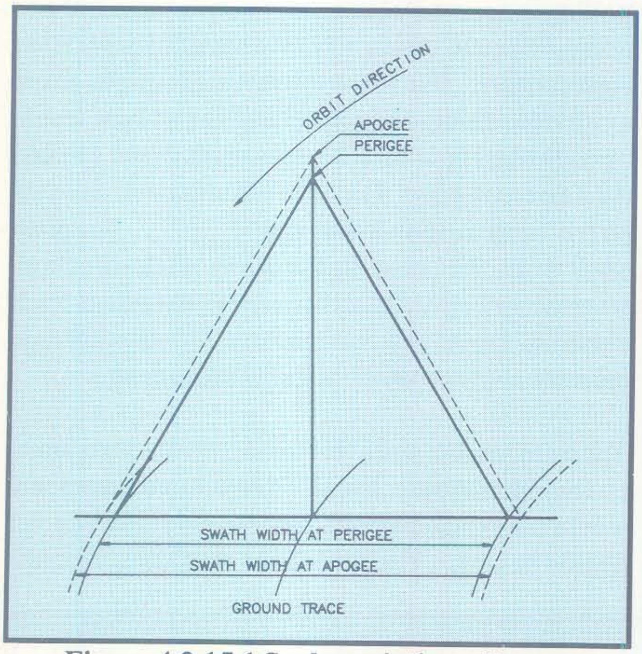


Figure 4.2.15.1 Scale variation of image with altitude

generating the referencing scheme. Equator is also being taken as reference during the actual operations and the descending node point is determined, based on the current ephemeris. Hence, the along track error due to eccentricity is negligible at this point. Taking this point as reference, the other LISS-III scene centres are marked on a given path, at cross over of latitudes defined for various rows.

However, the time difference and the number of lines between any two centres along the path varies due to the eccentricity of the IRS-1D orbit.

<u>Luni-Solar Gravitational Attraction and Solar Radiation Pressure</u> :

Additional perturbations to the orbit are examined here. This includes luni-solar gravitational attraction and solar radiation pressure. For IRS, the solar radiation pressure has negligible effects, whereas, luni-solar gravitational attaction causes secular variation of about 0.038 degree per year in inclination apart from periodic perturbations. Variations in the inclination, affects ground track pattern as well as local time. Since the variations are secular, compensation can be done easily. The nominal value of inclination for exact sun synchronism of IRS-1D orbit is 98.53 degrees. The orbit inclination achieved at the beginning of life is 98.62 degrees i. e., an inclination bias of about + 0.09 degrees is provided so that the mean local time at descending node builds up to 10:46 over a time duration of about 2.4 years and then the mean local time drifts back to 10:30 at the end of 4.8 years, as shown in figure 4.2.15.2.

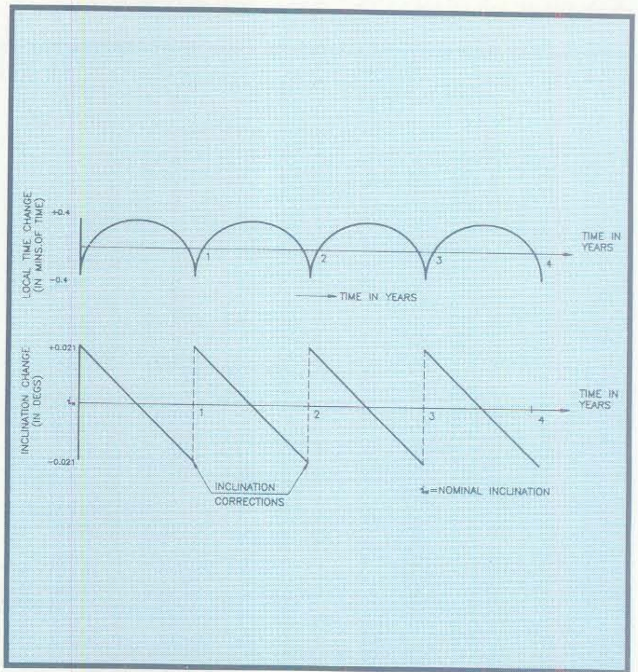


Figure 4.2.15.2 Local time control by inclination corrections

4.2.16. ORBIT DETERMINATION AND PREDICTION ERRORS

It is rather difficult to model accurately all the perturbing forces, to represent the true motion of the satellite. When orbit predictions are carried out, the trajectory deviates from the true trajectory and the deviation builds up continuously. Therefore, periodic orbit determinations would be carried out, using tracking observations of the satellite (like range, range rate, etc.). Since, both dynamic model and observations, are imperfect and there are many observations, than the number of parameters to be determined, this is an over determined system and therefore, orbit determination would be carried out using an estimation technique, in the statistical sense. The positional accuracy of the definitive orbit would be around 400 m (3 sigma) and after one day prediction, the positional accuracy will be around 1 Km. (3 sigma) for IRS. For browse products generation, one day predicted ephemeris and for standard products, definitive orbital ephemeris would be used. The image location accuracies in each of these products, are affected by the accuracies cited above.

4.2.17. DEVIATIONS OF ATTITUDE PARAMETERS

To align the payload cameras along the nadir line continusouly, IRS has been configured for 3 axes stabilised mode of attitude, which is achieved through a set of attitude sensors and control hardware. Controlling is necessary because of environmental and internal torques, which affect the attitude stabilisation continuously. Due to the presence of various errors in attitude sensing and controlling, the attitude would be controlled upto 0.15 degrees in pitch and roll and 0.2 degrees in yaw. The effect of pitch, roll and yaw on the image is shown in Figure 4.2.17.1. The pitch error shifts the scene in the along track direction, whereas, roll error shifts the scene in the across-track direction. Due to yaw error, the scene is rotated through the same angle about the nominal scene centre.

The earth sensors and gyro based attitude determination accuracy is better than the controlling accuracy and would be $\pm$ 0.07 degrees in pitch and roll and $\pm$ 0.1 degree in yaw. The deviations of scenes from the

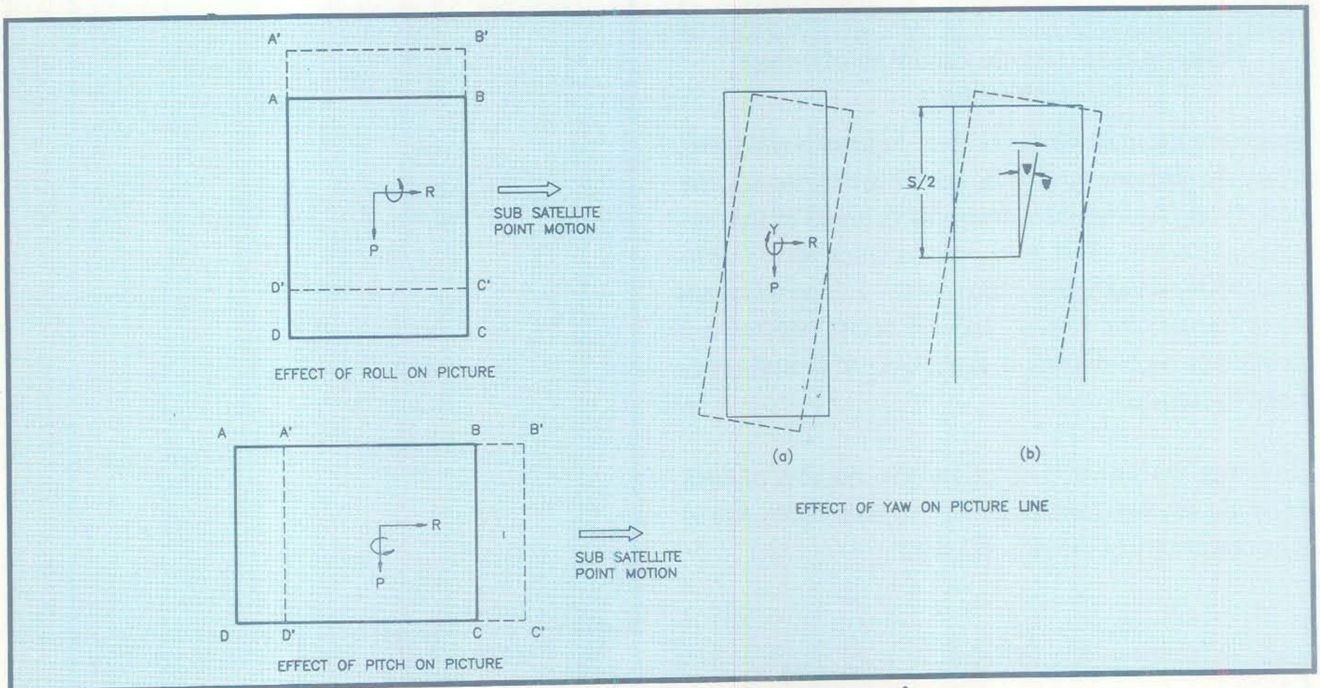


Figure 4.2.17.1. Effect of attitude errors on image

nominal, depends only on the controlling accuracies. Determined attitude information is used to correct the image and for annotation.

The star sensor based attitude determination accuracy will be better than the earth sensor based attitude. The improved attitude information from star sensor will be used in the operational level-0 system for IRS-1D.

Across Track deviations of the Image :

Across track deviations of the image essentially depends on ground track pattern deviations, the accuracy of information on ground track, roll and yaw errors, etc. Taking into account the uncertainties in orbit determination and orbit adjust system, the ground track pattern would be controlled within ± 8 Kms. about the nominal pattern. It is clear that the above implies a reduction in effective window, to account for orbit determination and orbit adjust system uncertainties. Roll error of 0.15 degrees causes across track deviations of about 2.1 Kms. and yaw error of 0.2 degrees would cause 0.35 Kms. across track deviations under the worst case. The Root Sum Square (RSS) of all these deviations, is about ± 8.3 Kms.

Along track deviations of the Image :

The along track deviations of the image are due to eccentricity, orbit determination/prediction accuracy, the shape of the earth and attitude control accuracy. Velocity variations due to eccentricity, are circumvented by utilizing satellite ephemeris. Pitch error of 0.15 degrees would cause 2.1 Kms. along track deviation, at the worst case. The component of yaw error introduces 0.3 Kms. If one day predicted ephemeris is used for browse products, which have positional information to the accuracy of about ± 2 Kms., the along track deviation is about 3 Kms. (RSS). If refined ephemeris is used for Browse products, the orbital position accuracy being 400 metres, the overall along track deviation is about 2.2 Kms.

This deviation is reduced by following an appropriate framing procedure during actual operations. However, the across track deviation within ± 8.3 Kms. cannot be reduced by any such procedures as it is a derivative of all the system components involved.

4.2.18. IMAGE FRAMING DURING ACTUAL OPERATION

In the earlier section, the deviations of the actual scenes with respect to nominal scenes have been described. For mosaic generation, user may have to use scenes obtained in different coverage cycles. With such large deviations, it was found that mosaic formation may be difficult, and also the user may have to order several scenes to get the required area information. During the process of evolvement, it was found that it is difficult to reduce the across track deviations, whereas, with an appropriate procedure for image framing, there is a possibility of reducing the along track deviations. Therefore, it was decided to adopt this method during actual operations. It may be noted, that, image deviation means the distance between the centre of the actual scene obtained and the centre of the corresponding scene defined in the path-row referencing scheme. This should be distinguished from the locational accuracy determined by the orbit and attitude information.

The following framing procedure is being adopted :

i. All the relevant row latitudes as defined in the referencing scheme should be stored.

ii. The same row latitudes for actual scenes is accomplished by interpolating the time for a given row latitude along the path for LISS-III and PAN payloads.

iii. All the LISS-III scene centres along the path should be marked by following the above procedure.

iv. The LISS-III scenes about the above scene centres, should be constructed by taking 3,000 lines above and below these points along the path. The end and beginning of each LISS-III scene along the path, should be marked.

v. WiFS and PAN scenes are then framed in and on LISS-III scenes, by adopting the same procedure, which is used while generating the referencing scheme.

The main advantage of the above procedure is that, major portion of along track deviation, with respect to the nominal scenes, get reduced. However, the distance between any two scene centres in terms of number of lines may not always be 5,703 lines and also the overlap between scenes may not be 297 lines. There will be small variations in them. Thus, the final deviations are :

along track $\pm$ 3.0 Kms.
across track $\pm$ 8.3 Kms.

4.2.19. IMPACT OF THE DEVIATIONS ON OVERLAP AND SIDELAP DURING OPERATIONAL LIFE TIME

While framing the images for the referencing scheme, adequate overlap (along track) and sidelap (across track), are provided to aid the users to form a mosaic for a particular area or the complete Indian region. Within a coverage cycle of 25 days, the impact of deviations is negligible and if the quality of all the images are good, then, it is possible to create a mosaic. However, in actual practice, quality of all the images may not be good due to the presence of cloud or some other reasons. Therefore, it is necessary to take images of different coverage cycles to generate the mosaic. In ideal situations, overlap or sidelap between adjacent images will exist. However, in actual practice, the deviation mentioned in the earlier sections will affect sidelap/overlap between images of one cycle and corresponding images of any other cycle, during the operational lifetime of the satellite. For example, a scene of cycle N1 corresponding to path and row of P1 and R1, has a prescribed amount of overlap with respect to a scene of the same cycle corresponding to path and row of P1, R1 + 1. However, it may not have the same amount of overlap, due to deviation, with a scene of cycle N2 corresponding to path and row of P1, R1 + 1. Similar is the situation for sidelap.

Overlap or sidelap varies due to the deviations mentioned in the earlier section and due to scale variation of the image, because of variation in the altitude. However, scale variation affects only sidelap but not overlap, as scanniang is accomplished line by line, along the track.

<u>Overlap Variation</u> :

The nominal overlap provided between any two LISS-III scenes (minimum) is about 8 Kms. The maximum deviation (along the track) is of the order of $\pm$ 5 Kms. with the new framing procedure. Due to this, the distance between two scenes of different cycles, will be different.

<u>Sidelap Variation</u> :

Sidelap is the common area between two adjacent scenes, of any two consecutive paths. However, sidelap between scenes of two consecutive paths of different cycles, is affected by acorss track deviations and scale variations. The nominal sidelap increases from equator to northern latitudes. Table 4.2.12.4. shows sidelap variations as a function of altitude and latitude. The across track deviation would be of the order of $\pm$ 8.3 Kms. near the equator. Therefore, the two adjacent scenes of different cycles can be near by or away, by twice this amount.

Altitude (Km)	Latitude 0.0.	5.0	10.0	15.0	20.0	25.0	30.0
	Sidelap (Km)						
737	15.768	16.194	17.468	19.582	22.519	26.256	30.765
742	16.635	17.061	18.335	20.449	23.386	27.123	31.632
747	17.501	17.927	19.202	21.316	24.252	27.990	32.499
752	18.368	18.794	20.069	22.183	25.119	28.856	33.366
757	19.235	19.661	20.936	23.049	25.986	29.723	34.233
762	20.102	20.528	21.803	23.916	26.853	30.590	35.100
767	20.969	21.395	22.669	24.783	27.720	31.457	35.966
772	21.836	22.262	23.536	25.650	28.587	32.324	36.833
777	22.702	23.128	24.403	26.517	29.454	33.191	37.700
782	23.569	23.995	25.270	27.384	30.320	34.058	38.567
787	24.436	24.862	26.137	28.251	31.187	34.924	39.434
792	25.303	25.729	27.004	29.117	32.054	35.791	40.301
797	26.170	26.596	27.871	29.984	32.921	36.658	41.168
802	27.037	27.463	28.738	30.851	33.788	37.525	42.034
807	27.904	28.330	29.604	31.718	34.655	38.392	42.901
812	28.771	29.197	30.471	32.585	35.522	39.259	43.768
817	29.638	30.064	31.338	33.452	36.389	40.126	44.635
822	30.504	30.930	32.205	37.256	37.256	40.993	45.502

Altitude (Km)	Latitude 35.0	40.0	45.0	50.0	55.0	60.0
	Sidelap (Km)					
737	36.012	41.957	48.555	55.755	63.503	71.739
742	36.879	42.824	49.422	56.622	64.370	72.606
747	37.746	43.691	50.289	57.489	65.236	73.473
752	38.613	44.558	51.156	58.356	66.103	74.339
757	39.480	45.425	52.022	59.222	66.970	75.206
762	40.347	46.292	52.889	60.089	67.837	76.073
767	41.213	47.159	53.756	60.956	68.704	76.940
772	42.080	48.025	54.623	61.823	69.571	77.807
777	42.947	48.892	55.490	62.690	70.437	78.674
782	43.814	49.759	56.357	63.557	71.304	79.541
787	44.681	50.626	57.224	64.424	72.171	80.407
792	45.548	51.493	58.090	65.290	73.038	81.274
797	46.415	52.360	58.957	66.157	73.905	82.141
802	47.282	53.227	59.824	67.024	74.772	83.008
807	48.149	54.094	60.691	67.891	75.639	83.875
812	49.015	54.960	61.558	68.758	76.506	84.742
817	49.882	55.827	62.425	69.625	77.373	85.609
822	50.749	56.694	63.292	70.492	78.239	86.476

Table 4.2.19.1. Sidelap variation (Typical) with respect to Altitude and Latitude

4.3 DATA PRODUCTS

4.3.1. INTRODUCTION

Data products from the various sensors of IRS-1D are of two types:

- Standard
- Special

Standard products are generated after applying radiometric and geometric corrections. Special products are generated after further processing the standard products.

The raw data recorded at the earth station is corrected to various levels of processing at the Data Processing System (DPS). Standard products can be supplied on either photographic or digital media. Black and White (B/W) and False Colour Composite (FCC) photographic products, will be available in the form of films or paper prints. Digital products will be supplied on various magnetic media that are currently popular, viz., Computer Compatible Tape (CCT), 8mm Exabyte tape and CD-ROM.

4.3.2 CORRECTIONS APPLIED TO RAW DATA

Raw data suffers from both geometric and radiometric distortions which have to be corrected. The various corrections applied are as follows :

Radiometric Corrections

Radiometric distortions arise due to the following factors :

i. Non-uniform response of the detectors and detector elements
ii. Specific detector element failure
iii Data losses during communication or archival/retrieval
iv. Narrow dynamic range;
v. Image to image variations.

A radiometric correction Look-Up-Table (LUT), is prepared for normalising the responses of all detector elements, with respect to a desired common response. The least saturation radiance value realised over the whole array, after disregarding extreme behaviour of one or two detectors, if any, is used as the reference. The same value can be used for conversion of radiometrically corrected Digital Number (DN) values back to absolute units, by the users of the data products . This can be done using the ground calibration data for all detectors.

The correction for major frame synchronization losses (scanline losses), is done using appropriate average of the neighbouring pixel values. If data losses occur in more than two consecutive scanlines, they are replaced by a line consisting of all dark (minimum DN value) pixels. The failed detector pixel values (if any), are replaced with the average of the adjacent pixels on the same scanline.

Geometric Corrections

Geometric distortions arising due to the following reasons are corrected :

i. Scene related
- earth rotation effect
- earth shape(geoid) induced distortions

ii. Sensor related
- sensor focal plane detector geometry
- alignment of optical axis with respect to spacecraft attitude reference
- multi-band and multi-array misregistration
- off-nadir pointing (for PAN) induced distortions

iii. Spacecraft related
- image orientation with respect to spacecraft heading
- altitude and velocity variations, affecting image scale
- attitude variations in roll, pitch and yaw directions

iv. Measurement / Calibration Errors
- estimation of spacecraft state vectors
- attitude and pointing angles measurement
- attitude change rate measurements
- calibration of various alignment angles involved
- synchronization of on-board and ground reception times

Geometric corrections use updated scene corners, orbit and attitude parameters, derived using swath modelling, which is a pass processing approach using a few Ground Control Points (GCP), spread over the pass.

Geometric corrections are performed through a dynamic model, which represents the imaging geometry. Through this model, an image to ground mapping is achieved, which is a function of payload parameters, satellite orientation, etc.,. This in turn consists of a series of transformations, from one co-ordinate system to another.

A grid of input co-ordinates (scanline, pixel) on the radiometrically corrected image, are selected and the corresponding output co-ordinates (lat,long) are calculated for all the grid points. For an user area given in the output space, a grid is defined and the input co-ordinates for these grid points are obtained through interpolation from the earlier computed points. The input co-ordinates for the intermediate points of output space are obtained by another interpolation, now in the output space only. The grey values for all the output points are obtained by resampling the input image.

Map projection and the image orientation (for geocoded products) are incorporated at the time of fixing the output grid. Finally, the data is formatted for generating the photographic or digital products, in the required format.

The photographic annotation format of all standard and special products are the same.

For details regarding the annotation format for all the types of products refer section 4.4.

4.3.3 STANDARD PRODUCTS

The various kinds of Standard products that will be supplied are as follows :

i. Path/Row products
ii. Shift Along Track products
iii. Quadrant products
iv. Basic Stereo products
v. Geocoded products.

4.3.3.1 Path/Row Based Products

These products are generated based on the referencing scheme of each sensor. The user has to specify the following.

i. Path/Row number as per referencing scheme
ii. Sensor Identification
iii. Subscene Identification (for PAN)
iv. Date of Pass
v. Band number for B/W products, band combination for FCC products
vi. Product Code

System Inputs :

i. Video data, line count, ground reception time and attitude change rates for LISS-III/PAN scanline

ii. Ancillary data in Disk files
iii. Radiometric calibration LUT file
iv. Mission specific constants from Parameter file
v. Job identification code (specifying request id, product sequence number)
vi. Product priority.

The SWIR band of LISS-III has a different resolution, hence, products which include SWIR band are made available in visible resolution.

In the case of PAN, a full scene is generated by mosaicing the data collected by the three arrays. The inputs to be specified are path, row and sensor as A, B, C or D.

4.3.3.2 Shift Along Track Products

If a user's area of interest is less than the dimensions of a full scene and falls in between two successive rows of the same path, then the data can be supplied by sliding the scene in the forward (along the path) direction. These are called Shift Along Track (SAT) products. This way, the required area can be accomodated in a single product.

In the case of SAT products, the percentage of shift has to be specified, in addition to the inputs specified by the user for Path/Row based products. The percentage of shift along the path has to be specified between 10% to 90%, in multiples of 10%. Figure 4.3.3.2 depicts the concept of a scene which has been shifted along track.

4.3.3.3 Quadrant Products

In the case of LISS-III, the full scene is divided into four nominal and eight derived quadrants (Figure 4.3.3.3.1). As seen from the figure, Quadrant numbers 1,2,3,4 are nominal quadrants. The remaining eight quadrants are obtained by sliding quadrants 1, 2, 3 and 4 by 25%, along and across the scene, within the path. LISS-III quadrant products are generated on 1:125,000 scale.

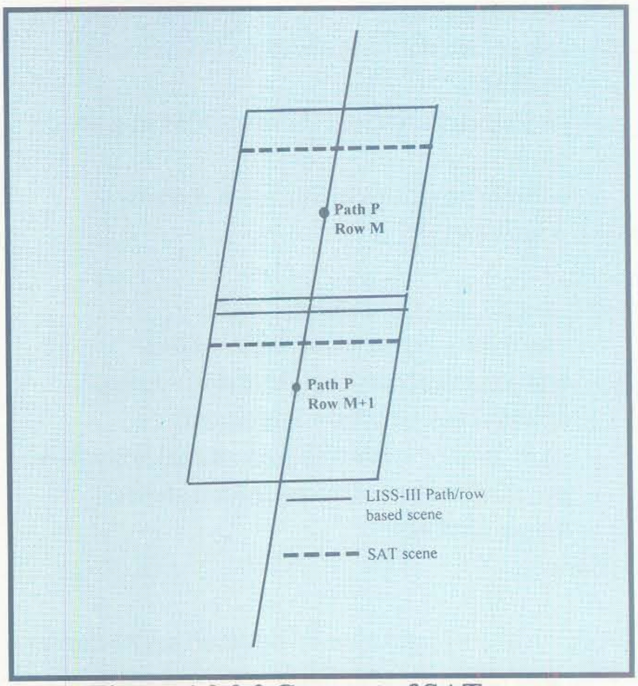


Figure 4.3.3.2 Concept of SAT scene

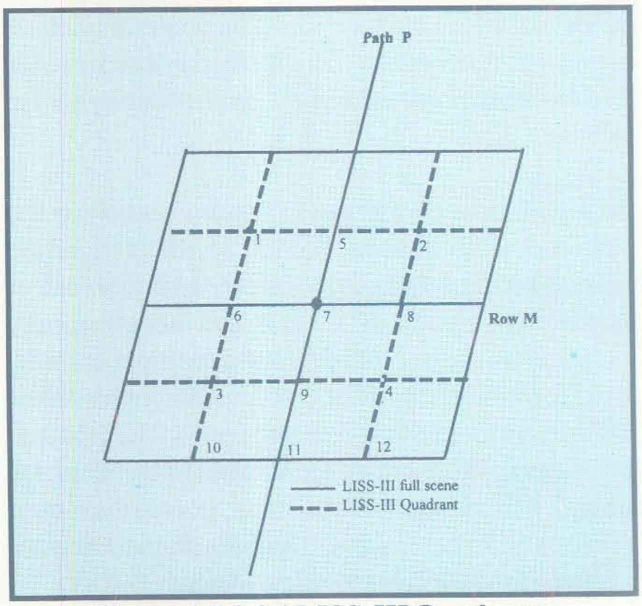


Figure 4.3.3.3.1 LISS-III Quadrants

The advantage of LISS-III quadrant, is the availability of photographic product on a higher scale, i.e., 1:125,000 and also because it can be compared with IRS1A/1B LISS-II products of the same scale, for temporal/change detection studies.

Quadrant products are supplied from the LISS-III sensor in the visible band resolution, for visible and near near infra-red bands only. Quadrant products are not available in SWIR band resolution. While placing a request for these products, the users need to specify the quadrant number, in addition to the details specified in the case of Path/Row based products.

In the case of PAN, the full scene is divided into four quadrants as shown in Figure 4.3.3.3.2. Here, each quadrant corresponds to one and a half array data. The scale of the 960mm master film will be 1:125,000. Photographic products will be supplied as 960 mm paper prints, on 1:125,000 scale.

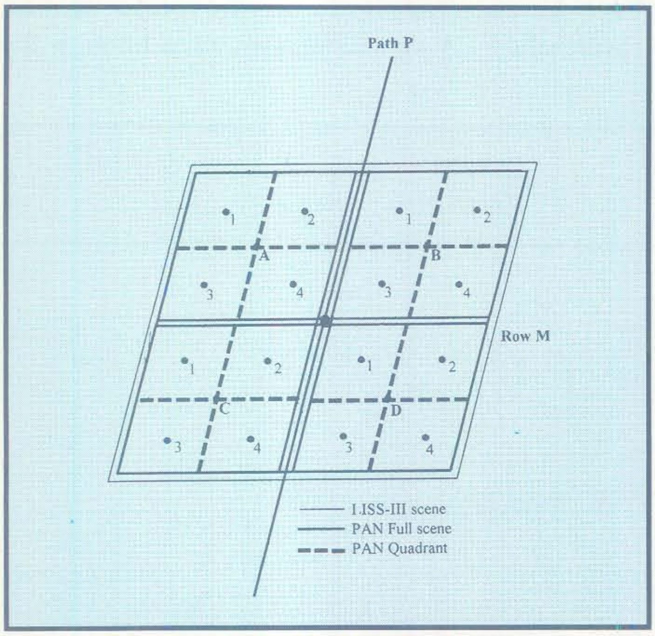


Figure 4.3.3.3.2 PAN Quadrants

4.3.3.4 Stereo Products

The oblique viewing capability of PAN sensor can be used to acquire stereopairs. A stereo pair comprises of two images of the same area, acquired on different dates and from different angles.

One of the parameters from which the quality of a stereopair can be judged, is the Base/Height (B/H) ratio. B/H ratio is the ratio of the distance between two satellite passes and the satellite altitude (Figure 4.3.3.4).

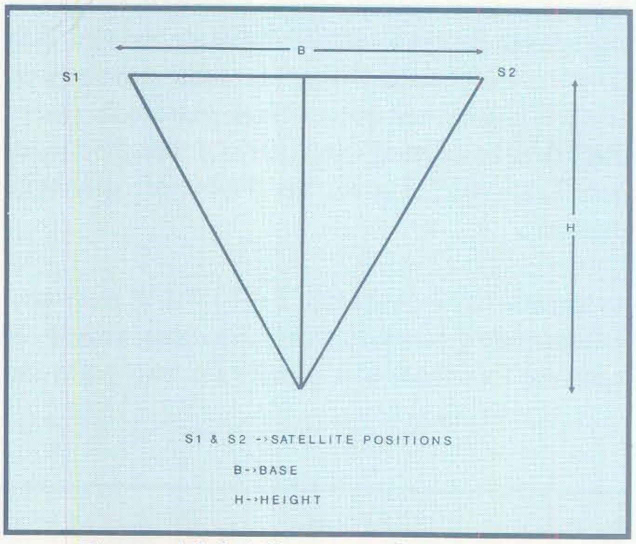


Figure 4.3.3.4 Concept of stereopairs

Stereo products are available from the PAN sensor only. The input required in addition to Path/Row details, is B/H ratio. Two scenes selected on two different dates, satsifying the user's B/H ratio are supplied as a stereopair. These are available as B/W photographic and digital products. Photographic products are available on 1:250,000 scale (approx.).

Stereo products are supplied with only radiometric correction. Stereopairs are widely used in photo interpretation for relief perception and also in photogrammetric studies for deriving DTM models.

4.3.3.5 Geocoded Products

Geocoding corrects the imagery to a source independent format, whereby multidate and multi-satellite data can be handled with ease. Geocoded products are generated after applying radiometric and geometric corrections, orienting the image to true north and generating the products with an output resolution, appropriate to the map scale. The advantage of a geocoded product is that it can be overlaid on a Survey of India (SOI) toposheet map.

Geocoded products are generated based upon the SOI toposheets, for PAN on 1:25,000 scale and for LISS-III on 1:50,000 scale. The inputs required to be specified by the user, in addition to those provided in case of Path/Row based products, is the SOI toposheet number. Table 4.3.3.5 gives the details of geocoded products.

In the case of PAN, when a 7 1/2' x 7 1/2' toposheet falls in more than one subscene, a mosaic is made. In case, the toposheet falls in between two paths, no mosaic will be made, instead, it is supplied with zero fills. The scales of the LISS-III and PAN geocoded master films are 1:250,000 and 1:125,000 respectively. By enlarging the film 5 times photographically, 1:50,000 and 1:25,000 scale products for LISS-III and PAN respectively, are generated. In order to account for the location inaccuracy, extra area corresponding to 2 1/2' is provided in LISS-III geocoded product and 1/2' extra area in case of PAN geocoded products. In total, a LISS-III geocoded product covers an area of 17 1/2' x 17 1/2' and a PAN geocoded product covers an area of 8' x 8'. The location accuracy of geocoded products is the same as that of Standard products.

In addition to the mapsheet based geocoded products, PAN 5' x 5' geocoded products is also supplied. Here, an area corresponding to 5' x 5' within a scene is extracted around a user specified point and aligned to true North after applying standard corrections. The inputs to be specified by the user are latitude/longitude of the point around which the 5' x 5' data is required, in addition to the

Product Type	Area	Output Resolution	Scale
Mapsheet based products			
LISS-III geocoded products in visible band resolution (B/W and FCC)	15'x15'	12.5m	1:50,000
PAN Geocoded products	7.5'x7.5'	6.25m	1:25,000
Special Geocoded Products			
User specified PAN point geocoded products	5'x5'	3.125m	1:12,500

Table 4.3.3.5 Details of geocoded products

details as in the case of Path/Row based products. The main advantage of this product over the mapsheet based geocoded products, is that it is on 1:12,500 scale.

4.3.4 SPECIAL PRODUCTS

Value added products are generated after further processing standard products, by extracting a specific area, mosaicing, merging and enhancing the data. These products are generated as per user requirement. In addition to the above, the following products are planned to be supplied :

i. PAN + LISS-III Merged products
ii. Orthoimage

4.3.4.1. PAN + LISS-III Merged Products

In order to exploit the dual advantage of the spectral resolution of LISS-III and the spatial resolution of PAN, it is planned to supply PAN+LISS-III merged products in PAN resolution. The criteria that will be considered while selecting the PAN and LISS-III scenes are:

i. PAN tilt is near nadir and the scene fits into a LISS-III scene.
ii. Day of pass is not separated by more than a few days.

These products will supplied on 1:25,000 (7 1/2' X 7 1/2' mapsheet based product) and 1:12,500 (floating geocoded product with an area coverage of 5' X 5') scale as FCC products.

4.3.4.2 Orthoimage

One of the important special products from IRS-1C/1D data is the Orthoimage generated from PAN stereo pairs. In the case of LISS-III, orthoimages can be generated using the DEM provided by the user and on the availability of atleat four GCPs. The product is corrected for all types of errors present in the raw data including distortions due to terrain relief and camera tilt. These products are made available on photographic and digital media. The scale of the photographic product is 1:50,000 and 1:25,000 for LISS-III and PAN respectively.

4.4 PHOTOGRAPHIC PRODUCTS

As mentioned in the earlier section, photographic products are available as:

B/W and FCC films
Paper prints

Masters of most of the photographic products are 240mm films. Figure 4.4.1 gives the layout of photographic products.

In this section, we will be discussing the image annotation of each of the photoproducts. It is very essential to know the annotation format of every product, since it gives information about the scene.

The geocoded product annotation format is nearly the same as that of the standard products, since, most of the geocoded products are supplied as a single product.

The annotation format has two lines on the top of the image data and one annotation line, at the bottom of the data (Figure 4.4.2).

The first line of annotation at the top gives details of the satellite, the type of product i.e., if the scene is fixed or shift along track , details of area covered i.e., Full/Quad/Geo, indication whether the data is OBTR data,band numbers,Gain settings, details about the product whether it is Path based, topoheet number, details regarding the projection i.e., POL (other options being SOM/LCC/UTM) and the resampling technique used i.e., CC/NN.

The second line of the annotation at the top gives details regarding the date of acquisition with time, path/row details, sensor, subscene details, quadrant number (the other option being percentage of shift), look angle information, the corrected scene centre and information on the Sun Elevation and Azimuth in degrees.

The annotation line at the bottom of the image data gives details regarding the generation-ID, date of generation with time,the type of enhancement used i.e. HLUT/ CLUT/ EQLUT, details about which DPS generated the product, place of generation, details regarding the DPSUSAGE and the information about the product generation agency. This annotation line is for internal use only.

A list of IRS-1C/1D photographic products is given in Table 4.4.1.

A few sample photographic images , extracted from the standard data products are shown in the next few pages. (Fig. Nos 4.4.3 to 4.4.13) .The sample images are not to scale.

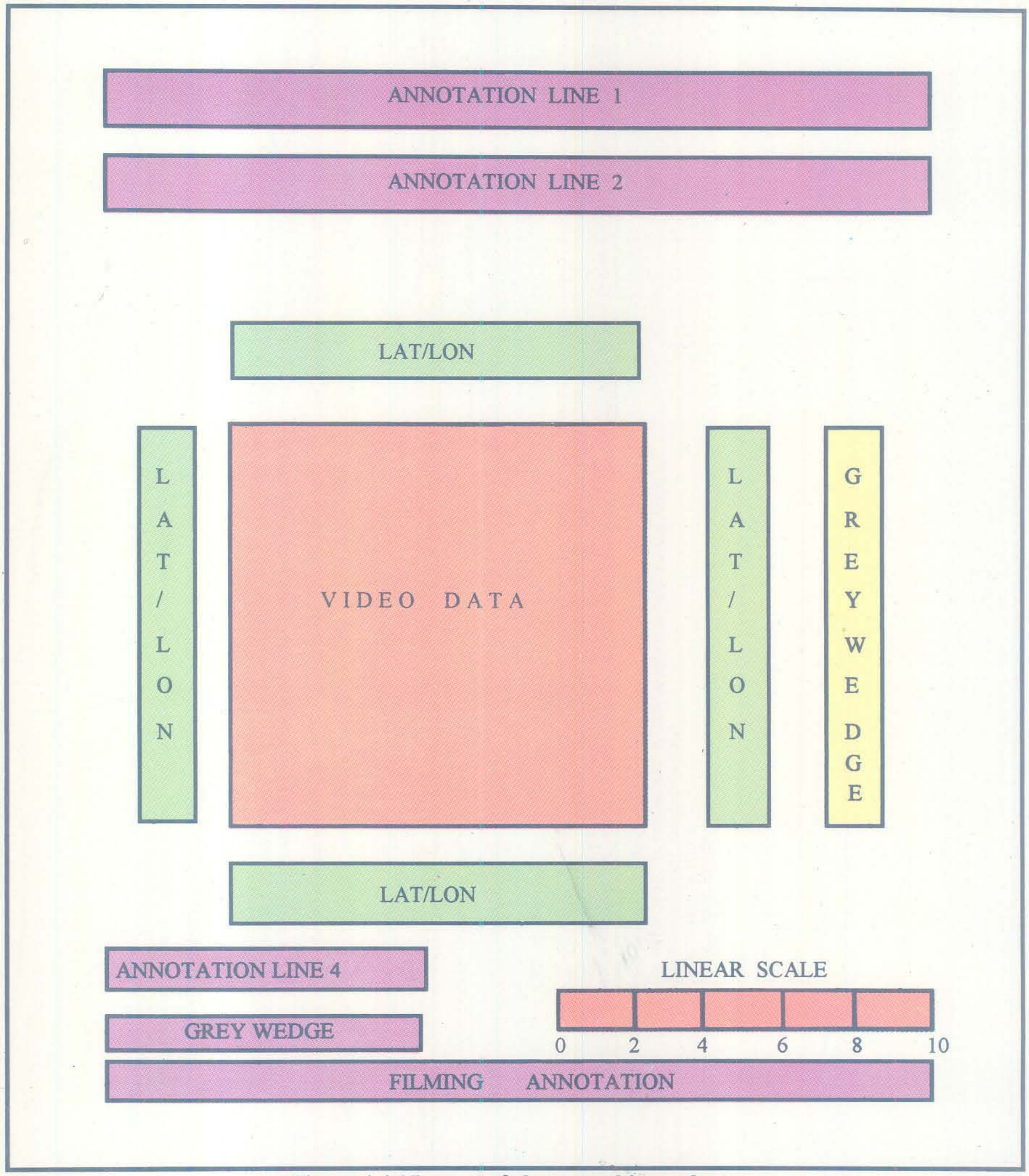


Figure 4.4.1 Layout of photographic products

ANNOTATION LINE NUMBER 1 (TOP)

IRS-1C STD FIXED FULI OBTR BANDS GAINS PATHBASED RESOL: MIR POL CC

A B C D E F G H I J K

CODES:

A SATELLITE_ID
B PRODUCT TYPE (OTHER OPTIONS ARE GEOCODED/MERGED/STEREO/VIM)
C OTHER OPTION IS FLOAT
D OTHER OPTIONS ARE QUAD/INDIA/GEO
E THIS SPACE WILL BE LEFT BLANK IF THE PRODUCT IS NOT A OBTR PRODUCT
F BAND NUMBER DETAILS, WILL BE BLANK IN CASE OF PAN PRODUCT
G GAIN SETTINGS
H OTHER OPTIONS ARE STEREOPAIR(1/2)/STEREOTRIPLET(1/3)/MERGED/ORTHOIMAGE/VIM/POINT BASED/MAPSHEET NUMBER
I THIS WILL BE LEFT BLANK. IN CASE PRODUCTS ARE SUPPLIED IN VISIBLE RESOLUTION
J TYPE OF PROJECTION (OTHER OPTIONS ARE SOM/UTM/PS/LCC)
K TYPE OF RESAMPLING

ANNOTATION LINE 2 NUMBER (TOP)

10APR96/10:30:10 P102/R025 L3 A0 QU:12 LA+15:30 FN:25-30-10/E72:30:45 E:90-A14

A B C D E F G H

CODES:

A DATE OF ACQUISITION WITH TIME
B PATH-ROW DETAILS
C SENSOR DETAILS (OTHER OPTION IS 'PN' FOR PAN AND 'WI' FOR WiFS)
D SUBSCENE DETAILS (APPLICABLE IN CASE OF PAN PRODUCTS)
E QUADRANT NUMBER (OTHER OPTION IS PERCENTAGE OF SHIFT)
F LOOK ANGLE IN DEGREES
G CORRECTED SCENE CENTRE LAT/LONG COORDINATES(Deg-Min-Sec)
H SUN ELEVATION AND AZIMUTH (Deg.)

ANNOTATION LINE NUMBER 4 (BOTTOM)

XT:12345 PROC ON:31-MAY-1996/22:40:10 NOLUT DPS-I HYDERABAD DPSUSAGE ISRO/NRSA

A B C D E F G

CODES:

A GENERATION_ID
B DATE OF GENERATION
C ENHANCEMENT(OTHER OPTION ARE CLUT/HLUT/EQLUT)
D DPS AT WHICH THE PRODUCT WAS GENERATED
E PLACE OF GENERATION
F DPSUSAGE,THIS IS FOR INTERNAL PURPOSE ONLY
G DATA GENERATION AGENCY

* ANNOTATION LINE NUMBER 2 (TOP) WILL BE REPEATED AS ANNOTATION LINE NUMBER 3 (TOP), IN CASE THERE IS MORE THAN ONE SCENE

Figure 4.4.2 Annotation format

User input	Sensor	Area covered (in Km)	Photoproduct scale	Remarks
Path/Row based and SAT products (B/W and FCC)				
Path, row, % of shift in the case of SAT products	LISS-III (Full scene)	127 X 145.5 (min) 141 X 142.1 (max) B234 (Visible) 133 X 153(min) 148 X 149(max) (SWIR) applicable in case of B/W products	1:1,000,000 1:500,000 1,250,000	B/W and FCC products
Path, Row, % of shift in the case of SAT products	PAN (full scene)	63 X 71.8 (min) 70 X 70 (max) (nadir)	1:125,000	B/W products
Path, Row % of shift in the case of SAT products and subscene No.	PAN (subscene)	21 X 23 (Nadir)	1:250,000 1:125,000 1:50,000	B/W products
Path, Row, % of shift in the case of SAT products	WiFS (full scene)	720 X 778 (min) 812X760 (max)	1:6,000,000 1:2,000,000	B/W and FCC products
Path, Row, quadrant No.	LISS-III (quadrant)	63.5 X 71 (min) 70.5 X 73.5 (max)	1:500,000 1:250,000 1:125,000	B/W and FCC products
Path, Row, quadrant No.	PAN (quadrant)	31.5 X 34.5 (Nadir)	1:125,000	B/W products

min=minimum area, max=maximum area

Table 4.4.1 IRS-1D photographic products

User input	Sensor	Area covered (in Km)	Photoproduct scale	Remarks
Special products				
Merged products				
Path,row of LISS-III and PAN	PAN + LISS-III	13.5 x 13.5 9 x 9	1:25,000 1:12,500	FCC products
Orthoimage				
Path,row B/H ratio	PAN	13.5 x 13.5 7 1/2' X 7 1/2'	1:25,000	B/W products
Path, row, DEM	LISS-III	28 x 28 15' x 15'	1:25,000	FCC products

Table 4.4.1 IRS-1D Photographic products (continued)

Figure 4.4.3 PAN image showing parts of Moscow city

Figure 4.4.4 LISS-III image showing parts of Saudi Arabia

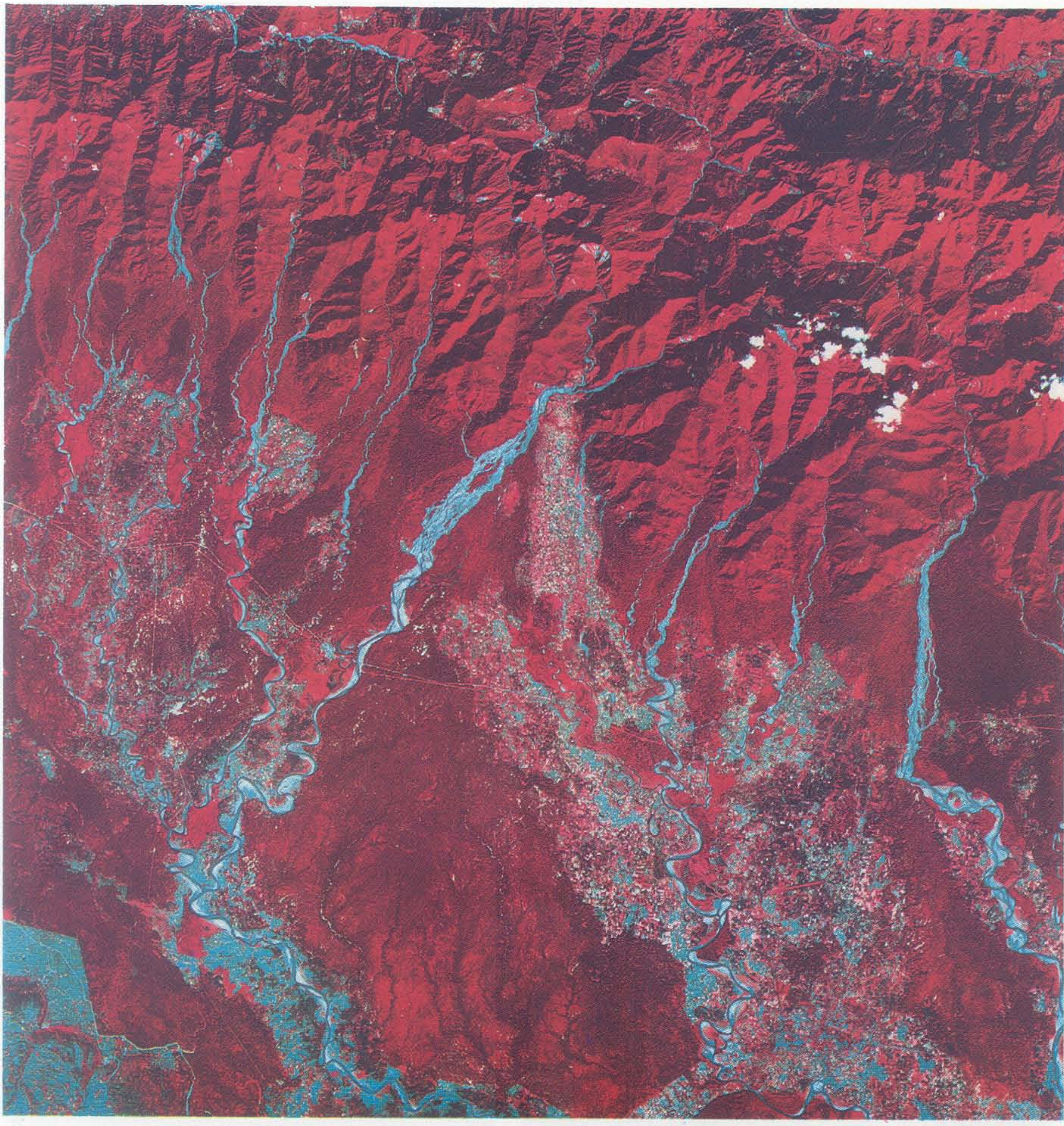


Figure 4.4..5 LISS-III image showing parts of Shiwalik hills (B4=Red, B3=Green, B2=Blue)

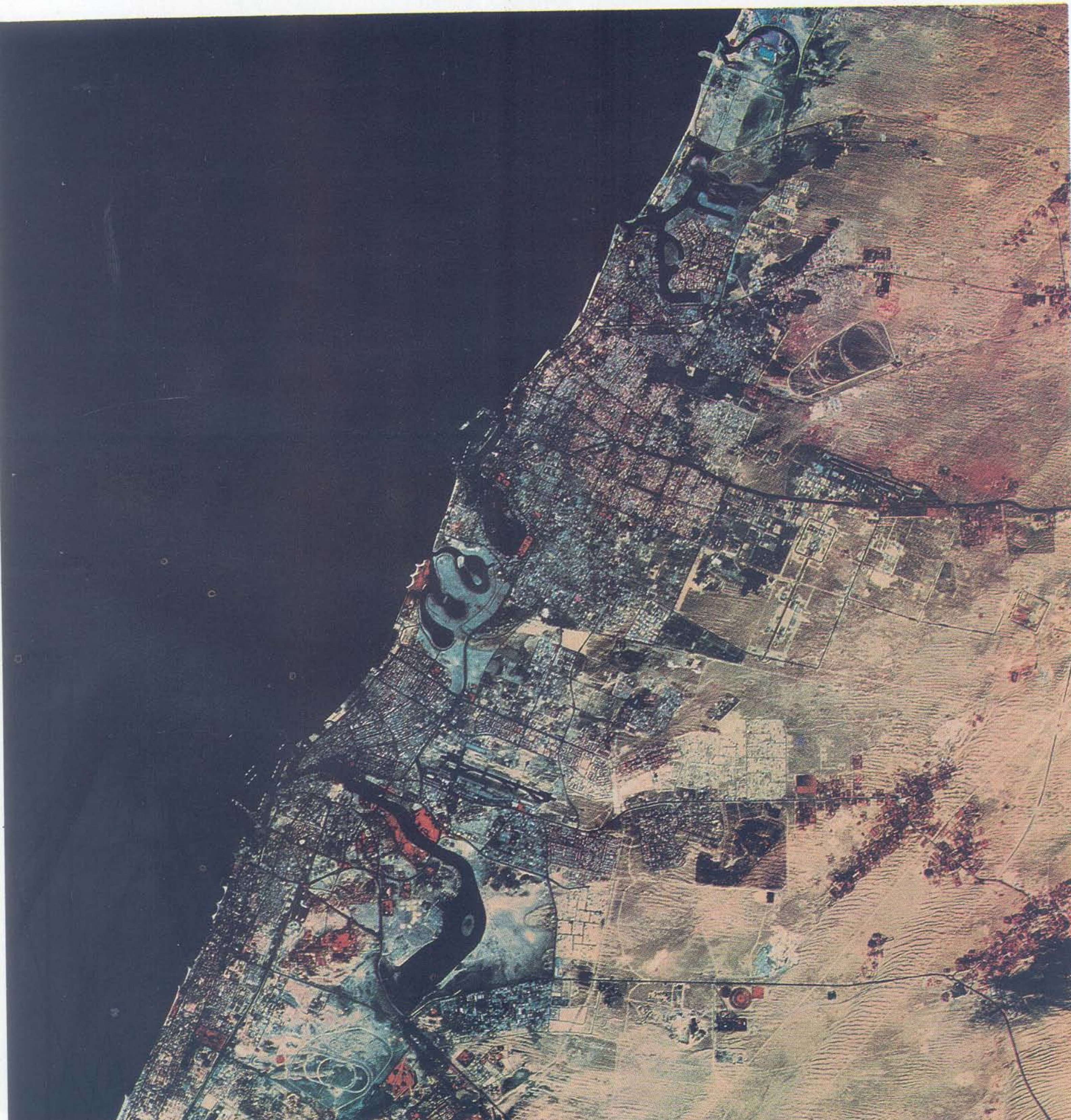


Figure 4.4.6 LISS-III image showing Dubai city and its surroundings

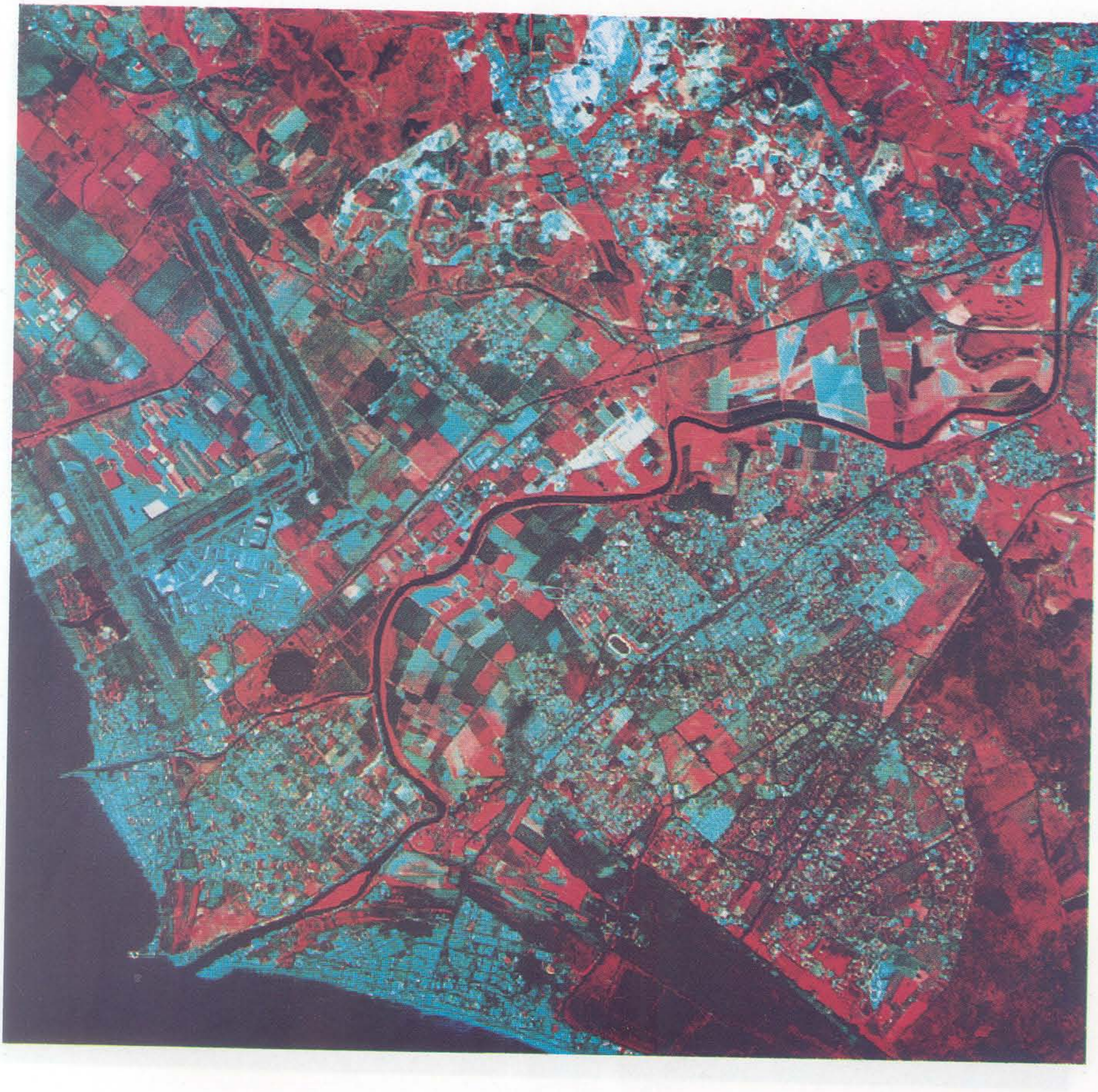


Figure 4.4.7 LISS-III image showing Rome airport and its surroundings

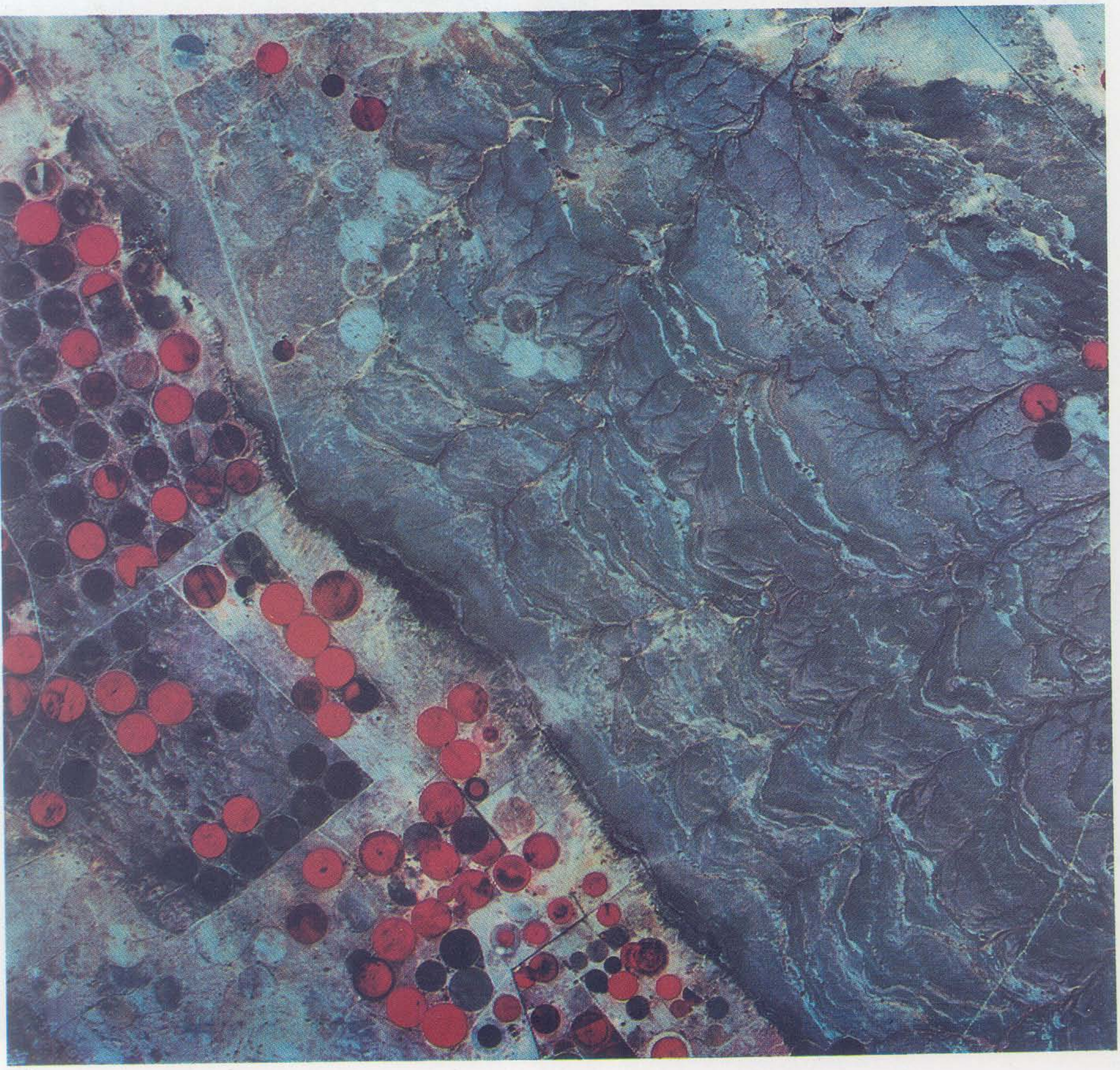


Figure 4.4.8 LISS-III image showing parts of IRAN. Circular patches in red colour are areas irrigated with sprinklers

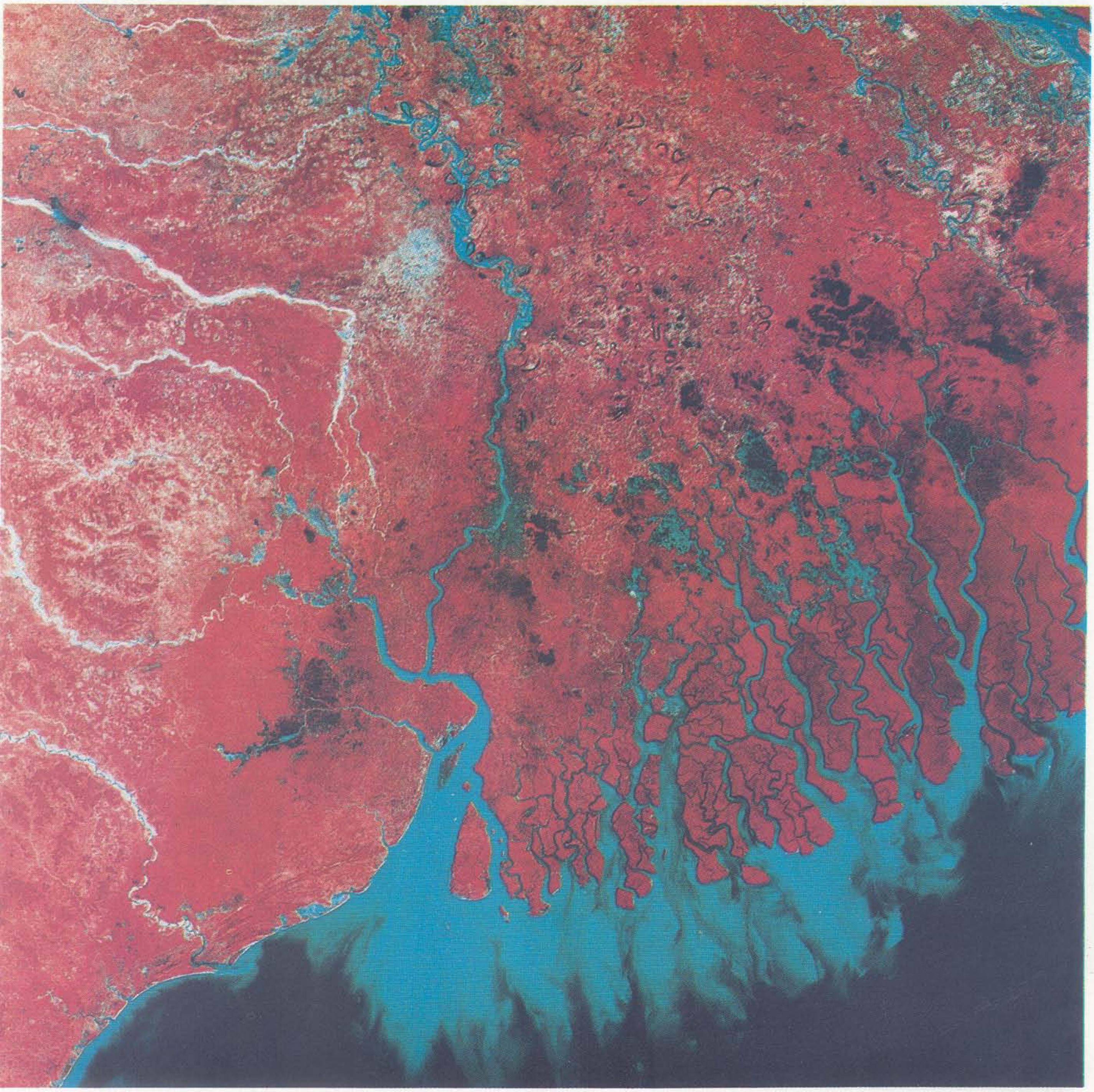


Figure 4.4.9 WiFS image showing parts of Sundarbans in the east coast of India

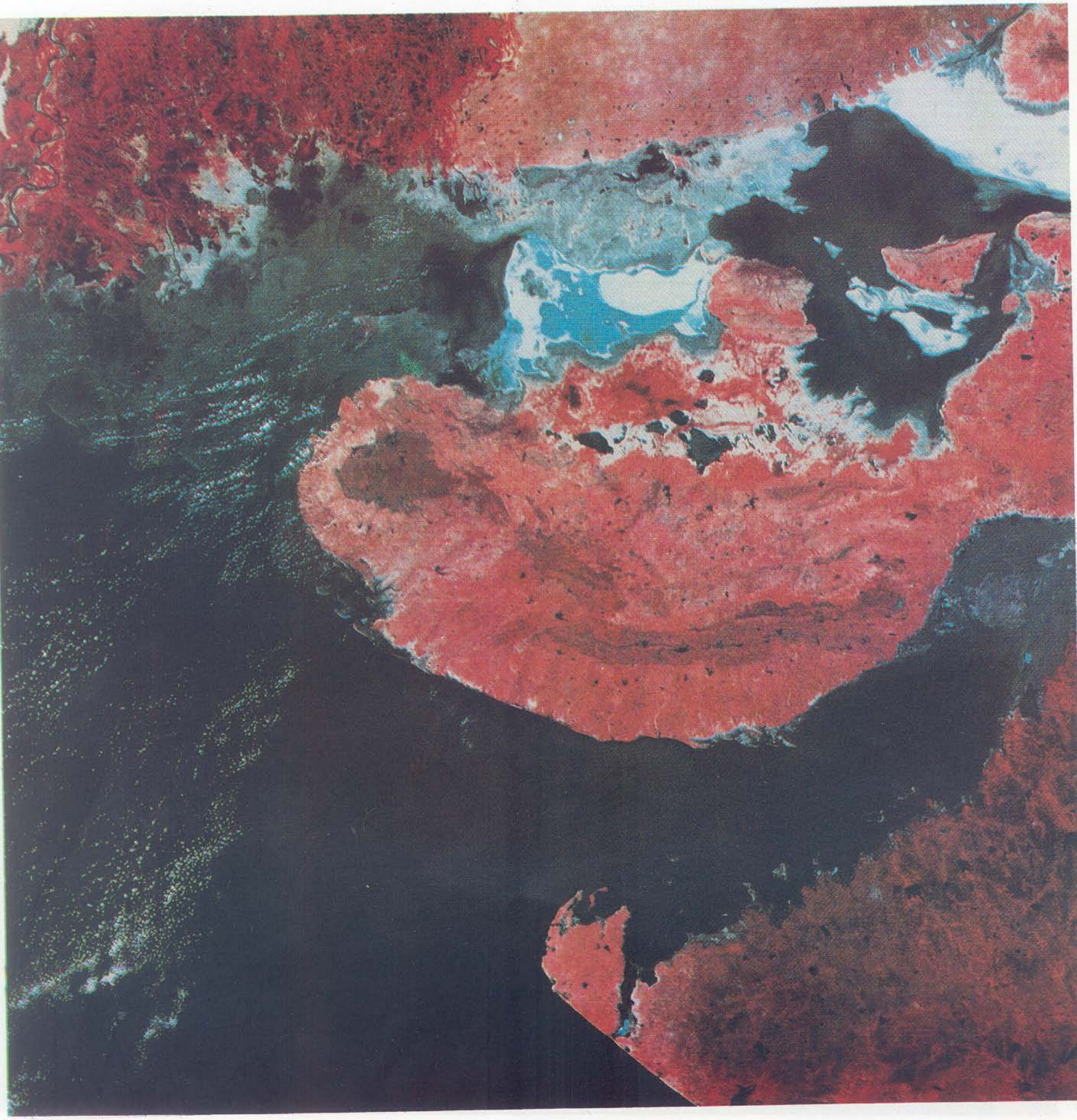


Figure 4.4.10 WiFS image showing parts of Gujarat in the west coast of India

Figure 4.4.11 PAN+LISS-III merged image showing parts of Bangalore City

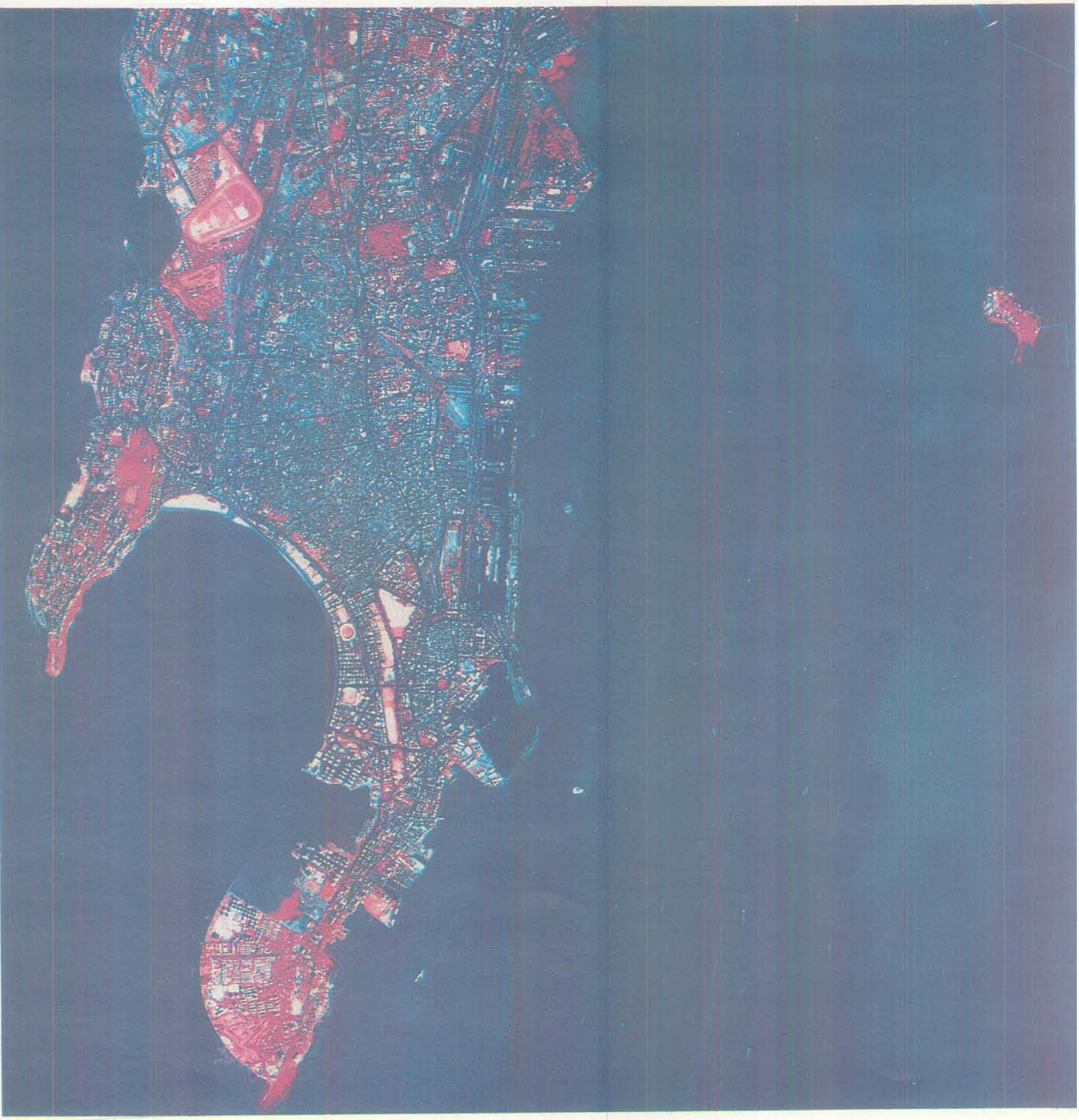


Figure 4.4.12 PAN+LISS-III merged image showing parts of Mumbai City

4.5 DIGITAL DATA PRODUCTS

4.5.1 INTRODUCTION

The data for all the sensors of IRS-1C/1D are supplied on digital media like Computer Compatible Tapes (CCTs), CD-ROMs, Cartridges and 8mm Exabyte tapes, based on user request. The file formats and structures in User CCT (UCCT) are the same for all levels of processing. The two formats in which digital data are supplied on are Fast format and LGSOWG Superstructure format. All digital data in super structure format are provided in BIL or BSQ modes. However, in Fast format, data is supplied in BSQ format only.

4.5.2 COMPUTER COMPATIBLE TAPES

CCTs are supplied with 6250 BPI density. Data on CCTs are supplied in the following formats :

4.5.2.1 Fast Format

There are two files in the UCCT for Fast Format - header file and image file.

Header file

This is the first file on each volume and contains header data in ASCII format. It contains map projection, resampling options and tick mark locations.

Image file

All image files contain only video data. There is no prefix and suffix data with the individual image record.

4.5.2.2 LGSOWG Format

In LGSOWG format, in addition to the video data for a scene, each product contains scene identification, location information, sensor, platform and processing related information. In the LGSOWG format, there are 5 files namely :

* Volume directory file
* Leader file
* Image data file
* Trailer file
* Null Volume file

Structure of these files is given in Table 4.5.2.1.

Logical volume

A logical volume is a logical collection of one or more files, recorded consecutively. A logical volume contains one or more band data of a scene.

All logical volumes have a volume directory as the first file and concludes with a null volume directory. When a logical volume is split between physical volumes, the volume directory is repeated in the continuation tape. All logical volumes conclude with a null volume directory.

Volume Directory

The volume directory file is the first file of every logical volume. It is composed of volume descriptor record, a series of file pointer records and a text record. The volume descriptor record identifies the logical volume and the number of files that it contains. A text record follows the volume descriptor record and identifies the data contained in the logical volume. There is a file pointer record for each type of data in the logical volume which indicates each file class, format and attributes.

Leader File

The leader file is composed of a file descriptor record and two types of data records. The data records are header and ancillary. Header record contains information related to mission, sensor, calibration coefficients and processing parameters. Ancillary records contain information pertaining to ephemeris, attitude, map projection, GCPs for image correction and image location and annotation.

Image file

Image file consists of file descriptor record and actual image record. Image data contains actual video data in BIL format (or) BSQ format. In addition to the image or video data, it also contains pixel counts, scan line identification, starting and ending of actual data in the line.

Trailer file

The trailer file shows the calibration data file and ancillary information file. This is composed of a file descriptor record and one trailer record for each band.

Null volume directory file

The file which terminates a logical volume is null volume directory file. The file is referred to as 'NULL', because it identifies a non existent logical volume. This file consists of a volume descriptor record only.

File 0	5 Records 360 Bytes	Volume Directory file (volume descriptor, file pointers and text record).
File 1	* Variable no of records 6120 bytes	Leader file (descriptor, header, ancillary, calibration, histogram, map projection, GCP, annotation record, boundary record and boundary annotation record.) Class LEAD
File 2	* Variable no. of records * Variable record length	Image Data file (Raw or Standard or Geocoded) Class IMGY
File 3	5 Records 360 Bytes	Trailer file (description and trailer records) CLASS-TRAI
NULL	One Record (360 bytees)	Null file (end of logical volume will be overwritten to add another logical volume.)

* No. of records and record length will vary as per the product or number of bands or sensors.

Table 4.5.2.1 Structure of files and records in UCCT

4.5.3 DATA ON 525MB CARTRIDGE AND 8MM EXABYTE TAPES

With the availability of cartridge 8mm Exabyte tape drives, data can be provided in a compact manner. Specifications of cartridge tape drives and 8mm Exabyte tape drive are given in Tables 4.5.3.1 and 4.5.3.2. These products essentially follow the same formats as in the case of CCTs.

4.5.4 CD-ROM PRODUCTS

Compact Disks (CDs) have the advantage of being compact, reliable, immune to magnetic fields, rugged and cost effective, with high memory capacity and random access.

CD-ROM is a Write Once Read Many times (WROM) device, with a memory of 650 MB. It can

Recording mechanism	:	Horizontal 9 tracks with Read after write
Recording code	:	GCR
Recording format	:	Digital, QIC-525
Capacity	:	525 MB
Recording Density	:	8,000 BPI
Tape Speed	:	90 IPS
MTBF	:	25,000 Hrs
MTTR	:	30 mts
Make	:	3M, SONY

Table 4.5.3.1. Specifications of 525 MB Cartridge tape drive

Type	:	8mm Exabyte tape
Recording mechanism	:	Helical scan with Read after write
Recording format	:	Digital with error correcting code
Capacity (112M)	:	5GB
Recording Density	:	35 million bits/sq inch
Tape Speed	:	0.458 IPS
Rotor Speed	:	1800 RPM
Rewind Speed	:	32.7 IPS
MTBF	:	160,000 Hrs
MTTR	:	30 mts
Make	:	3M, SONY, EXABYTE

Table 4.5.3.2 Specifications of 8mm Exabyte tape drive

be read on any system with a CD-ROM drive, in compliance with the ISO 9660.

CD-ROM Logical description

A CD-ROM may contain a full scene, quadrant or subscene. Apart from image (video) data, ancillary data and format document are copied onto the "PRODUCT" directory. The file CDINFO contains the identification of the product and request number. A general purpose display program (DISPLAY.EXE) is also available on each CD-ROM, which will display B/W data, only on a EVGA monitor.

Format of products on CD :

Data is supplied in two formats namely LGSOWG and Fast format. The contents of the files are exactly the same as that on a CCT.

File naming convention :

LGSOWG format

1. VOLUME.PAN/L3/WIF ---- Volume directory file
2. LEADER.PAN/L3/WIF --- Leader file
3. IMAGERY.PAN/L3/WIF ---Imagery file
4. TRAILER.PAN/L3/WIF --- Trailer file
5. NULL.PAN/L3/WIF --- Null volume file

Fast format

1. HEADER.PAN/L3/WIF --- Header file
2. BANDx.PAN/L3/WIF --- Imagery file of x where x=1,2,3,4 or 5

How to mount the CD ?

The following are a few procedures to mount the CD, depending on the operating system.

MS-DOS (IBM PC equivalent)

There is no need to mount the CD. The CD can be directly accessed by CD reader.

MACINTOSH system 7.x

The Apple CD drive and its extensions are needed. The CD is directly accessed by CD reader.

UNIX system, as root

1. Create a specific directory to access the CD (ex : mkdir cdrom)

2. Access the CD using the following commands:

For UNIX BSD 4.3	mount -rt hsfs/dev/srn/ CDROM (n=0,1 etc)
For UNIX system 5	mount -rt cdfs <CDROM drive unit>/CDROM
For DEC UNIX	mount -r -t cdfs - 0 novertion /dev/rz.../cdrom
For IBM Aix 3.2	mount <cdrom drive name>/cdrom
For SGI IRIX-5.3	Directly accessible
For SOLARIS-5.3	Directly accessible

VMS 5.5 Systems (VAX), as root

1. To mount CDROM,: CD_MOUNT OVER=ID <CD_ROM Drive unit no.> MEDIA=CD-ROM. CD-ROM files can be accessed.
2. To dismount the CDROM :CD_DISMNT <CD-ROM drive unit number>

VMS 6.0 Systems (VAX) as root

1. To mount CD-ROM : MOUT/OVER < CD-ROM drive unit number>
2. To dismount the CD-ROM : DISMOUNT <CD-ROM drive unit number>

Table 4.5.5 Digital data products

Type of Product	Sensor	Media	Capacity	Format	Physical volumes
STANDARD PRODUCTS					
Standard P/R, Shift along track, and Quadrant products	LISSIII	CCT	6250 BPI	BIL/BSQ LGSOWG & Fast format	2 1 (quadrant)
Area coverage 127 X 145.5 (min) 141 X 142.1 (max) (Full scene)		Cartridge Tape	525 MB	BIL/BSQ LGSOWG & Fast format	2/1 1 (quadrant)
63.5 X 71 (min) 70.5 X 73.5 (max) (quadrant)		8mm Exabyte Tape	5GB	BIL/BSQ LGSOWG & Fast format	1 1 (quadrant)
		CD-ROM	650 MB	BIL/BSQ LGSOWG & Fast Format	1
Geocoded (15'X 15') (28 km x 28 km)	LISS-III	CCT	6250 BPI	BIL/BSQ LGSOWG & Fast format	1
		Cartridge Tape	525 MB	BIL/BSQ LGSOWG & Fast format	1
		8mm Exabyte Tape	5GB	BIL/BSQ LGSOWG & Fast format	1

Type of Product	Sensor	Media	Capacity	Format	Physical volumes
Standard P/R, Shift along track products Area coverage 21 X 23 (Nadir)	PAN Subscene	CCT	6250 BPI	BIL/BSQ LGSOWG & Fast format	1
		Cartridge Tape	525 MB	BIL/BSQ LGSOWG & Fast format	1
		8mm Exabyte Tape	5GB	BIL/BSQ LGSOWG & Fast format	1
		CD-ROM	650MB	BIL/BSQ LGSOWG & Fast format	1
Geocoded (7 1/2' X 7 1/2') (14 km x 14 km)	PAN subscene	CCT	6250 BPI	BIL/BSQ LGSOWG & Fast format	1
		Cartridge Tape	525 MB	BIL/BSQ LGSOWG & Fast format	1
		8mm Exabyte Tape	5GB	BIL/BSQ LGSOWG & Fast format	1

Table 4.5.5 Digital data products (continued)

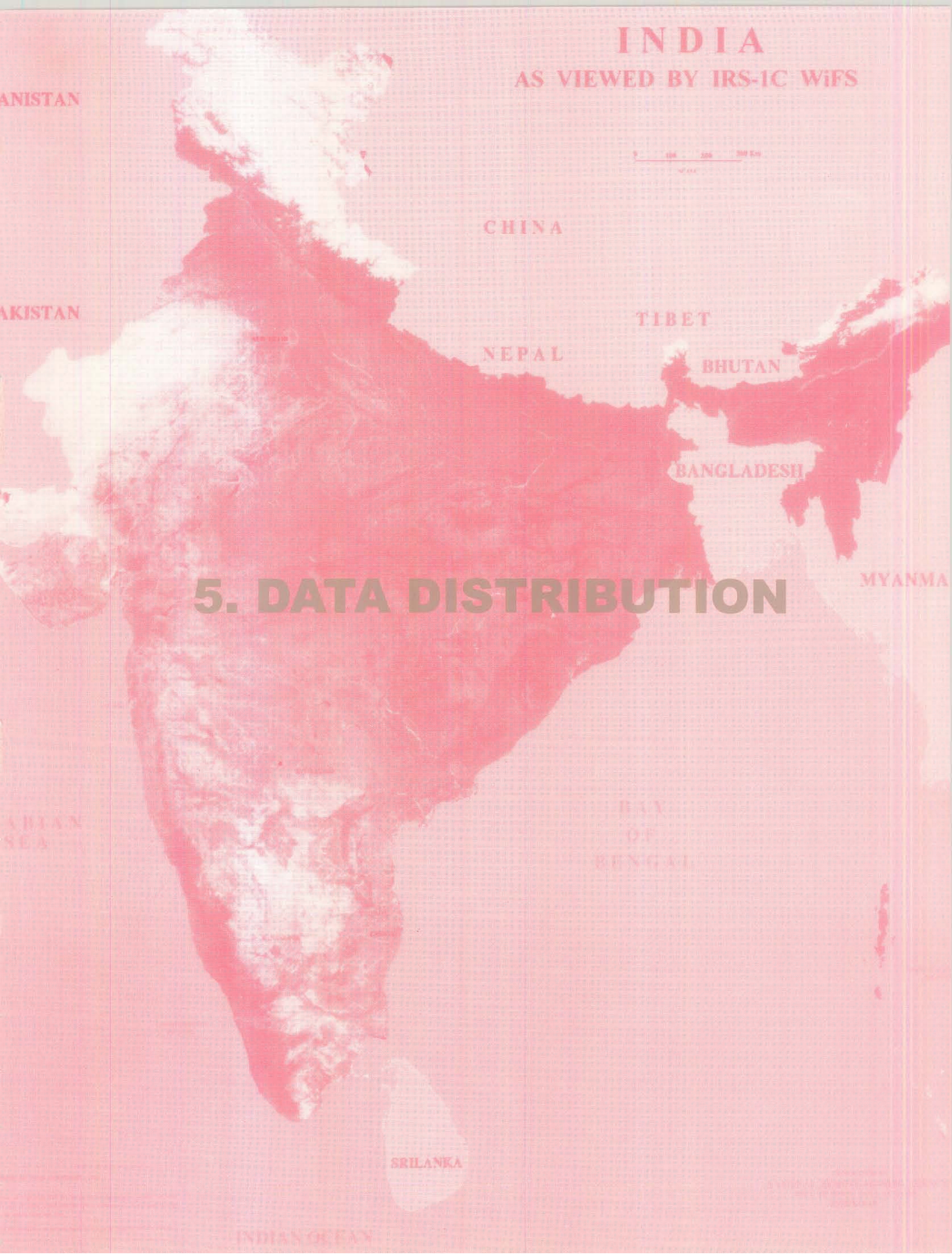
Type of Product	Sensor	Media	Capacity	Format	Physical volumes
		CD-ROM	650MB	BIL/BSQ LGSOWG & Fast format	1
Basic Stereo product (21 x 23 km)	PAN subscene	CCT	6250 BPI	LGSOWG format	1
		Cartridge Tape	525 MB	LGSOWG format	1
		8mm Exabyte Tape	5GB	LGSOWG format	1
		CD-ROM	650MB	BIL/BSQ LGSOWG format	1
Standard P/R, Shift along track products	WiFS	CCT	6250 BPI	BIL/BSQ LGSOWG Fast format	1
Area coverage 720 X 778 (min) 812 X 760 (max)		Cartridge Tape	525 MB	BIL/BSQ LGSOWG & Fast format	1
		8mm Exabyte Tape	5GB	BIL/BSQ LGSOWG Fast format	1
		CD-ROM	650MB	BIL/BSQ LGSOWG & Fast format	1

Table 4.5.5 Digital data products(continued)

Type of Product	Sensor	Media	Capacity	Format	Physical volumes
PAN Full/ Shift along track products	PAN	CCT	6250 BPI	LGSOWG & Fast format	2
Area coverage 63 X 69 (min) 70 X 71 (max) (nadir)		Cartridge Tape	525 MB	LGSOWG format & Fast format	1
		8mm Exabyte Tape	5GB	LGSOWG format & Fast format	1
		CD-ROM	650MB	LGSOWG format & Fast format	1
PAN Quadrant products	PAN	CCT	6250 BPI	LGSOWG format & Fast format	1
Area coverage 31.5 X 34.5 (Nadir)		Cartridge Tape	525 MB	LGSOWG format & Fast format	1
	Exabyte	8mm Tape	5GB format &	LGSOWG Fast format	1
		CD-ROM	650MB	LGSOWG & Fast format	1

Table 4.5.5 Digital data products (continued)

5. DATA DISTRIBUTION



5.1 DATA DISTRIBUTION

IRS-1C has established its versatality, both in the Indian and international market, for mapping and monitoring natural resources and cultural features. The information required for obtaining IRS-1C/1D data products and services, is provided in this section.

Users can obtain IRS-1C/1D data from :

1. NRSA Data Centre (NDC) or
2. Space Imaging - Earth Observation Satellite Company (SI-EOSAT) or
3. International Ground Stations (IGSs).

5.2 DATA DISSEMINATION

NDC distributes IRS-1C and IRS-1D data products pertaining to areas within the 5^0 elevation coverage of Shadnagar earth station (henceforth referred to as NRSA IRS data), to Indian and foreign users.

Users outside India, but within the 5^0 coverage of Shadnagar earth station, may approach NDC.

Users outside the coverage of Shadnagar earth station, can approach either SI-EOSAT or IGSs.

Figure 5.2.1 gives the details of IRS-1D data dissemination by various organisations.

Indian users who need data outside the 5^0 elevation coverage of Shadnagar earth station can approach NDC. These products will be supplied by programming the satellites for data acquisition using OBTR or by procuring the data from SI-EOSAT/IGSs.

5.2.1 NRSA DATA CENTRE

The NRSA Data Centre provides IRS-1C and IRS-1D data products to users. The main functions of NDC are:

* to provide information required for procurement of satellite data products. This includes the description/specifications of different types of products, changes in product specifications from time to time, price lists, reference maps, accession catalogues, orbital calendars, order forms etc.,.

* to provide assistance in the selection of appropriate data and checking the same for data quality and cloud-cover, using browse facilities.
* to process orders and co-ordinate the generation of products at different work centres within the organisation.
* to check the quality of the final products before despatching
* billing and accounts.
* to promote awareness of remote sensing through publications, seminars, exhibitions etc.,.
* handling all payload programming related activities.

5.2.2 SPACE IMAGING-EARTH OBSERVATION SATELLITE COMPANY (SI-EOSAT)

The SI-EOSAT, U.S.A., is involved in the distribution of Landsat, IRS-1B and IRS-1C data products. SI-EOSAT will acquire IRS-1D data at its ground station at Norman, Oklahoma, U.S.A. and distribute the data worldwide.

SI-EOSAT's exclusive marketing territory consists of the entire world outside the coverage area of Shadnagar earth station. The non-exclusive territory consists of the coverage area of Shadnagar earth station, except India.

5.2.3 INTERNATIONAL GROUND STATIONS

SI-EOSAT, with the help of ANTRIX Corporation Limited, the commercial arm of Department of Space, Government of India, has setup IGSs for receiving IRS-1C/1D data. Apart from Norman, U.S.A., IGSs at Neustrelitz, Germany; Chung Li, Taiwan, and Bangkok, Thailand are receiving IRS-1C data. These stations will be suitably upgraded to receive IRS-1D data also. Few more IGSs will be setup/upgraded to receive both IRS-1C and IRS-1D data. The IGSs will interact with SI-EOSAT for all their data requirements. For further details of data ordering information, users can contact the following addresses :

NRSA Data Centre
National Remote Sensing Agency
Balanagar, Hyderabad- 500037, India
Phone: 040-278560, 040-279572 to 77
FAX: 040-278664, 040-278158
or
Customer Service Department
SI-EOSAT
4300, Forbes Boulevard
Lanham, MD 20706
U.S.A.
Fax : +1 301 552 3762 / 5476
Email : Http/www.eosat.com

Figures 5.2.3.1 depicts the IRS-1C/1D ground stations and their coverage. Figures 5.2.3.2 to 5.2.3.4 depict some of the data received by the IGSs.

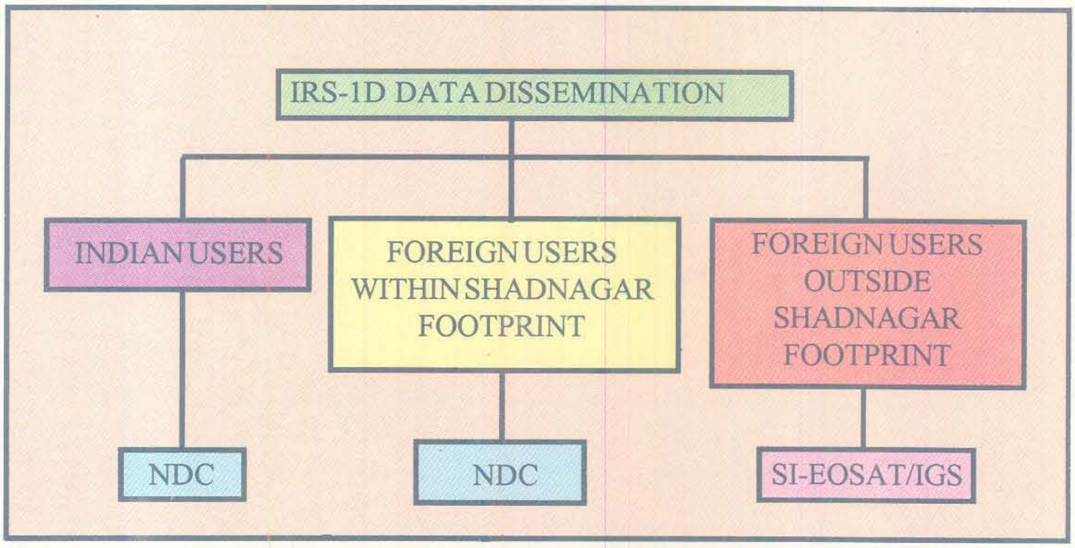
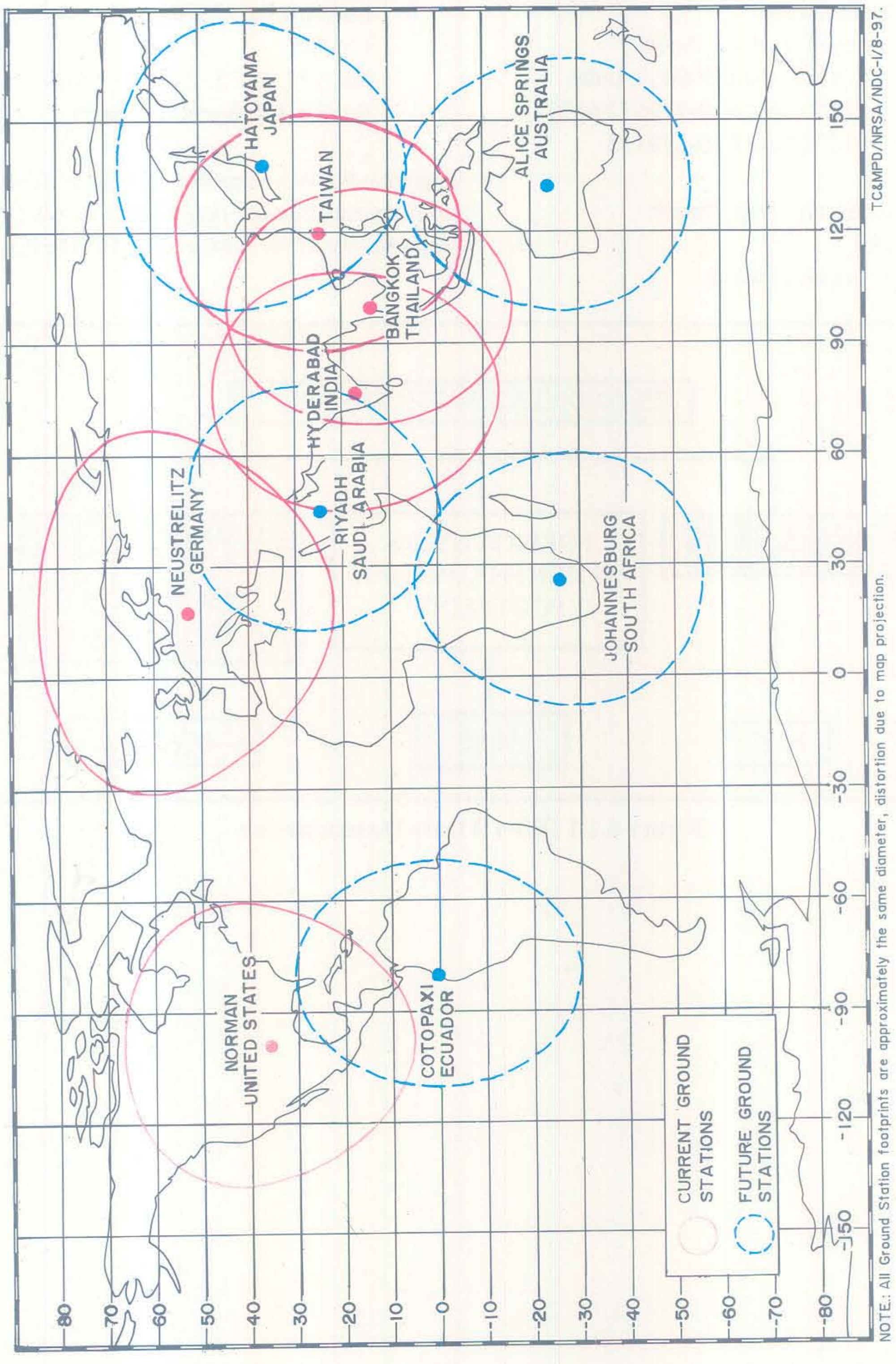


Figure 5.2.1 IRS-1D Data Dissemination



Figures 5.2.3.1 IRS-1D ground stations and their coverage

Figure 5.2.3.3 LISS-III Merged image showing Muscat

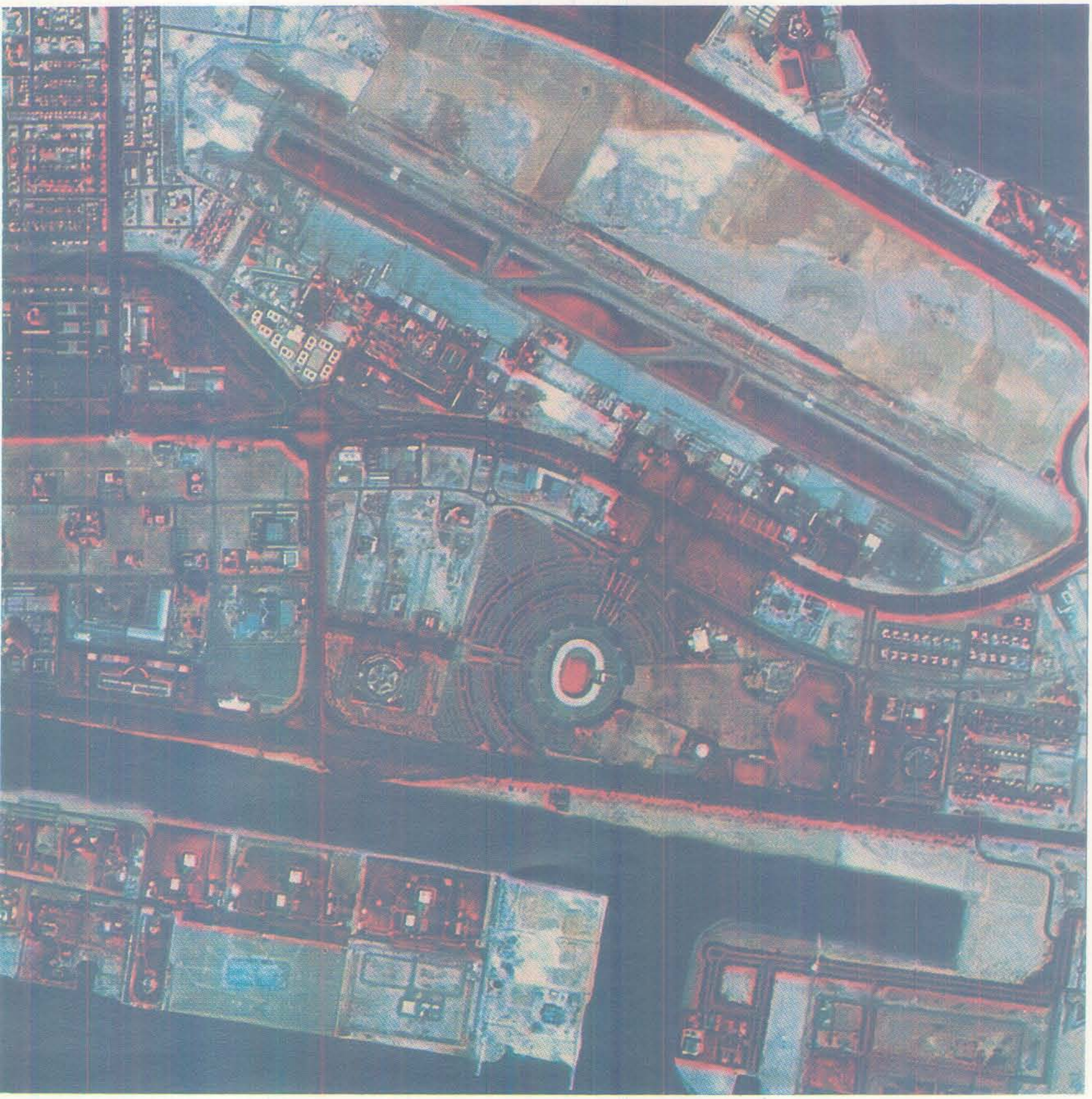


Figure 5.2.3.4 PAN + LISS-III merged image showing Abu Dhabi

5.3 DATA ARCHIVAL AND AVAILABILITY

Raw data acquired by NRSA from all the sensors will be archived in the form of HDTs and DLTs. Regarding processed photoproducts, only master films of geocoded and fixed full scenes will be archived.

Information on IRS-1C and IRS-1D data accessions archived at NRSA, will be available in the form of catalogues. These are updated periodically. Specific information on data availability of user identified area, with the desired cloud cover, data quality and period will be provided through the IIMS.

5.4. DIGITAL BROWSING FACILITY

Before ordering data, the users need to browse through the data, to check for cloud and quality of the data. To meet this need, NRSA is generating sub-subsampled and compressed browse images alongwith necessary ancillary information. Browse data is archived on mass data storage media like optical disks. Presently, the facility to browse through the archives is located at NDC only. During IRS-1D timeframe, it is planned to make browse data accessible to the users at their work place.

With the evolution of Internet and World Wide Web, dissemination and browsing of different forms of data has become a reality. It is planned to set up a web server so that the user can access browse archives through Internet or dial-up telephone network. While making the browse data available to the user across the globe, it is to be ensured that at the user's site, no format dependent software is necessary. Hence, it is proposed to develop the interfaces, with commercially available web browser software.

Browse image and catalogue generation are planned to be carried out at the data receiving station. The sub-sampled, compressed image data (JPEG standards) and the meta data will be transferred to the Browse Archival System (BAS) at NDC, either on media or via link. This meta data i. e., data describing the browse image for all the acquired passes will be stored on disk and will always reside on the system.

Four servers will be available; one for LAN users and others for Remote users, to browse data through Internet or dial-up lines. Users asking for browse data will have to choose the options provided in the Query form and submit it to the server. The server responds by placing the data and annotations at the user's end. Figure 5.4.1 depicts the browsing facility.

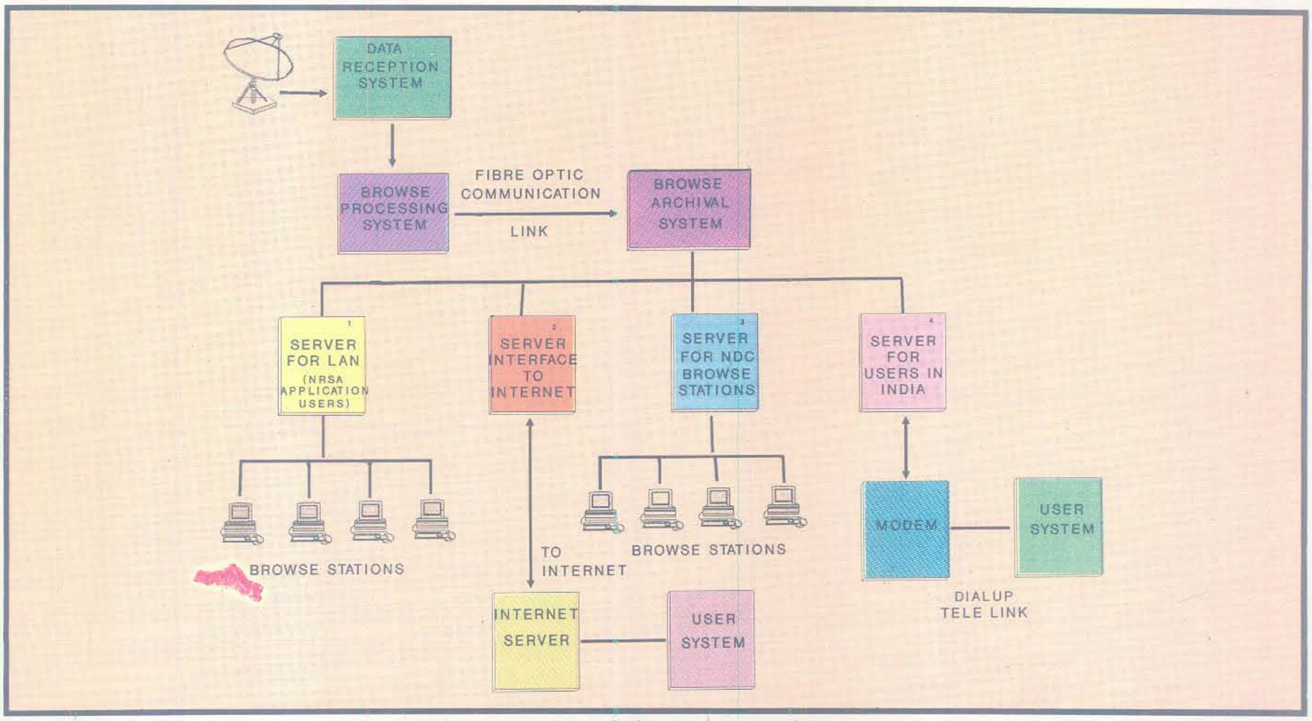


Figure 5.4.1 Digital Browse System

The user can ask for his area of interest in different ways. It is planned to accept queries based on:

* satellite and sensor/subscene and path and row
* latitude and longitude of the area
* mapsheet ID for a region (this input is valid only for Indian region)
* name of the location (for important cities only).

User can narrow down the list of available scenes by
* specifying the period of interest
* specifying the acceptable cloud cover

The following is the plan for archival of browse data:

Current Archives

Due to the large volume of data, only 6 months/1 year data will be made available to the users online. Users from International community and Metros will be able to access the Browse archives on Internet or through a Dial-up network. Due to the bandwidth limitations of these networks, it is planned to maintain two types of browse archives.

An archive with browse images of 1K X 1K resolution. This is maintained for LAN users of NRSA and also for the browse data exchange with International Ground Stations (on media).

Second archive with browse images of 256 X 256 size resolution. This is maintained for the remote user accessing through Internet or Dial-up connection.

Back-up Archives

As the size of the current archives is limited, the back dated data is moved to a back-up media like Digital Linear Tapes or Digital Video Tapes. The structure is designed to make the accessing method simple. Data from current archives, will be moved to this archives routinely.

PC-AT consisting of:

Hardware

1. INTEL 80386 processor @ 25 MHZ and above
2. Optional 80387 Math Co-processor for better performance.
3. 4 MB RAM
4. 720 MB Hard disk drive
5. VGA monitor (Colour)
6. VGA card (minimum resolution of 256 colours)
7. VRAM 2 MB

Software

1. MS Windows 3.1
2. Web browsing software with Java support

Communications	Hardware	Software
Intranet users LAN/WAN	8/16 bit ethernet controller card	TCP/IP Software and drivers for the ethernet card
Internet users	depends on the connectivity taken from the Internet service.	
Dial-up users	RS-232 serial port modem	TCP/IP software with slip support.

Table 5.4.1. Minimum required configuration of the browse system at user's end

The fields in meta data file(s) indicate whether the image is in current or back-up archives. The Archives Manager performs the archival and retrieval of data from archives.

Table 5.4.1 gives the required minimum configuration of the browsing system at user's end. However, users are requested to contact NDC before finalising the procurement of the system.

5.5 ORDERING INFORMATION

5.5.1 ORDERING DATA

Orders for data supply will be accepted by NDC from Government organisations, academic institutions, Industries and individuals in India and abroad. Orders may be placed with NDC in the prescribed format (Figure 5.5.1). Orders will be taken up for product generation when all the necessary information and full payment have been received from the customer. On receiving the payment, each customer is assigned an account number, to which reference should be made in all future transactions.

5.5.2. STANDING ACCOUNTS

Standing accounts may be established by customers who need products frequently. A standing account may be opened, by advance deposit of funds with NDC. The customer is given an account number, against which all subsequent orders will be processed. Status of standing account, is provided alongwith every invoice. Funds may be added to, or, a refund of the unused amount can be obtained at any time.

5.5.3 PAYMENT

All orders for supply of data products must be accompanied by full advance payment, in the form of bank draft and payable to NRSA. Payment in cash will not be accepted. In the case of standing accounts, the authorised account identification should be sent to enable processing of the order under that account.

Foreign payments have to be made in US dollars at rates indicated in the price list for supply of products to foreign users. All remittances may be credited to ANZ Grindlays Bank, 1177 Avenue of the Americas, New York NY 10036, U.S.A. (Telex : 667559 ; Fax : (212) 801 9859), under advice to ANZ Grindlays Bank plc, Hyderabad (Telex : 0425-6219; Fax : 0091 40-203734 marked to the attention of the Relationship Manager), in the following format :

TELECREDIT USD _________________ TO ANZ GRINDLAYS BANK, CHENNAI 001313, 00001 CHIPS 232293 FOR CREDIT TO NRSA, HYDERABAD, INDIA.

Alternatively, bank draft payable to NRSA, may also be sent by the user.

It may be noted that the date of full remittance of funds to NRSA, is treated as the effective date of placement of order.

5.5.4 PLACING A STANDING REQUEST

A standing request is intended to ensure supply of desired data products, pertaining to future dates. Automatic generation and supply of data, as they are acquired, is the most expeditious method for obtaining data products. A standing account is to be established and maintained to satisfy the prepayment requirements for such orders.

Two options can be exercised by the customer, for placing standing orders. The customer may either specify the area and cloud cover limitation, for which products are to be automatically generated and shipped, or, the user can confirm the order, after receiving information about the new acquisitions.

5.5.5 CUSTOM PRODUCTS

Processing of data to unique scales or formats, is available on selective basis and this must be specified explicitly.

NRSA DATA CENTRE

SATELLITE DATA REQUEST FORM

(IRS, LANDSAT,SPOT,ERS & NOAA)

Please remember incomplete forms will not be processed & will be returned

Name : Mr./Ms./Dr. Designation

Organisation:

Address :

City : Pin/Zip: Country

Phone : Telex : Fax:

Contact Person :

(List your address including PIN/ZIP code clearly. Listing of Telephone, Telex/Fax numbers or Cable/Telegraphic address will help NDC contact you faster in times of need.)

2. Your reference : ______________

3. SHIPPING ADDRESS (if different from above)

Name : Mr./Ms./Dr. Designation

Address :

City : Pin/Zip: Country :

Phone : Telex : Fax:

Contact Person :

4(a) User Organisation :

(Tick the category to which your organisation belongs.)

Central Govt. ☐ Industrial ☐
State Govt. ☐ Individual ☐
Academic Inst. ☐ Foreign ☐

4(b) Funding organisation if different from User Organisation :

5(a) NDC Account no :(Ex: 6-8888) __________ (b) New account to be opened Yes ☐ No ☐

6(a) In case of non-availability of good quality data for the requested date one can specify the alternative dates (either a period or a specific date). Please be sure to refer item 8 of guide lines and check column 8 on the next page.

7(a) Have you checked the browse print(s) Yes ☐ No ☐

(b) If no, tick the acceptable cloud cover

Approx. 0-10 % ☐
Approx. 11-25 % ☐
Irrespective of cloud cover ☐

Note: Cloud cover % mentioned in accession catalogue is only approximate.

8. Enhancement required: Common ☐ Scene specific ☐ (Default option is Scene specific)
(Only for photographic products)

9. Nature of application & Remarks (if any) : ______________

Figure 5.5.1 Data request form (page 1)

DATA REQUEST DETAILS

Please read all of the following guidelines before filling the table and use a seperate row for each product, don't club several products in one row.

Guidelines

1 Specify the satellite : (IRS, LANDSAT, SPOT, NOAA etc.)
2 Specify the sensor : (MSS, TM for LANDSAT, MLA, PLA for SPOT, LISS-I, LISS-II for IRS) or the subscene in case of IRS (LISS-II), for eg. LII-A1, LII-A2, LII-B1, LII-B2
3 Specify the Path or Orbit (Orbit in case of NOAA)
4 Specify the Row or Sector (Sector in case of NOAA)
5 Specify the Topo sheet No. or Quadrant No. (Quadrant No. in case of TM Standard CCT/Cartridge or Toposheet No. in case of geocoded product).
6&7 To order floppy products specify lat-long values and segment size (A-for 512x512, B-for 1024x1024)
8 Specify the date of pass required. Alternative dates can be mentioned incase of non availability of good quality data for the requested date. Indicate the alternative dates (period or specific date) in paranthesis just below the date of pass requested initially
9 Specify the product code as per the current price list.
10(a) Specify one band number for Black & White paper print OR 1k x 1k segment floppy and 4 band numbers in the case of 512x512 segment floppy
(b) Specify the band combination for False Çolor Composite
11 Specify the Unit price
12 Specify the Quantity
13 Specify the Value of the products ordered by multiplying columns 11 and 12.

Satellite	Sensor/ Sub-scene	Path/ Orbit	Row/ Sector	Topo Sheet/ Quadrant No.	Latitude		Longitude		Segment size A or B	Date of Pass	Product Code	Bands/Band Combination		Unit Price Rs.	Quantity	Value Rs.
					From	To	From	To				B&W	B G R			
1	2	3	4	5	6				7	8	9	10a	10b	11	12	13
														TOTAL		

Figure 5.5.1 Data request form (page 2)

GENERAL TERMS AND CONDITIONS OF SUPPLY OF DATA PRODUCTS

ORDERS

The order will be entertained only when the required information is furnished in full and payment made in advance. Once the order is processed, NDC sends a confirmation copy to the purchaser. Order once processed and confirmed cannot be amended or cancelled unless technical problems are encountered during data generation. NDC reserves the right to refuse/cancel any order in full or part.

PRICE

The price applicable to each order is the one in effect on the date of confirmation of the order at NDC. NDC publishes a price list of data products at periodic intervals.

PAYMENTS

* All orders must be accompanied by full advance payment for processing to be initiated.
* For Indian users, payment may be made by demand draft in Rupees payable to National Remote Sensing Agency, Hyderabad - 500037, Andhra Pradesh, India.
* For Foreign users, payment may be made by telecredit in US$ payable to **ANZ GRINDLAYS BANK, Account no Madras 001313.00001** chips 232293 for credit to NRSA, Hyderabad, India.
* For continued operation, a standing account can be opened by users by depositing a suitable amount. The user may add to the balance or obtain a refund of the balance at any time. Processing of data at any time will be limited to the balance amount in user's account.
* Same organisation/individual can open more than one account if required.

CONDITIONS OF SALE

* All products are sold for the sole use of purchasers and shall not be loaned, copied or exported without express permission of and only in accordance with terms and conditions if any, agreed with the NRSA Data Centre, National Remote Sensing Agency, Dept, of Space, Govt, of India.
* **Complaints and Inspection :** No complaint related to the quality and/or quantity of the products will be entertained unless the complaint is lodged at NDC within 30 days from the date of despatch. On acceptance of the complaint, poducts can be returned after confirmation by NDC. If the rejections are accepted by NDC, all attempts will be made to provide similar/equivalent data products.
* The purchaser is responsible for any use of the data prducts purchased from NDC, which has no liability or responsibility for the fitness of the products for any particular use. Consequently, the purchaser waives all claims against NDC.
* In general, all the data products will be despatched by registered insured post/air parcel. Products can be despatched by Courier service/speed post on specific request and at NDC's discretion.
* Supply of data products on the price list are governed by these general terms. No contrary terms or conditions of the purchaser are binding on the NRSA Data Centre.

The undersigned has verified the correctness of the order and accepted the General Terms and Conditions of supply listed above.

Signature : ____________________

Name : ____________________

Date : ____________________

Completed order form and payment may be mailed to :

Head, NRSA Data Centre
National Remote Sensing Agency
Balanagar, Hyderabad - 500037, INDIA
Telephone : 040 - 278560 ; 040 - 279572 Ext 2318
Telex : 0425 - 8080 ; 0425 - 8039
Fax : 040 - 278664 ; 040 - 278648

Figure 5.5.1 Data request form (page 3)

Guidelines to fill data request form

Please read the following guidelines before filling the order form. Please use separate rows for each product. Do not club several products in one row.

1. Specify the satellite (IRS-1A/1B, LANDSAT, SPOT, NOAA, ERS, IRS-1C, IRS-P3, IRS-1D)

2. Specify the sensor (MSS, TM for LANDSAT; MLA, PLA for SPOT ; LISS-I, LISS-II for IRS-1A/1B; AVHRR, TOVS for NOAA; SAR for ERS-1/2 and in case of IRS-1C/1D, LISS-III (3 for visible band resolution and M for SWIR band resolution, PAN, WiFS) or subscene, in case of IRS-1A/1B/ P2 LISS-II (A1,A2,B1,B2); in case of IRS-1C/1D PAN (A1 to A9, B1 to B9, C1 to C9, D1 to D9).

3. Specify the Path or Orbit (Orbit in case of NOAA)

4. Specify the Row or Sector (Sector in the case of NOAA)

5. Specify the toposheet number (eg. 56K/11 for 15'X15' and 56K/11 NE for 7 1/2' X 7 1/2') or quadrant number in case of TM standard CCT/Cartridge; A,B,C or D in case of PAN and quadrant 1 to 12 in case of LISS-III; Percentage of shift in increments of 10%, in case of SAT products and B/H ratio in the case of stereopair products.

6&7 Specify the latitude/longitude values in case of point geocoded products

8 Specify the date of pass/period of interest.

9 Specify the product code as per the current price list.

10a Specify the band number for B/W products for multispectral sensor

10b Specify the band combination for FCC.

11 Specify the unit price

12 Specify the number of copies of the product.

13. Specify the total price of products ordered by multiplying columns 11 and 12.

Appendix- III gives the Product Supply Agreement. Users are requested to carefully go through the same while placing the orders.

5.5.6 PRODUCT CODE

Each product is identified by a unique nine letter code. Table 5.5.6 gives the scheme used in arriving at the code of a product. Detailed list of type of product and its product code is given in Annexure 1.

PRODUCT CODE	PROJECTION	RESAMPLING	ENHANCEMENT	PROCESSING LEVEL	FORMAT	SIZE
ST Standard	0 No projection	0 No sampling	00 No enhancement	0 Raw	1 BW + ve	2 240mm
QU Quadrant	P Polyconic	C CC	01 Histo LUT	1 Radiometric correction	2 BW paper print	3 500mm
G3 15'x15' mapsheet based	S SOM	N NN		2 Radiometric & Geometric correction	3 FCC - ve	4 960mm
G4 7.5'x7.5' mapsheet based					4 FCC + ve	5 1000mm
SR Stereo					5 FCC paper print	7 6250 BPI
TR Shift Along Track					6 LOGSOWG BIL	H CART 525 MB Unix
J3 15'x15' geocoded with out SOI ref					7 LOGSWOG BSQ	I 5GB 8MM EXABYTE
J4 7.5'x7.5' geocoded with out SOI ref						J CD-ROM
J5 Point geocoded						

Table 5.5.6 Product code scheme

5.6 PAYLOAD PROGRAMMING

5.6.1. INTRODUCTION

The three main features of IRS-1C and IRS-1D which neccessiates programming of the satellite are:
Steerable nature of the PAN camera.
On Board Tape Recorder (OBTR) and
Reception of IRS-1C/1D data by IGS's.

The PAN camera can be steered upto ± 26^0, whereby a strip of 63-90 Km can be viewed within 407 Km on either side of the satellite track.This capability of PAN allows high revisit of an area and stereoscopic viewing. The revisit capability varies with latitude.

In the real-time mode, a ground station can acquire data from any/all of the three sensors viz. PAN, LISS-III and WiFS by setting to any one of the seven possible modes of real-time acquisition. (Table-5.6.1).

MODE	PAN	LISS-III	WiFS
1	+	+	+
2	+	+	
3	+		
4		+	
5		+	+
6	+		+
7			+

Mode 1 is the normal mode.

Table 5.6.1 Modes of acquiring real time data

It is possible to acquire data outside the visibility region of the Indian ground station, through an On Board Tape Recorder (OBTR). The OBTR will be able to record and store data in two segments of 8 minutes each .LISS III and WiFS data can be recorded simultaneouly, but, these cameras cannot be operated while recording PAN data. The five modes in which it can be operated are given in Table-5.6.2. Data recorded on the OBTR will be downlinked to the Indian data receiving station, only during night passes and products will be supplied as per user's requirements.

MODE	PAN I	PAN Q	LISS-III	WiFS
1	+			
2		+		
3			+	+
4			+	
5				+

Table 5.6.2 Modes of operating OBTR

IGS's will receive data, in the real-time mode, over areas which fall within their visibility zone. IGS's will interface with Space Imaging EOSAT, for all their requirements for the acquisition of the data and SI-EOSAT will, in turn, consolidate and priortise these requests and send them to NRSA Data Centre (NDC)

5.6.2 PROGRAMMING REQUESTS

General Users - Users send their Programming Requests (PR) to NDC (Figure 5.6.2). The PR is checked for its completeness , feasibility and also for the availability of data in archives which could satisfy the PR. The feasibility of a PR depends on technical constraints like specular reflection, the possible conflicts with other programming requests, climatic conditions of the area of interest etc.,.The PRs from various users are carefully studied and priorities are assigned depending on the order in which PR is received, size of the PR, acquisition mode etc.,. Based on these priorities, an optimal acquisition plan is prepared for the acquisition of every pass . NDC will send the acquisition plans to the Spacecraft Controlling Centre (SCC), where the necessary commands for the satellite to acquire/transmit the data, will be worked out. After the successful acquisition of a pass,the user will be informed and the scene that meets the user's requirement fully is processed and the products delivered to the user.

IGS'S- The IGS's have to communicate their requirements to SI-EOSAT which in turn would scrutinise, priortise conflicting requests, consolidate the requests on a weekly basis and send the final plan to NDC, atleast 10 days in advance. The programming request will define the area proposed for programming for each pass , in terms of path, start and end rows. NDC consolidates all user requests including those of IGS's on a weekly basis and sends to SCC 7 days ahead. The confirmation for the same to SI-EOSAT (which will inform the IGSs) will be sent by SCC on a weekly basis, 4 days before the first day of the specified week. SCC will generate the necessary commands for the satellite to acquire and transmit data to IGS's. SCC will also provide IGS's with the necessary information like state vectors,. for acquisition of data. After acquisition of each pass, EOSAT will inform NDC and SCC about anomalies if any. An overall flowchart of the programming activities is shown in Figure. 5.6.2.1. Figure 5.6.2.2 shows the programming request form.

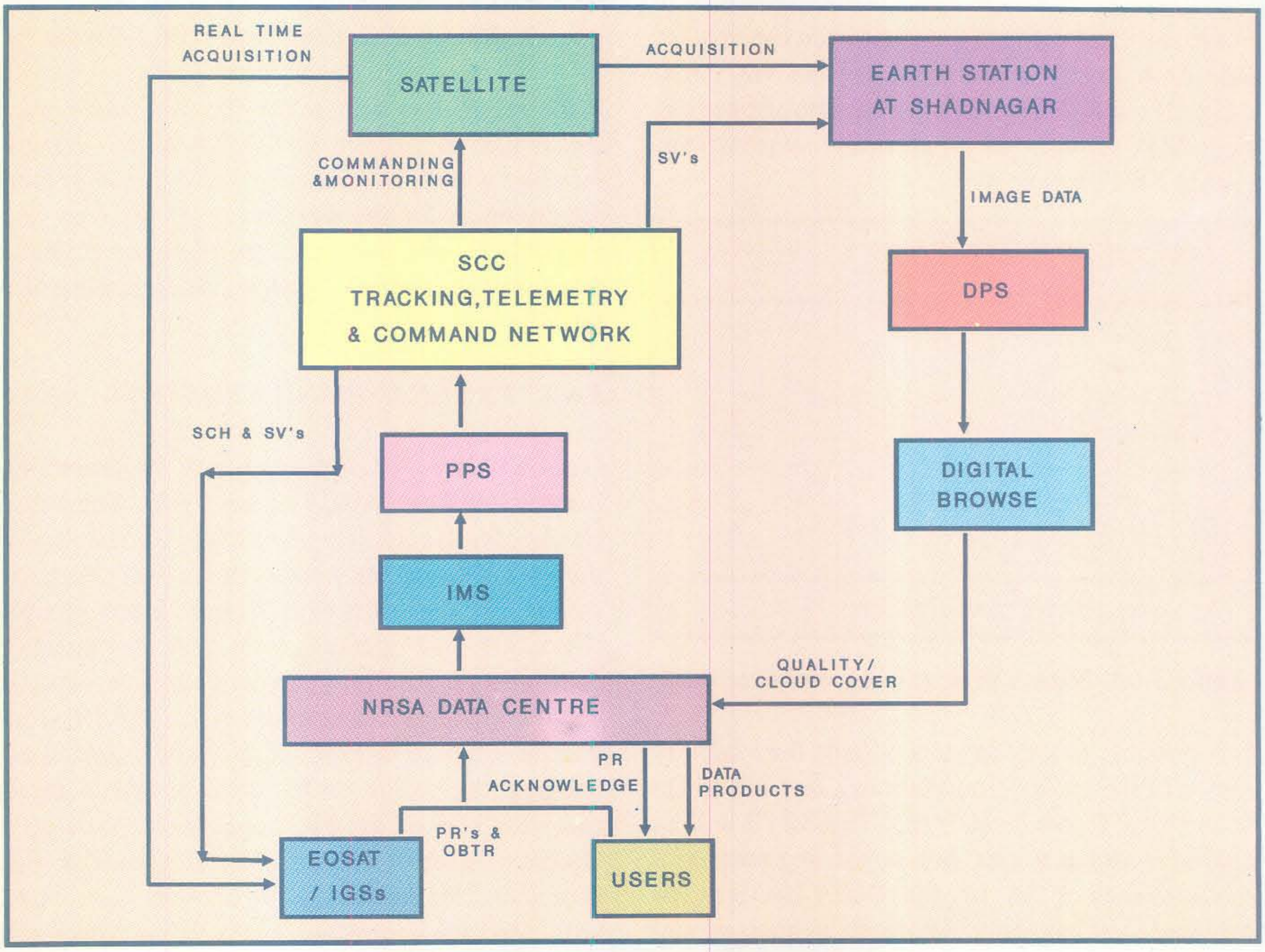


Figure 5.6.2.1 Programming activities

1. SURVEYING PERIOD :
(a maximum of 3 attempts only be made)

BEGIN	END

2. SPECTRAL MODE : PAN ☐ LISS-III ☐

3. SURVEYING METHOD (FOR PAN) :

NADIR
OFF-NADIR

	B/H RATIO	
	FROM	TO
STEREO		
TRIPLET		

4. CLOUD COVER : 0-10% ☐ 11-25% ☐ IRRESPECTIVE ☐

5. PRODUCT TYPE (SPECIFY THE CODE) :

i)
ii)
iii)
iv)

6. GEOGRAPHIC LOCATION OF AREA TO SURVEYED :
(POLYGON-GEOGRAPHIC CO-ORDINATES OF VERTICES)

	LAT.	LONG.
i)		
ii)		
iii)		
iv)		
v)		
vi)		

	FROM	TO
PATH		
ROW		

7. REMARKS :

8. SIGNATURE WITH DATE :

NAME :
OFFICE :
ADDRESS :

PHONE :
FAX :

Figure 5.6.2.2 Programming request form

5.6.3 PROGRAMMING SERVICES

NDC will try its best (a maximum of three attempts will be made) to acquire the data over the required area as per user specifications. If the data is acquired successfully within user specified cloud and meets quality criteria set forth by NRSA, the product will be generated and despatched to the user. Purchase of data products is mandatory.

5.6.4 PROGRAMMING SEQUENCE AND TIMELINE

* All users who are requesting for programming the satellite either for tilting the PAN camera or for OBTR request, have to send the request to NDC atleast three weeks in advance. NDC first checks the availability of the data in archives and based on this, a programming proposal is sent to user for confirmation. This will indicate the availability in archives (if any)as well as the areas to be freshly programmed. The confirmation /acceptance must be made by users atleast 10 days in advance.

* The confirmed Programming requests (PR) from users / EOSAT have to reach NDC atleast 10 days in advance.

* NDC will send weekly acquisition plan to SCC seven days in advance.

* SCC will send the confirmation schedule for a week, to the Indian ground station, SI-EOSAT and NDC, four days before the first date the week. This is a weekly transmission.

* State vector information will be transmitted to Indian ground station, SI-EOSAT and IGSs by SCC, on a daily basis.

* IGS has to send the pass performance report to SI-EOSAT within 24 hours after the acquisition of the pass, only by exception, in case of anamolies. This is retransmitted by SI-EOSAT to SCC and NDC.

The timeline of the programming activities is shown in the Table 5.6.4.

Sl.	Activity	Time frame (days)	From	To
1.	Programming request from user for PAN tilt and OBTR	T-21	User	NDC
2.	Acknowledgment of receipt of request	T-19	NDC	User
3.	Checking in archives and information to user on the above and areas to be reprogrammed	T-15	NDC	User
4.	Confirmed programming request	T-10	EOSAT/User	NDC
5.	Consolidation of all user requests at NDC for the target week.	T-7	NDC	SCC
6.	Clash analysis report between different requests	T-6	SCC	NDC
7.	Resolution of clashes.	T-5	NDC	SCC
8.	Confirmed schedules	T-4	SCC	Shadnagar, NDC,EOSAT-IGSs
9.	State vectors	D-1	SCC	Shadnagar, EOSAT and IGSs
10.	Pass Performance report	D+1 (by exception)	EOSAT	NDC and SCC
11.	Status of acquisition of user requests	D+3	NDC	User
12.	Product generation and despatch	D+14	NDC	User

"T" is the first day of the target week
"D" is the date of acquisition
A week is defined from Monday through Sunday

Table 5.6.4 Programming sequence and timeline

5.7 DESPATCH OF DATA PRODUCTS

The data products are securely packed and despatched by Speed post or Courier. Users should clearly specify the name and address, to which the products should be shipped at the time of placing the order. All shipments are prepaid and no postal charges are payable by the user.

An invoice accompanies the data products showing the details of the products under despatch, previous balance, current debit and current balance.

In the case of foreign orders, customs clearance and other formalities are the user's responsibility in his country. Despatches can also be made by DHL Courier on "Freight to collect basis" in case the user so desires.

5.8 USER FEEDBACK

The users are encouraged to keep the NRSA Data Centre informed about their experience with the data products supplied to them. Users may also inform, while placing the order, the hardware available for using the data, the operating system and other pertinent information. Such feed back will be continuously analysed to improve the quality of the products and services.

If the quality of the product supplied is found to be unsatisfactory, user should intimate NDC within a month from the date of receipt of the product, specifying the nature of the complaint and also arrange to send the products to NDC for evaluation. If it is observed that the product is indeed defective or a wrong product is supplied, the same will be replaced.

5.8 USER FEEDBACK

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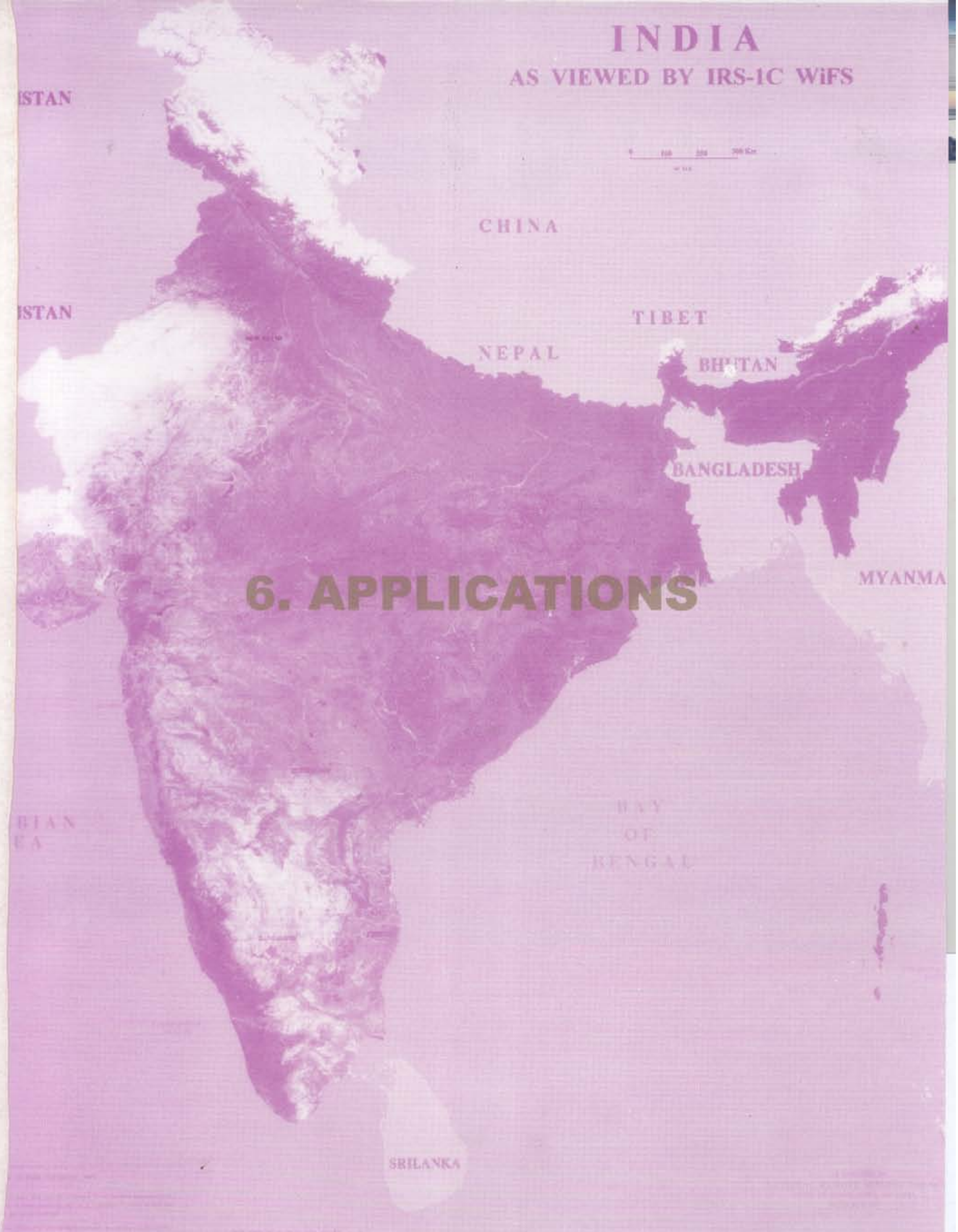
6. APPLICATIONS



6.1. INTRODUCTION

The launch of IRS-1C satellite with state-of-the-art sensors, on December 28, 1995 provided a new dimension and further boosted the applications of space-based remote sensing technology for natural resources management. With a unique combination of payloads, the IRS-1C has already earned reputation as "The Satellite for All Applications". IRS-1C/1D carry three imaging sensors characterised by different resolutions and coverage capabilities. Technical details of each of these sensor are provided in the earlier chapters. These three imaging sensors, provide image data for virtually all levels of applications, ranging from cadastral surveys to regional and national level mapping.

The PAN data with 5.2 - 5.8 m spatial resolution (at nadir) is a quantum jump from previously available IRS LISS-II sensor data (36.25 m resolution) on-board IRS-1A and 1B. This high resolution data, along with stereo-viewing capability and a revisit frequency of 5 days, provides an opportunity for large scale mapping of urban, cadastral level features, including infrastructure such as road/rail network.

The LISS-III data with 21.2 - 23.5 m resolution has significantly improved separability amongst various crops and vegetation types, leading to identification of small fields and better classification accuracy.

The frequent availability of data from the WiFS payload has helped in monitoring dynamic phenomena like vegetation, floods, droughts, forest fire etc.,. The availability of data with a five day repetitivity, has enabled the generation of spectral growth profiles at almost every stage of crop growth.

A major benefit of the multi-sensor IRS-1C /1D payload is the capability to merge the multi-spectral LISS-III data, with high resolution PAN imagery. This merger of multispectral and high resolution data, facilitates detailed land cover classification and delineation of linear and narrow roads/lanes, structures, vegetation types and parcels of land. It is therefore viewed as a break through for cadastral level mapping.

6.2 APPLICATION POTENTIAL

When the unique advantages offered by IRS-1C/1D data are translated into application possibilities, many innovative uses emerge, in addition to routine resource inventories. These are summarised discipline-wise.

<u>AGRICULTURE</u>

- Early season estimation of total cropped area (WiFS)
- Monitoring crop condition using crop growth profile (WiFS)
- Identification of crops and their acreage estimation in multi-cropped regions (LISS-III ; SWIR data improves crop discrimination)
- Crop yield modelling (WiFS + LISS-III)
- Cropping system/crop rotation studies (WiFS + LISS-III)
- Command area management (WiFS + LISS-III + PAN)
- Detection of moisture stress in crops and quantification of its effect on crop yield (LISS-III; in particular SWIR band data)
- Detection of crop violations (LISS-III + PAN)

<u>FORESTRY</u>

- Improved forest type mapping (LISS-III)
- Monitoring large scale deforestation, forest fire (WiFS+ LISS-III)
- Monitoring urban forestry (LISS-III + PAN)
- Forest stock mapping (LISS-III + PAN)

LANDUSE AND SOILS

- Mapping Landuse/cover (level-III classes), at 1:25,000 scale or better (LISS-III + PAN)
- Change detection (LISS-III + PAN)
- Identification of degraded lands/erosion prone areas (LISS-III + PAN)

GEOLOGY

- Lithological and structural mapping (PAN+ LISS-III)
- Geomorphological mapping (PAN+LISS-III and PAN stereo)
- Ground water exploration (PAN+LISS-III)
- Engineering geological studies (PAN + LISS-III and PAN stereo)
- Geoenvironmental studes (PAN+LISS-III)

URBAN LANDUSE

- Urban landuse level IV mapping (PAN)
- Updation of urban transport network (PAN)
- Monitoring urban sprawl (LISS-III + PAN)
- Identification of unauthorised structures (PAN)

WATER RESOURCES

- Monitoring surface water bodies frequently and estimating their spatial extent (WiFS)
- Snow-cloud discrimination leading to better delineation of snow area (WiFS + LISS-III; SWIR)
- Glacier inventory (LISS-III)

COASTAL ENVIRONMENT

- More detailed inventory of coastal landuse on 1:25,000 scale (LISS-III + PAN)
- Discrimination of coastal vegetation types (LISS-III; SWIR)
- Monitoring sediment dynamics (WiFS)
- Siting of coastal structures (LISS-III + PAN)

WATERSHED

- Delineation of watershed boundaries/partitioning of micro watershed (PAN stereo data)
- Watershed characterisation at large scale (Size, shape, drainage, landuse/cover (LISS-III + PAN)
- Siting of water harvesting structures (LISS-III + PAN)
- Monitoring watershed development (LISS-III + PAN)

ENVIRONMENT

- Impact assessment on vegetation, water bodies (WiFS + LISS-III)
- Siting applications (LISS-III + PAN)

DISASTERS

- Mapping flood inundated areas, damage assessment (WiFS, LISS-III, PAN)

DIGITAL ELEVATION MODELS

- Contours (> 10m) (PAN)
- Slope/Aspect analysis (PAN)

Large scale thematic mapping upto 1:25,000 scale (LISS -III + PAN)

6.3 DEMONSTRATED APPLICATIONS

Using data available so far from IRS-1C, a host of applications have been demonstrated, at various centres in the country.

6.3.1 CROP AREA ESTIMATION

Advantage of frequent repetitivity of WIFS data with not too coarse spatial resolution, has been demonstrated by its use in estimating total cropped area in rabi season, for Punjab State. The results gave an early pre-harvest estimate of 3.4715 Mha for 1995-96 rabi season. This provided encouragement for evolving a scheme, for the use of multitemporal WiFS data for national wheat acreage estimation for 1995-96. Multidate IRS-1C WiFS data analysis showed that the distinct phenological changes observed in each crop were manifested in the direction of change in signature, which could be used for crop identification and that the changes were prominent because of varying growth stages. Wheat acreage for the country was estimated to be 27.6 Mha. compared to 25.6 Mha. Similar efforts were also made for rice and cotton, during 1996-97 Kharif season. Figure 6.3.1.1 shows WiFS data indicating changes in signatures of different crops like soyabean, rice and cotton. Phenological changes of soyabean as seen in WiFS images are shown in Figure 6.3.1.2.

The results from multitemporal WiFS data covering Bardhman district in West Bengal, indicate that various crops exhibit characteristic temporal - spectral behavior, in terms of direction and rate of spectral change. Wheat and potato spectral signatures increase in NIR and decrease in red. This is associated with their growth, while mustard moved in opposite direction, due to senescene. However, the pseudo-invariant features (PIFs) like forest, urban and deep water areas showed little or no change. These features could be used to normalize the atmospheric effects in temporal data set, which is essential for generating spectral growth profiles.

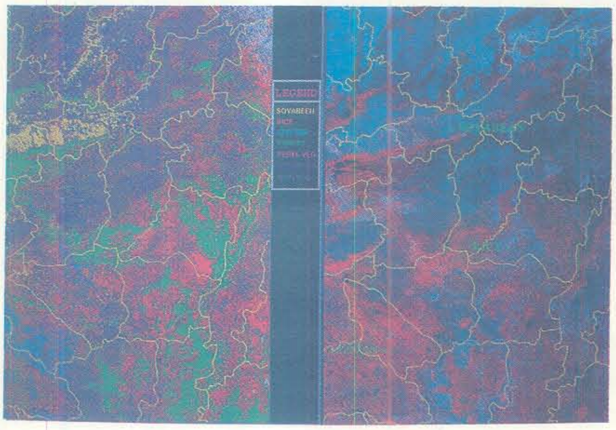


Figure 6.3.1.1 WiFS image depicting different crops

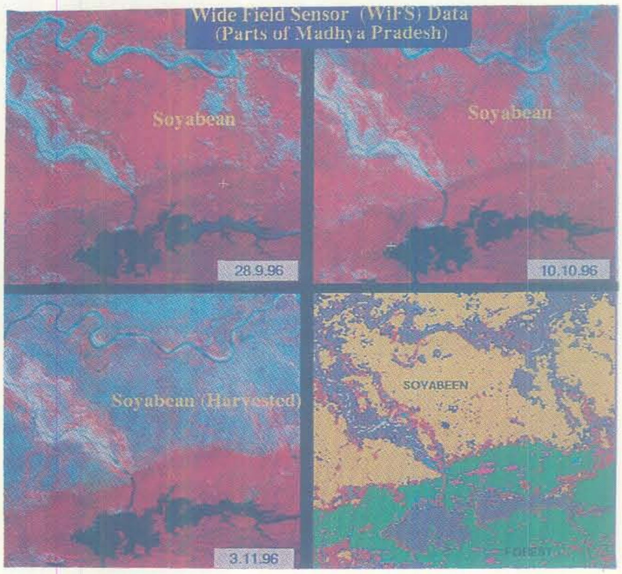


Figure 6.3.1.2 WiFS image depicting phenological changes.

6.3.2 CROP DISCRIMINATION

Crop discrimination, particularly in areas characterised by small size fields and co-existence of multiple crops requires data of high spatial resolution, frequent repetitivity and in specific spectral bands. Figure 6.3.2.1 shows images acquired over Sally farm, Hissar by IRS LISS-I, LISS-II and LISS-III during the same season. While cropped area is seen clearly in LISS-I, individual fields

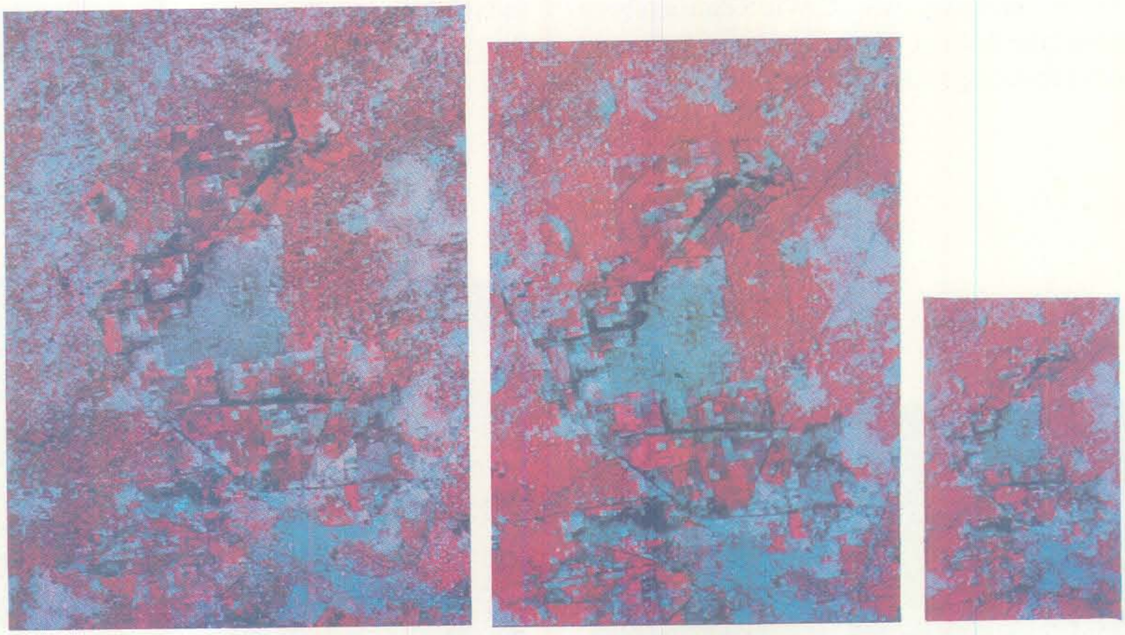


Figure 6.3.2.1 Sally farms as seen by LISS-I, II and III sensors

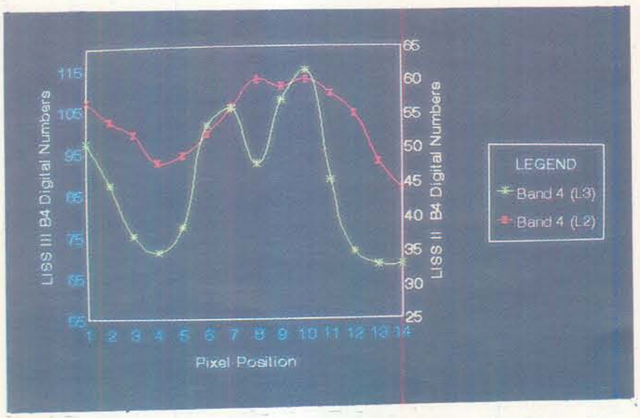


Figure 6.3.2.2 Transect plots of agricultural fields

are clearly discernible in LISS-III sensor. The effect of spatial resolution on crop classification accuracy was evaluated using IRS LISS-II and LISS-III data acquired on two consecutive dates for Saharanpur district in UP. The separability between wheat and sugarcane increased significantly in LISS-III data, as compared to LISS-II. Transect plots (Figure 6.3.2.2) showed that in LISS-II data there was smoothening of signal from crop fields and less number of peaks compared to LISS-III data. In one of the test areas having irrigated wheat and unirrigated gram (Bhopal Tehsil), it was observed that SWIR band made marginal improvement (2 to 3 per cent) towards crop separability using J-M distance criteria. Typical FCCs using bands 2, 3, 4 and 3, 4, 5 of LISS-III are shown in Figure 6.3.2.3. Similar observations were made for various other crops. However, the accuracy of orchards, improved significantly by including SWIR band in classification. In order to ascertain this, the

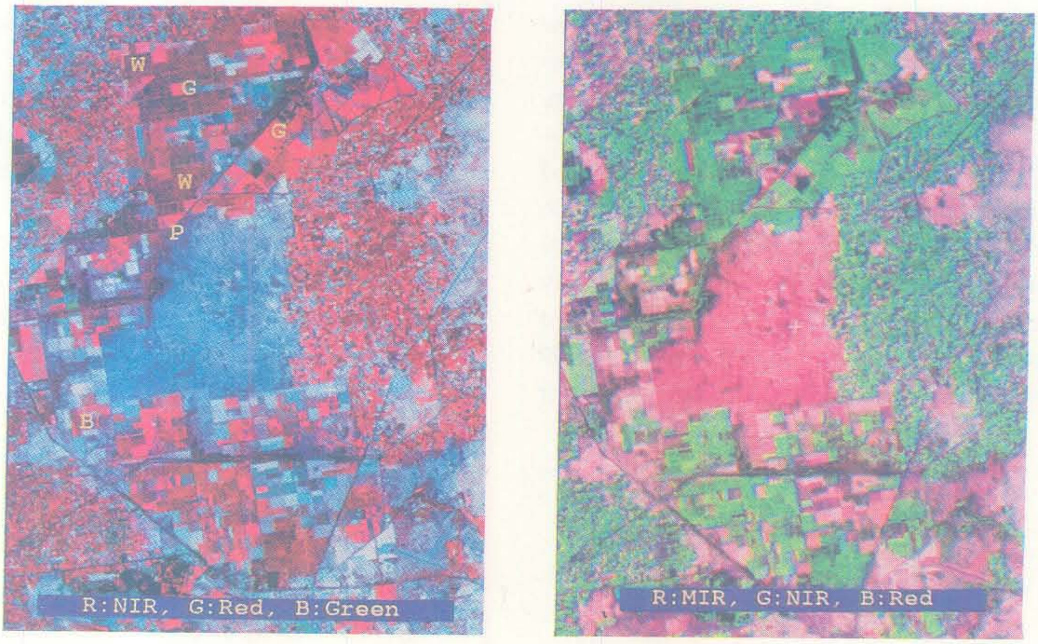


Figure 6.3.2.3 LISS-III FCCs with different band combinations

LISS-III data covering Bale tehsil in Pali district (Rajasthan) has been evaluated to study scene spectral characteristics, inter-band correlation, principal component characteristics and crop separability. The principal component analysis indicates that, the data over this scene lies in two major axes which explain 97.6% of variance (91.9% scene variance is from the component image which has contributions from B2, B3 and B5). The study on crop separability of wheat and mustard indicates improvement in crop type and condition assessment by inclusion of SWIR channel, whether measured by minimum Bhattacharya distance (BD) or average BD. Similar results have also been obtained from different test sites.

Use of merged product of LISS-III and PAN for identification of sugarcane, in individual fields and their condition was demonstrated for part of Yamunanagar, Haryana (Figure 6.3.2.4).

Figure 6.3.2.4 PAN+LISS-III merged image showing sugarcane crop

6.3.3 MULTIPLE CROP IDENTIFICATION

A study was conducted in Tullur Mandal, Guntur district, A.P. for identification and estimation of the acreage of crops grown under multiple cropping situation, using LISS-III data of 25 January, 1996. Digital analysis of the data, employing maximum likelihood classification algorithm, based on complete enumeration approach, with limited field checks, revealed that, LISS-III data can be effectively utilised for identification and acreage estimation of multiple crops, since field boundaries are clearly discernible in the data. The LISS-III image of Tullur mandal, alongwith classifed map is shown in Figure 6.3.3.1.

6.3.4 FOREST COVER MAPPING

The biotic pressure zone map of Agr. reserve forest prepared using LISS-III data and its comparison with LISS-II indicates that, level of details available in LISS-III is higher than LISS-II data. The LISS-III data also provided information on the accessibility to the forest, which is otherwise difficult to observe.

The use of either IRS-1C PAN data or combined use of PAN and LISS-III data would facilitate preparation of forest stock maps at 1:25,000 scale.

The different forest cover levels represented by different tones of PAN data, are shown in Figure 6.3.4.1 and 6.3.4.2.

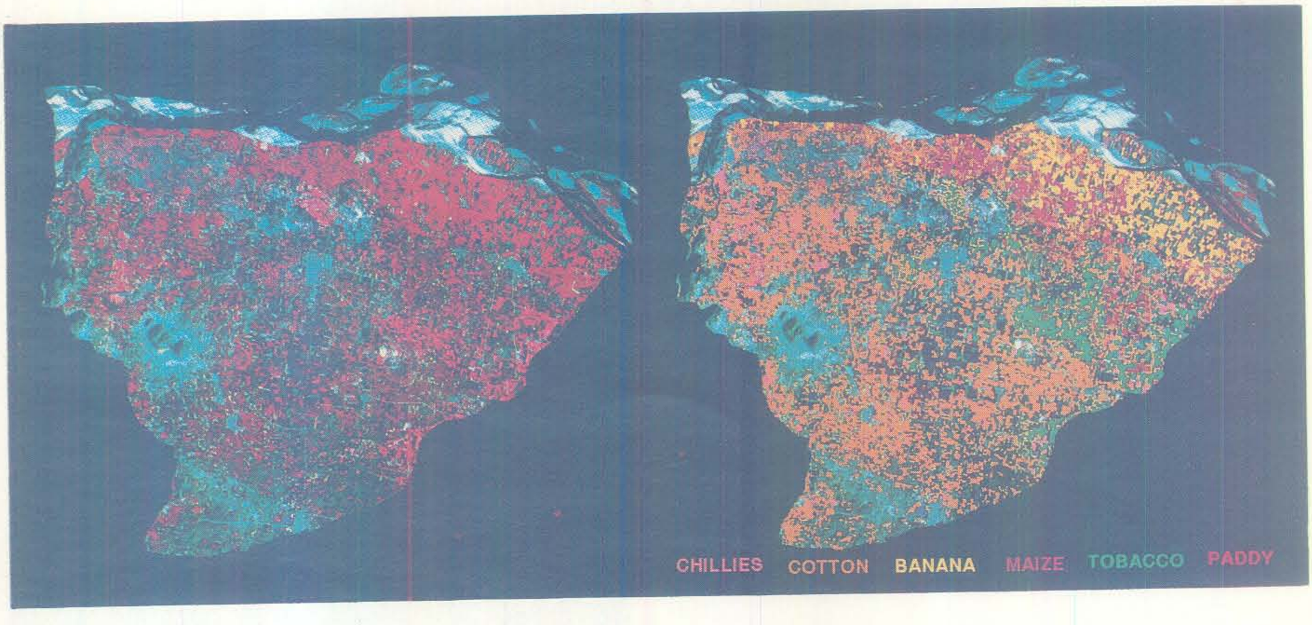


Figure 6.3.3.1 LISS-III image of Tullur Mandal alongwith classified map

Figure 6.3.4.1 PAN image showing forest cover in parts of western U.P.

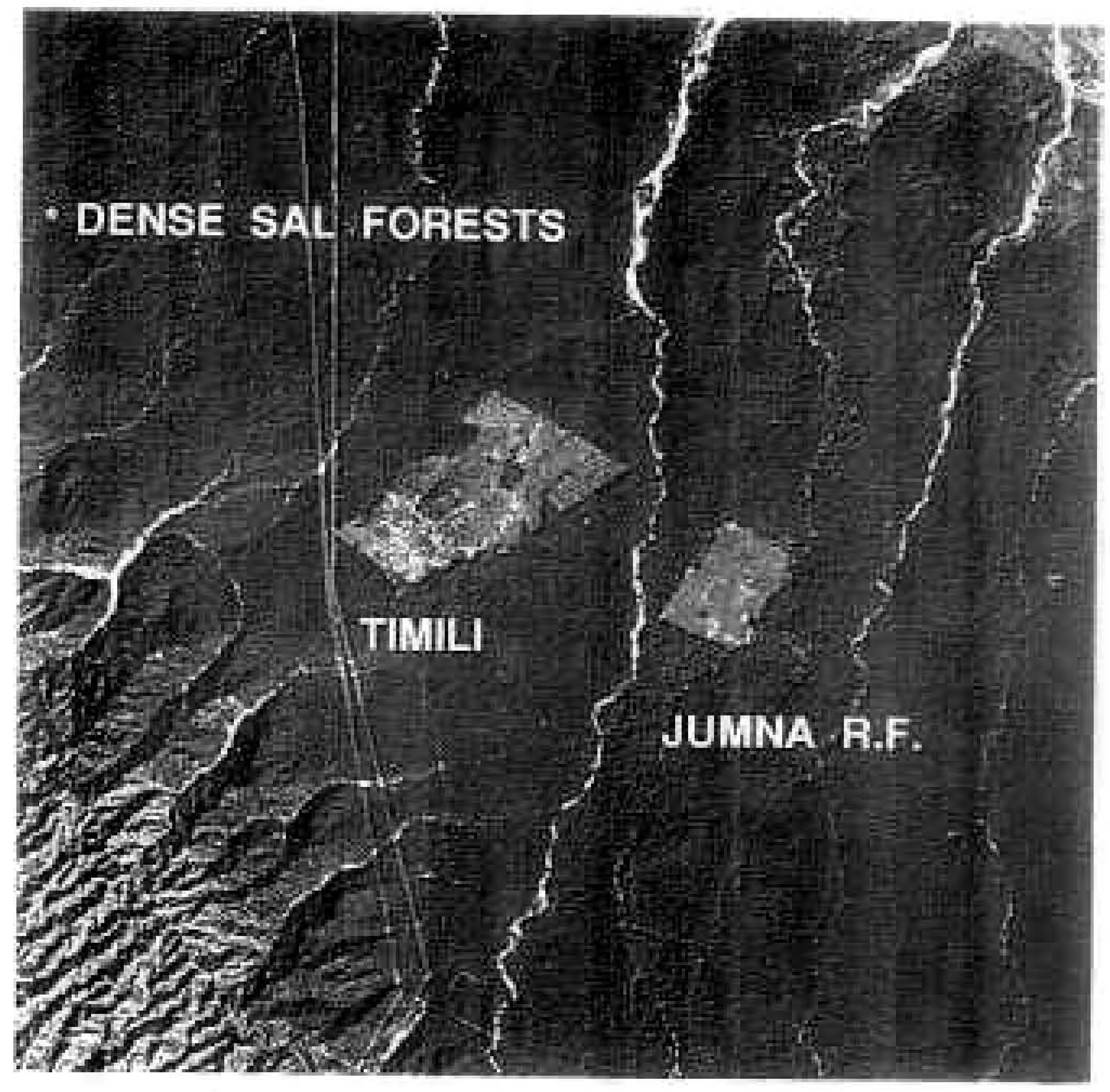


Figure 6.3.4.2 PAN image showing dense forest cover in parts of western U.P.

6.3.5 PLANTATIONS

The interpretation of panchromatic data for vegetation mapping shows that, even small plantations (around 0.25 hectares) could be mapped. PAN data was used for identification of plantations in Terai region of UP and teak plantations in Karnataka. (Figure 6.3.5.1 and 6.3.5.2).

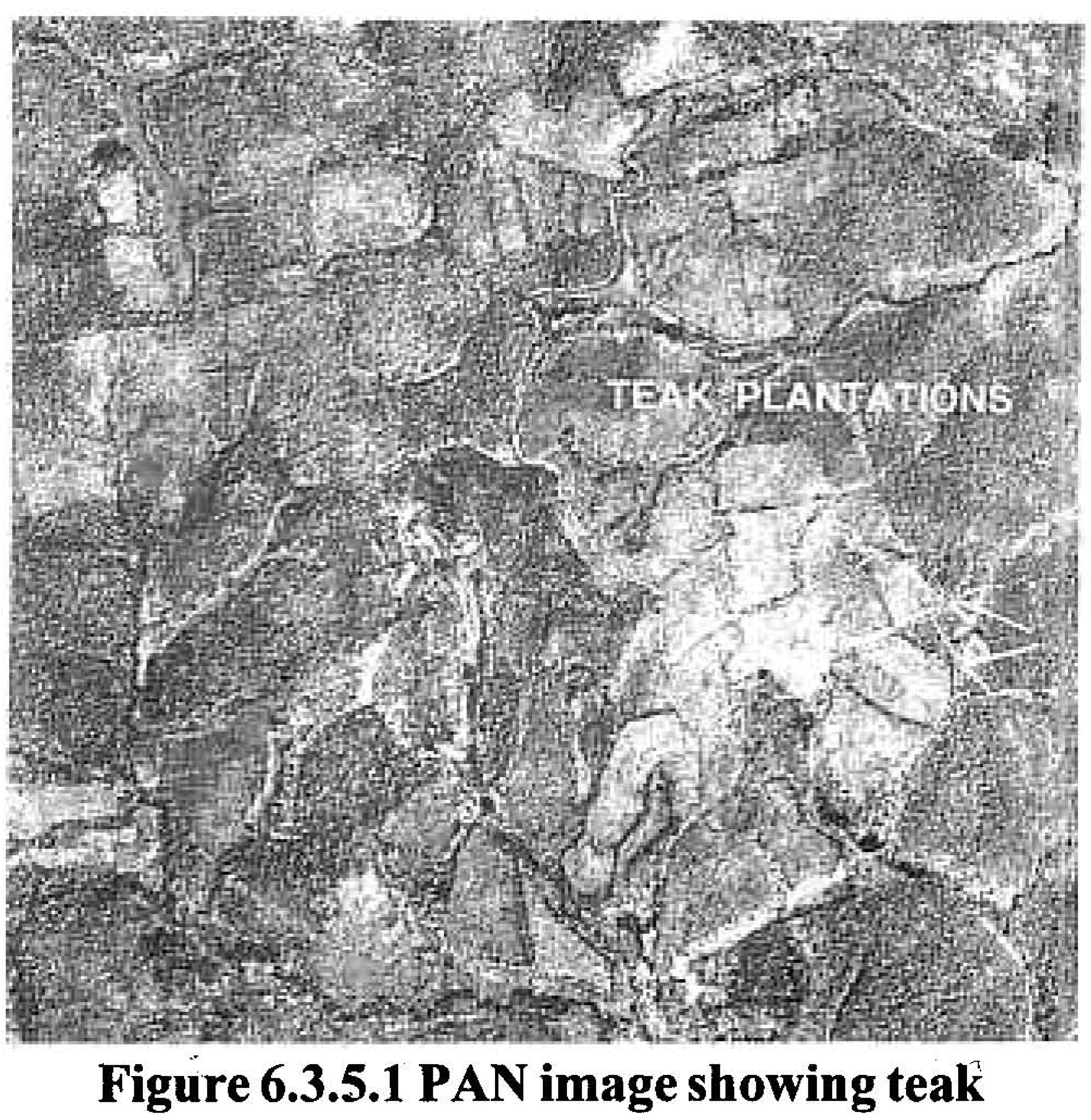


Figure 6.3.5.1 PAN image showing teak plantation in Karnataka

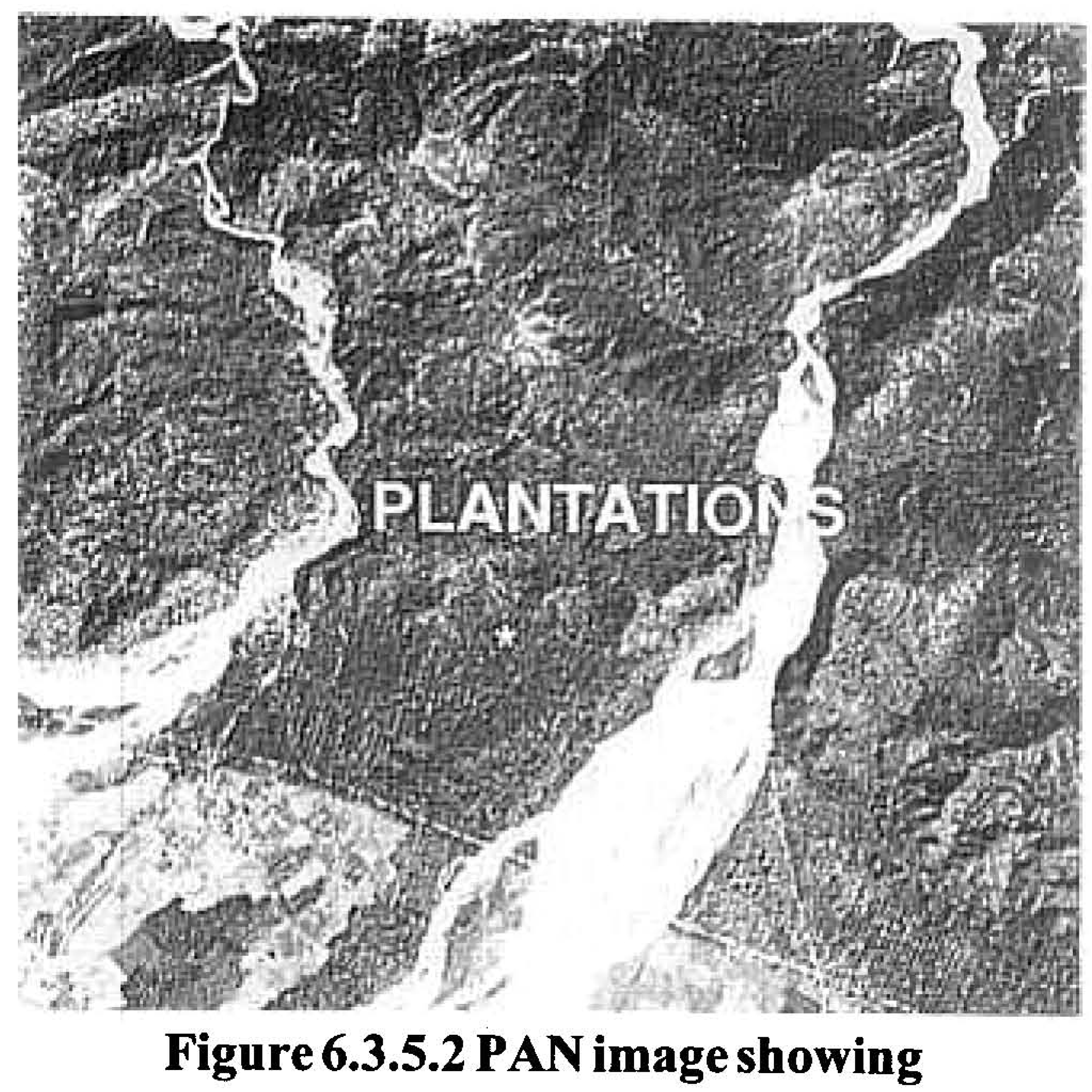


Figure 6.3.5.2 PAN image showing plantations in Western U.P.

6.3.6. URBAN FORESTRY

The merged product of panchromatic and LISS-III data has been employed, to find its potentiality in urban forestry application (Figure 6.3.6.1). In order to see the success story in a typical urban area, Gandhinagar city, the greenest capital, has been selected for multitemporal analysis. The reference data was of 1972 and the latest data was that of IRS-1C acquired during 1996. It was found that there is an upward trend of afforestation.

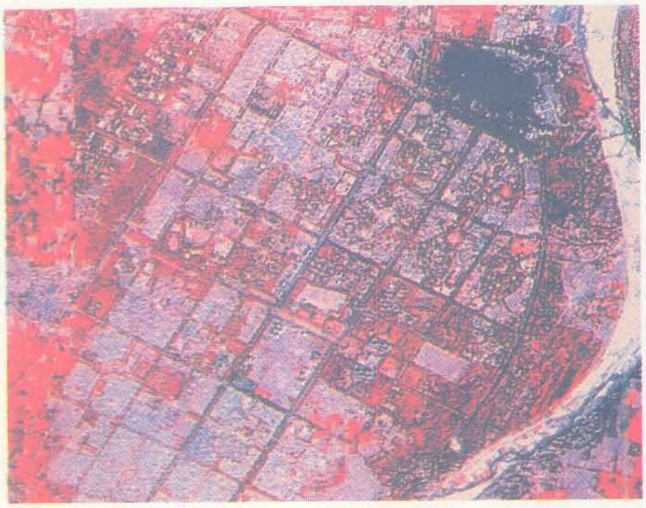


Figure 6.3.6.1 PAN + LISS-III data depicting Gandhinagar city

6.3 7 SHIFTING CULTIVATION

Shifting cultivation is more prevalent in north eastern parts of India and results in encroachments in forest lands. Therefore, the monitoring of shifting cultivation on an annual basis is required for assesment of the encroachments, especially small areas. The encroachment of forest lands, specifically by shifting cultivation, could be identified to a minimum size of 0.25 ha (Figure 6.3.7.1) using PAN data alone or PAN data in conjunction with LISS-III data.

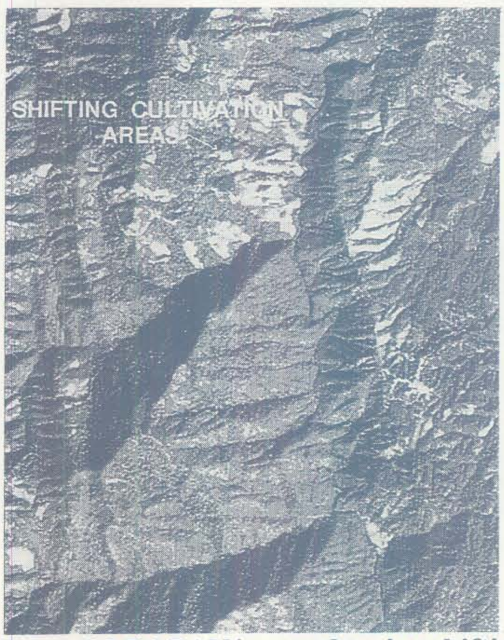


Figure 6.3.7.1 PAN image showing shifting cultivation in Mizoram

6.3.8 COASTAL GEOMORPHOLOGY

Analysis of IRS-1C data indicates that coral reef zonation (Figure 6.3.8.1), identification of tree and shrub mangroves (Figure 6.3.8.2), seaweed/sea grass beds, improved delineation of coastal features such as fringe mangroves, mudflats, beach-dune vegetation, saline areas etc., as well as better understanding of suspended sediment patterns (Figure 6.3.8.3), are now possible. The results from IRS-1C PAN and LISS-III merged product of Van and Koswari reefs show that the live coral areas as small as 50 sq m and the sea grass bed, only 15-20m wide, were identified and mapped. Merged data is extremely useful to monitor condition of individual coral knoll/reef patch and in estimating total sea grass/sea weed resources, available in an area. The merged data of IRS-1C PAN and IRS-1B LISS-II data covering Tuticorin area (Figure 6.3.8.4), shows improved accuracy in boundary delineation of tidal flat, beach, dunes,

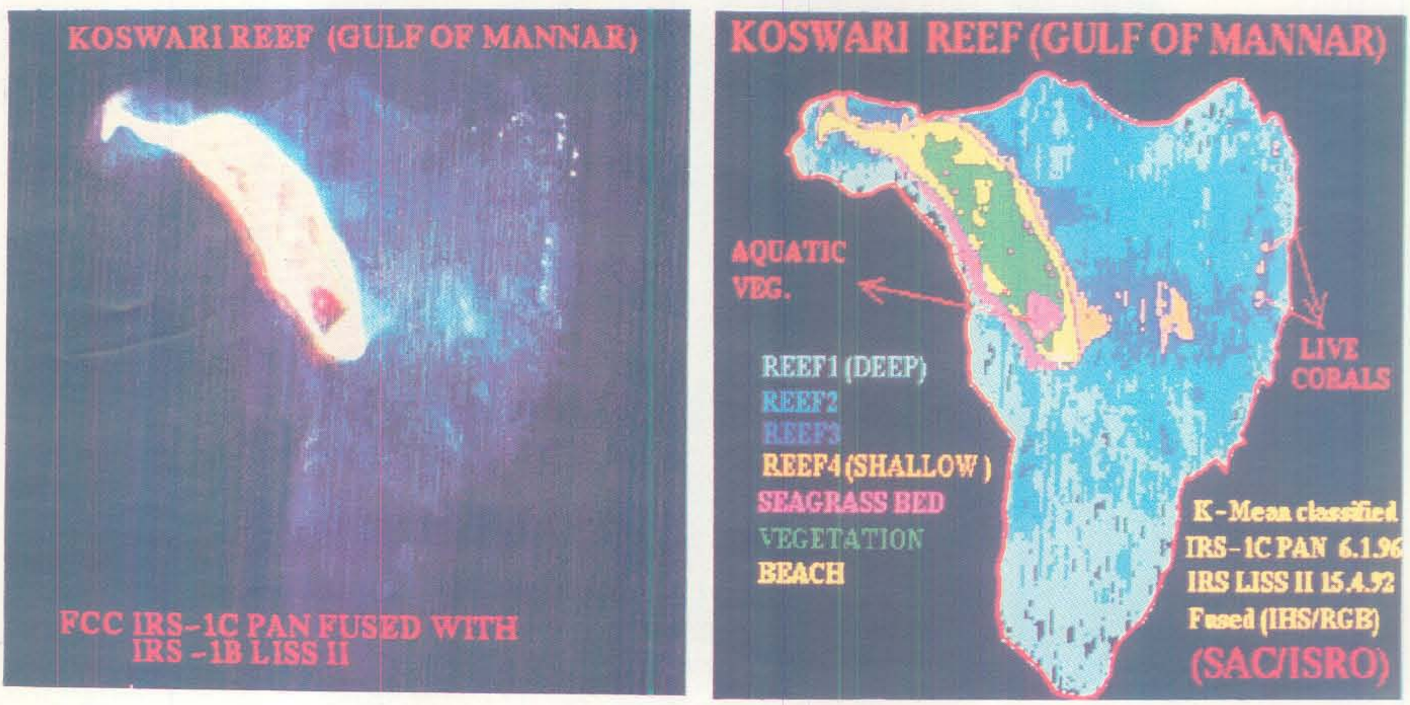


Figure 6.3.8.1 PAN+LISS-II image and classified map depicting Koswari reefs in Gulf of Mannar

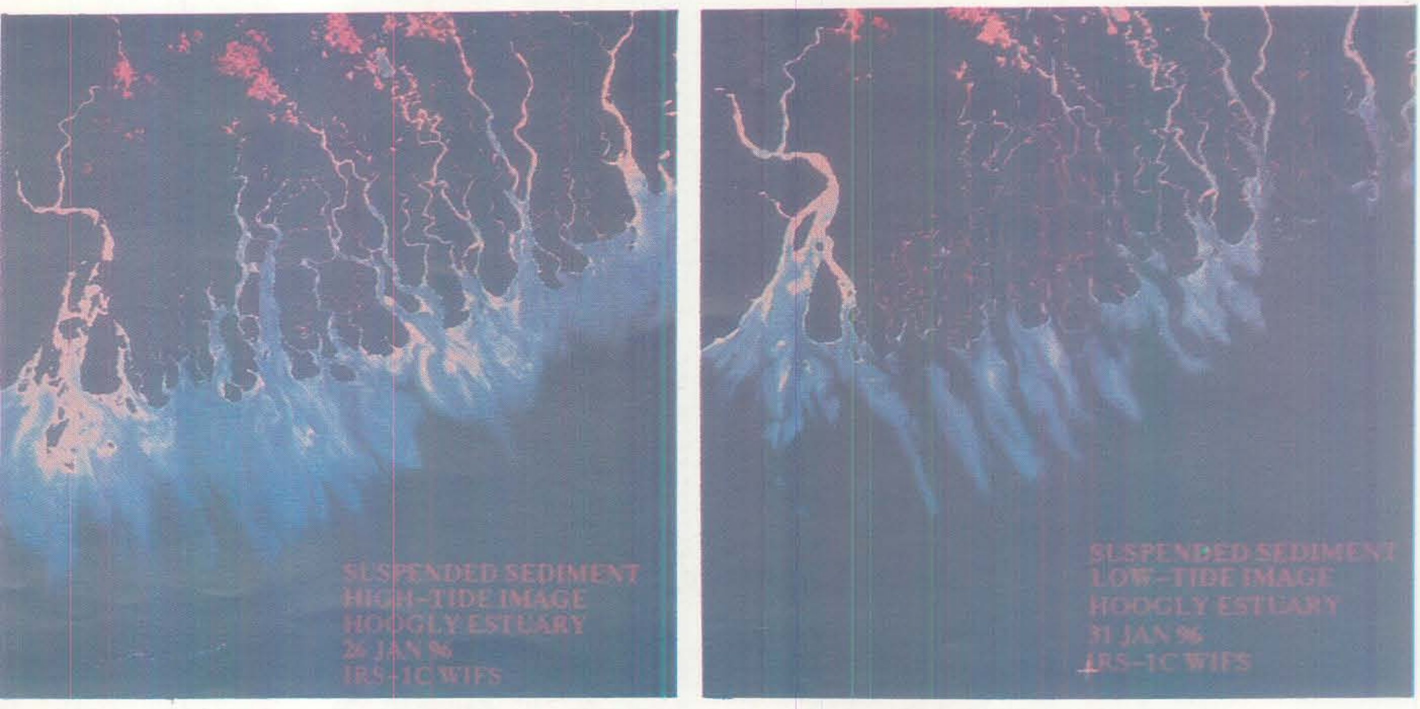


Figure 6.3.8.2 WiFS image showing mangrove and suspended sediment

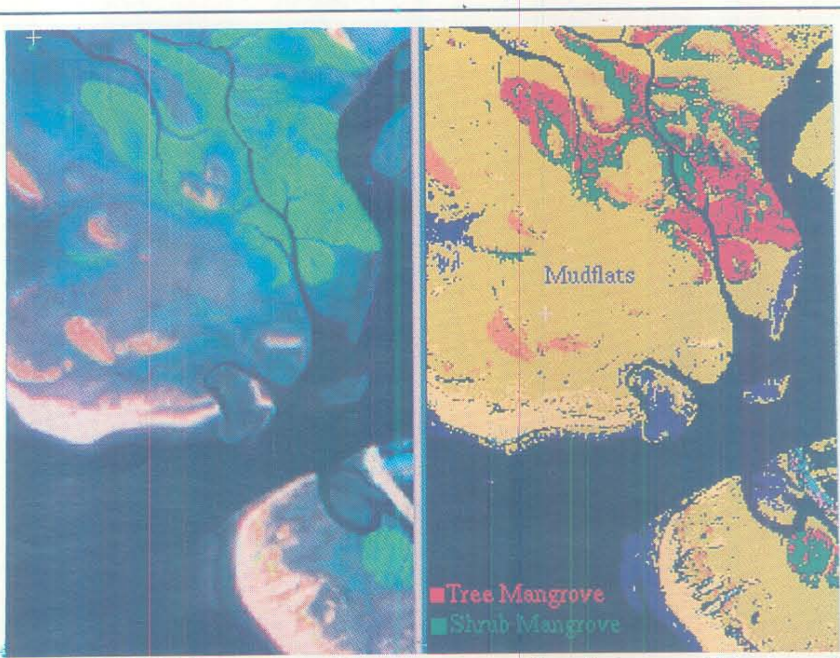


Figure 6.3.8.3 LISS-III image showing mangrove density map of Kori creek, Gujarat

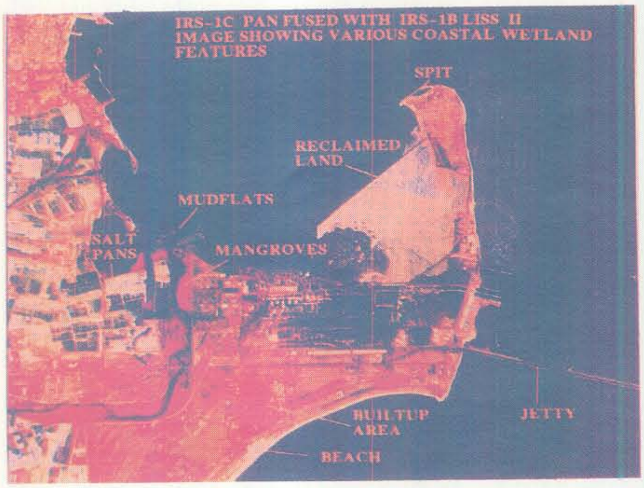


Figure 6.3.8.4 PAN+LISS-III merged image of Tuticorin, Tamilnadu

dunes, categorization of reclaimed area, delineation of jetty, built-up area etc.,. This product is found extremely useful in providing detailed information on 1:25,000 scale or larger, about the reclamation and construction activities which are required for regulating these activities, in the coastal regulation zone (the area between high tide line and low tide line and 500m from high tide line).

6.3.9 URBAN PLANNING AND MAP UPDATION

Preliminary analysis of IRS-1C data has shown a marked improvement in detecting, discriminating and delineating various level-III urban land use features at larger scale data. The study carried out using merged product of IRS-1C PAN and LISS-III covering Ahmedabad city, indicated, that it was possible to map level-III urban land use features such as low/medium and high rise structures associated with the residential use, slum areas, major and minor industrial complexes, different types of roads, bridges, educational institutes, open spaces such as parks, gardens, play grounds, stadiums, utilities such as sewage treatment plants, bus depots, vacant lands and newly developing layouts (Figure 6.3.9.1).

From this analysis, it has also been noted that it is possible to prepare urban land use map on 1:15,000 scale depicting level-III land use information. A study also has been attempted to monitor the urban development on a plot by plot basis, by superimposing the cadastral map of Jodhpur gram panchayat on the merged data, with the help of ground control points at an accuracy of about 12m. The study indicates that it is possible to provide information of development at plot level. This information, helps planners to monitor whether the development is as per the original plan or not.

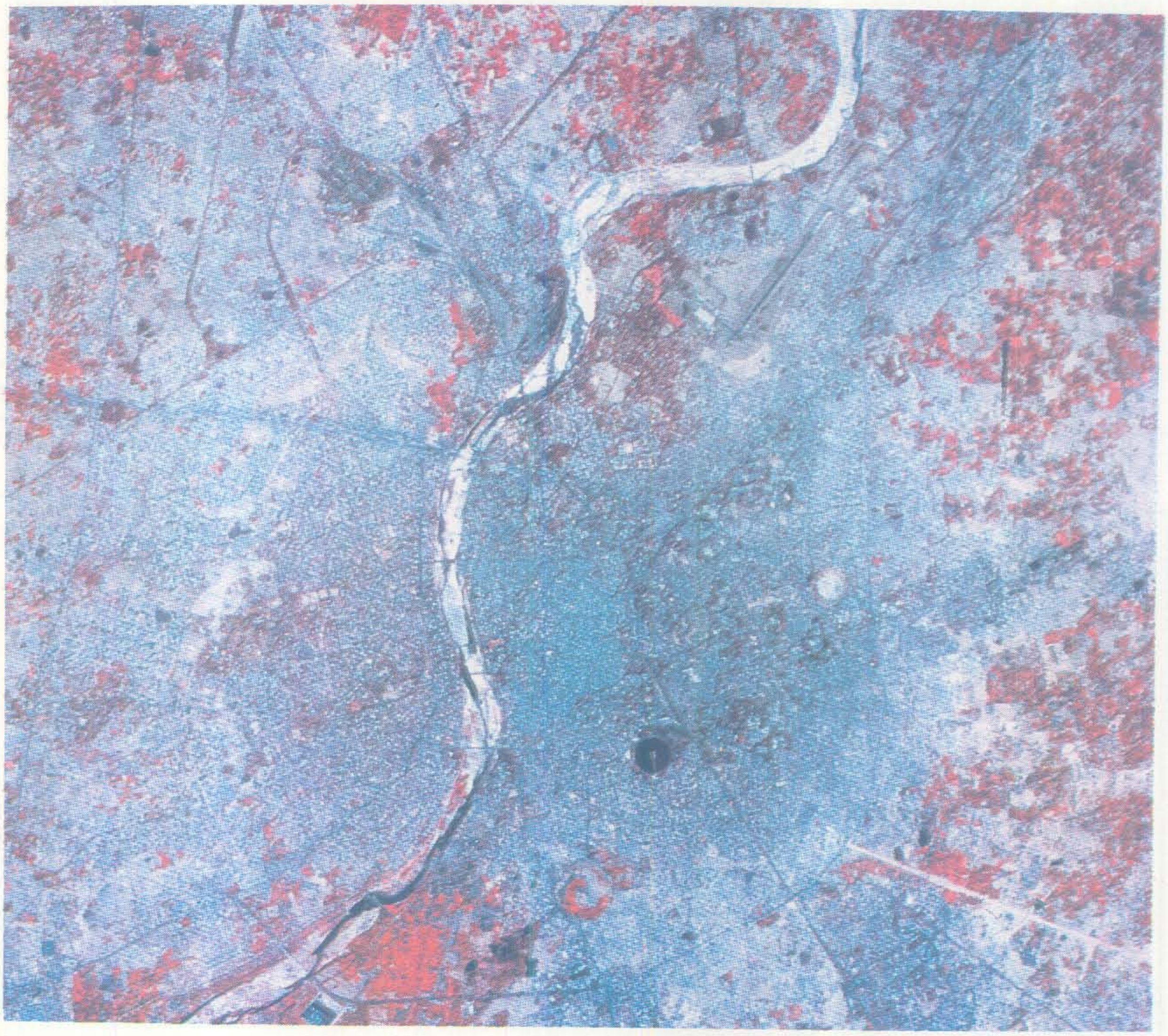


Figure 6.3.9.1 PAN+LISS-II image of Ahmedabad city

6.3.10 ROAD NETWORK MAPPING

Transportation network forms an important infra-structure element of the whole urban area. It allows connectivity and movement of people, traffic and goods from both intra (within) city and inter (outside) city hinterlands. Studies have been carried out to prepare a transportation network map of Ahmedabad, Bangalore and Hyderabad cities employing IRS-1C panchromatic data. In case of Bangalore city, segments of approximately 2km x 2km size, representing different types of

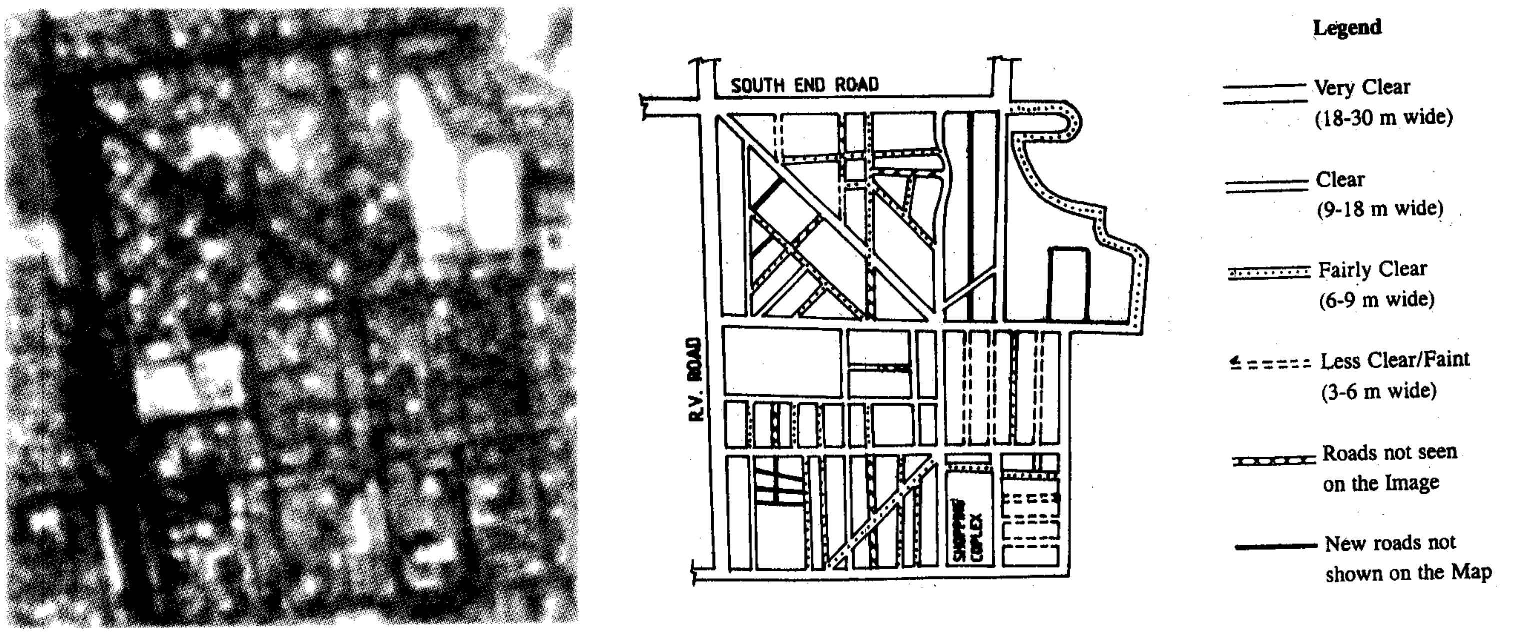


Figure 6.3.10.1 PAN image of Jayanagar in Bangalore (Well planned area) and road network map

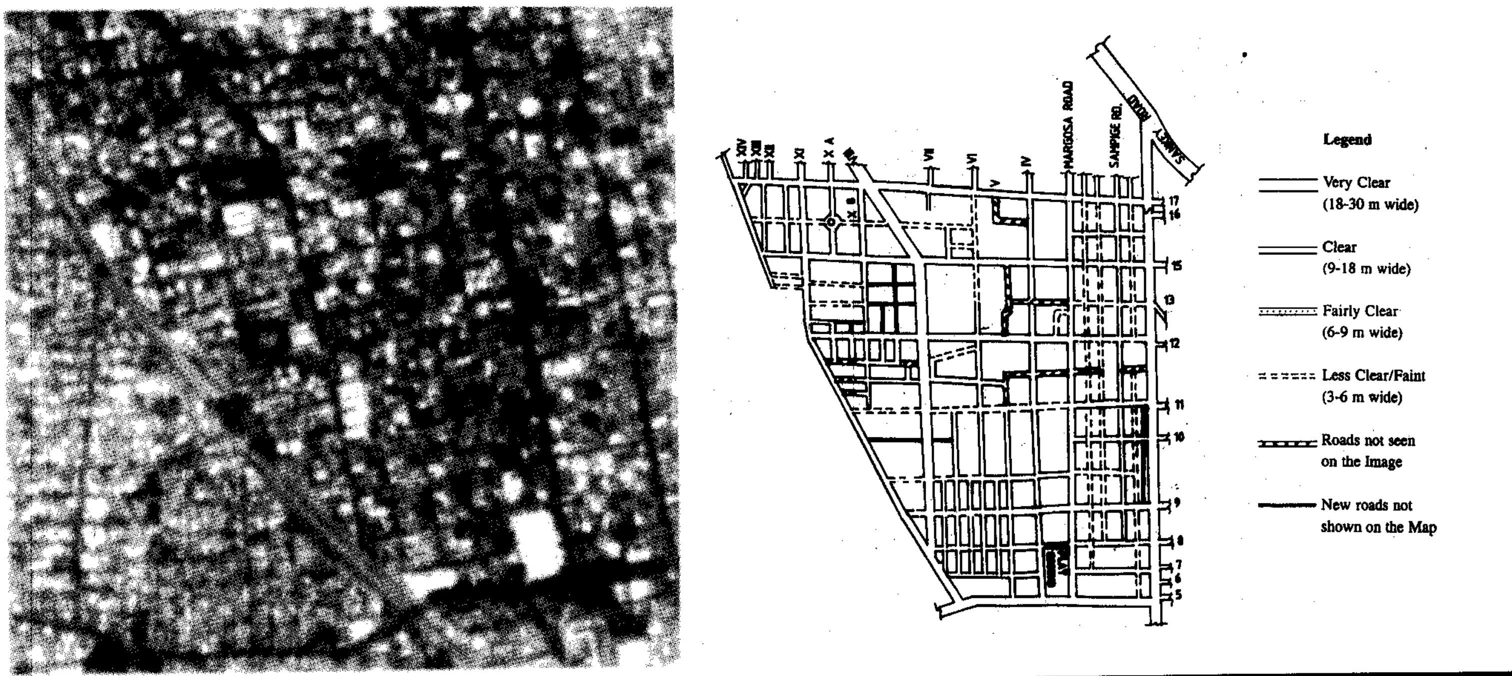


Figure 6.3.10.2 PAN image of Malleshwaram in Bangalore (semi-planned medium populated area) and road network map

settlements were identified and the road network mapped (Figure 6.3.10.1 to 6.3.10.4).

All the trunk roads and highways could be very well mapped using the PAN data.The roads in well planned areas like Jayanagar, could be mapped easily with 95% accuracy, in semi-planned areas (Malleswaram Chamarajapet) with 80% accuracy

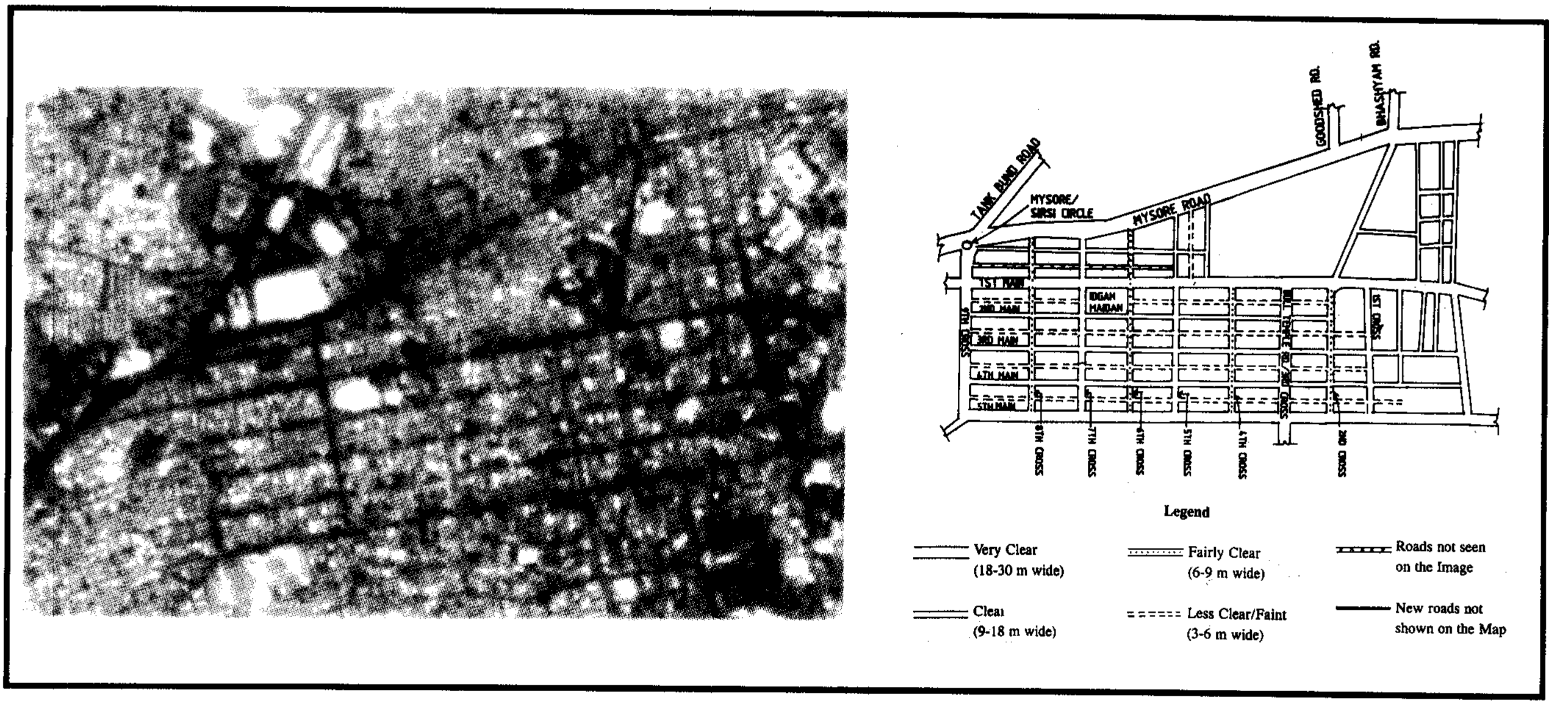


Figure 6.3.10.3 PAN image of Chamarajpet in Bangalore (semi-planned densely populated area) and road network map

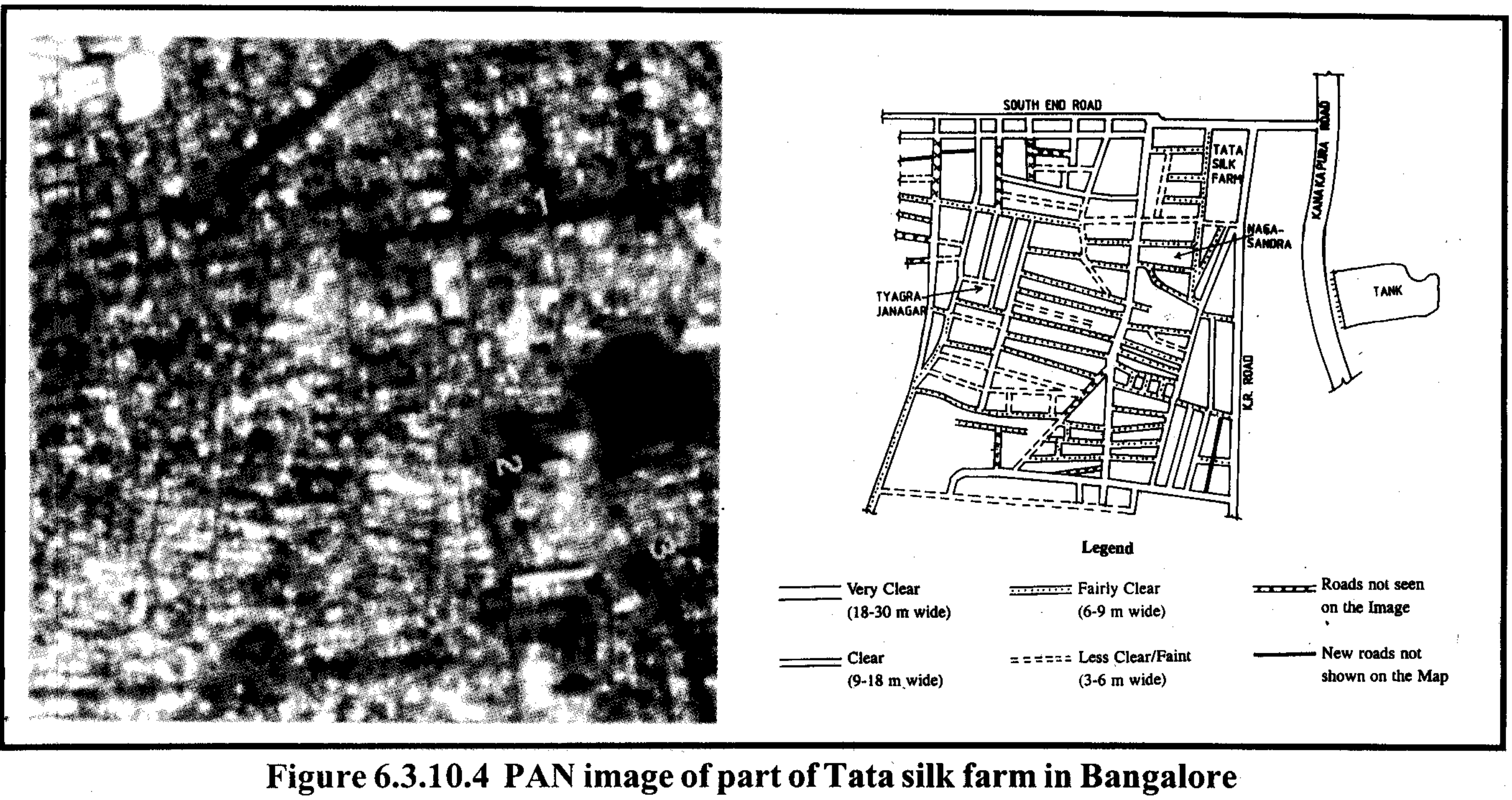


Figure 6.3.10.4 PAN image of part of Tata silk farm in Bangalore (unplanned semi-rural) and road network map

and in unplanned areas, mapping accuracy was achieved only to about 60%. Thus, the high spatial resolution of IRS-1C PAN data, is useful for the preparation of transportation network map on 1:25,000/1:12,500 scale. Even the existing city guide maps, could be easily updated using this data.

6.3.11 CADASTRAL MAPS OVERLAY

Land ownership details are available on cadastral maps, which are generally available on 1:4000 to 1:8000 scale without a projection system. It is essential to update for planning purposes. A methodology has been designed and developed to overlay cadastral maps, on special data products generated using IRS-1C PAN and LISS-III. The methodology consists of satellite data processing, creation of raster cadastral images, registration of cadastral images and generation and overlay of cadastral vectors (Figure 6.3.11.1).

6.3.12 FLOODS

A severe cyclonic storm originating in the Bay of Bengal, crossed the Andhra Pradesh coast, about 50Km South of Kakinada at about 21:30 hours on 6th November, 1996. Extensive damage to property and human lives were reported in East and West Godavari districts of the state. Near real time assessment of cyclonic impact, using remote sensing

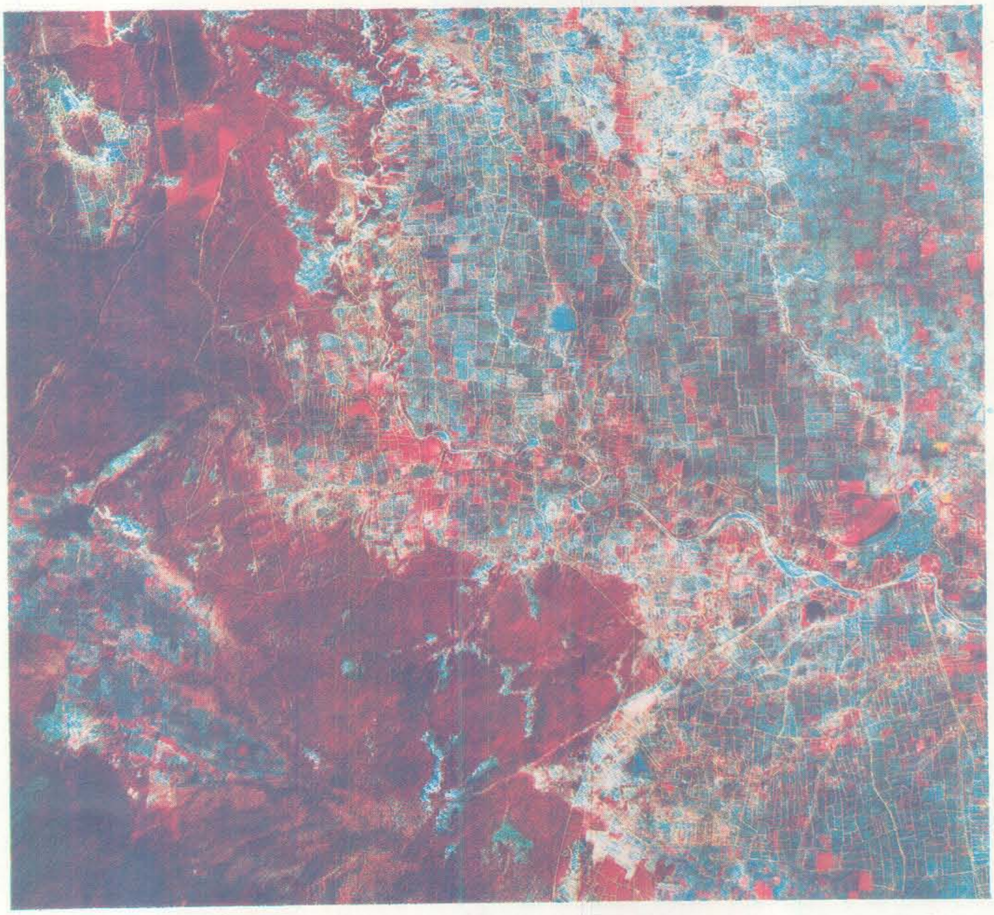


Figure 6.3.11.1 PAN+LISS-III merged image of Uma-Gani watershed, Maharastra, overlaid with cadastral map

data was taken up. The first satellite data after the cyclone crossing was obtained from IRS-1C WiFS data on 9th November, 1996 and by steering the PAN camera on the same day (Figure 6.3.12.1). The post cyclone data was compared with pre-cyclone data provided by IRS-1C WiFS on 25th October, IRS-1B LISS-II sensor of 30th October and NOAA AVHRR data and WiFS data of 4th November.

The analysis of satellite data was supported by field visits during 12th to 17th November, to provide ground information on the extent of damage to various agricultural crops and coconut plantations. The second field visit on 24th and 25th November provided more details on selected areas.

Analysis of pre-cyclone data hel extent of agricultural area and sta paddy was harvested or not and plantations. Pre and post cyclo differential vegetation index data 9th November have brought out t cyclone.

PAN data of 9th Novemb identification of paddy stacked i also damaged due to heavy rains the field. Stacks are visible as wh also helped in the detailed assess caused by the cyclone in Kakinad drains.

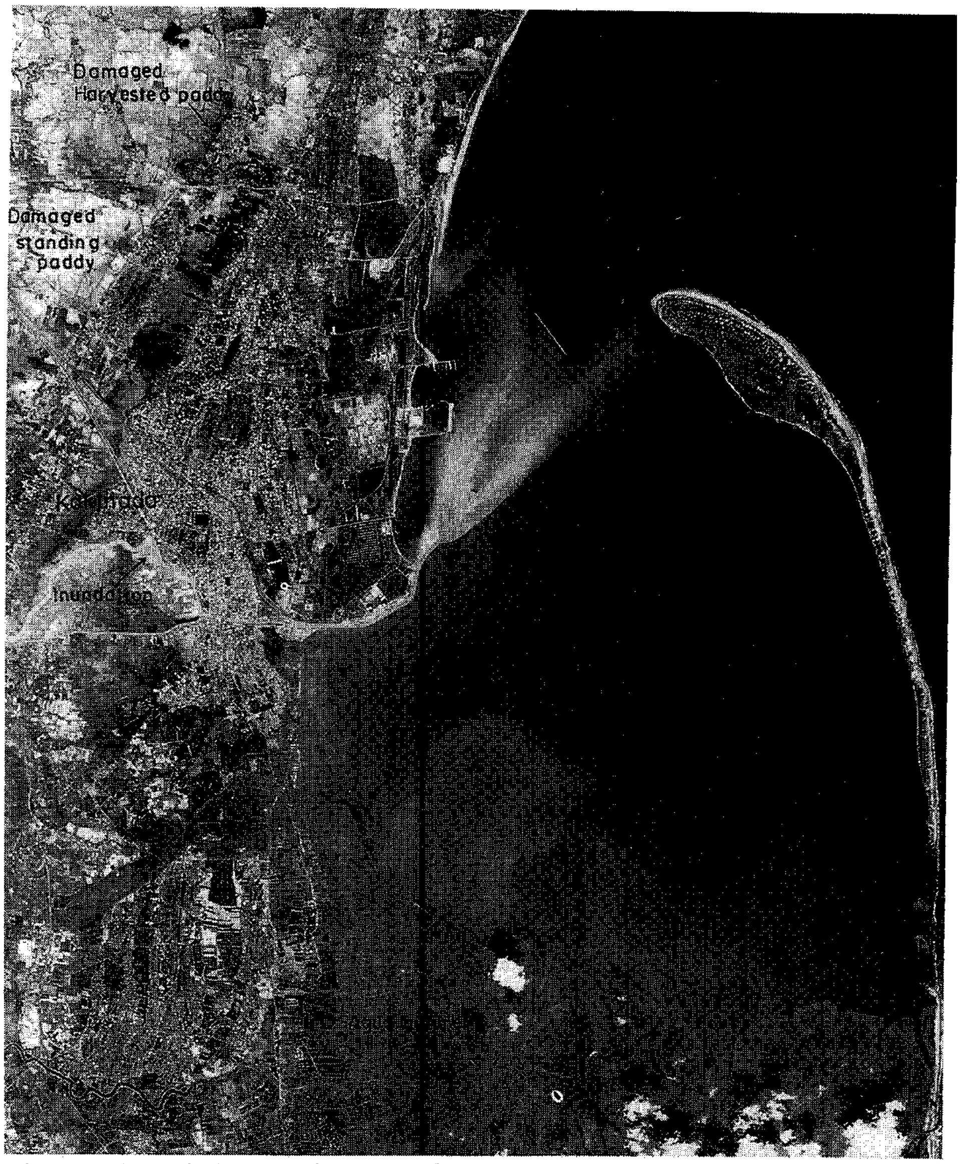


Figure 6.3.12.1 PAN image of Kakinada coast, Andhra Pradesh

6.3.13. GEOLOGICAL MAPPING

The visual interpretation of IRS-1C LISS-III and PAN data of parts of Cuddapah basin, Andhra Pradesh, was done with enlargements with varying scales. The studies indicate that the boundaries between different lithological units i.e., Paniam quartzite (A) forming cuestas, Owk shale (B), Narji limestone (C), Banganapalli sandstone (D) exposed along cuesta scarps, Tadapatri shales (E) and basic sills (F), both forming homoclinal ridges could be mapped more accurately. Minor structural details like faults, fractures could be observed very clearly. Minor faults (shown as F-F on the image) could be mapped indicating shifts in geological formations (Figure 6.3.13.1).

A hybrid image was generated for the area (Figure 6.3.13.2) using LISS-III (4=R, 3=G and PAN=B) datasets, to have the advantage of higher spatial resolution of PAN and multispectral resolution of LISS-III. In this image, even the minute details like banding and variations within a lithological formation could be observed clearly. It has been observed, that, the hybrid image can withstand scale enlargements upto 1:15,000, which is useful for detailed geological mapping.

Legend

A Paniam quartzite	B Owk shale
C Narji limestone	D Banganapalli sandstone
E Tadapatri shale	F Basic sills
G Bands of basic sill	H Bands in Owk shales
I Conjugate fractures	F Fault
Fr Fracture	SF Scarp face T Dip facet

Figure 6.3.13.1 IRS-1C LISS-III FCC (432=RGB) of part of Cuddapah basin, A.P.

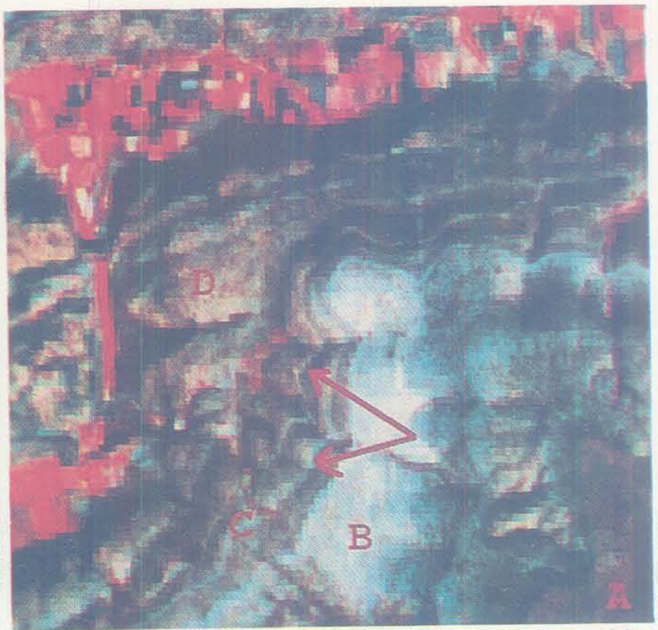


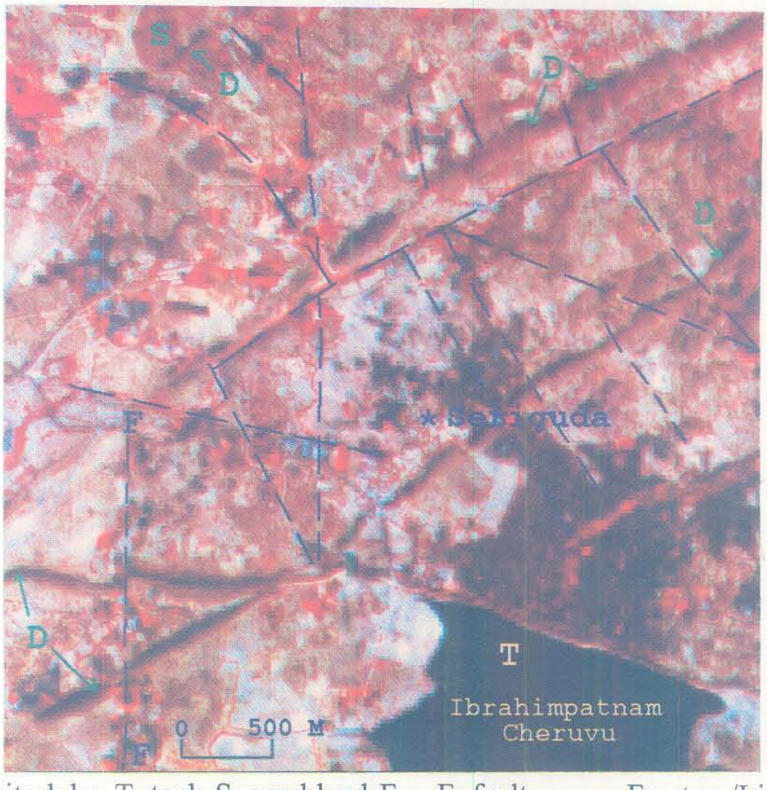
Figure 6.3.13.2 IRS-1C LISS-III +PAN hybrid image of part of Cuddapah basin, A.P.

6.3.14 GROUND WATER STUDIES

Satellite data has been proved to be highly useful for ground water studies and mapping. Using Landsat, SPOT, IRS-1A and IRS-1B data, prospective ground water zone maps could be prepared upto 1:50,000 scale. The launch of IRS-1C satellite, has significantly boosted the application of satellite data in ground water studies. The high spatial resolution of data obtained from IRS-1C has been found useful for detailed mapping upto 1:15,000 scale.

Figure 6.3.14.1 shows the LISS-III and PAN merged FCC image of parts of Ranga Reddy district, Andhra Pradesh. The area is occupied by granitic gneisses, intruded by dolerite dykes and cut across by a number of faults and lineaments. The dolerite dykes form barriers for movement of ground water, whereas, the faults which cut across them act as conduits for ground water movement. The weathered zones within the granite gneisses, contain limited quantities of ground water. The tanks seen on the image as black patches which form the surface irrigation sources in the area also contribute towards recharge of ground water.

The bright red patches located outside the tank commands are the grounwater irrigated crops. By providing spatial distribution of irrigated crop lands it is possible to estimate where and how much of ground water is being tapped for irrigation. Based on this the entire area can be classified into into overdeveloped, underdeveloped and undeveloped zones, indicating the status of ground water development.



D= dolerite dyke, T=tank, S=scrubland, F----F=fault, -------=Fracture/Lineament

Figure 6.3.14.1 LISS-III and PAN merged FCC image of parts of Ranga Reddy district, A.P.

6.3.15 DIAMOND EXPLORATION

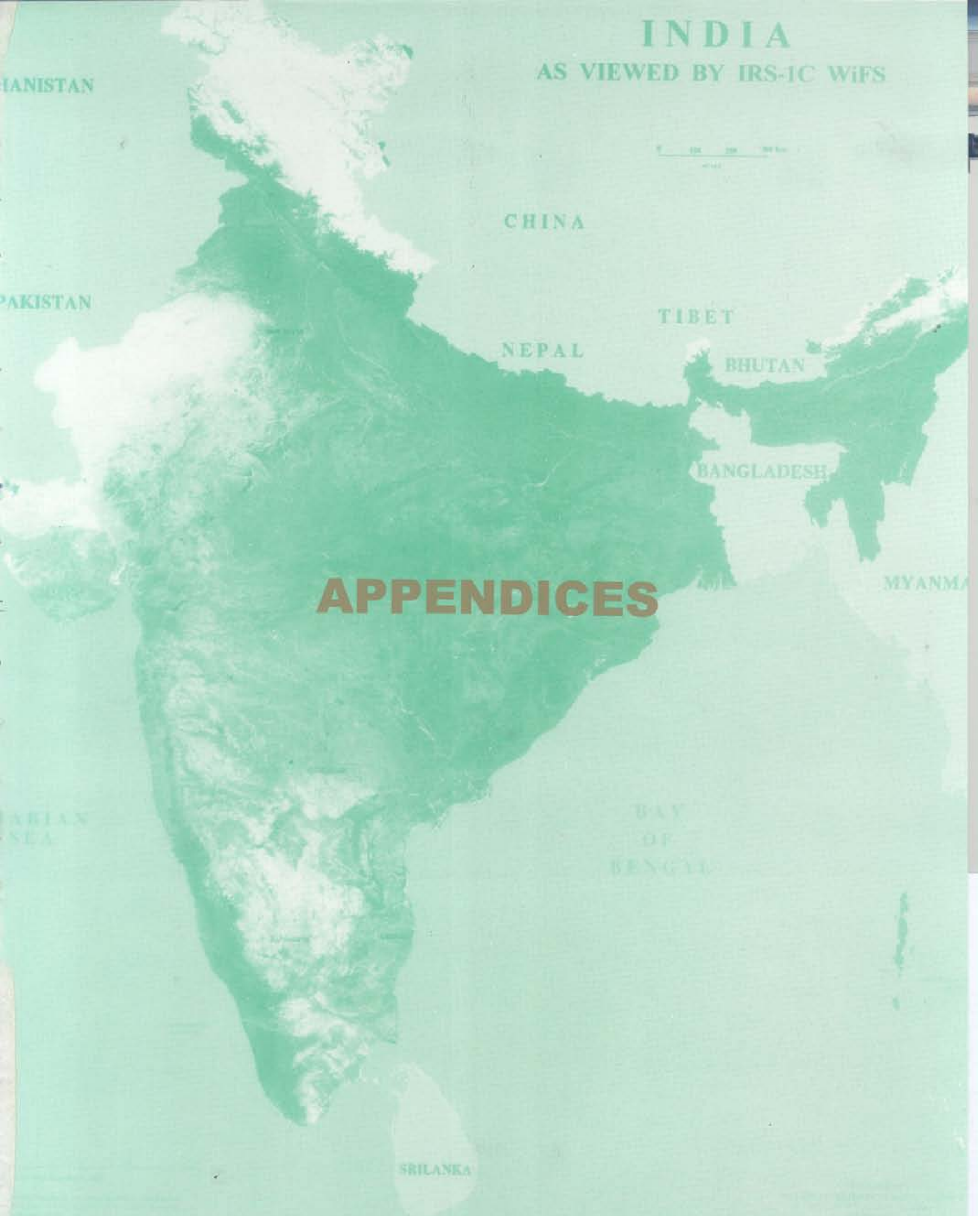
Diamonds are associated with the rarely occurring kimberlite rock, which is a particular type of ultrabasic suite and intrudes as volcanic pipes, whose planar geometry is circular to near circular. A new kimberlite pipe (2) in Proterozoic Indravathi basin at Bhejripadar village, Baster District in Madhya Pradesh, has been found recently through interpretation of IRS-1C LISS-III data (Figure 6.3.15.1), followed by ground based geological and geophysical surveys. Besides the circular shape and spectral anomaly as seen on satellite image, it has favourable structural and geomorphic setup i.e., its nearness to secondary lineaments, relatively low lying area compared to the surroundings and minor drainage turning around the pipe. All these related geological features, can be better extracted from this high resolution data.

Legend

1. Tokapal kimberlite pipe 2. Bhejripadar kimberlite pipe

Figure 6.3.15.1 LISS-III FCC image showing Kimberlite pipes

APPENDICES


INDIA
AS VIEWED BY IRS-1C WiFS
CHINA
TIBET
NEPAL
BHUTAN
BANGLADESH
BAY
OF
BENGAL
SRILANKA
INDIAN OCEAN

I. IRS-1D PRODUCT CODES

STANDARD PRODUCTS

A LISS-III PRODUCTS

1. PATH/ROW AND SHIFT ALONG TRACK PRODUCTS

AREA COVERED : B2/B3/B4 : 141*141Km.
B5 (SWIR) : 141*148Km.(Applicable to B/W products)

PRODUCT CODE POL	SOM	DESCRIPTION
1.1. B/W PRODUCTS (FOR SWIR BAND ONLY)		
STPC00222	STSC00222	1:1m 240mm paper print (1X print)
STPC00224	STSC00224	1:250,000 960mm paper print (4X print)
1.2 FALSE COLOUR COMPOSITE (FCC)		
STPC00242	STSC00242	1:1M 240mm film positive
STPC00252	STSC00252	1:1M 240mm paper print (1X print)
STPC00254	STSC00254	1:250,000 960mm paper print (4X print)
1.3 DIGITAL PRODUCTS WITH BIL LGSOWG FORMAT		
STPC00267	STSC00267	CCT 6250 BPI
STPC0026H	STSC0026H	CRT 525 MB UNIX
STPC0026I	STSC0026I	8MM Exabyte Tape 5 GB
STPC0026J	STSC0026J	CD-ROM 650 MB
1.4 DIGITAL PRODUCTS WITH BSQ LGSOWG FORMAT		
STPC00277	STSC00277	CCT 6250 BPI
STPC0027H	STSC0027H	CRT 525 MB UNIX
STPC0027I	STSC0027I	8MM Exabyte Tape 5 GB
STPC0027J	STSC0027J	CD-ROM 650 MB

1.5 DIGITAL PRODUCTS WITH FAST FORMAT

STPC002B7	STSC002B7	CCT 6250 BPI
STPC002BH	STSC002BH	CRT 525 MB UNIX
STPC002BI	STSC002BI	8MM Exabyte Tape 5GB
STPC002BJ	STSC002BJ	CD-ROM 650 MB

* **In case the scenes are to be shifted, the first two letters of the product code i.e,. "ST" have to be replaced with "TR".**

2 QUADRANT PRODUCTS (12 Quadrants)

AREA COVERED : 72 * 72 Km.

2.1 FALSE COLOUR COMPOSITE (FCC) IN VISIBLE BANDS ONLY

QUPC00242	QUSC00242	1 : 500,000 240mm film positive
QUPC00252	QUSC00252	1 : 500,000 240mm paper print (1X print)
QUPC00254	QUPC00254	1 : 125,000 960mm paper print (4X print)

2.2 DIGITAL PRODUCTS WITH BIL LGSOWG FORMAT

QUPC00267	QUSC00267	CCT 6250 BPI
QUPC0026H	QUSC0026H	CRT 525 MB UNIX
QUPC0026I	QUSC0026I	8MM Exabyte Tape 5GB
QUPC0026J	QUSC0026J	CD-ROM 650 MB

2.3 DIGITAL PRODUCTS WITH BSQ LGSOWG FORMAT

QUPC00277	QUSC00277	CCT 6250 BPI
QUPC0027H	QUSC0027H	CRT 525 MB UNIX
QUPC0027I	QUSC0027I	8MM Exabyte Tape 5GB
QUPC0027J	STSC0027J	CD-ROM 650 MB

2.4 DIGITAL PRODUCTS WITH FAST FORMAT

QUPC002B7	QUSC002B7	CCT 6250 BPI
QUPC002BH	QUSC002BH	CRT 525 MB UNIX
QUPC002BI	QUSC002BI	8MM Exabyte Tape 5GB
QUPC002BJ	QUSC002BJ	CD-ROM 650 MB

3. GEOCODED PRODUCTS

3.1 PHOTO PRODUCTS CORRESPONDING TO 15' X 15' SOI TOPOSHEET

G3PC00255	FCC 1000mm paper print 1:50,000 (5x print)

3.2 DIGITAL PRODUCTS WITH BIL LGSOWG FORMAT

G3PC00267	CCT 6250 BPI
G3PC0026H	CRT 525 MB UNIX
G3PC0026I	8MM Exabyte Tape 5GB
G3PC0026J	CD-ROM 650 MB

3.3 DIGITAL PRODUCTS WITH BSQ LGSOWG FORMAT

G3PC00277	CCT 6250 BPI
G3PC0027H	CRT 525 MB UNIX
G3PC0027I	8MM Exabyte Tape 5GB
G3PC0027J	CD-ROM 650 MB

3.4 DIGITAL PRODUCTS WITH FAST FORMAT

G3PC002B7	CCT 6250 BPI
G3PC002BH	CRT 525 MB UNIX
G3PC002BI	8MM Exabyte Tape 5GB
G3PC002BJ	CD-ROM 650 MB

B. PAN PRODUCTS

1. STANDARD PRODUCTS

1.1 PAN FULL SCENE (PATH/ROW AND SHIFT ALONG TRACK PRODUCTS)

AREA COVERED : NADIR : 70*70Km.
OFFNADIR : 70*90Km.

1.1.1. B/W PRODUCTS (LFFR)

STPC00214	STSC00214	1:125,000 960mm film positive
STPC00224	STSC00224	1:125,000 960mm paper print (1X print)

1.1.2. DIGITAL PRODUCTS LGSOWG FORMAT

STPC00277	STSC00277	CCT 6250 BPI
STPC0027H	STSC0027H	CRT 525 MB UNIX
STPC0027I	STSC0027I	8MM Exabyte Tape 5GB
STPC0027J	STSC0027J	CD-ROM 650 MB

1.1.3. DIGITAL PRODUCTS FAST FORMAT

STPC002B7	STSC002B7	CCT 6250 BPI
STPC002BH	STSC002BH	CRT 525 MB UNIX
STPC002BI	STSC002BI	8MM Exabyte Tape 5GB
STPC002BJ	STSC002BJ	CD-ROM 650 MB

1.2. PAN QUADRANT PRODUCTS (PAN I/PAN Q)

AREA COVERED : NADIR : 36 * 36 Km.
OFFNADIR : 36 * 46 Km.

1.2.1 B/W PRODUCTS

QUPC00214	QUSC00214	1:125,000 960mm film positive
QUPC00224	QUSC00224	1:125,000 960mm paper print (1X print)

1.2.2 DIGITAL PRODUCTS LGSOWG FORMAT

QUPC00277	QUSC00277	CCT 6250 BPI

QUPC0027H	QUSC0027H	CRT 525 MB UNIX
QUPC0027I	QUSC0027I	8MM Exabyte Tape 5GB
QUPC0027J	QUSC0027J	CD-ROM 650 MB

1.2.3. DIGITAL PRODUCTS FAST FORMAT

QUPC002B7	QUSC002B7	CCT 6250 BPI
QUPC002BH	QUSC002BH	CRT 525 MB UNIX
QUPC002BI	QUSC002BI	8MM Exabyte Tape 5GB
QUPC002BJ	QUSC002BJ	CD-ROM 650 MB

1.3. PAN SUBSCENE (PATH/ROW AND SHIFT ALONG TRACK PRODUCTS)

AREA COVERED : NADIR : 23.9*23.9Km.
OFFNADIR : 23.9*30.5Km.

1.3.1. B/W PRODUCTS

STPC00212	STSC00212	1:250,000 240mm film positive
STPC00222	STSC00222	1:250,000 240mm paper print (1X print)
STPC00224	STSC00224	1:50,000 960mm paper print (5X print)

1.3.2. DIGITAL PRODUCTS LGSOWG FORMAT

STPC00277	STSC00277	CCT 6250 BPI
STPC0027H	STSC0027H	CRT 525 MB UNIX
STPC0027I	STSC0027I	8MM Exabyte Tape 5GB
STPC0027J	STSC0027J	CD-ROM 650 MB

1.3.3. DIGITAL PRODUCTS FAST FORMAT

STPC002B7	STSC002B7	CCT 6250 BPI
STPC002BH	STSC002BH	CRT 525 MB UNIX
STPC002BI	STSC002BI	8MM Exabyte Tape 5GB
STPC002BJ	STSC002BJ	CD-ROM 650 MB

* **In case the scenes are to be shifted, the first two letters of the product code i.e,. "ST" have to be replaced with "TR".**

1.4. BASIC STEREO PRODUCTS (TWO PRODUCTS PER SCENE)

(Only Radiometric and no Geometric correction)

AREA COVERED :	NADIR	:	23.9*23.9Km.
	OFFNADIR	:	23.9*30.5Km.

1.4.1 DIGITAL PRODUCTS LGSOWG FORMAT

SR0000177	CCT 6250 BPI
SR000017H	CRT 525 MB UNIX
SR000017I	8MM Exabyte Tape 5GB
SR000017J	CD-ROM 650 MB

2. GEOCODED PRODUCTS

2.1 B/W PRODUCTS (corresponding to 7 1/2' X 7 1/2' SOI toposheet)

G4PC00225	B/W 1000mm paper print 1:25,000 (5X print)

2.2 DIGITAL PRODUCTS LGSOWG FORMAT (corresponding to 7 1/2' X 7 1/2' SOI toposheet)

G4PC00277	CCT 6250 BPI
G4PC0027H	CRT 525 MB UNIX
G4PC0027I	8MM Exabyte Tape 5GB
G4PC0027J	CD-ROM 650 MB

2.3 DIGITAL PRODUCTS FAST FORMAT (corresponding to 7 1/2' X 7 1/2' SOI toposheet)

G4PC002B7	CCT 6250 BPI
G4PC002BH	CRT 525 MB UNIX
G4PC002BI	8MM Exabyte Tape 5GB
G4PC002BJ	CD-ROM 650 MB

3. PAN POINT GEOCODED

3.1 B/W PRODUCTS (corresponding to 5' * 5' area)

J5PC00225	1:12,500 1000mm paper print (5X print)

C WIFS PRODUCTS

1. STANDARD PATH/ROW AND SHIFT ALONG TRACK PRODUCTS

AREA COVERED : 810* 810 Km.

1.1. FALSE COLOUR COMPOSITE (334 COMBINATION)

STLC00242	1:6m 240 mm film positive
STLC00252	1:6m 240 mm paper print (1x print)
STLC00254	1:2m 960 mm paper print (3X print)

1.2 DIGITAL PRODUCTS WITH BIL LGSOWG FORMAT

STLC00267	CCT 6250 BPI
STLC0026H	CRT 525 MB UNIX
STLC0026I	8MM Exabyte Tape 5GB
STLC0026J	CD-ROM 650 MB

1.3 DIGITAL PRODUCTS WITH BSQ LGSOWG FORMAT

STLC00277	CCT 6250 BPI
STLC0027H	CRT 525 MB UNIX
STLC0027I	8MM Exabyte Tape 5GB
STLC0027J	CD-ROM 650 MB

1.4 DIGITAL PRODUCTS WITH FAST FORMAT

STLC002B7	CCT 6250 BPI
STLC002BH	CRT 525 MB UNIX
STLC002BI	8MM Exabyte Tape 5GB
STLC002BJ	CD-ROM 650 MB

* **In case the scenes are to be shifted, the first two letters of the product code i.e,. "ST" have to be replaced with "TR".**

II ACRONYMS

AC	Alternate Current
ADIF	Ancillary Data Information File
A/D	Analog to Digital
AOCS	Attitude and Orbit Control System
AOS	Acquisition Of Signal
AH	Ampere Hour
AVHRR	Advanced Very High Resolution Radiometer
BAS	Browse Archival System
BCD	Binary Coded Decimal
BIL	Band Interleaved by Line
BPSK	Bi-Phase Phase Shift Key
BSQ	Band SeQential
B/H	Base/Height
B/W	Black & White
CC	Cubic Convolution
CCD	Charge Coupled Device
CCT	Computer Compatible Tape
CFRP	Carbon Fibre Reinforced Plastic
DAQLB	Data Archival and Quick Look Browse
DGPS	Differential Global Positioning System
DLT	Digital Linear Tape
DMCR	Dedicated Mission Control Room
DN	Digital Number
DOS	Department Of Space
DPGF	Data Products Generation Facility
DPS	Data Processing System
DTM	Digital Terrain Model
DQE	Data Quality Evaluation
dB	Decible
dBm	Decible-milliwatt
dBw	Decible-watt
deg	Degree
ECL	Emitter Coupled Logic
EM	Electro-Magnetic
EOM	Electro-Optic Module
EOF	End Of File
EOL	End Of Line
FCC	False Colour Composite
FM	Frequency Modulation
FSKM	Frequency Shift Key Modulation
FSC	Frame Sync Code
GCP	Ground Control Point
GDQE	Geometric Data Quality Evaluation
GPS	Global Positioning System
G/T	Gain/Noise Temperature
GMT	Greenwich Meridian Time
HDT	High Density Tape
HDTR	High Density Tape Recorder
HK	House Keeping
HP	Horse Power
Hz	Hertz
IDRS	Integrated Digital Referencing Scheme
IGS	International Ground Station
IMGY	Image data file in UCCT
IIMS	Integrated Information Management System
IMSD	Integrated Mission for Sustainable Development
IPS	Inches Per Second
IR	Infra-Red
IRS	Indian Remote Sensing satellite
ISAC	ISRO Satellite Centre
ISRO	Indian Space Research Organisation
IST	Indian Standard Time
ISTRAC	ISRO Telemetry, Tracking and Command Network
JPEG	Joint Photographic Experimental Group
KB	Kilo Bytes
KHz	Kilo Hertz
Km	Kilometre
Lat	Latitude
LAN	Local Area Network
LBT	Low Bit rate Telemetry
LCC	Lambertian Conformal Conic Projection
LFFR	Large Format Film Recorder
LED	Light Emitting Diode
LGSOWG	Landsat Ground Station Operators Working Group
LISS	Linear Imaging and Self Scanning
LOS	Loss of Signal

LSB	Least Significant Bit
LTC	Light Transfer Characteristics
LUT	Look-Up Table
Long	Longitude
MAR	Mission Analysis Room
MCR	Mission Control Room
MB	Mega Bytes
MCC	Mission Control Centre
MFPH	Multi-mission Front end Processing Hardware
MHz	Mega Hertz
MOS	Modular Opto-electronic Scanner
MSB	Most Significant Bit
MSMR	Multi Frequency Scanning Radiometer
ms	milli second
MTF	Modulation Transfer Function
mw	milliwatt
N	Newton
ND	Neutral Density
NB	Narrow Band
NDC	NRSA Data Centre
NIR	Near Infra Red
NN	Nearest Neighbour
NNRMS	National Natural Resources Management System
NRIS	Natational Resources Information System
NRSA	National Remote Sensing Agency
OBTR	On-Board Tape Recorder
OCM	Ocean Colour Monitor
OSR	Optical Solar Reflectors
PAN	Panchromatic
PC	Personal Computer
PCT	Photo Compatible Tape
PCM	Pulse Code Modulation
PM	Phase Modulation
Pol	Polyconic
PPS	Payload Programming System
PR	Programming Request
PS	Polar Stereographic
PSLV	Polar Satellite Launch Vehicle
PSK	Phase Shift Keying
PSM	Payload Steering Mechanism
QAS	Quality Assurance Scheme
QC	Quality Control
QHS	Querry Handling System
QL	Quick Look
QPSK	Quadrature Phase Shift Keying
RAID	Redundant Array of Inexpensive Disks
RCS	Reaction Control System
RDQE	Radiometric Data Quality Evaluation
RF	Radio Frequency
RHC	Right Hand Circular
RMS	Root Mean Square
RNRZ(L)	Randomised Non-Return to Zero (Level)
RNRZ(S)	Randomised Non-Return to Zero
RPM	Rotations Per Minute
RRSSC	Regional Remote Sensing Service Centre
RSS	Root Sum Square
RST	Raw Star Sensor
SAC	Space Applications Centre
SAT	Shift Along the Track
S/C	Spacecraft
SCC	Spacecraft Control Centre
SCR	Silicon Controlled Rectifier
SI-EOSAT	Space Imaging - Earth Observation Satellite Company
SNR	Signal to Noise Ratio
SPS	Satellite Positioning System
SOM	Space Oblique Mercator
SOI	Survey of India
SWIR	Short Wave Infra Red
SWR	Square Wave Response
TC	TeleCommand
TCG	Time Code Generator
TCT	Time Code Translator
TRAI	Trailer file in UCCT
TIU	Telemetry Interface Unit
TM	Thematic Mapper
TTC	Telemetry, Tracking and Command
TWTA	Travelling Wave Tube Amplifier
UT	Universal Time
UTM	Universal Transverse Mercator
UCCT	User Computer Compatible Tape
WiFS	Wide Field Sensor

III. PRODUCT SUPPLY AGREEMENT

This agreement covers the sale of any Satellite data from the NRSA Data Centre (NDC), Hyderabad, India.

SECTION 1: Data orders

Satellite data may be ordered by the Purchaser at the prices,payment and delivery terms established from time to time by NDC.

* The order will be entertained only when the required information is given in full.
* The order may be submitted on forms provided by NDC. The orders may be made by fax, E-mail or by letter post. The Purchaser may also use its own forms, but any terms and conditions they contain are of no force or effect.
* NDC reserves the right to accept or reject any order from the Purchaser in full or part. NDC shall also be entitled to provide partial deliveries.
* Once the order complete in all respects is received and processed by NDC, a confirmation letter is sent to the Purchaser within 7 days from the date of receipt of complete order.
* Orders once processed and confirmed cannot be amended or cancelled unless technical problems surface during generation.

SECTION 2: Price

The price applicable for each product, is the one in effect on the date of confirmation of order at NDC. NDC publishes a price list for all types of data products from time to time. The prices are listed either in Rupees or in US$ and exclude any taxes, custom duties, insurance fees and delivery charges.

SECTION 3: Payment

* All orders must be accompanied by full advance payment for processing to be initiated.
* Payment may be made by telecredit in US $ payable to ANZ GRINDLAYS Bank, Account No. Madras 001313.00001 Chips 232293 for Credit to NRSA, Hyderabad, India.

Indian users may pay by means of a Demand Draft drawn in favour of National Remote Sensing Agency, Hyderabad.

* For EOSAT orders, payment may be made by EOSAT based on the monthly invoice sent by NDC. Payment may be made in the name of Antrix Corporation Limited, through Swift transfer to Canara Bank Account at Chase Manhattan Bank, New York, USA Account No.#001-1-395969, U1D CHIPS 107777.

SECTION 4: Confidentiality of Satellite Data

Purchaser acknowledges that the Satellite Data is a special, valuable and unique asset of NRSA and that Satellite Data is confidential information which is disclosed in confidence to the Purchaser and purchased only for his own internal purposes. NDC retains the right to satellite data and therefore;

* The satellite data shall not be loaned, reproduced or exported or given access to any person for any purpose except to Purchaser's employees, affiliates and consultants for purposes directly related to Purchaser's authorized use of the satellite data.
* The customer acknowledges the copyrightable character of satellite data under the legislation and conventions concerning copyrights. Accordingly, the customer acknowledges the NRSA ownership (including ownership of copyright and intellectual property rights) of satellite data.
* Purchaser agrees to take appropriate action with any person permitted access to satellite data for the purpose of satisfying the obligations under this agreement, including measures to prevent inadvertent disclosure.No customer may claim exclusive use of any NRSA satellite data.
* Purchaser agrees to use, translate, enhance or display the satellite data purchased only for its own authorized purposes directly related to the Purchaser's link of activities / business.

SECTION 5: Limited Warranty

* NDC warrants that the Satellite data it provides will cover the area of the Earth and spectral bands specified in the Purchaser's order and will be radiometrically or geometrically corrected if requested in Purchaser's order,subject to specified accuracy limits. NDC's warranty is limited to replacement of the data if deemed to show faulty workmanship.
* The purchaser is responsible for any use of the data products purchased from NDC and NDC has no liability or responsibility for the fitness of the products for any particular use. NDC shall be held blameless for any change in the availability of satellite data.Consequently, the purchaser waives all claims against NDC resulting from any use or planned use of the satellite data.
* NDC warrants that the media used to carry the data shall be free from defects in materials and workman ship under normal use for 90 daysfrom the date of despatch to Purchaser.

SECTION 6: Complaints and Inspection:

No complaint related to the quality and/or quantity of the satellite data products will be entertained unless the complaint is lodged at NDC in writing within 90 days from the date of despatch of the satellite data product.

* On acceptance of the complaint, products can be returned to NDC/EOSAT after confirmation by NDC/EOSAT.
* NDC may refuse to accept the complaint as long as the customer does not fulfil his obligation.
* If the rejections are accepted by NDC, all attempts will bemade to provide similar / equivalent data products.
* If similar / equivalent data products could not be provided,then, the purchase price will be refunded.
* The replacement or refund shall be the Purchaser's exclusive remedy for any delivery or non-delivery of satellite data.
* NDC's liability for damages to the Purchaser for any cause whatsoever, shall not exceed the purchase price paid by the purchaser for the defective satellite data.

SECTION 7: Mode of delivery

* Periods of delivery shall commence upon despatch of order confirmation from NDC.
* The period of delivery shall be extended by a reasonable time, if unforseen obstacles arise (e.g. force majeure, public measures, seizures, riots, labour disputes of any kind, operational troubles, delay in delivery of raw materials). In important cases, NDC shall notify the customer as soon as possible of the beginning and end of such obstacles.
* Compliance with the period of delivery presupposes fulfillment of the customer's contractual obligations.
* In general, all data products will be despatched by Speed Post and separate delivery charges are not made.
* If specifically requested, the products can be despatched byDHL courier on 'Freight to Collect basis".
* The customer is responsible for payment of all taxes or customs duties.

SECTION 8: General

Supply of satellite data products are governed by these general terms. No contrary terms and conditions of the purchaser are binding on NDC. None of the terms can be cancelled or waived, except by a written agreement signed by both parties. The undersigned has accepted the General Terms and Conditions listed above. Any modifications of and amendment to the General conditions and of the other contractual agreements shall only be valid if made in writing.

Signature:
Name:
Organisation:
Date: