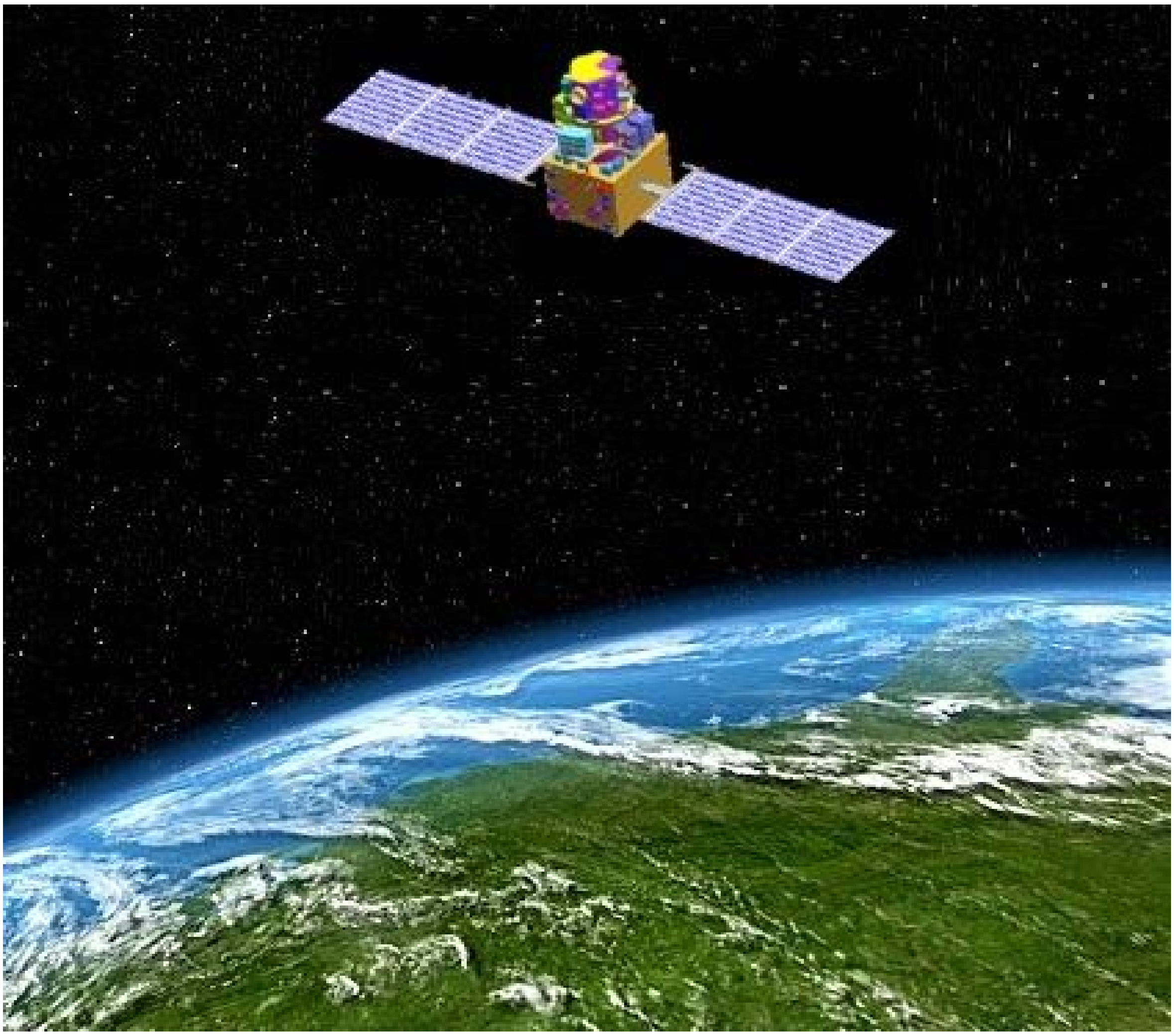
RESOURCESAT-2 *Data Users' Handbook*



December 2011

National Remote Sensing Centre

Indian Space Research Organisation

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NATIONAL REMOTE SENSING CENTRE

DOCUMENT CONTROL SHEET

<table>
<tr><td>1.</td><td>Security Classification</td><td colspan="4">Unrestricted</td></tr>
<tr><td>2.</td><td>Distribution</td><td colspan="4">Remote Sensing Data Users' Community</td></tr>
<tr><td>3.</td><td>Document version</td><td>(a) Issue no.</td><td>01</td><td>(b) Revision & Date</td><td>00</td></tr>
<tr><td>4.</td><td>Document Type</td><td colspan="4">Handbook</td></tr>
<tr><td>5.</td><td>Document Control Number</td><td colspan="4">NRSC:SDAPSA:NDCNDC:DEC11-364</td></tr>
<tr><td>6.</td><td>Title</td><td colspan="4">Resourcesat-2 Data User's Handbook</td></tr>
<tr><td>7.</td><td>Particulars of collation</td><td>Pages
142</td><td>Figures
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Resourcesat-1 Data User's Handbook</td></tr>
<tr><td>8.</td><td>Author(s)</td><td colspan="4">Resourcesat-2 Project Team, ISRO</td></tr>
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<tr><td>11.</td><td>Originating unit</td><td colspan="4">National Remote Sensing Centre (NRSC)</td></tr>
<tr><td>12.</td><td>Sponsor(s) / Name and Address</td><td colspan="4">NA</td></tr>
<tr><td>13.</td><td>Date of Initiation</td><td colspan="4">NA</td></tr>
<tr><td>14.</td><td>Date of Publication</td><td colspan="4">December 2011</td></tr>
<tr><td>15.</td><td>Abstract (with Keywords)</td><td colspan="4">A reference document containing information regarding Resourcesat-2 mission, orbit and coverage, sensors, data reception, data processing, products and services and dissemination.

LISS-III, LISS-IV, AWiFS, OBSSR, Mono and multi-spectral mode, Data Reception, Orbit and Coverage, Referencing Scheme, Path/Row, Steerability, Payload Programming, Data Processing, Products, Services, Digital Browse, User Order Processing System, Dissemination.</td></tr>
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ORGANISATION OF THE HANDBOOK

The Resourcesat-2 Data Users' Handbook is published to provide essential information to the users about the mission, satellite, sensors, orbit and coverage, referencing scheme, data acquisition, products and services.

Chapter 1 provides an overview of the mission objectives and specifications.

Chapter 2 provides an overview of the satellite sub-systems, spacecraft, payload and data handling systems.

Chapter 3 deals with the satellite's orbit, coverage and referencing scheme

Chapter 4 covers various aspects of the ground segment such as TTC/Payload networks

Chapter 5 provides in detail about the data acquisition, archival and computer storage network systems.

Chapter 6 will give an insight of the data products generation and processing systems.

Chapter 7 provides information on the data products quality evaluation.

Chapter 8 provides information on the user data order processing and payload programming services provided by NDC.

Chapter1

1. MISSION OVERVIEW

1.1 Mission objectives

The main objectives of Resourcesat-2 mission are:

Resourcesat-2 Mission is planned to provide continuity of services to the Resourceast-1 (IRS-P6) data users for integrated land and water resources management at micro level with enhanced multi-spectral and spatial coverage. To further carry out studies in advanced areas of user applications like improved crop discrimination, crop yield, crop stress, pest/disease surveillance, disaster management and urban management.

Resourcesat-2 Payload system is conceived around Resourcesat-1 with certain improvement of Payloads electronics like new data handling system, MIL 1553 interface with SSR (indigenous), SPS, Star Sensor and AOCE (IRS-P5 type) and miniaturized Payload electronics.

1.2 Mission Specifications

The satellite is designed to provide both multi-spectral and panchromatic imagery of the Earth's surface. The payload system comprises of three optical remote sensing cameras, viz., LISS-IV, LISS-III and AWiFS. LISS-IV provides 5.8m resolution in three bands with 70Km swath, LISS-III provides 23.5m resolution in four bands with 140 Km swath and AWiFS camera provides with a spatial resolution of 56m in four bands with 740Km Swath. A new Payload COMDEV AIS is planned to be -flown on-board Resourcesat-2 as an experimental payload for ship surveillance in VHF band. All the three cameras will be working on the 'pushbroom scanning' concept using linear arrays of Charge Coupled Devices (CCDs). In this mode of operation, each line of image is electronically scanned and contiguous lines are imaged by the forward motion of the satellite.

The LISS-IV can be operated in two modes - Mono and Multi-spectral. In the multispectral mode, data is collected either with 70 km (only over Indian region) swath or 23.5 km swath (short Mx) in three spectral bands viz.,

Band 2: 0.52 to 0.59 m (Green)

Band 3: 0.62 to 0.68 m (Red)

Band 4: 0.76 to 0.86 m (NIR)

In the Short Mx multispectral mode, the LISS-IV sensor provides data corresponding to pre-selected 4096 contiguous pixels. The 4K strip can be selected anywhere within the 12K pixels by commanding the start pixel number using electronic scanning scheme as in Resourcesat-1. The 70 km Mx data is captured with one band transmission in real time and the other two bands are stored in onboard SSR to be downloaded later. In Mono mode, the data of full 12K pixels of any one selected band, corresponding to a swath of 70Km, can be transmitted. Nominally, Band-3 data will be transmitted in this mode. The LISS-IV camera has the additional feature of off-nadir viewing capability by tilting the camera by+/- 26deg. This way, it can provide a revisit of 5 days for any given ground area.

The LISS-III is a multi-spectral camera operating in four spectral bands, three in the visible and near infrared and one in the SWIR region, as in the case of Resourcesat-1. The new feature in Resourcesat-2 is that for LISS-III and LISS-4 data which is acquired with 10 bit resolution. A Delta Pulse Code Modulation (DPCM) compression technique is used to transmit the data and in the ground through a reverse algorithm the 10 bit data is restored for product generation.

The AWiFS camera is realized in two electro-optic modules viz., AWiFS-A and AWiFS-B which provides a combined swath of 737 Km. The AWiFS camera provides 12 bit radiometry through Multi Linear Gain (MLG) technique. Data is transmitted in 10 bits and restored to 12 bits on ground, through decoding algorithms. The onboard calibration scheme is through LEDs as in Resourcesat-1.

Chapter2

SYSTEM OVERVIEW

2.1 Satellite Sub-system:

Resourcesat-2 is a three axes body stabilized spacecraft launched by PSLV into a Sun Synchronous Orbit at an altitude of 817 Km. The spacecraft is designed for a nominal mission life of five years. Resourcesat-2 carries three optical cameras as payload.

2.1.1. Linear Imaging Self Scanning Sensor (LISS-IV) Camera

LISS-IV is a high resolution multi-spectral camera operating in three spectral bands (B2, B3, B4). LISS-IV provides a ground resolution of 5.8 m (at Nadir) and can be operated in either of the two modes. In the multi-spectral mode (Mx), a swath of 23.5 Km (selectable out of 70 Km total swath) is covered in three bands, or in 70 km swath with two of the bands into SSR and one in Real Time transmission. In mono mode, the full swath of 70 Km can be covered in any one single band, which is selectable by ground command (nominal is B3 – Red band). The LISS-IV camera can be tilted up to ± 26° in the across track direction thereby providing a revisit period of 5 days.

2.1.2. Linear Imaging Self Scanning Sensor(LISS-III) Camera

The LISS-III camera is functionally identical to the LISS-III flown in Resourcesat-1 spacecraft except that the 10 bits data is transmitted using Delta Pulse Code Modulation (DPCM) technique. To keep the data rate as in Resourcesat-1, the overall transmission of bits are kept similar to RESOURCESAT-1 but at the ground the full 10 bits are extracted using DPCM decoding algorithms.

2.1.3. Advanced Wide Field Sensor (AWiFS) Camera

AWiFS camera is as flown in Resourcesat-1. AWiFS operates in four spectral bands identical to LISS-III, providing a spatial resolution of 56 m and covering a swath of 737 Km. To cover this wide swath, the AWiFS camera is split into two separate electro-optic modules, AWiFS-A and AWiFS-B. The Resourcesat-2 spacecraft mainframe is configured with several new features and enhanced capabilities to support the Payload operations. The payloads can be operated either in Real Time mode by direct transmission to ground station or in Record and Playback mode using an on-board 2X240 GB capacity Solid State Recorder(SSR). The various modes of Payload operations can be programmed *apriori* through a telecommand processor (TCP) which has enhanced features compared to Resourcesat-1.

The Ground Segment consists of :

(i) 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.

(ii) An Image segment comprising of data reception, data acquisition, data processing and product generation systems, along with centralized data dissemination centre. The overview of Resourcesat-2 mission is shown in Fig. 2.1

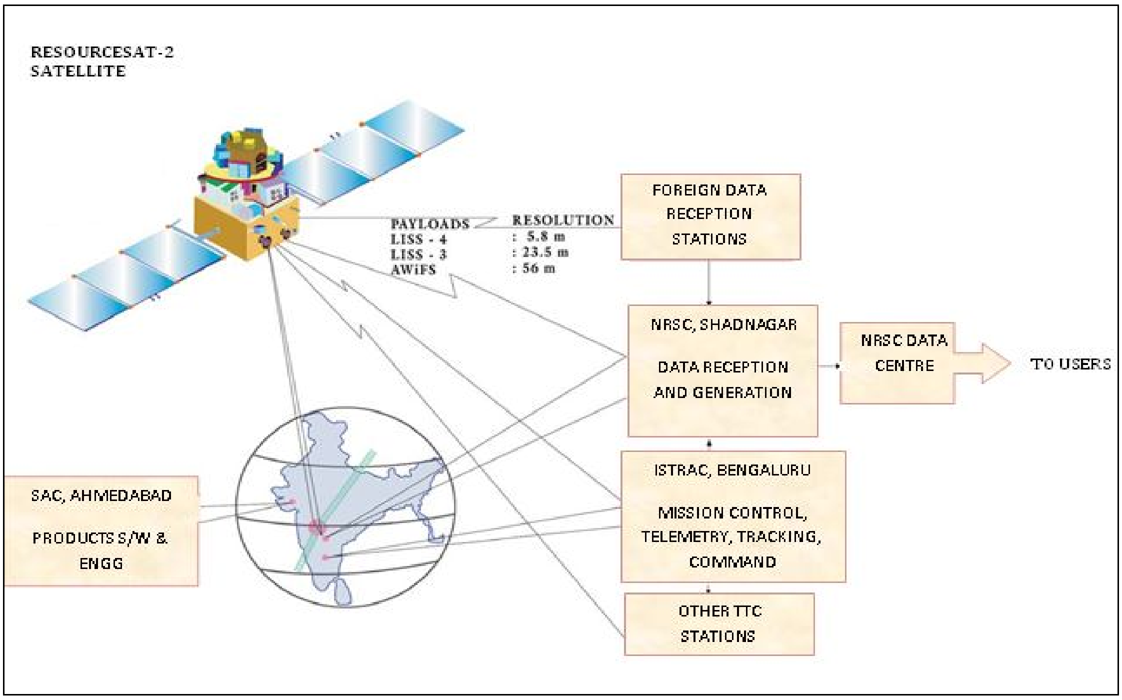


Figure 2.1 Overview of the Resourcesat-2 mission

2.2 Spacecraft Segment

The Space segment of Resourcesat-2 carries out the following functions :

- Image the earth features in the required spectral band.
- Format the payload sensor data along with auxiliary information and transmit the same to the ground station in two X-band carriers, either in RT or in Play back of on-board recorded data.
- Provide necessary power for main frame subsystems and payload operations with a positive power margin.
- Provide required pointing accuracy and platform stability during imaging.
- Maintain the proper orbit by periodic correction maneuvers
- Transmit housekeeping information for various subsystems and accept telecommands to control the spacecraft.

A brief description of the spacecraft is given in the following paragraphs.

The Structure of the spacecraft consists of a Main Platform (MPL) and a Payload Platform (PPL). The overall height of the spacecraft is about 2902 mm. The Main Platform (MPL) is cuboid, consisting of a primary structure viz., Cylinder, Shear webs, satellite interface ring, four vertical decks and top deck together form the secondary structure of the MPL. The top ring of the cylinder interfaces with the top deck and PPL cylinder. All the four equipment panels are supported by the Top/Bottom decks and shear webs. All the payloads are mounted on PPL deck. Overall size of main structure is 1582(P) mmx1652(Y) x1173(R) mm. The main platform is built around a central load bearing cylinder of 877 mm diameter and consists of four vertical panels and two horizontal decks. The bottom of cylinder is attached to an interface ring which interfaces with the launch vehicle. The vertical panels and the horizontal decks carry various subsystem packages. Four shear panels connecting the vertical panels to the main cylinder provide structural stiffness and also support for the solar array drive motors on the sun side and anti-sun side. Various Attitude sensors, Satellite Positioning System (SPS) and data transmitting antennas are mounted on the outside surfaces of the equipment panels and the bottom deck. Two star trackers are mounted with skewed orientation on the top deck.

The payload platform consists of a two-tier system – the PPL deck and the rotating deck. The PPL deck accommodates LISS-III, AWiFS-A and AWiFS-B camera modules. The LISS-IV camera is mounted on a rotating deck which is attached to a Payload Steering Motor (PSM) which can rotate by ± 26°across track. The various electronics package associated with LISS-IV are mounted on a hexagonal shaped aluminum honeycomb cover which also serves as a thermal cover for LISS-IV. The entire rotating deck is held down during launch to take care of launch vibrations and will be released in-orbit using a steel wire rope pyro Cutter. The entire PPL assembly is attached to a CFRP mono-coque cylinder, which in turn is attached to the main cylinder of the MPL through a strut assembly for effective load transfer.

The mono propellant hydrazine based Reaction Control System (RCS) consists of a single propellant tank of 390 liters capacity mounted inside the MPL main cylinder. Eight 1 Newton and four 11 Newton thrusters are mounted on the bottom deck. The thermal control system maintains the temperature of different subsystems within the specified limits using semi- active and active thermal control elements like paints, Multi Layer Insulation (MLI) blankets, Optical Solar Reflectors (OSR) and auto-temperature controllers. The LISS-IV CCD temperature control is implemented using a radiator plate coupled to each band CCD through heat pipes and copper braid strips. Appropriate heaters are mounted on the detector head assembly which are in the control loop of a temperature controller maintain the CCD temperature within its operating limits of 20 ± 4 deg. C.

The power system of Resourcesat-2 consists of six deployable solar panels, with three panels in each wing (Sun side and anti-Sun side), each panel of size 1.4 x 1.8 m^2. These solar arrays are deployed immediately after spacecraft separation from the launcher using deployment mechanism. Then onwards, they are continuously rotated to track the Sun using the Solar Array Drive Motor (SADM). Two solar panel Sun sensors provide the position error of each solar array with respect to the Sun vector, which is automatically corrected by SADA electronics. The rotation of solar arrays is arrested during payload operation to minimize the disturbance on the platform. The solar arrays generate a power of 1250 W at end-of-life (EOL). Two Ni-Cd chemical batteries of 24AH capacity each provide support during eclipse and peak loads. The power conditioning and distribution to various subsystems is achieved using core power electronics and user specific DC/DC converters. An Ampere-Hour meter (which is implemented through AOCS processor) is provided to monitor the battery charge - discharge condition.

The TTC system is configured to work in S-band and comprises of three sub-systems Telemetry, Telecommand and Transponder. The Telemetry system collects the house keeping (HK) data from each subsystem, formats and modulates onto the subcarrier. There are two formats viz., Dwell and Normal which can be simultaneously received. The telemetry data is transmitted at 1 Kbps in normal mode and 16 Kbps in play-back mode. The normal mode telemetry is modulated on 25.6 KHz subcarrier while the play back / dwell data is modulated on 128 KHz sub-carrier for transmission. An onboard storage of 6.3 M bits capacity stores the telemetry data during non-visible period for later play back.

The Telecommand system provides the uplink for the effective in-orbit control of different functional modes of the various satellite subsystems, attitude and orbit control of the spacecraft, payload operation and changing over to standby units in-case of failure of the main units. The system will operate in S-band having complete redundancy. Necessary changes have been incorporated to meet resourcesat-2 command interface and processing.

The measure features of telecommand systems are:

- The system incorporates shortened BCH code for error free command message reception.
- It uses two types of asics i.e. Core, tc asic (dsg-01) and 6 to 64 line decoding matrix asic (dsg-02) designed with two micron technology.
- It uses hybrid micro circuits for some of the repetitive circuits in order to reduce weight and volume.
- It supports auto commanding with suitable override commands for auto deployment, safe mode auto commanding etc.
- Commands critical to satellite mission are treated as priority-1 and provided with special implementation logic. It provides the OBT based multiple payload sequencer to control the operations of payload, data handling, SSR, TWTAs and all required systems with various flexibility and programmability features.
- It provides command execution facility in non-visibility region by time-tag execution in both OBT based and differential mode.
- It has additional facility of user defined command sequence execution based on onboard time named as configurable command block (CCB)execution.
- It provides all the required command status monitoring through telemetry.

The baseband signal (PCM/FSK) from receivers is fed to the decoders separately.

Changes w. r. t. Resourcesat-1: the major changes in telecommand processor software to provide many new facilities and programmability to the user are:

- Configurable command block (CCB) execution facility that provides user defined sequence-programming facility with full flexibility of programming.
- Payload off timer facility, which provides the facility of executing commands by issuing only two commands from ground.
- Facility of execution of differential mode time tag command.

- Removal of restriction of forbidden range during OBT overflow giving total flexibility of up linking and executing at any time.
- Introduction of more flexibility features in payload sequencer.

The TTC transponder transmits the telemetry data, receives the tele-command signals, demodulates the ranging tones and re-transmits them to ground with a fixed turn around ratio of 240/221 for two-way Doppler measurement. The transponder system consists of receiving and transmitting system and can operate either in coherent mode or non-coherent mode. In coherent mode, the down link carrier is derived by PLL technique from the uplink signal. In non-coherent mode, the down link carrier is derived from an independent TCXO.

The Attitude and Orbit Control System (AOCS) supports the functions of Earth acquisition after launch, three axis body stabilization as well as orbit maintenance throughout the mission life. The AOCS is configured with microprocessor based control electronics with hot redundancy. The control electronics receives the attitude error measurements from sun sensors, earth sensors, star trackers, magnetometers, gyroscopes and drives the actuators – reaction wheels, magnetic torques and RCS thrusters to minimize the attitude errors. There are several special logics like auto-acquisition sequence, safe mode, auto-reconfiguration of reaction wheels in case of a single wheel failure etc.,.

The overall specifications of Resourcesat-2 are given in table 2.1.

Spacecraft	Three axes body stabilized spacecraft
Orbit	Near polar, sun-synchronous, 817 Km with ECT of 10.30 a.m, descending node
Repetevity	341 orbits / cycle (24 days)
Revisit	5 days (LISS-IV Mono & AWiFS)

Mainframe Systems	
Structure	Aluminium and Aluminium honeycomb with CFRP elements for MPL and PPL
Weight	1220 Kgs

Thermal Control	Passive, semi-active and active elements like OSR, MLI, Heat pipes, tape/foil heaters etc,.
Battery	5 + 5° C
Payload cameras	20 +/- 4° C
Electronics	0 - 40° C

Power System	
Solar Array	6 Solar panels (1.4 x 1.8 sq.m each) generates 1250 W power at EOL
Battery	2 x 24 Ah Ni-Cd batteries

Power electronics	Two Raw buses 28 to 42 V Discrete and Hybrid DC-DC converters

AOCS	
Attitude Sensors	Earth sensors, Digital Sun sensors, Star trackers, 4 Pi Sun sensors, Gyroscopes / AD accuracy 0.1 deg with Earth sensors 0.014 deg. with Star trackers
Actuators	4 nos. Reaction wheels (5 NMS); 8 nos. x 1N & 4 nos. 11N Hydrazine thrusters ; 2 nos. Magnetic torquers
Control Electronics	Pointing accuracy < + 0.05 deg (3 sigma) Drift rate < + 5 x 10-5 deg/sec (3 sigma)

TTC	
Telemetry	
Real time/Dwell	1024 Bits/sec
Playback	16 Kbps
Sub-carrier	25.6 KHz (RT), 128KHz (PB)
Modulation	PCM/PSK/PM
On-board Storage	6.3 Gbits
Telecommand	
No. of ON/OFF commands	804 (capacity 1024)
No. of Data commands	33 (63)
Command bit rate	100 bits/sec
Modulation	PCM/FSK/FM/PM
FSK sub-carrier for '1'	5.555 KHz
FSK sub-carrier for '0'	3.125 KHz
Time Tagging Range	0 TO 36 hrs with 2 sec resolution
OBT based operation range	0 TO 36 hrs with 2.048 sec resolution
No. of Time-tag commands	254(diff TT) + 200(OBT-TT)
Probability of erroneous command execution	1.8 x 10-42
Probability of command rejection	0.98 x 10-13
Transponder	
Uplink frequency	2071.875 MHz
Down link frequency	2250 MHz
Turn around ratio	240/221

Table 2.1 Overall specifications of the Resourcesat-2 mission

2.3 Payload System

Resourcesat-2 (RS-2) is configured to provide continuity of data with enhanced performance. Resourcesat-2 has 3-tier imaging capability using Electro-optical payloads namely LISS-IV (Linear Imaging Self Scanning), LISS-III and AWiFS (Advanced Wide Field Sensor). All the three payloads are multi-spectral push-broom scanners with linear array CCDs as detectors. All payload chains are configured in such a way that any single point failure will not jeopardize multispectral imaging capability. The configuration is kept similar to that of Resourcesat-1 with following major enhancements:

2.3.1 Miniaturization of electronics:

The Camera electronics hardware is miniaturized resulting in significant improvement in terms of size, weight and power. A total mass reduction of ~ 70 Kg and power of ~ 30% is achieved.

2.3.2 Enhancements in Radiometry:

Radiometric improvements have been carried out in all the payloads of Resourcesat-2 using either Delta Pulse Code Modulation (DPCM) or Multi Linear Gain (MLG).

LISS-IV camera uses 10 bit digitization both during Resourcesat-1 & Resourcesat-2. In Resourcesat-1 bit sliding (selection of 7 bits out of 10) feature was chosen based on the radiance settings requirement. However, in Resourcesat-2, by compression technique full radiance settings is achieved in a single gain using all 10 bits. This is achieved using DPCM algorithm wherein 10 bits are mapped to 7 bits and reconstructed to 10 bits on ground. Same was incorporated in LISS-III camera. Also the sensors capability has been enhanced to 100% albedo as compared to limited albedo during Resourcesat-1. NESR has improved to 0.05 $mW/cm^2/Sr/\mu$ with respect to 0.25 $mW/cm^2/Sr/\mu$ in Resourcesat-1. Discrimination of the target is enhanced to photon noise limited and it has been made independent of scene radiance. AWiFS payload uses 12 bit digitization and provides 10 bits for data transmission so as to maintain data rate. This has been achieved using Multi Linear gain (MLG). This scheme provides enhanced radiometric performance at lower scene radiances.

2.3.3 Full swath coverage in MX mode for LISS-IV:

Using increased onboard storage, it is now feasible to provide full 70 Km swath of all three bands of LISS-IV compared to 23.5 Km in Resourcesat-1. Detailed payload configuration is described below:

2.3.4 LISS-IV Camera

The LISS-IV camera is realized using the three mirror reflective telescope optics (same as that of the PAN camera of Resourcesat-1) and 12,000 pixels linear array CCDs with each pixel of the size 7 micron x 7 micron. Three such CCDs are placed in the focal plane of the telescope along with their individual spectral band-pass filters. An optical arrangement comprising an isosceles prism is employed to split the beam into three imaging fields which are separated in the along track direction. The projection of this separation on ground translates into a distance of 14.2 Km between B2 and B4 image lines. While Band-3 is looking at nadir, Band-2 will be looking ahead and Band-4 will be looking behind in the direction of velocity vector. Each CCD has 12K pixels, separated into 6K each of odd and even pixels. These odd and even pixel rows are separated by 35 microns (equal to 5 pixels). To avoid any gap in the image due to this separation coupled with the earth rotation,

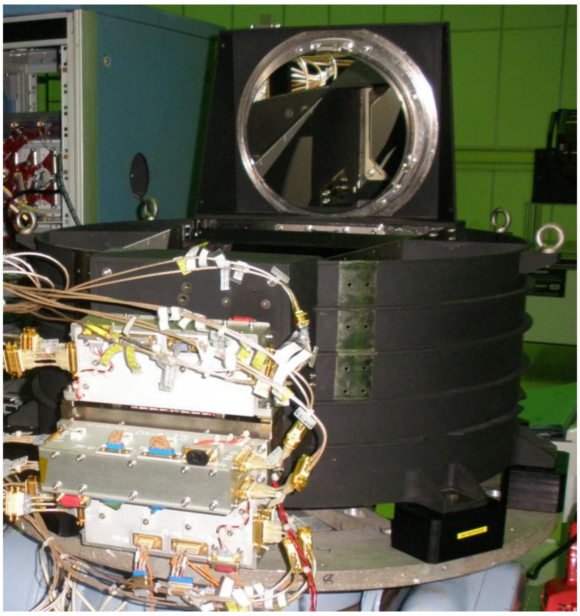


Figure 2.2 LISS-IV Payload

the spacecraft is given a rate about Yaw axis. There are 8 output ports for each CCD and each port gives output data for 1500 video pixels + 14 pre-scan pixels + 20 dummy pixels + 2 post scan pixels (total 1536 pixels per port). Each detector has eight Light Emitting Diodes (LED) for in-flight calibration. The analog output signals from the CCDs are processed through independent port-wise electronic chains, comprising of amplifiers, DC restoration and 10 bit Analog to Digital converter. The 10bit data is DPCM encoded and converted into 7 bit data in order to keep BDH interface same as that of Resourcesat-1. The DPCM converted data is recovered at ground through reverse DPCM algorithm incorporated in DP chain. The major specifications of LISS-IV camera are given in Table 2.2. The Integrated Payload is shown in Figure 2.2.

2.3.4.1 Inflight Calibration

Pre-launch light transfer characteristics (LTC) of the overall Payload system are generated in the laboratory covering performance parameters like spectral response, dark current, dynamic range, temperature and linearity. This LTC data is used for radiometric corrections of the image data. However, to monitor the long term performance of the detector and processing electronics, an in-flight calibration scheme is implemented using LEDs. Eight LEDs are positioned in front of the CCD (without obstructing the light path during imaging). These LEDs are driven with a constant current and the integration time is varied to get 16 exposure levels, covering the dynamic range in a sequential manner. This sequence repeats in a cyclic form.

IGFOV (across track) (m)	5.8 at nadir
Spectral Bands (microns)	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86
Swath (km)	23.9 (MX mode) 70 (Mx mode using onboard memory) 70 (Mono mode)
Bands Saturation radiance (mw/cm^2/sr/micron) Square Wave Response (%)	B2 B3 B4 53 47 31.5 >20 >20 >20
Signal to Noise Ratio @ camera saturation	>128

Integration time (msec)	0.877714
Quantization(bits)	10 (7bit data is transmitted to BDH after DPCM)
No. of gains	Single gain

Table 2.2 Major specifications of LISS-IV camera

2.3.5 LISS-III Camera

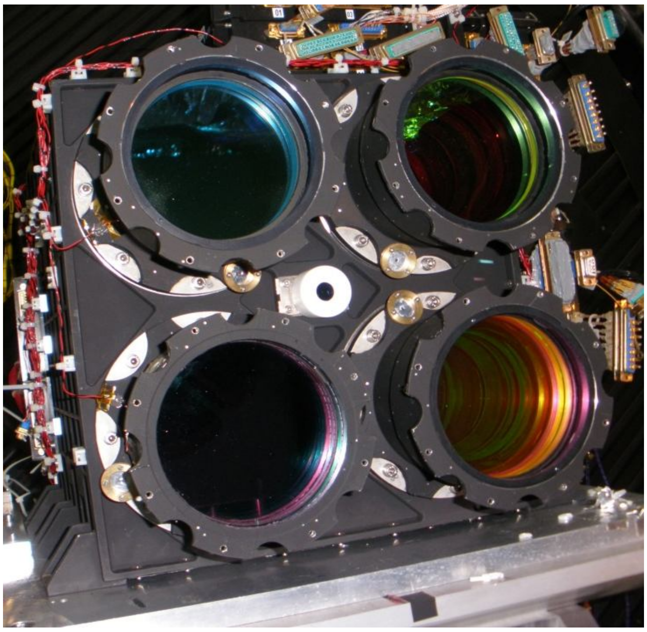


Figure 2.3 LISS-III Payload

The LISS-III Camera operates in four spectral bands in the VNIR and SWIR range. Each band consists of a separate lens assembly and a linear array CCD. Each lens assembly is realized with 8 refractive lens elements (a combination of convex and concave lenses), an interference filter and a thermal filter. The VNIR bands (B2, B3, B4) use 6,000 element CCDs each with pixel size of 10 microns x 7 microns. The SWIR band (B5) uses a 6,000 element Indium Gallium Arsenide CCD with pixel size of 13 micron x 13 micron. The SWIR CCD employs CMOS readout technique for each pixel, thereby improving noise performance. The major specifications of LISS-III camera are given in Table 2.3.

The four band imaging optical assemblies are mounted on a rigid Invar structure with their optical axis co-aligned for band to band registration. The camera electronics supplies various Clocks and bias required for the operation of the CCD and output signals from the CCDs are processed in the video processing electronics. The data from the VNIR and SWIR bands are digitized to 10 bits and using DPCM technique, 7 bit data is transmitted to BDH, keeping the Resourcesat-1 interface unchanged. In the ground reception chain DPCM coded data is recovered to generate 10 bit image. This configuration allows to cover the full dynamic range with single gain setting, as against four gains of Resourcesat-1.

2.3.5.1 In-flight Calibration

In-flight calibration using LEDs for VNIR bands is provided with 16 intensity levels. For SWIR, new LEDs are used in place of old IR LEDs used in Resourcesat-1. SWIR calibration cycle consists of 2048 lines providing six non zero intensity levels. Each intensity level is generated sequentially by LED-1 ON, LED-2 ON and LED-1 and 2 ON.

IGFOV (across track) (m)	23.5
Spectral Bands (microns)	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86 B5 1.55 - 1.70
Swath (km)	141
Bands Saturation radiance (mw/cm²/sr/micron) Square Wave Response(%)	**B2 B3 B4 B5** 53 47 31.5 7.5 >30 >30 >20 >20
Signal to Noise Ratio @ camera saturation	>128
Integration time (msec)	3.32
Quantization(bits)	10 (7bit data is transmitted to BDH after DPCM)
No. of gains	Single

Table 2.3 Major specifications of LISS-III camera

2.3.6 AWiFS Camera

The AWiFS camera operates in four spectral bands which are identical to LISS-III. In order to cover the wide field imaging with a minimum geometric distortion, the AWiFS camera is realized using two separate electro-optic modules which are tilted by 11.94° with respect to nadir so as to provide combined swath of 740 Km. The major specifications of AWiFS camera are given in Table 2.4.

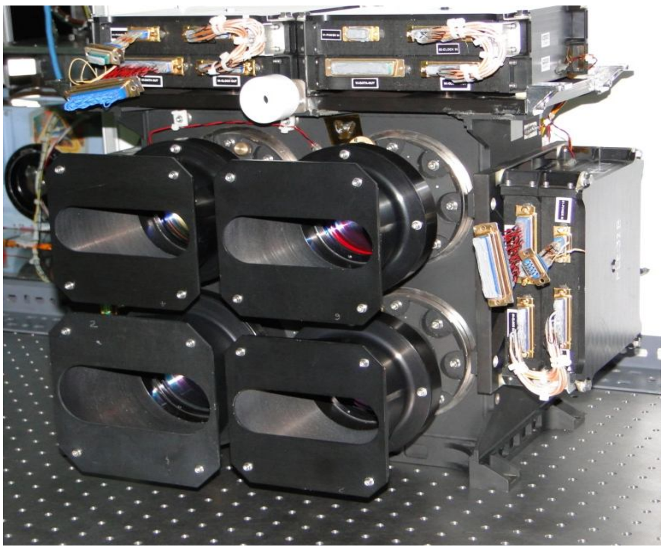


Figure 2.4 AWiFS Payload

The electro-optic module contains refractive imaging optics along with band pass interference filter, a thermal filter and a 6000 pixels linear array CCD detector for each spectral band. The CCDs used in AWiFS are identical to those of LISS-III. The output signals from each CCD are amplified and digitized into 12 bit parallel data in the video processing electronics. The Multi Linear Gain (MLG) method is implemented on digitized data to transmit 12 bit information on 10 bits. The in-flight calibration is implemented using 6 LEDs in front of each CCD. For the VNIR bands (B2, B3, B4), the calibration is a progressively increasing sequence of 16 intensity levels through exposure control. For the SWIR band, the calibration sequence is similar to that of LISS-III SWIR through a repetitive cycle of 2048 scan lines.

IGFOV (across track) (m)	56 at nadir , 70 m (at field edge)
Spectral Bands (microns)	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86 B5 1.55 - 1.70
Swath (km)	740
Bands Saturation radiance (mw/cm^2/sr/micron) Square Wave Response(%)	**B2** **B3** **B4** **B5** 53 47 31.5 7.5 >30 >30 >20 >20
Signal to Noise Ratio @ camera saturation	>512
Integration time (msec)	9.96
Quantization(bits)	12 (10 bit transmission after MLG)
No. of gains	08

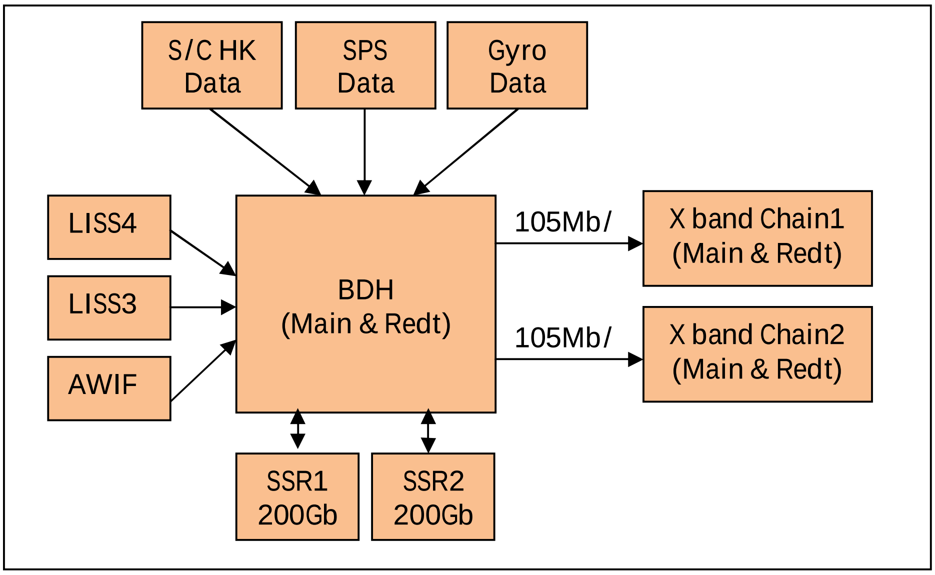
Table 2.4 Major specifications of AWiFS camera

2.4 Payload Data Handling System

The payload data handling system receives the digital data from each camera in bit parallel - byte serial mode, formats it with auxiliary data, modulates it on the RF carrier and transmits to the ground. Like Resourcesat-1 spacecraft, Resourcesat-2 also has two separate downlink chains in X band, both operating at 105 Mbits/sec data rate. Unlike Resourcesat-1 where each chain was dedicated to LISS-IV and LISS-III /AWiFS, in Resourcesat-2, there exists flexibility of down linking payload data through any one of the chains. The DH system of Resourcesat-2 spacecraft essentially consists of two subsystems – Base band Data Handling (BDH) and X-band data Transmitting system. A brief description of these systems is covered in the following sections.

2.4.1 Base band Data handling system

The system receives LISS3, LISS4 and AWIFS payload data, formats them suitably along with Auxiliary information and send the data to X band or SSR system for downlink transmission or recording respectively.



2.4.2 BDH for LISSIII and AWIFS Payload camera

LISSIII payload camera of Resourcesat-2 consists of four bands B2, B3, B4 (VNIR) and B5 (SWIR) with output encoded according to Differentially Pulse Code Modulation(DPCM). DPCM encodes ten bit pixel information to seven bits. BDH for LISSIII formatter receives seven bit DPCM encoded data, multiplex the different band data, formats them in to frames along with auxiliary information. The frame data is RS encoded, randomized, and differentially encodes for transmission.

AWIFS payload camera of Resourcesat-2 consists of four bands B2, B3, B4 (VNIR) and B5 (SWIR) with output encoding twelve bits to ten bits with help of onboard multi linear gain algorithm (MLG). BDH for AWIFS formatter receives ten bit MLG encoded data, multiplex different band data, formats them in to frames along with auxiliary information, RS encodes the frame data, and differentially encodes for transmission.

Formatted data may be recorded into any of the Solid state recorder and played back based on commanding.

Auxiliary information in both formatted data consists of frame or line number, data from Satellite position system data, fine precision gyro data and health keeping telemetry information of space craft.

2.4.3 BDH for LISS-IV Payload camera

LISS-IV payload camera of Resourcesat-2 consists of three bands B2, B3, B4 with output encoded according to Differentially Pulse Code Modulation (DPCM). DPCM encodes ten bit pixel information in to seven bits. BDH for LISS III formatter receives seven bit DPCM encoded data, multiplex the different band data, and formats them in to frames along with auxiliary information.

The frame data is RS encoded, randomized, and differentially encoded for transmission. There are different modes by which LISSIV data may be downloaded. Like its predecessor Resourcesat-1, there exists downloading of data either in mono or 23KmMx mode. Mono mode provides 70 Km of swath and any one of the band may be selected for download. In 23KmMx mode, all three bands for a swath 23 Km from a selected position in 70Km may be downloaded. An additional 70KmMx mode exists in Resourcesat-2 compared to Resoucesat-1. In this mode one of the band data is transmitted in real time and other two are recorded for later down loading through both chains of RF. In case of ground station non visibility, all the three bands may be recorded and played back according to station availability.

Auxiliary information in formatted data consists of frame or line number, data from Satellite position system, fine precision gyro data and health keeping telemetry information of space craft.

2.4.4 Solid State Recorder (SSR)

There are two Solid State Recorders, with each one of them having capacity of 200 Gbit and two chains for recording and playing back. Based on command, payload data can be recorded in either of SSR and data may be played through any of the two available X band RF chain. The system records the data as files and at a given time there can exists maximum of sixteen files in each chain. SSR system has various functional utilities like, onboard file management for enabling operation easiness and diagnostics utilities for checking health status of memory modules etc.

2.4.5 Data Handling System (RF)

The data handling system (RF) accepts the baseband data of LISS-IV and LISS-III + AWiFS at 105 Mbps from the BDH system and modulates this data on two independent X-band carriers to transmit to the ground. Each chain is configured with passive redundancy for the transmitter. The LISS-IV data are transmitted on carrier-1 at 8125 MHz and LISSIII + AWiFS data are transmitted on carrier-2 at 8300 MHz. Each transmitter has its own basic crystal oscillator (270.833 MHz for LISS-IV and 276.666 MHz for LISS-III chains). These basic frequencies are multiplied by 30 times through different stages to get the final carrier frequency. The output from TCXO is amplified to a level of + 22dBm in two stage VHF amplifier and is fed to an L-band multiplier and a band pass filter. Here the signal is multiplied by X6 and after further amplification (to + 23 dBm), it is passed through the final multiplier where it is multiplied by X5 to get the final X-band carrier.

The TTL compatible data from base band system are modulated on the carrier through a QPSK modulator. I and Q data each at 52.5 Mbps modulate the X-band data transmitter-1 chain at 8125MHz. Similarly, I and Q data each at 52.5 Mbps modulate the X-band data transmitter-2 chain at 8300MHz. Passive redundancy is provided for each of the transmitters. The modulated signal is amplified through a 40W TWTA and is fed to the shaped beam antenna for transmission. There are three TWTAs – one each for LISS-IV and LISS-III chains and the third one will serve as a redundant to either of them. A link margin of about 5 dB is available in both these chains. The schematic diagram of DH (RF) is given in Figure 2.5.

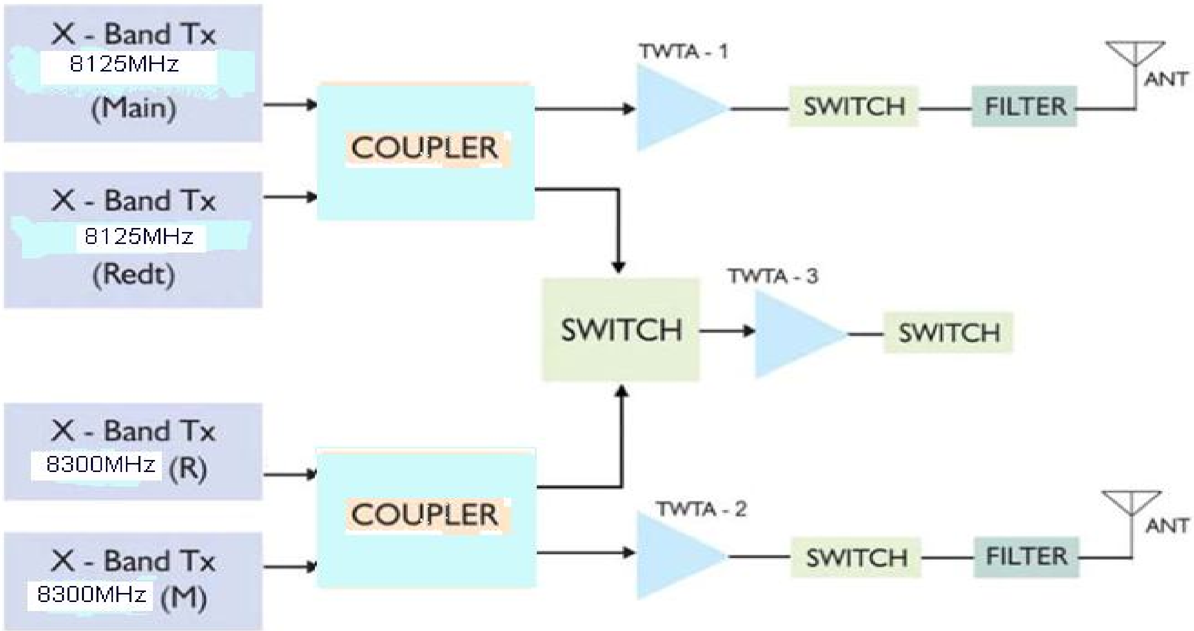


Figure 2.5 Schematic Diagram of DH(RF)

2.4.6 Satellite Positioning System

The Satellite Positioning System (SPS) on-board Resourcesat-2 consists of 10/8 channel GPS receivers operating at 1575.42 MHz frequency. The SPS provides position and velocity vectors of the spacecraft at each instance in the orbit. There are two SPS units with full redundancy.

Each SPS consists of 10 & 8 channel high dynamics Receiver Core Engines in hot redundancy. A common Spacecraft Interface Module selects the output from either 10-channel (main) or 8-channel (redundant) system based on built-in on-board logic. Both SPS units are mounted on the anti-earth face of the satellite to track GPS satellite signals. The received signals are fed to a single stage Low Noise Amplifier followed by a two stage L-band amplifier.

The SPS data outputs are available in two formats- MIL-1553B real-time data at every second and playback data with a rate of one sample in 10 seconds. The SPS data consists of X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$, GPS time, tracked GPS satellite IDs, pseudo range, delta range, received CNDR (Carrier to Noise Density Ratio), indication of GPS satellites used for computation, PDOP (Position Dilution of Precision), ephemeris of the GPS satellites. The MIL-1553B data are sampled at once every second. The playback data are sampled at once every 10 seconds and stored in SPS on-board memory. The PB parameters also consist of same data like MIL-1553B data except for some parameters like frame numbers of the stored SPS data. The playback data is transmitted to a ground station at a rate of 16kbps after PSK modulation on 128 KHz sub-carrier.
Through MIL-1553B interface, OBT (on-board timer of AOCE system) is synchronized to GPS time once every 60 seconds through a time synchronization command. The house-keeping telemetry parameters are a subset of the MIL-1553B SPS data sampled every 16 seconds.

Chapter 3

ORBIT, COVERAGE AND REFERENCING SCHEME

The primary objective is to provide systematic and repetitive acquisition of data of the earth's surface under nearly constant illumination conditions. The orbit is same as that of Resourcesat-1 i.e., the satellite operates in a circular, sun-synchronous, near polar orbit with an inclination of 98.69 deg, at an altitude of 817Km. The satellite takes 101.35 minutes to complete one revolution around the earth and completes about 14 orbits per day. The entire earth is covered by 341 orbits during a 24 day cycle. The orbital parameters are summarized in Table 3.1.

Orbits/ cycle	341
Repeat cycle	24 days
Altitude	817 Km
Semi-major axis	7195.11 Km
Inclination	98.689 deg
Eccentricity	0.001
Orbit period	101.35min
Distance between adjacent traces	117.5 Km
Distance between successive ground tracks	2820 Km
Ground Trace Velocity	6.65 Km/Sec

Table 3.1 Resourcesat-2 orbital parameters

The mean equatorial crossing time at descending node is 10:30 a.m. ± 5 minutes. 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 ±1 Km of the reference ground trace pattern. The sensors collect data with different swaths. The swath of LISS-III sensor, similar to that of Resourcesat-1, in the visible bands is 141 Km., the swath of SWIR band is also 141 Km. The LISS-IV camera is operates in two modes Mono and Multi-spectral (MX). The Mono mode is similar to that of Resourcesat-1 with 70 Km swath in any one of the spectral bands. In the MX mode, 4000 pixels of each spectral band are transmitted to provide 23.5 Km swath like in RESOURCESAT-1. Also in Resourcesat-02 MX mode, 12000 pixels of each spectral band are transmitted to provide 70 km swath, which is new compared to Resourcesat-1. The swath of AWiFS is 737 Km which same as that of Resourcesat-1.

Details of overlap and sidelap between scenes of a sensor are given in Table 3.2. The successive orbits are shifted westward by 2820 Km at the equator. Figure 3.1 shows a typical ground trace of the orbits. The entire globe is covered in 341 orbits between 81 deg North and 81 deg South latitudes, during the 24 day cycle.

Payload	Resolution (m)	Swath (Km)	Ground Image Size (Km)	Overlap (Km)	Side Lap (Km)
LISS-III (Visible & SWIR)	23.5	141	142 x 141	7	23.5
LISS-1V					
Mono	5.8	70	70 x 70	2.5	5 (within LISS-III scene)
SMX	5.8	23.5	23.5 x 23.5	14.2	
FMX	5.8	70	70 x 70	2.5	5 (within LISS-III scene)
AWiFS	56(nadir)	737	738 x 737	82%	84%

Table 3.2 Overlap and side lap between the scenes

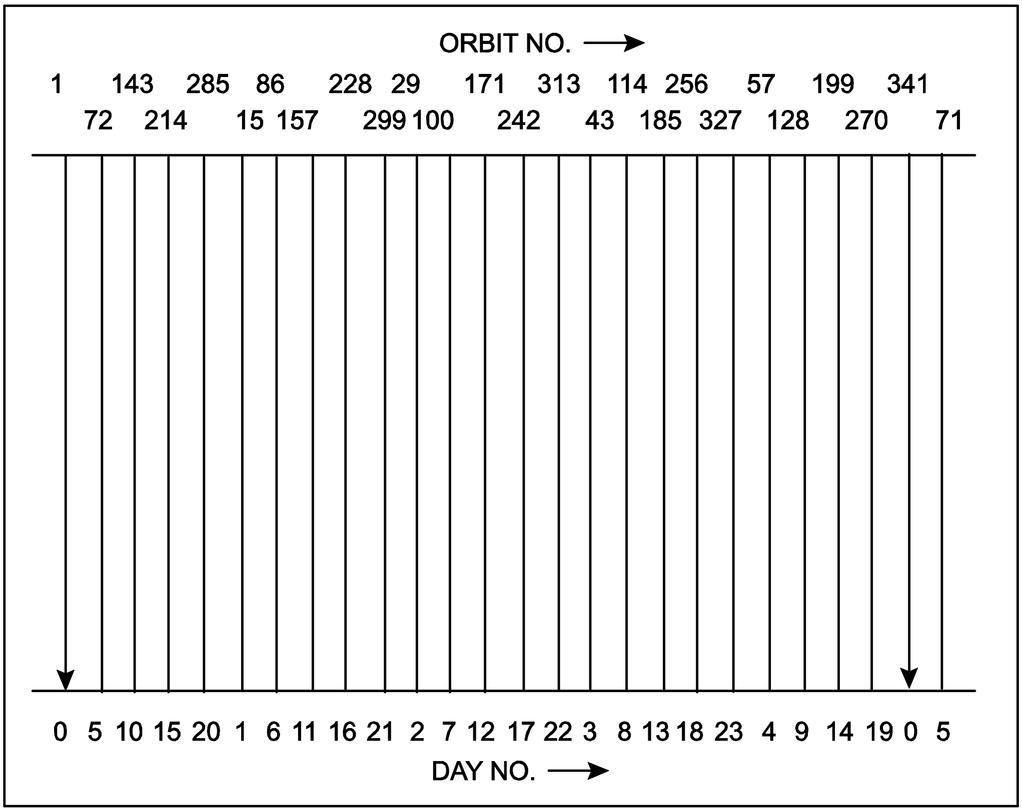


Figure 3.1 Ground Trace Pattern

3.1 Scene layout

Figure 3.2 shows the scene layout of LISS-III and LISS-IV mono scenes within an AWiFS scene. The corners are numbered for AWiFS scene as shown in the figure. The same pattern of marking the corners is followed for other payload scenes also. There is an overlap of 7 Km between adjacent scenes of LISS-III along a path and a sidelap of 23.5 Km 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. Typically, at 40 deg latitude the sidelap is around 40% of the swath and at 81 deg latitude, it is 99%. As the swath of AWiFS is very large, there is a sidelap of about 84% between AWiFS scenes of adjacent paths at equator. But, between n^{th} and $n+5^{th}$ path which occur on consecutive days, the sidelap is around 149 Km at equator. Thus global coverage by AWiFS is still achieved in 5 days even with a reduced swath of 737 Km. There is an overlap of around 82% between adjacent scenes in a path. But the overlap between the m^{th} and $m+5^{th}$ scenes along a path is around 62 Km. Hence one out of every consecutive five scenes can be downloaded for data products generation. Four subscenes are defined in each AWiFS main scene. More details about the referencing scheme is discussed in section 3.2.

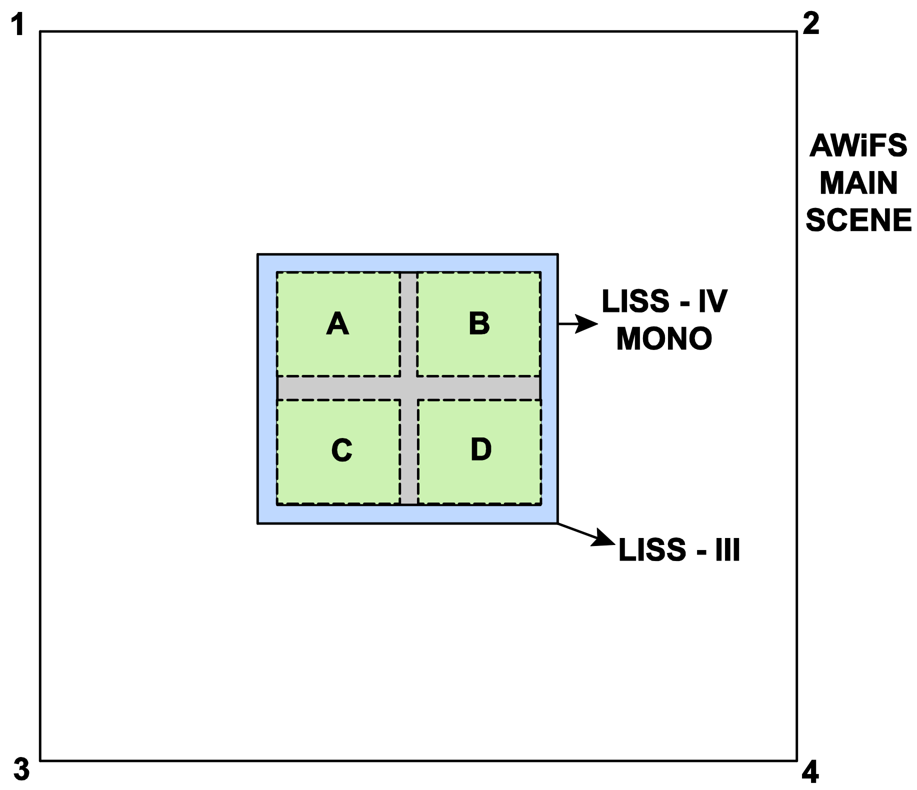


Figure 3.2 Scene layout of LISS-IV and LISS-III in AWiFS main scene

3.1.1 Revisit capability of LISS-IV

Because of the tilting capacity of LISS-IV, a given area can be viewed more than once within a cycle. This is known as revisit due to tilting of LISS-IV. Figure 3.3 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 occur relative to the central path. From the figure, it can also be seen that the maximum wait period to view an area is 5 days only. The maximum tilt angle being ±26 deg, LISS-IV 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 LISS-IV at high latitudes.

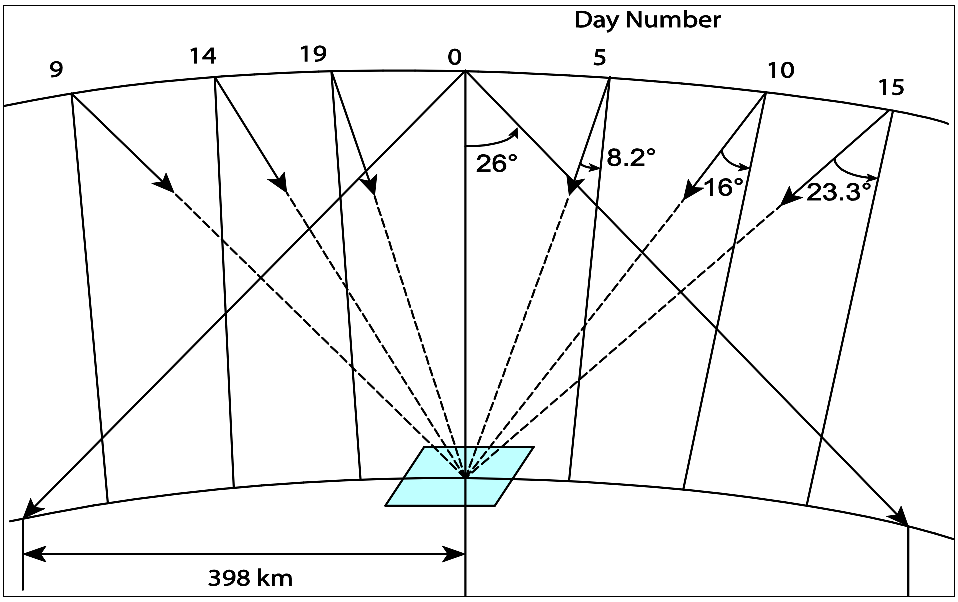


Figure 3.3 Coverage due to LISS-IV off-nadir capability

3.2 Referencing Scheme

3.2.1. Introduction

Referencing scheme, which is unique for each satellite mission, is a means of conveniently identifying the geographic location of points on the earth. This scheme is designated by Paths and Rows. The Path-Row concept is based on the nominal orbital characteristics. This section describes the referencing scheme and related information. The Referencing Scheme for Resourcesat-2 is same as that of Resourcesat-1.

The high resolution multi spectral camera LISS-IV works in two modes viz., Mono mode providing 70 Km swath in any one of the spectral bands and Multi-spectral mode providing 70 Km and 23.5 Km swath in all the three spectral bands. The swath of 23.5 Km could be selected anywhere within the 70 Km, by electronic switching facility as in the case of Resourcesat-1.

Apart from the S-band based orbit determination, the position of the spacecraft is determined accurately using GPS measurement data obtained from the Satellite Positioning System onboard the satellite.

The pointing accuracy is 0.05 deg and the attitude determination accuracy using star sensor would be 0.014 deg in each of the axes in the case of Resourcesat-1, where as in the case of Resourcesat-2 the post facto attitude determination accuracy will be better than 0.014 deg due to the increased number of stars from 5 to 7 and the frequency of sampling from one second to half a second.

3.2.2. 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'. The orbit being similar to Resourcesat-1, the satellite completes 341 orbits in 24 days with an orbital period of 101.35 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 14, which as per the referencing scheme will be path numbers 1, 318, 294, 270, 246, 222, 198, 174, 150, 126, 102, 78, 54 and 30 assuming that the cycle starts with path 1. So orbit 1 corresponds to path 1 , orbit 2 to path 318, orbit 3 to path 294 etc., The fifteenth orbit or first orbit of day two (D2), is path 6 which will be to the east of path 1 and is separated from path 1 by 5 paths. The path pattern is the same as that of Resourcesat-1. Path number one is assigned to the track which is at 29.7 deg West longitude. The gap between successive paths is 1.055 deg. All subsequent orbits fall westward. Path 1 is so chosen, that, the pass with a maximum elevation greater than 86 deg for the data reception station of NRSC at Shadnagar can be avoided. This is due to the limitation of antenna drive speed, since, it is difficult to track the satellite around zenith. In fact, above 86 deg elevation, if a pass occurs, the data may be lost for a few seconds around zenith. Hence, the path pattern is chosen such that the overhead passes over the data reception station is reduced to a minimum. To achieve this, path 1 is positioned in such a manner that the data reception station is exactly between two nominal paths, namely 99 and 100. During operation, the actual path may vary from the nominal path pattern due to variations in the orbit by perturbations. Therefore, the orbit is adjusted periodically, after a certain amount of drift, to bring the satellite into the specified orbit. The path pattern is controlled within ±1 Km about the nominal path pattern.

3.2.3. Row

Along a path, the continuous stream of data is segmented into a number of scenes of convenient size. As in case of Resourcesat-1, LISS-III is the primary payload and the scene centres of LISS-III are considered for defining rows. In case of Resourcesat-2, the scene centres of LISS-III are fixed to be same as that of Resourcesat-1 as the orbit is same and the primary payload, LISS-III, is very much similar to that of Resourcesat-1. With respect to each scene centre, a LISS-III scene consisting of 6420 lines is framed so that the selected scene centre is the centre of the scene. The uniformly separated scene centres are, such that, same rows of different paths fall at the same latitude. The lines joining the corresponding scene centres of different paths are parallel to the equator and are called Rows. The row number 1 falls around 81 deg North latitude, row number 41 will be near 40 deg North and row number of the scene lying on the equator is 75. The Indian region is covered by row numbers 30 to 90 and path numbers 65 to 130.

3.2.4. 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 to 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 a 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 used to constitute that scene.

3.2.5. 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.

However, 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 the border region of any scene, the user may have to order the overlapping scenes in addition to the nominal scene.

3.2.6. Resourcesat-2 referencing scheme

The referencing scheme of Resourcesat-02 is same as that of Resourcesat-1 as the orbit is same and the payloads are similar.

The size of LISS-III scene is same as that of Resourcesat-1. i.e. 142 Km x 141 Km.

The size of AWiFS scene is 738 Km x 737. Also in addition to the AWiFS main scene of 738 Km x 737 Km, four sub-scenes within the AWiFS main scene, each of size 374 Km x 372 Km are defined corresponding to the two CCD arrays.

There are four LISS-IV mono / Mx scenes A, B, C and D within one LISS-III scene. The overlap between the A / C scenes and B / D scenes is 5 Km. The overlap between A (or B) and C (or D) is 2.5 Km

3.2.7 LISS-III referencing scheme and scene coverage

The swath of LISS-III is 141 Km in all the four bands. Since the swath of LISS-III in all the four bands is greater than the inter orbit distance (117.5 Km), the sensor scans the entire globe once in every cycle without gaps. The referencing scheme of LISS-III consists of 341 paths numbered from west to east. Each path consists of 149 rows. Consecutive paths are covered with a separation of five days. If Path 1 is covered on day one, Path 2 will be covered on day six (Figure 4.2.1). Each LISS-III scene covers an area of 142 Km x 141 Km. The side lap between two LISS-III scenes is 23.5 Km at the equator. The overlap between successive scenes in a path is 7 Km. (Figure 3.4)

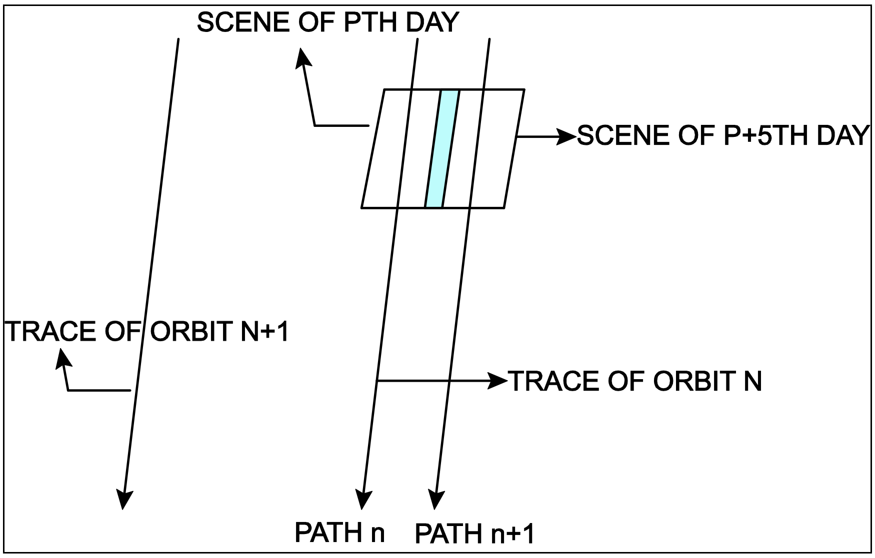


Figure 3.4 LISS-III coverage pattern.

3.2.8 LISS-IV referencing scheme and scene coverage

3.2.8.1 Mono Mode

As already mentioned in section 2.4, LISS-IV camera consists of three CCD arrays having 12000 elements in each of the three spectral bands. The camera operates in two modes *Mono* and *Multi-spectral*. In Mono mode, the data corresponding to 12000 pixels of one of the CCD arrays is downlinked. So, Mono mode provides a swath of 70 Km in one of the spectral bands. *Mono* scenes from nadir view lead to gaps between the scenes as the path to path separation is 117.5 Km at the equator and the swath is only 70 Km. Therefore, four mono scenes A, B, C and D are defined in one LISS-III scene. The mono scenes are referred to by the same path number and row number as that of LISS-III along with the suffixes A, B, C and D. The A/C strip is acquired with approximately –2 deg tilt and B/D strip is acquired with approximately 2 deg tilt. So by tilting the camera, entire globe can be covered, in two cycles. Figure 3.5 provides the layout of LISS-IV mono scenes in LISS-III scene. The overlap between A and C (or B and D) is 2.5 Km within a LISS-III scene and the overlap between C and A (or D and B) The side lap between A /C and B/D is 5 Km which ensure overlap taking into account ground track shift and attitude errors. It is to be noted that this layout for LISS-IV is chosen for referencing scheme only. Otherwise due to tilting up to ±26 deg, the scenes can be anywhere within ±400 Km from nadir in the cross-track direction.

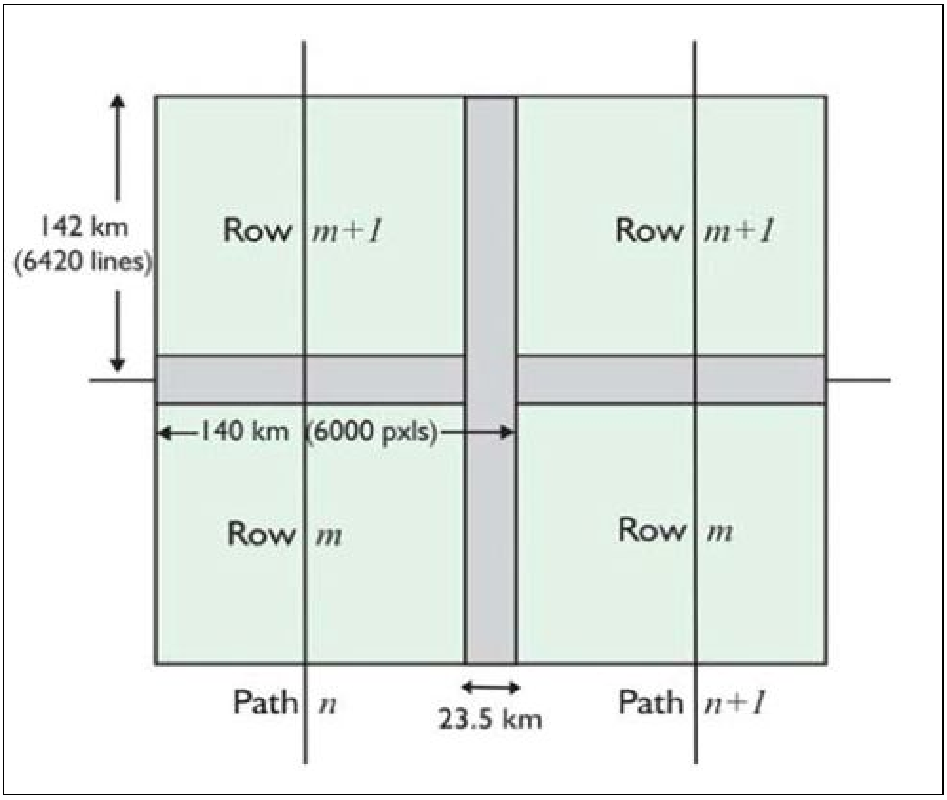


Figure 3.5 LISS-III scene layout

3.2.8.2 Multi-spectral (MX) Mode (Swath 23 Km)

In MX mode, data corresponding to 4000 pixels of each spectral band is transmitted. Due to the electronic switching facility, this set of 4000 pixels could be selected anywhere within 12000 pixels i.e. the start pixel could be any value from 1 to 8001. This gives the advantage of selecting 23.5 Km swath (corresponding to 4000 pixels) anywhere within the chosen 70 Km due to tilt. Because of the electronic switching facility, many MX requests could be serviced with a single tilt. As the acquired MX strips could be anywhere longitudinally because of the tilt and electronic switching facility, there is no path based scheme for MX mode. Hence, the user has to specify his area of interest in terms of latitude and longitude.

3.2.8.3 Multi-spectral (MX) Mode (Swath 70 km)

In Resourcesat-2 MX mode, 12000 pixels of each spectral band are transmitted to provide 70 km swath, which is new compared to Resourcesat-1.

3.2.9 AWiFS referencing scheme and scene coverage

The AWiFS referencing scheme is also based on LISS-III scene centre. However, due to the large coverage of AWiFS scene (737 Km x 737 Km), there is an overlap of 84% between adjacent paths at equator. Similarly, the overlap between adjacent rows is 82%. So, if a user requires continuous area, say, 1200 Km x 1200 Km, it is enough if he orders for four AWiFS scenes. The point to be noted here, is that, the user should order data pertaining to path P and path P+5 (which is covered on the next day) and rows *m* and *m* + 5 of paths P and P+ 5 to cover his entire area. This way user gets data pertaining to his area within two days (Figure 3.8).

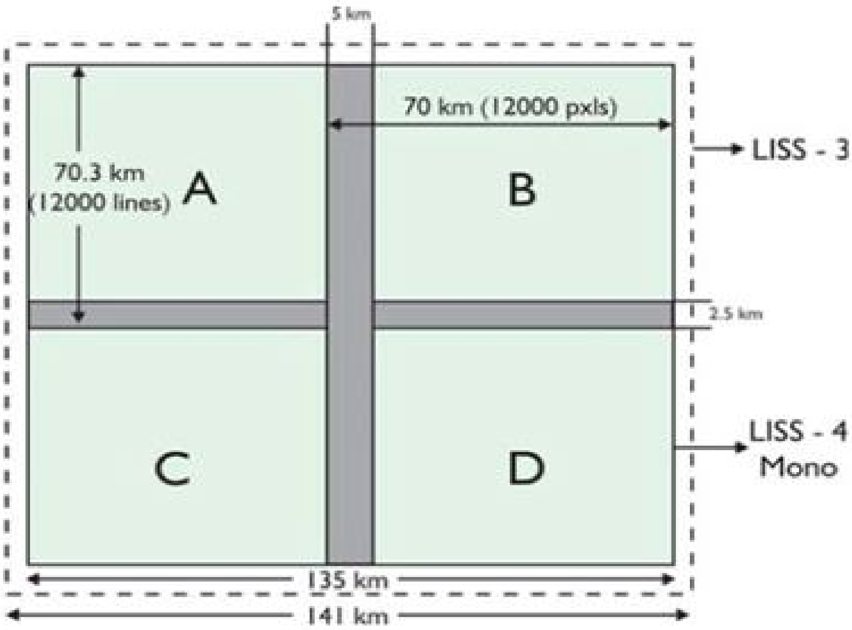


Figure 3.6 LISS-IV scene (Mono) within a LISS-3 scene

The huge overlaps between the AWiFS 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. This is the case at the equator. Since at higher latitudes the overlap is more, the coverage becomes more frequent.

Combination of	Day of the cycle paths
P2 -P337	6th and 24th
P2 -P338	6th and 5th
P2 -P339	6th and 10th
P2 -P340	6th and 15th
P2 -P341	6th and 20th
P3 -P338	1st and 5th
P3 -P339	11th and 10th
P3 -P340	11th and 15th
P3 -P341	11th and 20th
P4 -P339	16th and 10th
P4 -P340	16th and 15th
P4 -P341	16th and 20th

In addition to the AWiFS main scene of 738 Km X 737 Km, four sub-scenes A, B, C and D are defined within AWiFS main scene corresponding to the two CCD arrays of 6000 elements each. Each sub-scene is of size 374 Km x 372 Km. The sub-scene layout is similar to that of LISS-IV mono scenes within a LISS-III scene. There is a sidelap of 8.4 Km (150 pixels) between A/C and B/D scenes and there is an overlap of 10 Km (150 lines) between A (or B) and C (or D) (Figure. 3.7).

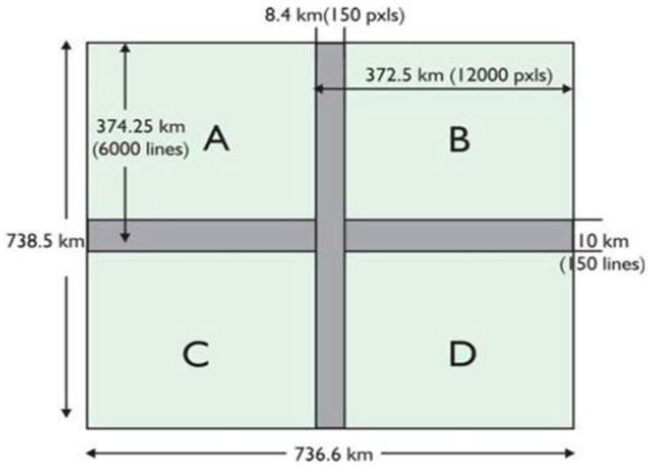


Figure 3.7 AWiFs quadrants

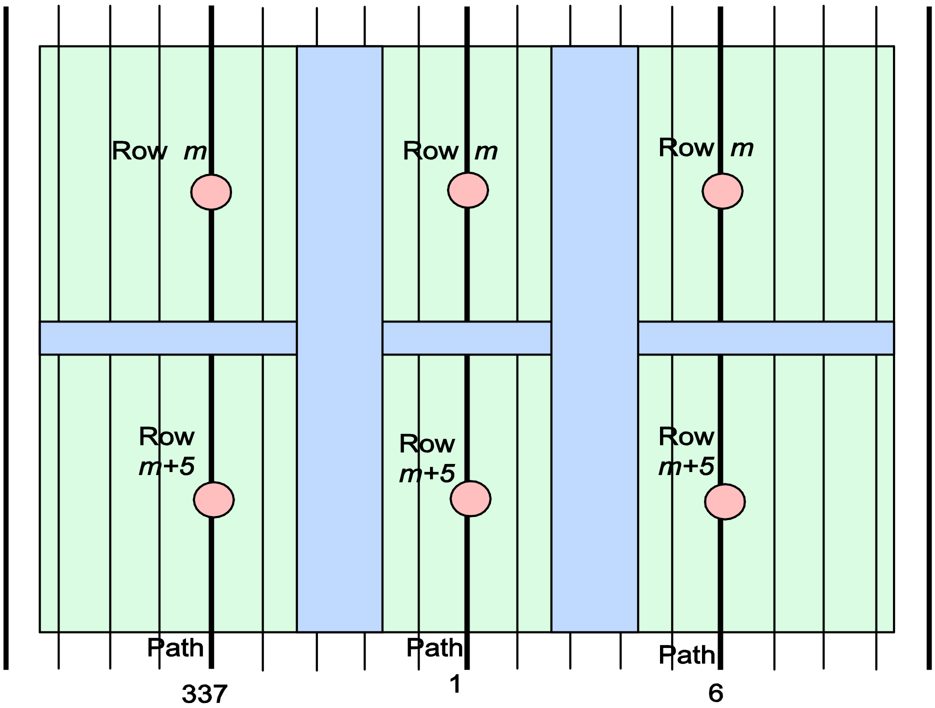


Figure 3.8 AWiFs Scene Coverage

3.2.10 Indian and World referencing scheme maps

The following referencing scheme maps are available for users reference:

i) India and neighboring countries on 1: 6,000,000 scale

ii) The entire coverage of Hyderabad earth station on 1: 12,800,000 scale

A world referencing scheme map is also available for ready reference of path and row numbers over the total coverage of Resourcesat-02 on land and water from 81°N to 81°S. The map is in mercator projection. The scale of this map is 1: 62 million.

3.2.11 Digital Referencing Scheme

The Digital Referencing Scheme for Resourcesat-2, facilitates convenient and unique identification of a geographic location. Using the software, users can arrive at the number of scenes that cover their area of interest.

Users can search their area of interest in the following ways:

- Search based on Point
- Search based on Polygon
- Search based on location (State name, District Name, Taluk Name and City Name)
- Search based on SOI toposheet number for the Indian Region
- Search based on a Shape file

Using the software users can also know the possible dates on which his area of interest gets covered. For the given input, first the corresponding paths and rows which cover the user's area of interest are calculated. For each path, the possible dates on which it is covered during the desired period of interest is presented. The search based on Point or Polygon can either be in Degrees Decimal (DD) or Degrees-Minutes-Seconds (DMS) format.

3.2.12 Determination of observation dates

For the chosen path, the ground track repeats every 24 days after 341 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 throughout 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 3.2), assuming that path number 1 is covered on January 11, if data over a geographic area covered by path 60 is required, it is seen that this path is covered on days, 18th of January, 11th of February, 06th 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.

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

3.2.13 Estimation of path and row, local clock time and other details for any point on the 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 3.3 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 3.3 gives the descending node longitude of all paths over the 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 3.4 gives the descending node time (GMT) expected for each path over the 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 of 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 3.3 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.

3.2.14 Framing procedure and scene centre corner co-ordinates evaluation for the referencing scheme

Based on the reference orbit, ephemeris is generated for all the 341 orbits of a 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 scene centres. All the details of LISS-III scenes along the paths are obtained taking descending nodal points as reference. While assigning the row numbers, counting is done from northern most scene centre on a path. The size of LISS-III scene is 6000 pixels X 6420 lines. The scene centre latitudes are obtained from the nominal referencing scheme and the corresponding time is computed based on ephemeris. Once scene centre time is known, by taking 3210 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 of and the side lap is given by ground track placements. Similarly, all the LISS-III scenes are sized along the track. By evaluating comer coordinates of each scene, the framing is completed. The details about corner co-ordinates computation is provided in the next section. Scene framing for payloads AWiFS and LISS-IV is done in a similar manner.

Latitude	Row No.	Longitude	Latitude	Row No.	Longitude
81.30	1	-88.78	42.79	39	-11.12
81.06	2	-81.05	41.61	40	-10.70
80.68	3	-73.82	40.43	41	-10.30
80.18	4	-67.23	39.25	42	-9.91
79.56	5	-61.34	38.07	43	-9.53
78.84	6	-56.15	36.89	44	-9.16
78.05	7	-51.58	35.71	45	-8.80
77.20	8	-47.59	34.53	46	-8.44
76.30	9	-44.08	33.34	47	-8.10
75.36	10	-41.00	32.16	48	-7.76
74.38	11	-38.29	30.97	49	-7 .42
73.37	12	-35.87	29.79	50	-7.10
72.35	13	-33.72	28.60	51	-6.77
71.30	14	-31.79	27.41	52	-6.46
70.23	15	-30.05	26.22	53	-6.15
69.16	16	-28.48	25.04	54	-5.84
68.07	17	-27.04	23.85	55	-5.54
66.97	18	-25.73	22.66	56	-5.24
65.86	19	-24.53	21.47	57	-4.94
64.74	20	-23.41	20.28	58	-4.65
63.62	21	-22.38	19.09	59	-4.36
62.49	22	-21.42	17.89	60	-4.08
61.36	23	-20.53	16.70	61	-3.79
60.22	24	-19.69	15.51	62	-3.51
59.07	25	-18.90	14.32	63	-3.23
57.93	26	-18.16	13.13	64	-2.96
56.78	27	-17.45	11.93	65	-2.68
55.62	28	-16.79	10.74	66	-2.41
54.47	29	-16.16	9.55	67	-2.14
53.31	30	-15.55	8.35	68	-1.87
52.15	31	-14.98	7.16	69	-1.60
50.98	32	-14.43	5.97	70	-1.33
49.82	33	-13.90	4.77	71	-1.06
48.65	34	-13.39	3.58	72	-0.80
47.48	35	-12.91	2.39	73	-0.53
46.31	36	-12.43	1.19	74	-0.27
45.13	37	-11.98	0.0	75	0.00
43.96	38	-11.54			

Table 3.3 The difference in longitude of a given row latitude and descending time

Path	Longitude	Path	Longitude
65	37.866	101	75 .72
66	38.922	102	76.928
67	39.977	103	77.983
68	41.033	104	79.039
69	42.089	105	80.095
70	43.145	106	81.150
71	44.200	107	82.206
72	45.256	108	83.262
73	46.312	109	84.318
74	47.367	110	85.373
75	48.423	111	86.429
76	49.479	112	87.485
77	50.535	113	88.540
78	51.590	114	89.596
79	52.646	115	90.652
80	53.702	116	91.708
81	54.757	117	92.763
82	55.813	118	93.819
83	56.869	119	94.875
84	57..925	120	95.930
85	58.980	121	96.986
86	60.036	122	98.042
87	61.092	123	99.098
88	62.148	124	100.153
89	63.203	125	101.209
90	64.259	126	102.265
91	65.315	127	103.321
92	66.370	128	104.376
93	67.426	129	105.432
94	68.482	130	106.488
95	69.538	131	107.543
96	70.593	132	108.599
97	71.649	133	109.655
98	72.705	134	110.711
99	73.760	135	111.766
100	74.816		

Path	GMT	Path	GMT
65	7:59	101	5:27
66	7:54	102	5:22
67	7:50	103	5:18
68	7:46	104	5:14
69	7:42	105	5:10
70	7:37	106	5:05
71	7:33	107	5:01
72	7:29	108	4:57
73	7:25	109	4:53
74	7:21	110	4:49
75	7:16	111	4:44
76	7:12	112	4:40
77	7:08	113	4:36
78	7:04	114	4:32
79	6:59	115	4:27
80	6:55	116	4:23
81	6:51	117	4:19
82	6:47	118	4:15
83	6:43	119	4:11
84	6:38	120	4:06
85	6:34	121	4:02
86	6:30	122	3:58
87	6:26	123	3:54
88	6:21	124	3:49
89	6:17	125	3:45
90	6:13	126	3:41
91	6:09	127	3:37
92	6:05	128	3:32
93	6:00	129	3:28
94	5:56	130	3:24
95	5:52	131	3:20
96	5:48	132	3:16
97	5:43	133	3:11
98	5:39	134	3:07
99	5:35	135	3:03
100	5:31		

Table 3.4 Equatorial crossing longitude Equatorial crossing time (GMT) for paths over Indian region for paths over Indian region (Local time at descending node 10:30 hrs)

3.2.15 Estimation of the centre and corner co-ordinates of LISS-III and LISS-IV scenes

From the ephemeris information, it is possible to compute geographical co-ordinates of LISS-III scene centres which lie on the ground track. However, this is not the case with LISS-IV scene centers as they lie on either side of the ground track. The time of occurrence of any LISS-IV scene center or any corner co-ordinate is obtained by using the information that the scanning is 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 3.9, let A1 be a point on the ground track with coordinates (φ_1, λ_1). Let P be a corner point of a scene. The coordinates of P say (φ_2, λ_2), can be calculated as follows.

$$\text{Sin } \varphi_2 = \text{Cos } \theta \text{ Sin } \varphi_1 \pm \text{Sin } \theta \text{ Cos } \varphi_1 \text{ Cos } \alpha \quad \text{..........(1)}$$

where $\alpha = 2\pi - \zeta \pm \pi/2$ and θ, $\varphi\varphi$ and ζ are the angles as shown in Figure 3.9 [1,2]

$$\text{Cos } \theta = \text{Sin } \varphi_1 \text{ Sin } \varphi_2 \pm \text{Cos } \varphi_1 \text{ Cos } \varphi_2 \text{ Cos } \Delta \quad \text{........................(2)}$$

Where Δ is longitudinal difference of λ_2 from λ_1 and θ is the angle subtended by arc alP (Fig. 3.14) at the centre of the Earth.

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

$$\text{Cos}\Delta = (\text{Cos}\theta - \text{Sin}\varphi_1 \text{Sin}\varphi_2) \;/\; (\text{Cos}\varphi_1 \;\; \text{Cos}\varphi_2) \quad \text{...................(3)}$$

Appropriate sign is used to denote depending on whether the point P (φ_2, λ_2) is east or west of point al (φ_1, λ_1). The longitudeλ_2 is therefore obtained as

$$\lambda_2 = \lambda_1 \pm \Delta$$

Thus, the geographical co-ordinates of any required point can be obtained either for any comer or the centre of the scene.

3.2.16 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.

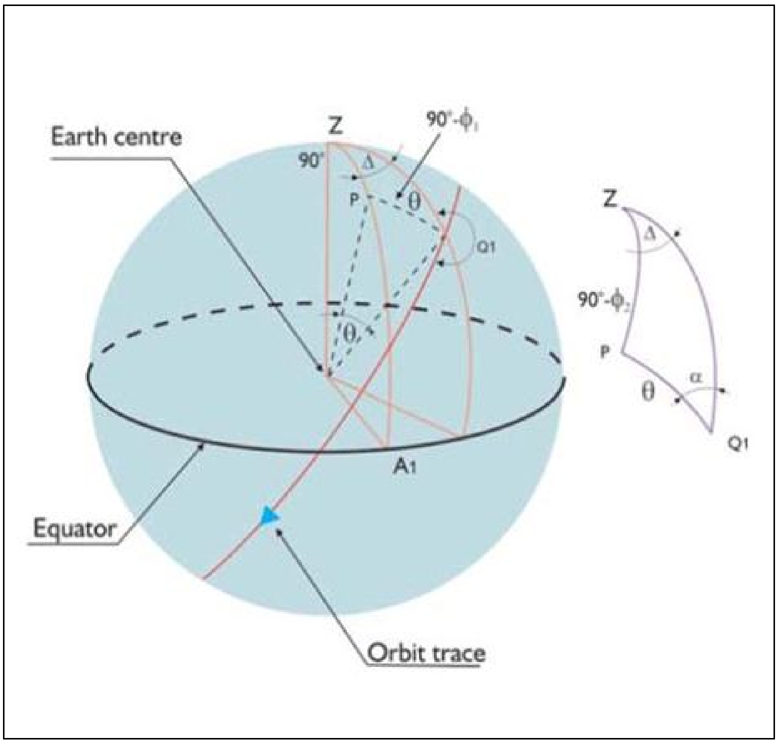


Figure 3.9 Calculations of coordinates of a point P on the earth surface.

3.2.16.1 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 lifetime 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 close 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 luni-solar 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.

3.2.16.2 Atmospheric Drag

Though the atmospheric density is small at an altitude of about 1000 Km, the same cannot be neglected, as it causes gradual loss of altitude continuously, if the same 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 to within ±1 Km of the nominal pattern. This would be achieved by suitably controlling the altitude within corresponding limits. Periodicity of altitude corrections depends on the decay rate.

3.2.16.3 Asphericity of the Earth

Asphericity of the earth has two major effects, namely:

i. Circular orbit becomes eccentric and 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 orbit is estimated to be around 132 days. Due to the frozen orbit concept, to be adopted for IRSP6, the perigee is almost maintained near the orbital pole and the mean eccentricity is maintained at 0.0010033.

Eccentricity leads to variations in altitude as well as velocity. Since the earth is geoid shaped, even for a pure circular orbit, satellite does not have same altitude throughout the orbit. The altitude variations cause scale variations of the image (Figure. 3.10) for a given camera system. Due to the frozen perigee, altitude variations over the Indian region would be within 10 Km.

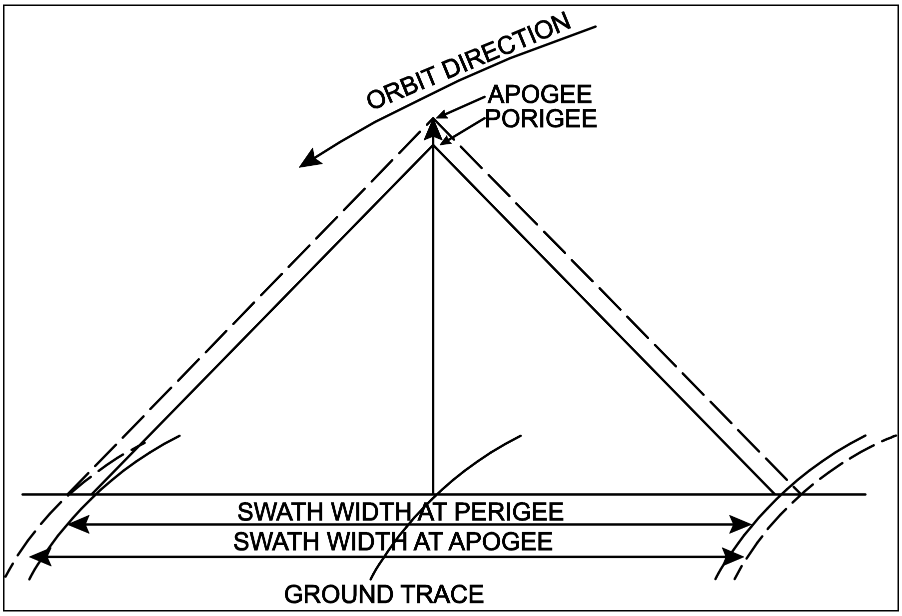


Figure 3.10 Scale variations of image with altitude

Equator is taken as the reference for framing the scenes while 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 equal time intervals.

3.2.16.4 Luni-solar Gravitational Attraction and Solar Radiation Pressure

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 attraction causes secular variations of about 0.041 degree per year in inclination, apart from periodic variations. Variations in the inclination affects ground track pattern as well as local time. Since the variations are secular, compensation can be done easily. The inclination is biased by 0.02 degree towards a favorable side, so that it drifts to the nominal value after 6 months. Yearly corrections to inclination will be done to restrict its contribution to local time variation within ±0.4 minutes, as shown in Figure. 3.11.

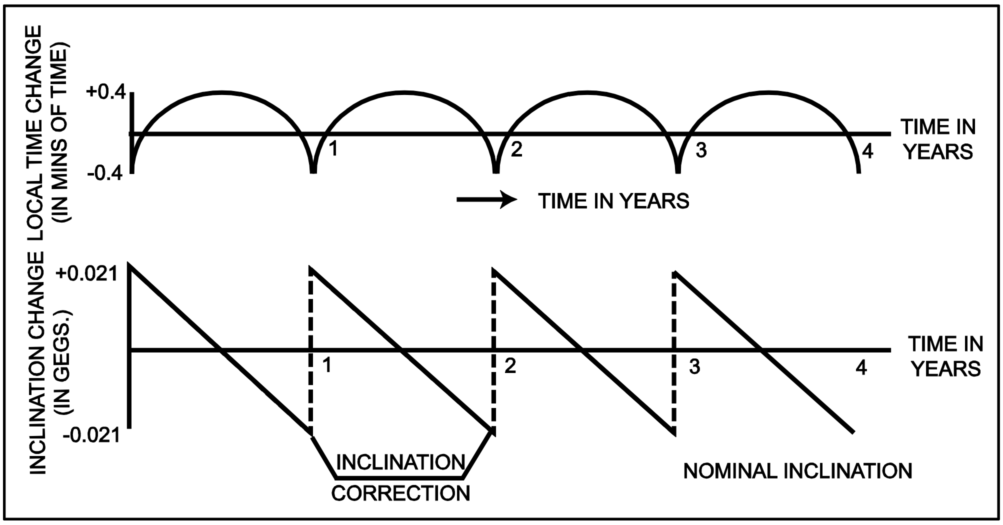


Figure 3.11 Local time control by inclination correction

3.2.17 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.

In Resourcesat-2, the position of the spacecraft is also available by means of SPS (Satellite Positioning System). For browse and standard products, definitive orbital ephemeris are used. The image location accuracy in each of these products are affected by the accuracy cited above.

3.2.18 Deviation of attitude parameters

To align the payload cameras along the nadir line continuously, IRS has been configured for 3 axis stabilized 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 affects the attitude stabilization continuously. Due to the presence of various errors in attitude sensing and controlling, the attitude would be controlled up to 0.05 degree in each of the yaw, roll and pitch axes with star sensor in control loop. The effect of pitch, roll and yaw on image is shown in Figure 3.11. 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 attitude determination accuracy is better than the controlling accuracy and would be ±0.014 degree in each of the axes using star sensor. The pointing accuracy is 0.05 deg and the attitude determination accuracy using star sensor would be 0.014 deg in each of the axes in the case of Resourcesat-1, where as in the case of Resourcesat-2 the Post Facto Attitude Determination accuracy will be better than 0.014 deg due to the increased number of stars from 5 to 7 and the frequency of sampling from one second to half a second.

The deviation of scenes from the nominal depends only on the controlling accuracy. Determined attitude information is used to correct the image and for annotation.

3.2.18.1 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 ±1 Km. 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 0.05 degree causes track deviations of about 0.7 Km and yaw error of 0.05 degree would cause 0.09 Km under the worst case. The Root Sum Square (RSS) of all these deviations is about 1.2 Km.

3.2.18.2 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. The eccentricity effect is considered to some extent by choosing the frozen orbit concept. Velocity variations due to eccentricity are considered in the referencing scheme itself. Pitch error of 0.05 degree would cause 700 m along track deviation at the worst case. The component of yaw introduces 80 m error. One day predicted ephemeris are used for browse products which have positional information to the accuracy of about 150 m. With all these, the along track deviation is about 720 m (RSS). This deviation is reduced by following an appropriate framing procedure during actual operations. However, the across track deviation within 1.2 Km cannot be reduced by any such procedures as it is a derivative of all the system components involved.

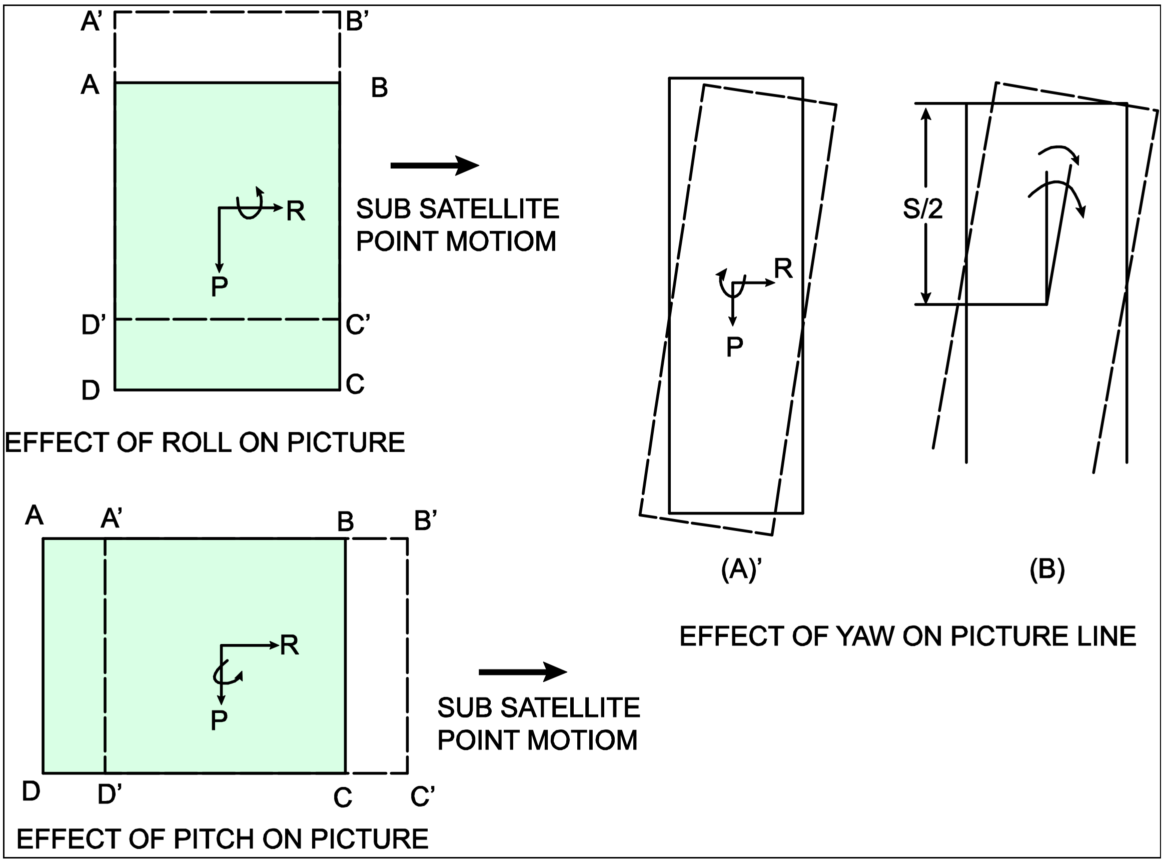


Figure 3.12 Effect of attitude errors on image

3.2.19 Image framing during actual operations

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 location 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 are stored.

ii. The same row latitudes for actual scenes are adopted. This is accomplished by interpolating the time for a given row latitude along the path.

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

iv. The LISS-III scenes about the above scene centres are constructed by taking 3120 lines above and below about these points along the path. The end and beginning of each LISS-III scene along the path are marked.

v. AWiFS and LISS-IV scenes are then framed in and on LISS- 3 scenes, by adopting the same procedure.

The main advantage of the above procedure is, that, major portion of the along track deviation with respect to the nominal scenes get reduced. Thus, the final RSS deviations are

Along track : ± 720 m Across track : ± 1.2 Km

3.2.20 Impact of the deviations on overlap and side lap during operational lifetime

While framing the images for the referencing scheme, adequate overlap (along track) and side lap (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 24 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 side lap between adjacent images will exist. However, in actual practice, the deviation mentioned in the earlier sections will affect side lap/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 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 deviations, with a scene of cycle N2 corresponding to path and row of PI, RI + I. Similar is the situation for side lap.

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

3.2.20.1 Overlap Variation

The nominal overlap provided between any two LISS-III scenes is 7 Km. The maximum deviation (along the track) is of the order of 720 m, with the new framing procedure. Due to this, the distance between two scenes of different cycles will be slightly different.

3.2.20.2 Side lap Variation

Side lap is the common area between two adjacent scenes of any two consecutive paths. However, side lap between scenes of two consecutive paths of different cycles is affected by across track deviations and scale variations. The nominal side lap increases from equator to northern latitudes. Due to this, deviation in side lap happens at the equator. Therefore, the side lap variation at equator is discussed here. The nominal side lap at the equator would be 23.5 Km for LISS-III scene. The across track deviation would be of the order of ±1.2 Km near the equator for LISS-III scene. Therefore, the two adjacent scenes of different cycles can be near by or away by twice this amount.

3.2.21 Accuracy of orbit and attitude parameters used for generating data products

In the earlier sections, the deviations and overlap side lap variations of the actual scenes from the nominal scenes were described. Since orbit and attitude corrections are carried out continuously, during the mission, the information about the actual scene (deviating from the reference scheme) are known to the best accuracy possible only under operational environment. This information is used to generate browse and data products. For browse products generation, one day predicted ephemeris with no attitude information is used, whereas for standard products generation, definitive orbit and attitude parameters are used.

3.2.22 Impact of continuous yaw steering on LISS-III, LISS-IV and AWiFS

In LISS-IV, the even and odd CCD elements are staggered by five lines in each of the three CCD arrays. This means that on ground there is an along track separation corresponding to five lines between the images of the even and odd elements at a given instant. After the time corresponding to five lines, even pixels which are supposed to fit perfectly with odd pixels, will not do so because of earth rotation and there is a gap between even pixels and odd pixels. The effect of earth rotation depends on the latitude. It is maximum at equator and decreases with latitude. It could be compensated by yaw steering. The yaw required is maximum (4 degree) at equator. It goes on decreasing with latitude and it is almost zero at poles.

As discussed in section 3.2.18.2, the effect of yaw is to rotate the scenes (Figure 4.2.9). The maximum effect is at equator as the yaw applied is maximum there. In case of nadir payloads LISS-III and AWiFS , the corners 1 and 3 shift up and corners 2 and 4 shift down due to rotation. The maximum shift is 5 Km in case of LISS-III and 25 Km in case of AWiFS main scene. In case of LISS-IV mono scenes A and C embedded in LISS-III scene, the corners 1 and 3 shift up by 5 Km and there is little shift in corners 2 and 4 as they are close to the axis of rotation. In B and D the corners 2 and 4 shift down by 5 Km and there is little shift in corners 1 and 3 for the same reason as quoted above. But with tilt, the effect of yaw increases and at maximum tilt of 26 deg, the shift is around 30 Km. The referencing scheme for all the payloads is generated considering the nominal yaw profile.

Chapter 4
GROUND SYSTEMS

4.1 Ground Segment Overview

The main functions of the Ground Segment are :

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

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, Mauritius, and Biak, with selective support from stations like Svalbard, Trolls etc. The reception and recording of payload data are done at the earth station of the National Remote Sensing Centre (NRSC), located at Shadnagar, near Hyderabad. Mission control support is provided from ISTRAC, Bangalore. Data is also transmitted to different International Ground Stations (IGS). The various elements of the Resourcesat-2 Ground Segment are given in Table 4.1 and the Ground Segment Organisation in Figure. 4.1.

Element	Location	Functions
TTC	ISTRAC ground stationa at Bangalore, Lucknow, Biak and Mauritius	
Mission Control	ISTRAC, Bangalore	1.Network coordination and Control 2. Scheduling spacecraft operations 3. Spacecraft HK data logging 4. Communication links between concerned ground segment elements
Data reception	NRSC, Shadnagar	1.Reception and recording of payload and OBSSR data 2. Generation of browse imagery 3. Generation of ancillary data for product generation

		4. Transfer of all data
Data products generation, Dissemination and Analyses	NRSC, Shadnagar	1.Generation and distribution of different types of data products 2. Data quality evaluation, data and browse and Analyses archival and management 3. Payload programming and request processing

Table 4.1 Ground Segment Elements

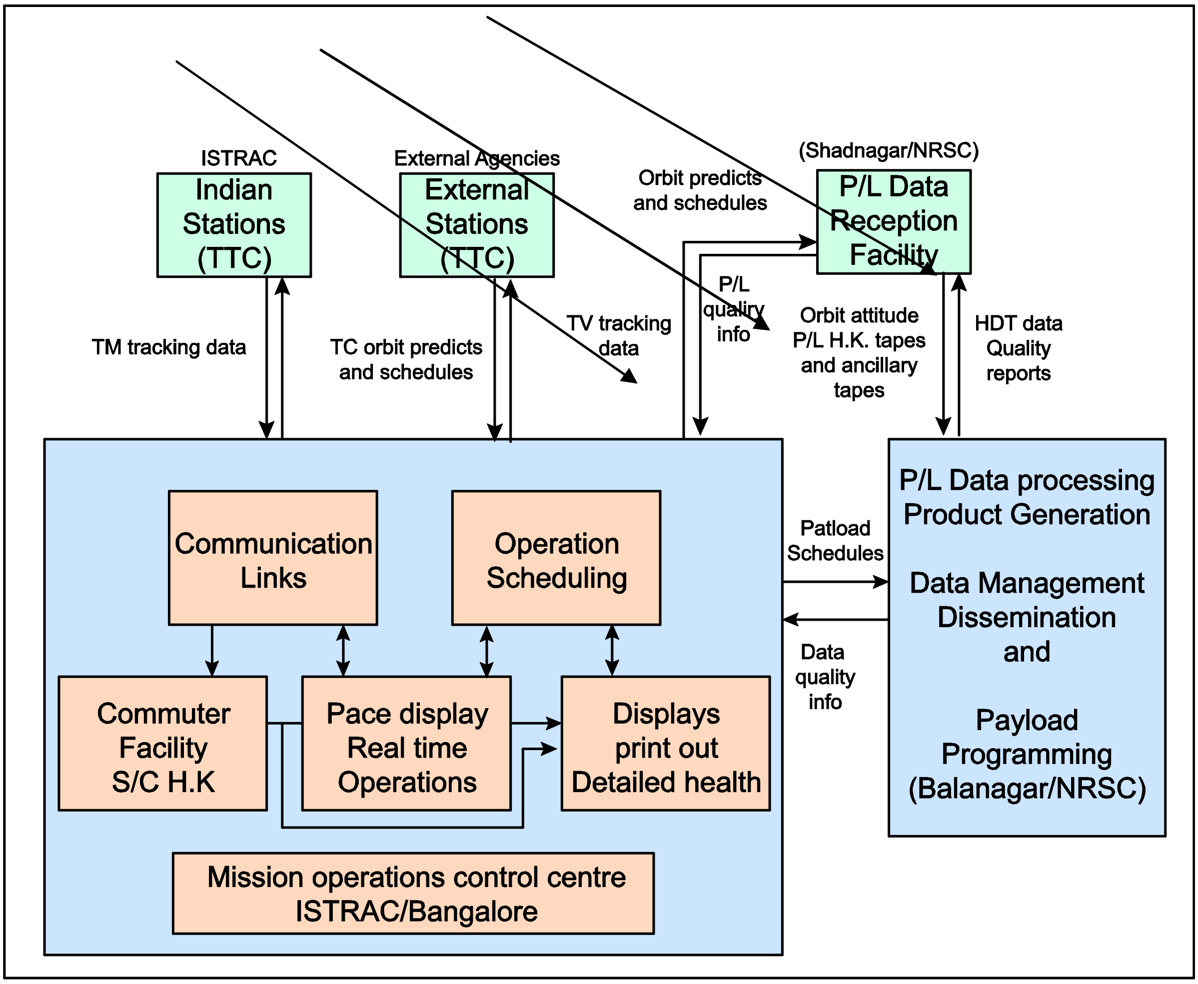


Figure 4.1 Ground Segment Organisation

4.2 TTC/ Payload Network

4.2.1 Introduction

ISTRAC provides ground segment support for

- Telemetry, Tracking and Command (TTC) activities through the ISTRAC TTC ground stations located at Bangalore, Lucknow, Sriharikota, Mauritius, Biak, Svalbard, Tromso, Troll and Kiruna during all phases of the mission
- Health monitoring and control of the spacecraft during pre-launch, LEOP and normal phase of the mission is carried out at MOX.
- COMDEV P/L data reception and dissemination to COMDEV Centre at Canada.
- Reception of Processed COMDEV data related to Indian region and dissemination to authorized Indian Users.
- The simultaneous reception of two chains of X band data at MAU ground station to fulfill the requirements of LISS-4, 70 km MX imaging and subsequent data transfer to NRSC in Near Real Time.

4.2.2. Scope of the Mission:

The overall activities of Resourcesat-2 Mission will have the following components and the organisation set up for the Ground Segment Operation is shown in Figure 4.2.

- To maintain the spacecraft in polar sun synchronous orbit providing 24 days repetivity cycle. The orbit height and path pattern to match Resourcesat-1 path pattern.
- The payload system for imaging any area on the ground with their specified characteristics and transmit data to ground for producing Data products for use by the user agencies.
- A spacecraft bus to provide support to the payload system in terms of structure, thermal, attitude and orbit control, power supply, data formatting and transmission, data storage, Telemetry, Telecommand, tracking functions. The bus in addition to have necessary propulsion and communications systems.
- An attitude determination system capable of providing the requisite support for data products generation system.
- Orbit maintenance strategy and timely maneuvers to control local time and ground track.
- The TTC ground station Network with Spacecraft Control Centre at Bangalore for Spacecraft data processing, health monitoring and required commanding for control of the spacecraft and Payload programming to consolidate image requests and program payload for operation accordingly.
- The on-board COMDEV Payload data transmission to the ground is in S-band by a separate carrier.
- COMDEV payload data reception at SCC Bangalore and transferred to ISSDC and later transferred to COMDEV center, Canada.
- The maintain Local time of Resourcesat-2 at 10.30 AM ± 5 min

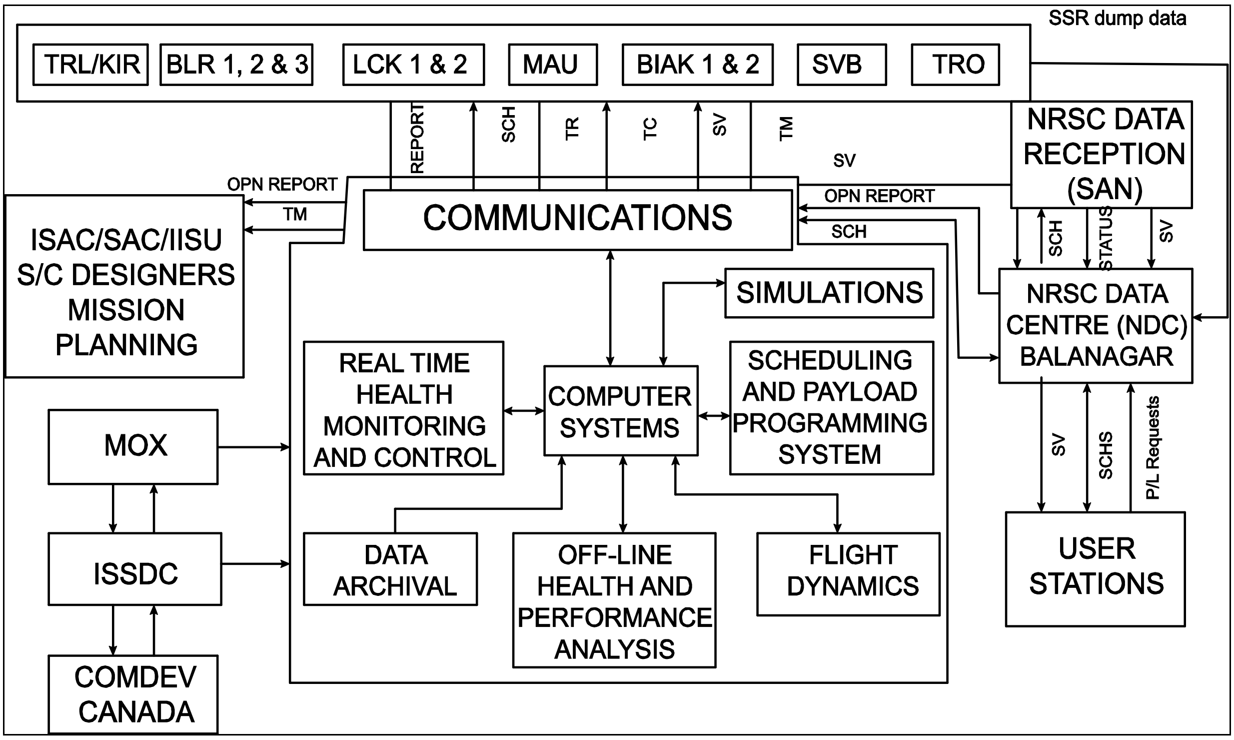


Figure 4.2. Organization of ground segment operations

4.2.3 Normal phase operations

The mission will be declared to have entered the normal or routine operations phase after a thorough checkout and evaluation of Resourcesat-2 satellite. On declaration of normal phase, the satellite control operations are shifted to the normal phase operational facility (shared dedicated mission control room) at MOX. Initial phase operations is formally concluded with Mission Management Board meeting where mission team presents the operations carried out during initial phase and Sub-System designers present the performance and status of each subsystem. The normal phase spacecraft operations will be conducted as per procedures defined in Normal Phase operations Guidelines and procedures. During normal phase, the satellite will be maintained in 3-axis stabilized mode with reaction wheels and magnetic torquers and all the onboard safety logics in enabled mode. Spacecraft operations will include payload operations in all the defined modes SSR recording and SSR dump operations, tracking data collection, TM storage/dumping, SPS data collection, up-linking of state vectors for on-board ephemeris generation, star sensor related commands etc as per schedule. Thermal and power management and orbit maneuvers will be carried out as and when required. The Mission requirements and updated contingency recovery procedures will be handed over to OD (normal phase) while declaring normal phase of mission. ISO-9001:2008 quality system will be followed during this phase. SCC activity consists of spacecraft operations scheduling, spacecraft health monitoring and control, health analysis, daily orbit determination, transfer of daily state vector to NDC and TTC Stations, archival of data at SCC and planning and execution of special operations such as orbit maneuvers. Spacecraft contingencies are handled as per approved procedures. Spacecraft subsystem designers, the software designers, the initial phase operations team and ISTRAC subsystem team will be available for any consultation and executions of special operations. Scheduling office will take into account the multi-mission support requirements and schedule the TTC network support and spacecraft operations for Resourecsat-2 along with other missions based on pre-defined scheduling guidelines. Scheduling office will interface with P/L users/NDC, NRSC, COMDEV center and OD/SOM of Resourcesat-2 for payload programming.

4.2.4 General Schedule guidelines

- TM reception from BLR, LCK, MAU, BIAK, SVB, TRO, TRL and KIR in all passes above 2deg max elevation.
- SPS reception from BLR and LCK during payload operations once a day with common visibility of Shadnagar.
- TC Operation for passes with elevation above 5 Deg for SVB, TRO, TRL, KIR and above 2deg for BLR, LCK , MAU and BIK.
- TR data collection as per requirement for passes with max elevation above 8 deg.
- HK Storage dump in all the visible passes with maximum elevation greater than 5 deg. Sample mode of operation if visibility gap is more than one orbit.
- Visibility gap of not more than 2 to 3 orbits.
- Payload operations as per request from NDC, NRSC. Payload operation commands transmission in list mode. Command confirmation through command counter and Aux register content verification.
- Payload calibrations will be as per normal phase mission operations guide lines.
- OM operation for Ground track and local time maintenance requirements.
- Up-linking of State vectors for onboard ephemeris generation.

To support Resourcesat-2 mission the schedules for ISTRAC Ground Stations and SCC operations are generated weekly as general schedules and communicated via Text/Fax/E-Mail messages to all ground stations and spacecraft consoles. Fig 4.3 provides the flow of scheduling and reporting procedure for the TTC and Mission Control Centre operations. Different types of schedule messages, reporting messages and their formats are given in Resourcesat-2.

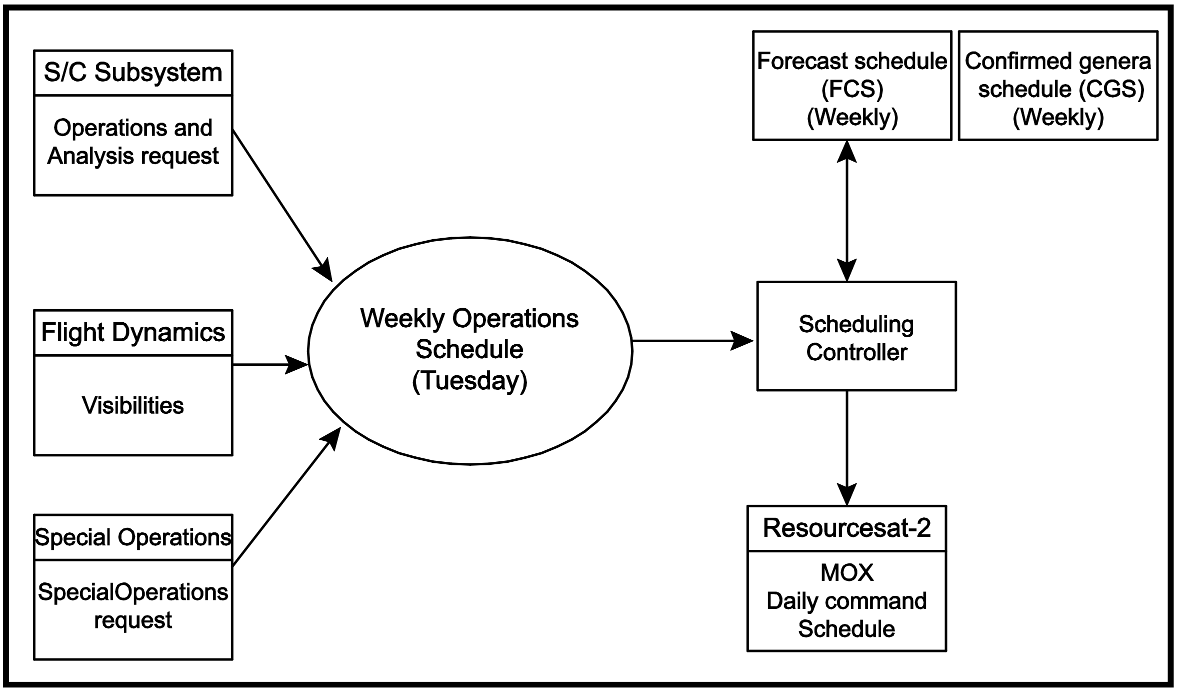


Fig. 4.3 Operations Scheduling Sequence

Chapter 5
DATA RECEPTION SYSTEMS

5.1 Introduction

Resourcesat-2 carries three payloads viz; LISS-3, AWIFS and LISS-4 .This satellite will provide continuity for RESOURCESAT-1 services. NRSC is responsible for data reception, archival, processing, product generation and data dissemination facilities.

This part explains the data reception and level-'0' processing facilities of NRSC Ground station, Shadnagar.

The Ground Stations are capable to receive Image data in X-Band and telemetry data in S- band. The ground stations are highly efficient. Each station is equipped with an Antenna System consisting of 7.5 meter dual shaped parabolic reflector in a Cassegrain configuration. These ground stations are configured to track and receive data from several national and international satellites. Configuration also supports mission clashes and redundancy for important data reception and level '0' products generation. It has a Bore sight test facility to evaluate the total data reception chain for all ground stations. The station is connected to NRSC Balanagar, ISTRAC and ISAC through spacenet. The spacenet is mainly used to transfer the ADIF, Browse and Histogram files to NRSC, Balanagar and to receive state vectors, pass schedules from ISTRAC, Bangalore.

5.2 Ground Station Configuration

The detailed configuration of ground station covering both data reception and level-'0' systems is shown in Table 5.1. The ground stations are of highly efficient dual shaped 7.5 meter antennas and they are in use for data acquisition of Resourcesat-2. Level-0 operations were carried out by Linux based Data Archival & Quick Look Browse (DAQLB) systems in multi mission environment along with Resourcesat-1, Cartosat-1 and Cartosat-2.

	X-Band	S-Band
Frequency operation	8,025 – 8.4 GHz	2.2 to 2.3 GHz
System G / T	31.5dB / ° K	16 dB / ° K
Polarization	RHCP & LHCP	RHCP & LHCP
Antenna Gain	54.5dB	40 dB
3 dB Beam width	0.27°	0.9°
First side lobe suppression	-14 dB (max)	-14 dB (max)

Table 5.1 Ground Station Specifications

Reflector	7.5 M dia.
Sub reflector size	736 mm
Feed	Cassegrain, Monopulse, S-Band Helices Conical dielectric
Weight of Antenna	1.4 Tons
F / D	0.39
RMS (Reflector)	0.41 mm
RMS (Sub reflector)	0.15 mm
No. of panels	16

Table 5.2 Antenna Sub-system

5.3 Data Reception Systems

The data reception systems consists of the following subsystems:

- Antenna & feed system
- Front end electronics
- Pedestal & drive system
- IF & baseband systems
- Tracking & servo control system
- Station automation
- Data logger System

5.3.1 Antenna & Feed system

The Antenna system consists of 7.5 meter dual shaped parabolic reflector in a cassegrain configuration. The feed & sub-reflector are mounted on the main reflector with a quadripod support structure assembly. The reflector consists of a machined, reinforced circular hub, which supports 16 radial trusses and other interconnecting braces. The 16 trusses support 16 solid surface reflector panels. Aviation warning lights and lightening arrestor are mounted on the reflector. Sub-reflector is hyperboloid supported by four aluminum quadripods. The Shaped antenna system together with Gallium Arsenide Field Effect Transistor (GaAs FET) low noise amplifiers provide a G/T of better than 31.5 dB/^{0}K at 5 deg. Elevation.

The Feed produces both tracking and data outputs in Right Hand Circular (RHC) polarization. The feed is of Single channel monopulse tracking type, capable of receiving both S & X-band signals. The feed comprises of 4 conical radiating elements in conjunction with septum polarizer capable to receive RHCP&LHCP signals in X-band, and 8 helix elements to receive RHCP & LHCP signals in S-band.

Parameters	Specifications
Main reflector size	7.5 meter shaped parabolic
Sub reflector size	0.736 meters shaped parabolic
Weight of the antenna	1.4 tons
F/D	0.39
Surface accuracy - main reflector	0.41 mm
Surface accuracy - sub reflector	0.15 mm
No of panels	16
Mount	Elevation over Azimuth

Table 5.3 7.5-meter Antenna specifications

5.3.2 Frontend Electronics

The X and S band front end electronics configuration is shown in figure 5.6. The output of four conical elements of X-band is connected to monopulse comparator, which gives three outputs as Σ (sum), ΔAZ and ΔEL (difference signals).
The Sum (Σ) output of monopulse comparator is fed to LNA (45°K with 50 dB gain) through a test coupler. The azimuth and elevation error signals are fed to monoscan converter, which produces an error signal combining the difference input signals (ΔAZ & ΔEL) with reference to a set of synchronizing pulses. This error signal is passed through a band pass filter and a low noise amplifier and then fed to the X-band DPC box.

The sum output of LNA is fed to X-band DPC box consisting of a power divider, phase shifter and a coupler. The error signal from the MSC is modulated over the sum channel signal to generate amplitude modulated tracking signal. The second output of the sum channel (data signal) and the tracking signal from the DPC are fed to the 3 channel down converter unit to generate three 720 MHz IF signals. Similarly, the output of four helices of S-band is connected to monopulse comparator, which gives three outputs as Sum (Σ), ΔAZ and ΔEL. The azimuth and elevation error signals are fed to mono scan converter and then to DPC box to generate S-band carrier.

5.3.3 Pedestal and Drive System

The 7.5 meter antenna is installed on an elevation over azimuth pedestal and its configuration is shown in figure 5.5. The drive system is a dual drive system with two power amplifiers in azimuth and elevation axes, using brush less DC motors. The drive system is configured with precision anti backlash gear system and torque bias arrangement to provide better tracking and pointing accuracies. The brushes less DC servomotors are coupled to the output axis by means of a high efficiency gear reducer and torque coupling. This configuration provides full hemispherical coverage with less than 2 deg of key-hole for tracking overhead passes.

Parameters	**Specifications**
Mount	Elevation over Azimuth
Type of Drive	Dual in both azimuth and elevation
Gear ration	1350:1
Max. velocity	22°/sec² for Azimuth 01°/sec² for elevation
Travel limits – Primary (Electrical)	± 360° for Azimuth -2 to 182 for elevation
Secondary (Mechanical)	± 380° for Azimuth -5 to185 for elevation

Table 5.4 Antenna pedestal & drive specifications

5.3.4 IF & Base Band Systems

The functional block diagram of IF and baseband system is shown in figure 5.1. The data and tracking carrier from the DPC box are fed to down converter to generate two data and one tracking IF signals. The data and tracking IF signals from the down converter are driven through fibre optic link to the control room, where the baseband equipments are located. The IF signals are routed to different data demodulators and integrated tracking system.

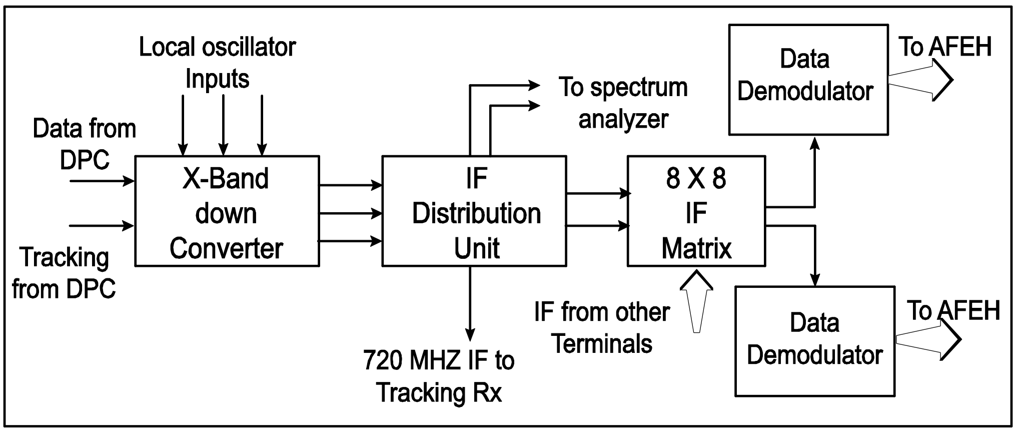


Figure 5.1 Block Diagram of IF and Base Band Systems

The X-band down converter is designed to cater for multi mission data reception requirements and is capable of receiving any frequency in the band of 8025-8400 MHz. The down converter is dual down conversion type. In this first IF is in the range of 2370 MHz to 2750 MHz and this IF is further down converted to 720 MHz in second conversion unit using tunable synthesizers.

Parameters	X-band	S-band
Input frequency range	8.0 - 8.4 GHz	2.2 – 2.3 GHz
IF output frequency	720 MHz	70 MHz
Down conversion type	Single/dual	Single
Input level	- 45 dBm	- 50 dBm
Conversion gain	20 dB	20 dB
Noise figure	12 dB	12 dB
Image rejection	< -50 dBc	< -50 dBc

Table 5.5 Down converter specifications

The data and tracking IF signals are fed to data demodulators through IF distribution amplifier and IF matrix. The second output port of the IF distribution amplifier is used for monitoring the signal strength in the spectrum analyzer. The function of the IF matrix is to route the IF from different terminals to different data receivers. The data receivers are fully programmable and are capable of receiving any data ranging from 1MBPS to 160 MBPS.

Parameters	Specifications
Carrier input	720 MHz
Input level	-10 dBm to -50 dBm
Acquisition time	< 250 msec.
Acquisition range	± 1MHz
Type of demodulation	QPSK
Clock acquisition	± 0.3 % of Symbol rate
Data rate	1 to 160 MBPS
Differential decoding	4 state grey coded
Output logic level	ECL single ended unterminated
Output channels	Serial (I+Q) / Parallel (I, Q)
Outputs	LVDS and ECL

Table 5.6 Data receiver specifications

5.3.5 Tracking & Servo control system

The servo control system is a closed loop Type-II system with provision for both wide band and narrow band operation. The Servo control system comprises of a servo loop electronics unit, data logger, antenna control computer and its associated software. The configuration of tracking and servo control system is shown in figure 5.2 below.

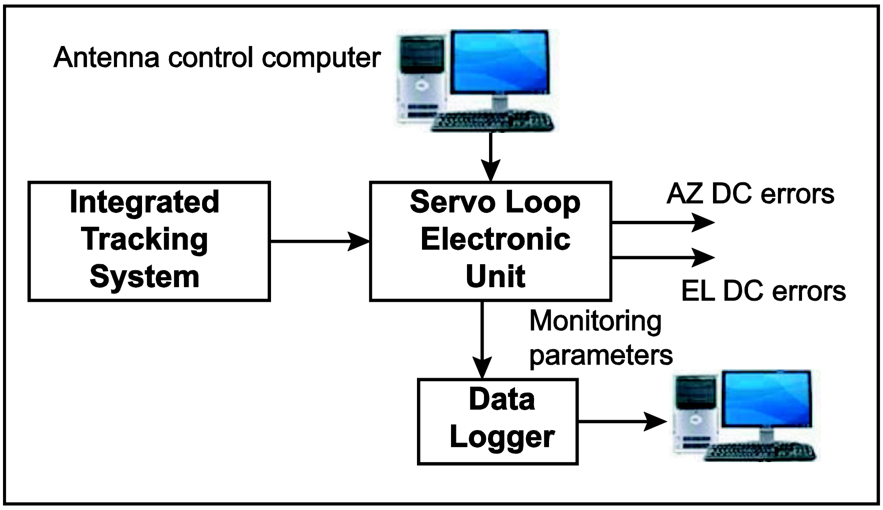


Fig. 5.2 Tracking & servo control system

5.3.5.1 Integrated Tracking System

The down converted tracking IF signal is fed to the integrated tracking system. Integrated tracking system comprises of three tracking receivers, tracking and phase shifter control units. RHCP & LHCP X-band tracking IF and S-band tracking IF signals are fed as inputs to integrated tracking system. Integrated tracking system is a digital signal processor based system and main function of this unit is to demodulate the tracking signal IF and extraction of the AM tracking video information and DC errors of azimuth and elevation. The input signal of S-band IF 70 MHz, X-band RHCP and LHCP down converted tracking IFs (720MHz to 70 MHz within the unit) are routed thru low noise amplifier and band pass filters whose band width in case of X-band is 6 MHz and S- band case is 500KHz. Outputs of band pass filters are routed to envelop detectors through automatic gain control circuits . The envelop detector output video is used to extract azimuth error and elevation error. All the three channels are continuously sampled with a fixed regular interval of 500 microseconds. IN auto mode, DSP detects the channel with more signal strength, then video extraction and error extraction process will be done on the selected channel and the extracted errors of the selected channel will be routed to servo control system for tracking the satellites. In manual mode, video extraction and error extraction process will be done on the selected channel. The extracted DC error signal corresponding to the antenna-pointing vector in both elevation and azimuth axes.
The integrated tracking system unit also consists of a scan code generator module, which generates two sets of scan code pulses for both elevation and azimuth channels. These pulses are

simultaneously applied to the monoscan converter module in both elevation and azimuth channels for synchronizing the process of error generation and demodulation. The azimuth and elevation auto track errors from this unit are applied to the servo loop electronics unit for driving the antenna towards the target position and to nullify the tracking errors.

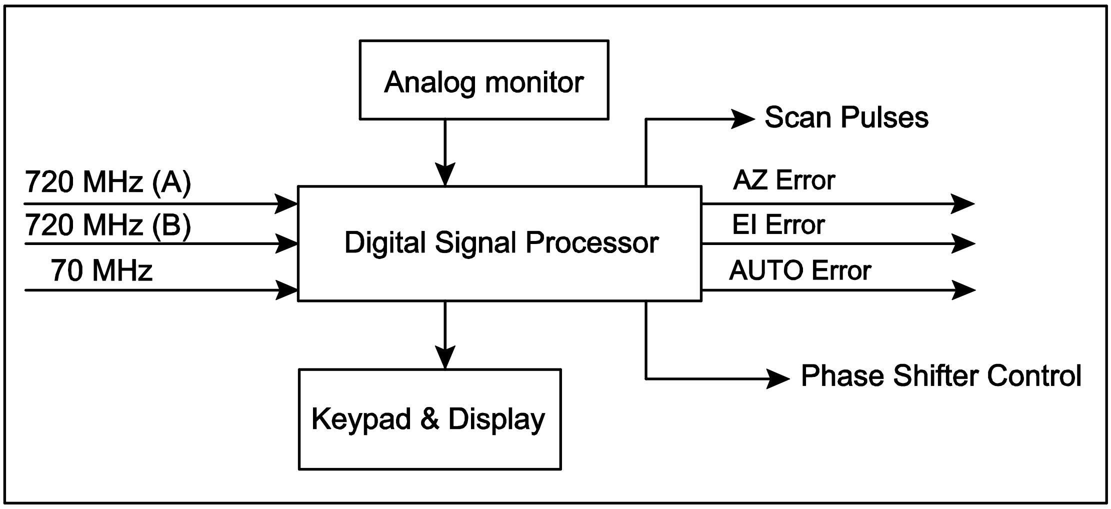


Fig. 5.3 Block Diagram of Integrated Tracking Systems (ITS)

5.3.5.2 Servo Control System

Parameter	Specifications
Type of servo system	Type-II
Position loop bandwidth	0.9 Hz
Rate loop bandwidth	2.2 Hz
Pointing error	0.08^0 at peak
Tracking accuracy	0.1^0 in steady state
Modes	Standby, Rate, Auto & Program
Amgle readout accuracy	0.01^0
Band width	0.5 Hz for narrow band 0.9 Hz for wide band
Modes of operation	Auto & Program track

Table 5.7 Servo control system specifications

SLEU provides complete antenna control through standby, position, manual, rate and auto track modes for each axis independently. It consists of mode control logic for positioning of antenna, servo loop compensation networks, torque bias circuitry and monitoring & control for various servo interlocks. The servo system is provided with safety interlocks for the safety of personnel as well as equipment. The purpose of safety interlocks is to extend the 3phase, 230V AC power to the drive unit after checking certain safety aspects of servo systems like interlocks and travel limits. It reads the angle information from the encoder for both elevation and azimuth axis with a resolution of 0.01^{0} and provides to ACC. This unit facilitates digital secant correction of azimuth error for high elevation pass tracking. This unit connected through GPIB to Antenna Control Computer. The SLEU accepts tracking errors either from tracking control unit or Antenna Control Computer depending on mode selection in each axis. It processes these errors in position and rate loops with appropriate biasing in order to drive dual drives in each axis.

The ACC controls and monitors various parameters of the antenna positioning and tracking system. The ACC software computes the look angles or trajectory of the satellites to be tracked based on the State vector inputs and schedules the passes as per the visibility and missions to be tracked. Thus it facilitates automatic positioning and tracking of the satellite in real-time. It also configures the LO frequency of down converters based on the satellite. The Data logger monitors the critical tracking and servo parameters and transfer it to PC through RS-232 in real-time.

5.3.6 Station Automation

The Station Automation System automates the station operations of ground station by configuring the various sub systems in the data reception chain in multi mission scenario. The other important function is to program tracking of the satellite with servo loop electronics unit. In multi-mission scenario, around 20 passes will be acquired covering both Indian and foreign satellites from three different antenna terminals. These terminals will be operated simultaneously to acquire the data from different/same satellites based on the clash scenario. In the operational scenario, it is required to reconfigure the chain and get ready for the next pass with in 2 minutes. These functions are distributed between antenna control computer and data logger system. Around 25 parameters need to be monitored / configured on various subsystems for each pass. Some of these important parameters are:

Monitoring parameters

- Auto errors, DC errors, Azimuth & Elevation Tacho
- AGC levels, Acquire/lock status from X & S bands
- Sector (CW/CCW) and limit checks of antenna
- Received signal strength C/No
- Quality factor (E_b/N_o)
- demodulator lock status

Control parameters

- ❖ Local oscillator frequency and its output level of down converter
- ❖ Programming of digital phase shifter
- ❖ Programming of demodulators
- ❖ Mission selection

Antenna Control Computer

The main functions of antenna control computer are

- ❖ State vector update
- ❖ PPP generation
- ❖ Selection of passes as per pass schedules
- ❖ Visibility clash and elevation analysis
- ❖ Scheduling of the passes
- ❖ Pre-pass selection/configuration of Sub systems
- ❖ Program tracking of the satellite with SLEU
- ❖ Generation of interface files required for Ground Station Information System

5.3.7 Data Logger System

The main function of the data logger is to monitor the various tracking and servo parameters. These parameters logged and archived on to computer system through RS-232 interface for all the scheduled passes. Later these files are used for analyzing the various sub system problems. These parameters include DC errors for elevation and azimuth, azimuth and elevation tacho, S and X band AGC levels etc.,

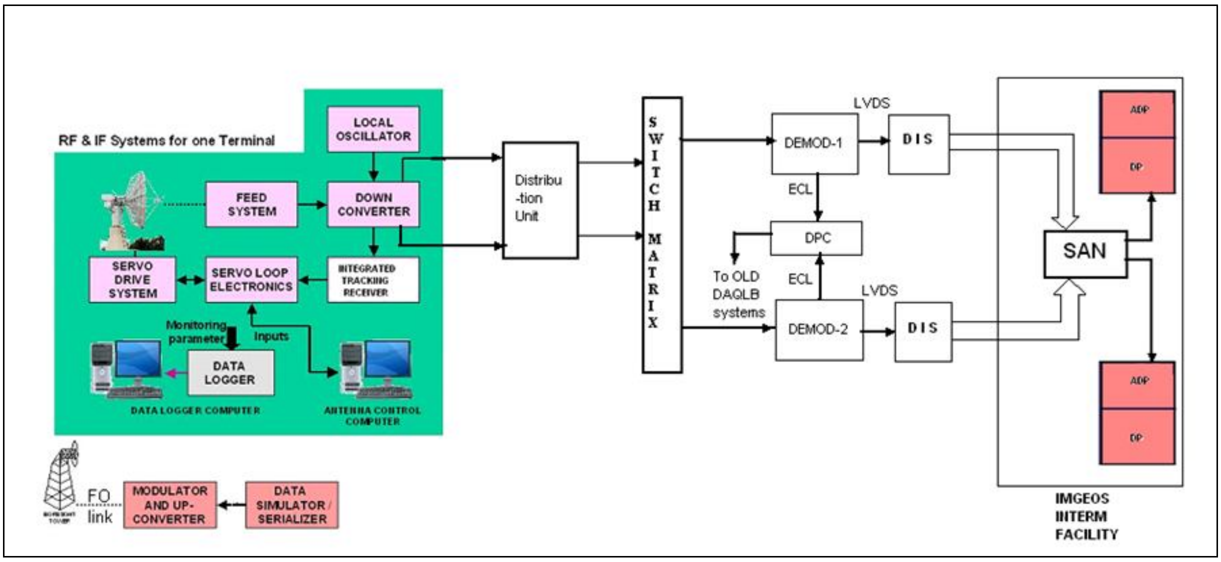


Fig. 5.4 Shadnagar Ground Station Configuration

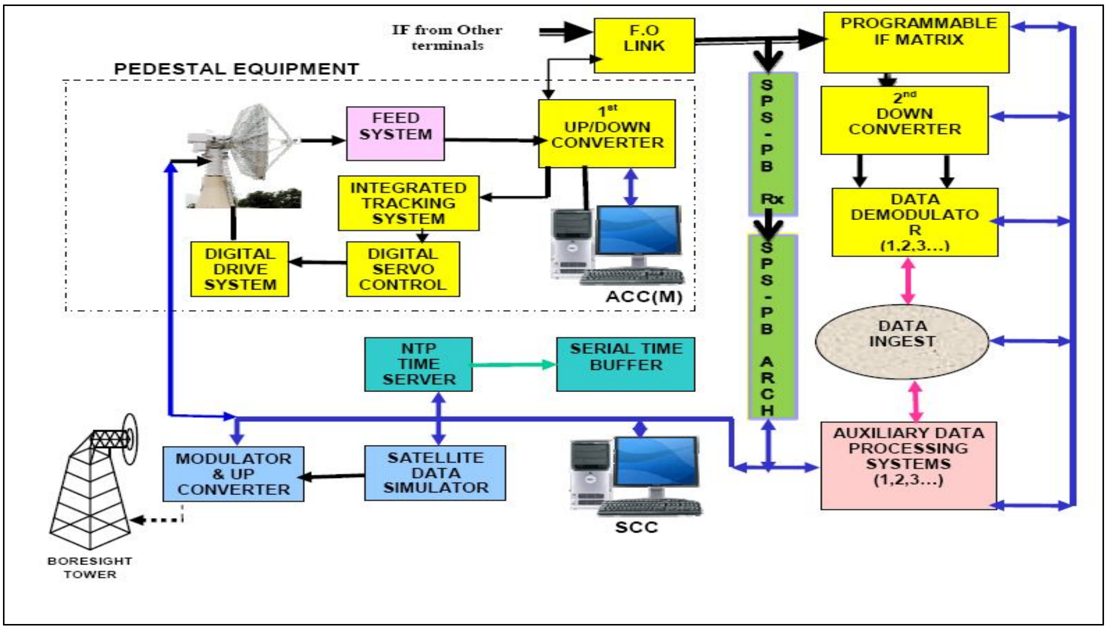


Fig. 5.5 Data Reception System Block

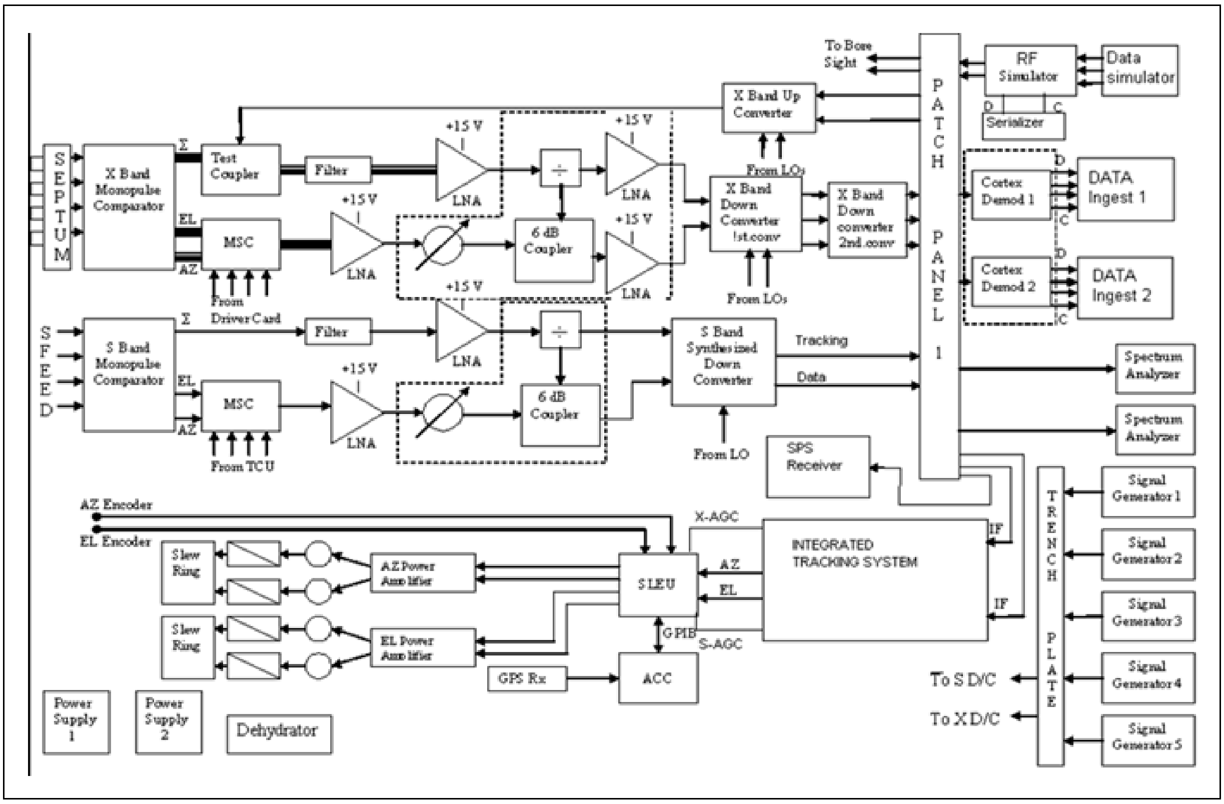


Fig. 5.6 Block Schematic of Data Receive system

5.4 Level '0' systems

Functions of Level '0' Ingest system

- Supports processing of R/T passes and SSR passes.
- Generation pre pass planner reports and quick look input files.
- Generation of pass support details for scheduler.
- Data archiving and sub sample data display during R/T.

ADP chain Processing

- Accessing the SAN raw data.
- Performing data decoding /decrypting.
- Decompression
- Generation of ADIF, Browse and Port wise Histograms.
- Archives the raw data on super DLT in initial phase till SAN fully configured.
- Provision to be identify emergency strips through the aux data.
- Generation of CAL DLT.

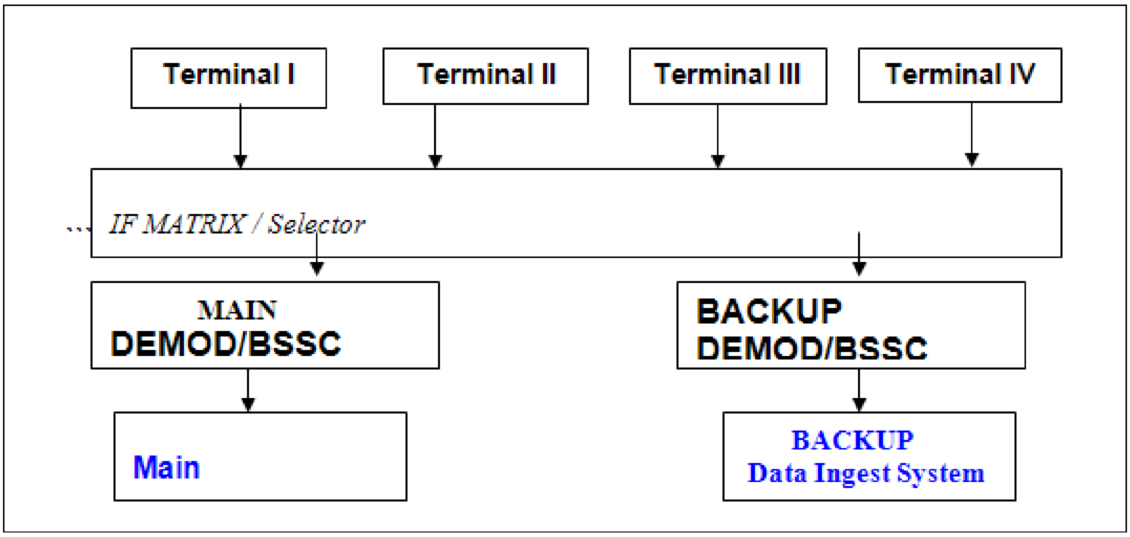


Fig. 5.7 Data Chain diagram Resourcesat-2 mission

Level '0' Systems for Resourcesat-2 comprises of

- Direct Ingest Systems
- SPS data logging System
- Timing systems
- Network systems
- Data Serializer System

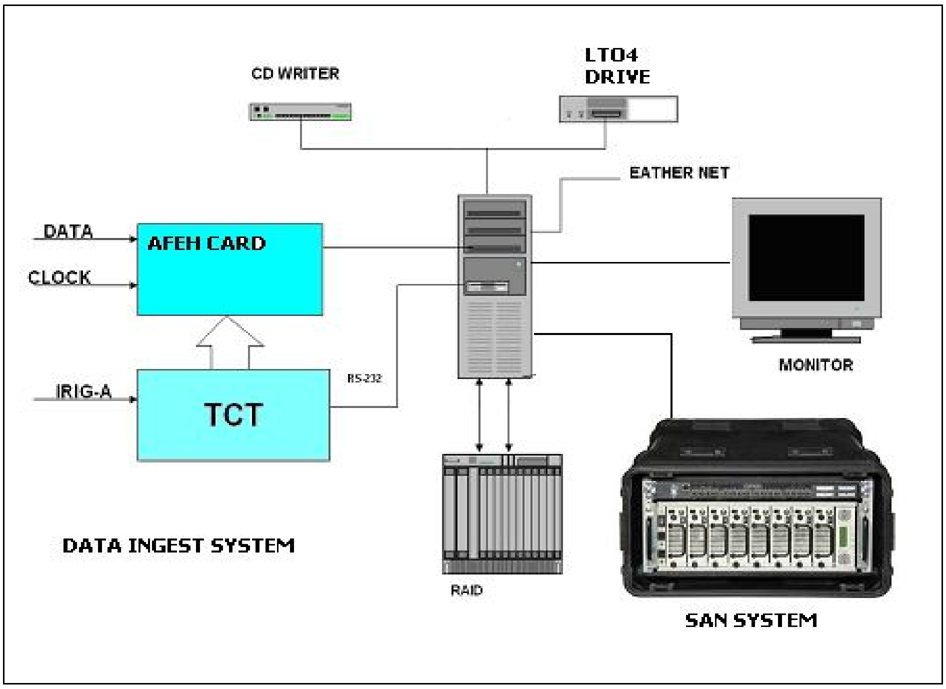


Fig. 5.8 Direct Ingest System

5.4.1 Data Ingest System

Data Ingest sysytem consists of PC servers with RAID & RAID controller, RS232 interface, SCSI interface, CD/DVD writer and LTO4 tape drives, AFEH PC cards (2 nos) and Time code Translator.

The Station time code (IRIG-A) is fed to the TCT unit. The TCT unit provides parallel BCD Time to the AFEH Cards. The payload data & clock from BSSC in R/T is fed to advanced FEH cards sitting in the PC as an add-on card.

AFEH does frame synchronization and word synchronization and also time stamping on the incoming payload data and transfers the raw data to local RAID system connected to Data Ingest system in R/T.

During real-time for payload passes, the AFEH provides raw data along with GRT to data acquisition system through ultra SCSI interface. The Quick look system provides sub-sampled video data which is displayed on the PC monitor in the R/T for data quality assessment.

DAQLB software does raw data archival on local RAID and later in near RT transfers RAW data to SAN system. The ADP System accesses the raw data from SAN and extracts Aux data, and the telemetry master frames are constructed and validated.

5.4.2. SPS data Logging System

SPS PB data in S-band chain at 16kbps data rate is archived at SPS direct Archival system. This SPS-PB data is transferred to level'0' product chain immediately after the acquisition. SANGAM S/w in level'0' chain processes the data and provides converged ephemeris. The ephemeris generated from State vectors received from SCC are compared with ephemeris converged from SPS-PB and best of two is selected by ORION S/W for orbital information. This information along with the ancillary information including data quality, line count is used for generation of ADIF.

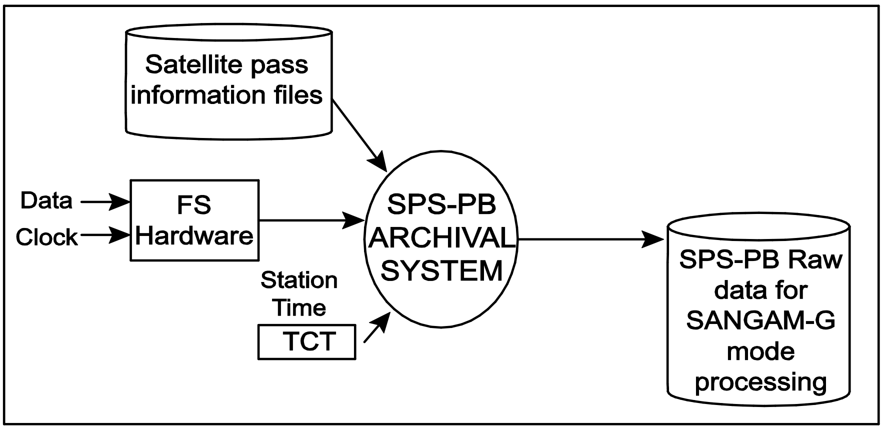


Fig. 5.9 Context diagram of SPS-PB data

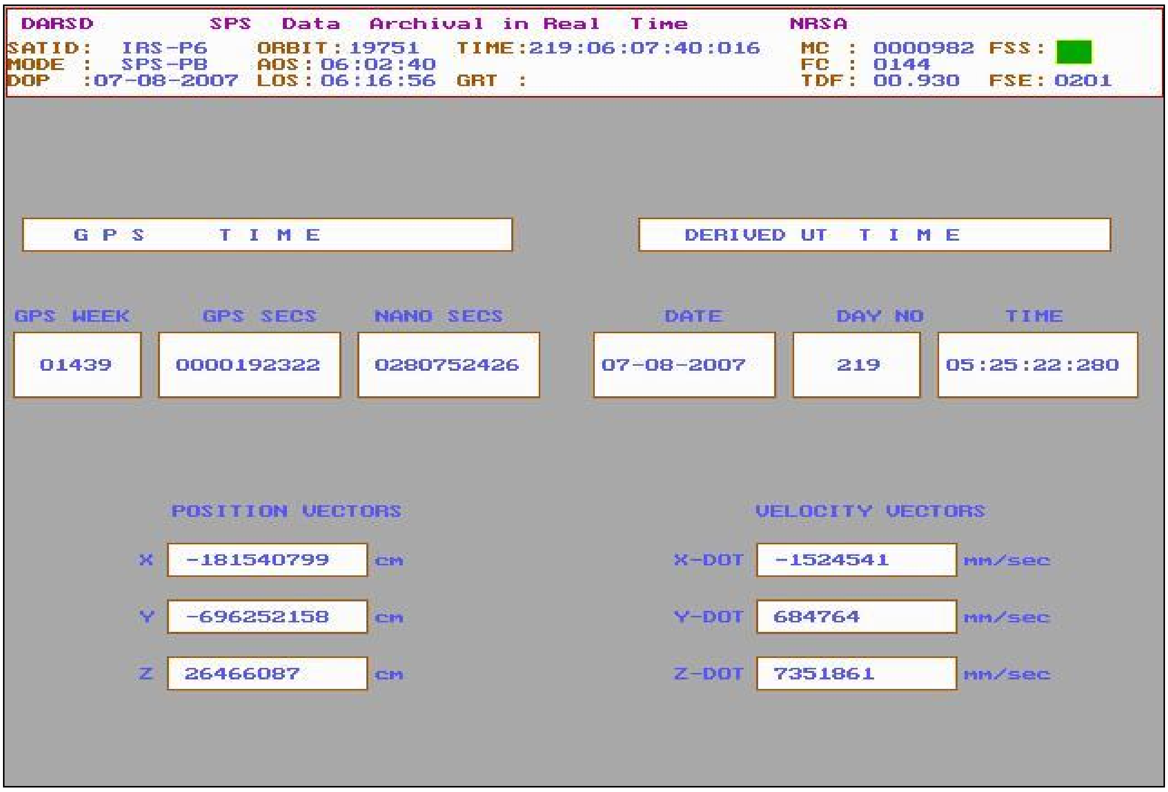


Fig. 5.10 Display of SPS parameters in R/T

Compressed Browse images are generated from Raw Browse data and transferred on Network to DP Server. ADIF is also transferred to IMS over network. SDLT/ LTO is generated from RAID for both payloads and sent as final product.

Night operations include CAL, SSR PB. For CAL passes on board calibration data is archived on DA system in R/T for specified sensor. The ADP system extracts auxiliary data & Quick look system displays CAL pattern in R/T. Telemetry master frame construction, selected cycles calibration disk load and transfer on network to CAL DQE system. It is also accepted in principle to carry out the Quick DQE at level'0'.

For SSR PB, raw data archival, extraction of auxiliary data, QL display, OBT GRT correlation, telemetry master frame extraction, ADIF generation, DLT generation are the activities carried out.

5.4.3 Timing Systems

Time is the most critical factor in framing of data. An offset in time results in an offset in scene frame thereby location accuracy.

The Timing system consists of XLI Time and Frequency Unit (NTP Server), Serial Time code Distribution Unit and Time Code Translator Units.

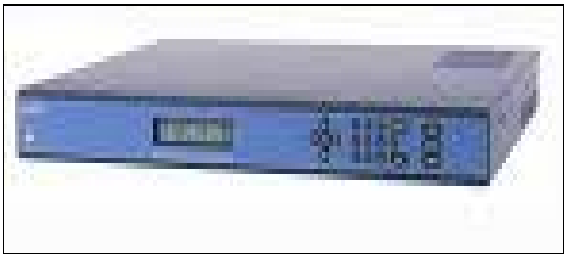


Fig. 5.11 XLI Time and Frequency Unit (NTP Server):

The station time is maintained with XLI Time and Frequency Unit (NTP Server) with an accuracy of 10 nano secs. The XLI Time and Frequency unit (NTP Server) is the source of time for all missions' operations. It has built in GPS receiver, Rubidium Oscillator and Time code generator.

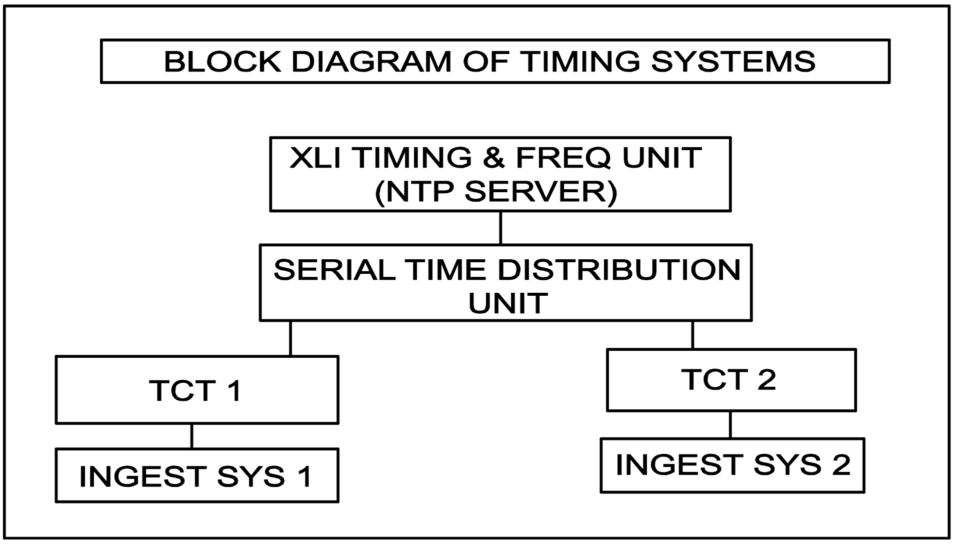


Fig. 5.12 Block diagram of Timing Systems

Serial Time code Distribution Unit accepts Serial Time code as input and drives to many TCT units.

Time Code Translator unit receives serial IRIG A time and converts it into packed BCD form and also provide a time of the day display. The parallel time is tagged to the incoming serial data in the AFEH unit.

5.4.4 Network systems:

Level-'0' Intranet

The Level – 0 Data Ingest Systems, PC based direct archival systems and the O2 systems are interconnected through a Network Backbone consisting of Switches, routers and hub.

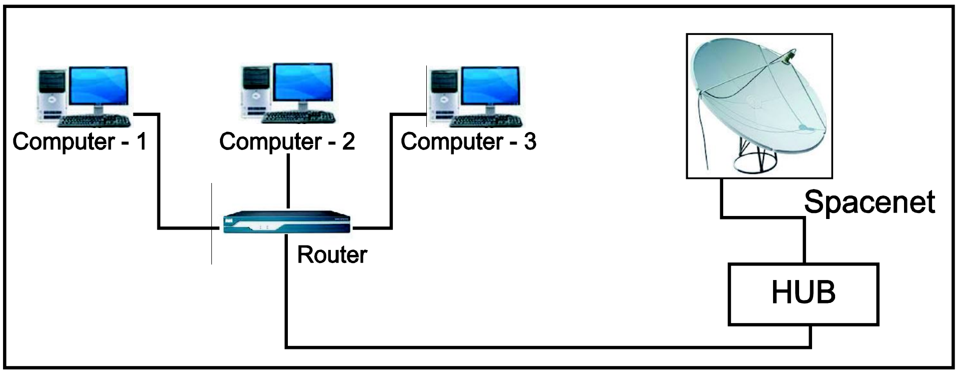


Fig. 5.13 Data Transfers & Spacenet Interfaces

Level-'0' System's interaction on Spacenet With SCC:

- SCHEMACS system for designer's connectivity.
- State Vectors

With DQE, IMS and NDC:

- ADIF for LISS-III and LISS-IV to IMS
- Browse for LISS-III and LISS-IV for RT and SSR to Browse Archival System to NDC
- CAL Analysis Data to DQE

All the data transfers from the Level-0 systems are managed by the NETMGR System with automated data transfer routines and confirmation report generation.

5.4.5 Data Serializer System

Data serializer system will read data from DLT and outputs it in a synchronous serial format. The system consists of a high end PC server system, a high speed PCI parallel data acquisition card and a serializer unit. The data is first copied onto RAID. Data on RAID is pumped into the external serializer unit via PCI-7300A data acquisition interface card. The serializer hardware can serialize incoming parallel data into four synchronous streams. The data received is de-multiplexed and serialized into either two ((I+Q) type) or four (I1,I2,Q1,Q2 type) streams. The output streams or driven by ECL line drivers.

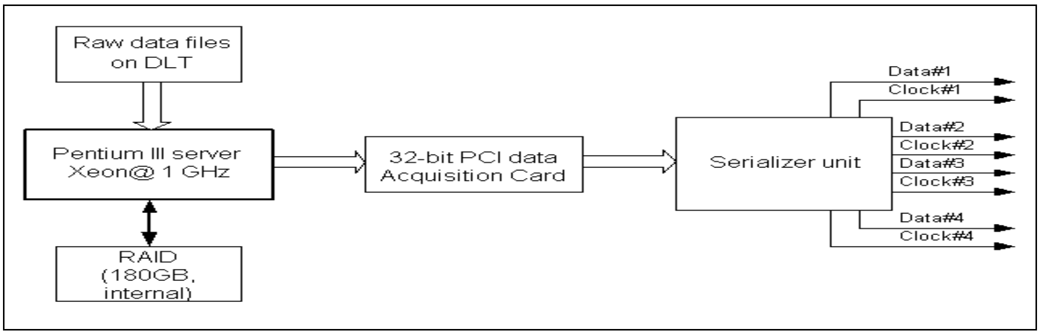


Fig. 5.14 Functional Block diagram of data serializer system

Serializer unit:

The serializer can be used to generate 1, 2 or 4 synchronous streams from parallel data received via 32-bit PCI data acquisition card. Resourcesat-2 data for LISS3, AWIFS and LISS4 is interleaved and written as a single file onto the RAID. This enables *stream synchronization* while serializing data. The data, via PCI-7300A, is written into dual 128k X 32 FIFO banks by the PC server system. Data router logic in serializer takes care of reading data from FIFOs and routing it at byte level and serializing it into four streams. Thus four streams of serial data can be generated from the received data. The data router and control logic are implemented in Xilinx FPGAs. The TTL level signals are converted into ECL using 100324 and driven using 100112 ECL line drivers.

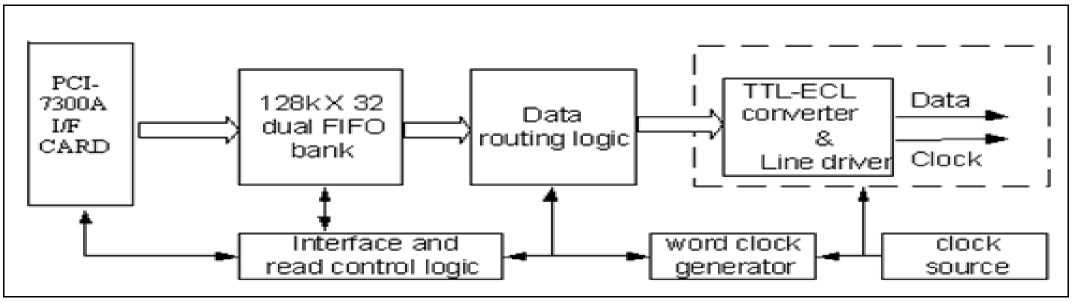


Fig. 5.15 Functional Block diagram of serializer

5.5 Computer Storage and Network Systems

5.5.1. Introduction

The Integrated Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS) activity envisages reengineering the entire chain of operations at the EO ground segment facilities of NRSC at Shadnagar and Balanagar campuses to adopt an integrated multi-mission approach, achieve minimum lead time from satellite launch to product launch and to make available the products to user community on the web. The reengineered facility would be state-of-the-art, world class and capable of being reconfigured and adapted to cater to the current as well as future EO missions.

The operational activities are reception of satellite data, quick look, generation of browse, production of standard and value-added data products, production chain management, data quality evaluation, quality control and product dissemination. For each of these activities, there are numerous other detailed sub-activities and pre-requisite tasks that need to be implemented to support the above operations. One important activity that influences all other activities is the design of appropriate and commensurate storage and network architecture for realizing all the envisaged operations in a highly streamlined, reliable and secure environment.

5.5.2. Requirements:

Storage :

- Provide online tape archival storage for all satellites data acquired at Shadnagar and other ground stations for 3 years of future acquisition and for existing archived data (Approx 1PB). Provide expandability of this storage to archive data for another 5 years of future data acquisitions.
- Provide cost effective online disk storage for all recently acquired satellites data (latest one year data) to facilitate generation of satellite data products.
- Provide high speed online disk storage for all satellites data (latest three months data) to facilitate faster generation of satellite data products
- Provide about 5 TB of high-speed disk space for data processing systems for generation of products.
- Provide about 5 TB of high-speed disk space for databases like GCPL, Carto DEM, TCPL and etc.

Servers and Workstations

- ❖ Provide systems for four antenna terminals for real-time Data reception in N+1 configuration.
- ❖ Provide three systems for near real-time Ancillary Data Processing of all missions.
- ❖ Provide Systems for Satellite Data processing of Microwave, Optical and Non-Imaging sensors of current and future missions.
- ❖ Provide systems for functional activities of the like PPS, Station Automation, Workflow, Event Monitoring, Data Screening, Cataloging, DQE, VADS, PQC, Data Dissemination, Version Control and Testing & Development
- ❖ Provide about 20 TB of high-speed disk space for all data ingest systems connected to various antenna terminals.

Networks

- ❖ Facilitate high speed (4Gbps/FC) data transfer between storage, data-acquisition and processing systems (Storage Area Network).
- ❖ Facilitate data transfer (1Gbps/GbE) among all the acquisition & processing systems, workstations, peripherals and others (Systems Network).
- ❖ Facilitate dissemination of satellite data products to users through public network.
- ❖ Provide connectivity for ISRO participating centers, (SAC, ISAC, NRSC-Balanagar, ADRIN...) operations and maintenance.

5.5.3 Implementation Plan:

The project implementation is split into two phases. In the first phase, it is planned to realize scaled down IMGEOS infrastructure, which caters to current missions with available software using a new scheduler for automating data reception to product generation & dissemination. Development of unified process scheduler processes and standard interfaces will also be initiated in the first phase. In the second phase, it is planned to implement final Work flow Manager (WfM), user services, unified schedulers & processes for Ancillary Data Processing / Data Product Generation / Data Quality Evaluation / Product Quality Checking and interface standardization. Systems and storage will be procured in both phases supporting the development & implementation.

5.5.4. Interim Facility:

An Interim facility is made available at Shadnagar adjacent to the existing control room to realize IMGEOS Phase-1 to support generation of data products in addition to existing capacity at Balanagar (without main SAN storage).

Chapter 6

DATA PRODUCTS GENERATION SYSTEM

The Ground segment processing of Resourcesat-2 is realized in IMGEOS which is an integrated facility for planning, acquisition, processing, qualifying and dissemination of satellite data products with a storage area network for data sharing across the facility. It is an enterprise of systems which collaborate with each other to generate the final products and the services. The processing in IMGEOS is user driven and gets initiated by the jobs/orders created using the services provided by UOPS system. The enterprise has the interface with satellite tracking and control system for the programming the satellite and payload. As per the Payload Pass schedule the ground station acquires the data through the antenna and RF systems. The production chain then process the data acquired and generates the products as required and disseminates to the users. The input payload data is acquired in the Shadnagar station or may be acquired in any other ground station. The users are classified as external users, NDC users, Ground station users, Special project users, etc. The jobs/orders may be data products of different levels, raw data of a pass, value added products, etc.

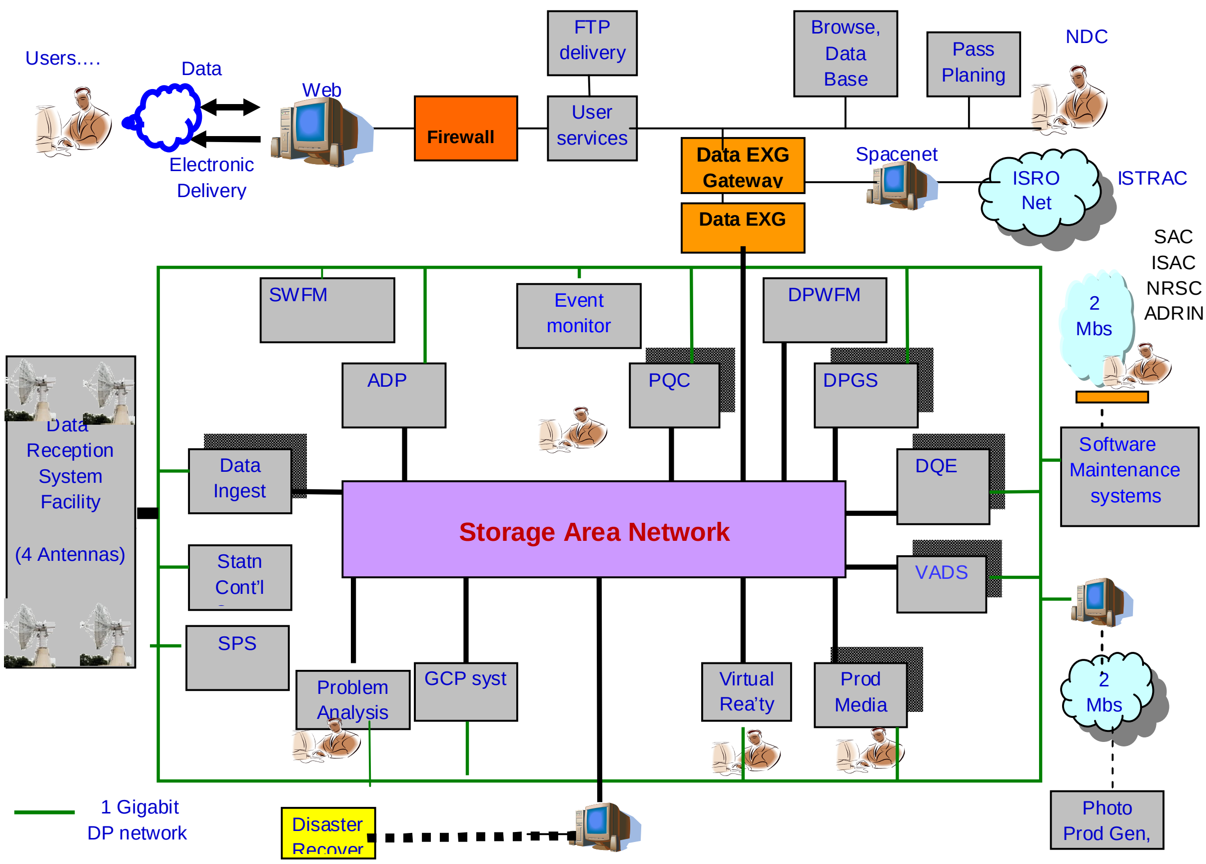


Fig. 6.1 Overview of Ground Segment Processing

There are basically two types of production chains for Resourcesat-2 in IMGEOS i.e., pass wise product generation chain and request based product generation chain. The pass wise product generation chain consists of the Level-0 chain , calibration data processing chain and the full pass off the shelf (OTS) product generation chain. The request based product generation chain generates the scenes of standard, ortho-corrected and value added products. The systems used for production consists of the Station workflow manager(SWFM), Direct Ingest System(DIS), Ancillary Data Processing System (ADP), ADIF population and Browse Archival server, User Order Processing system, Data Products Work Flow Manager, Data Product Generation System, ValueAdded Product generation, Product Quality check system, Media generation system and the ftp server. The Resourcesat-2 production is monitored by Enterprise Monitor and Control system (EMC). The Mission parameters and the product specifications are evaluated and monitored by the Data Quality Evaluation system (DQE). The data transfer across networks from trusted to un-trusted networks is realized by Data Exchange Gateway system (DEG). The complexities of Resourcesat-2 which are handled in Level-0 and entire processing chains are

- Handling of DPCM, MLG decompression, RS-decoding.
- Handling of Pass-wise processing and sensor-wise processing in Level 0.
- Handling of Processing of 70 Km LISS-IV MX in the entire processing chain.
- Handling of high volumes of Data due to enhanced radiometric quantization.
- Band wise transmission of LISS-IV -70 km MX data at different points of time in different ground stations.
- Partial dump transmission at different ground stations.
- Generation of all scenes of a Pass for all sensors of a default product type (Off the Shelf Products).
- Generation of new types of Valued added products.
- AUTOMATIC production chain.
- Centralized monitoring of all systems.
- Ensure Product Quality specifications and turnaround time specifically for 70 km MX .
- Near Real time processing timings.
- Configurable product types, production routes, processing systems and chains.

6.1 Station Work Flow Manager (SWFM)

In IMGEOS facility Station workflow manager provides centralized operations at ground station in a distributed environment for Level-0 operations. It manages and provides ground station level task automation based on pass schedule file availability and provision to process data received from other dumping stations also. After the assignment of antenna multiple Data ingest systems are triggered based on the work-orders. It populates the status and information details of activities like pass details, processing details, products details etc which can be later used for analysis or reporting. The system resolves inter dependency between sensor-wise processing through predefinition and thereby parallelizing independent processing chains.

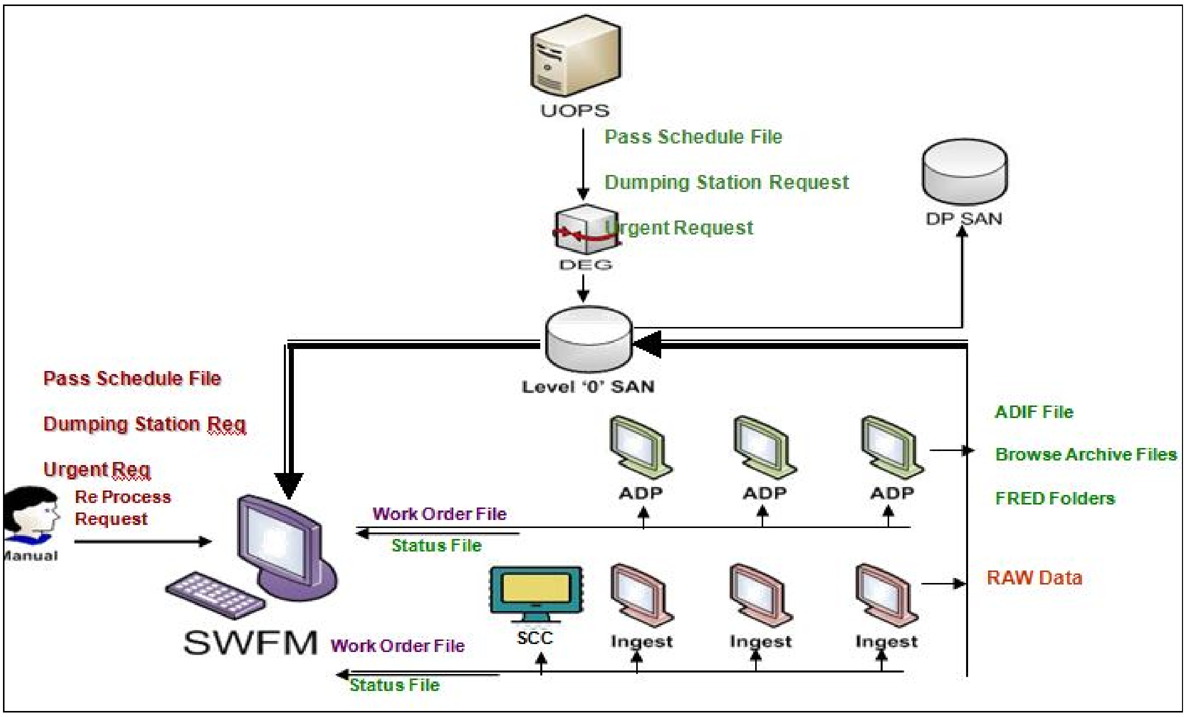


Fig. 6.2 Overview of Station Work Flow Manager

6.2 Direct Ingest System (DIS) :

Direct Ingest System (DIS) for Resourcesat-2 is a real time system for acquisition of LISS-IV, LISS-III and AWiFS payload data. This is a system which schedules the satellite passes for acquisition and then acquires LISS-IV, LISS-III and AWiFS payload data, archives the data on to RAID, provides a sub sampled scrolling display of two of the three payloads. DIS of Resourcesat-2 is interfaced with Station Work Flow Manager, Acquisition Hardware and Storage Area Network for its scheduling, acquiring and archival functions.

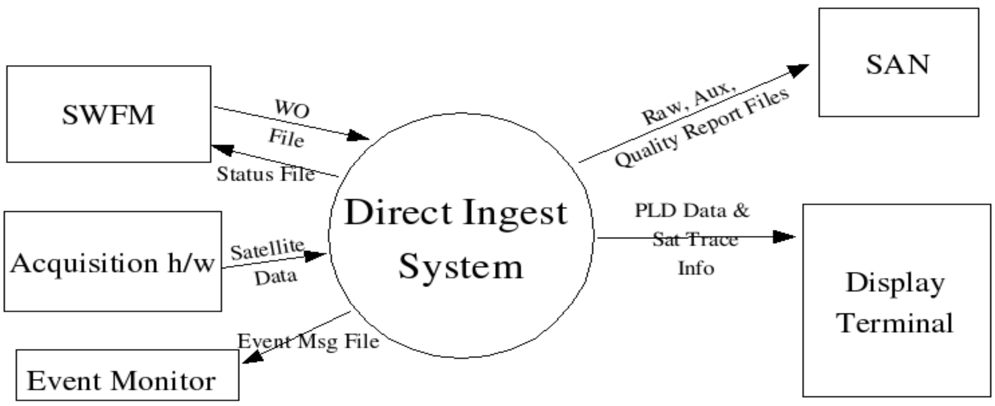


Fig. 6.3 Overview of Direct Ingest System

Major features of Direct Ingest system are:

- Automated scheduling of RS-2 satellite pass data acquisitions based on Work Order files.
- Acquisition and archival of LISS-IV stream and LISS-3 + AWiFS stream data from PCI based acquisition hardware in real time onto RAID.
- Handling of mode change where during a single satellite pass, one stream data stops coming and in the same stream another stream data starts coming. Also same stream data in both carriers.
- RS-decoding, auxiliary data extraction and decompression of payload data and archival of band-wise raw files for each sensor. In case of LISS-4 and LISS-3 sensors DPCM decompression is done and in case of AWiFS sensor MLG decompression is done.
- Providing a sub sampled scrolling display of the LISS-4, LISS-3 and AWiFS payloads' data during real time for quick quality assessment of the received image data.
- Providing an on-line analysis of the payload data in terms of good frames of data received, time stamping jumps in the data frames, download progress indication, RS-decoding errors, etc.
- Providing the status of pass acquisition at the end of the satellite pass to SWFM for further action and a status message to Event Monitor sub-system.
-

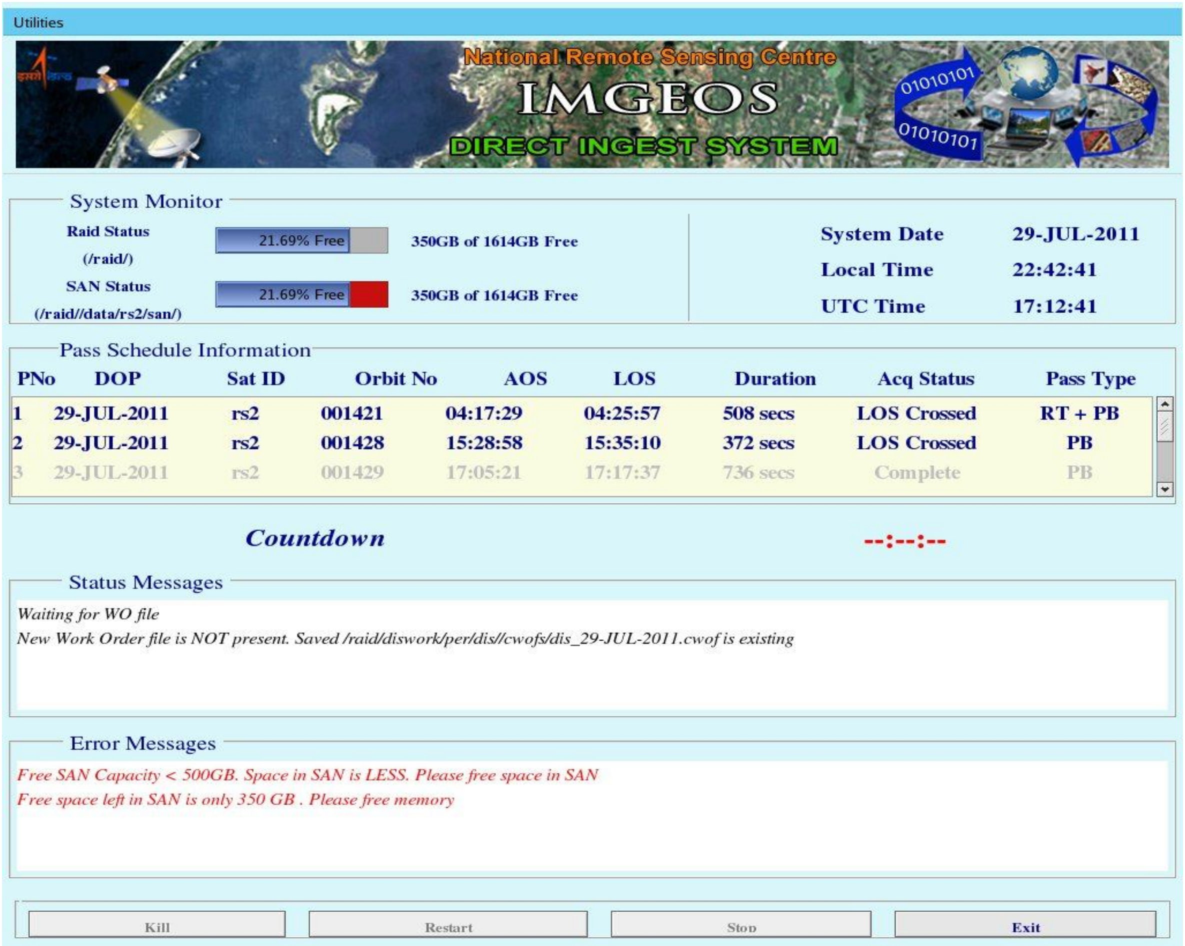


Fig. 6.4 Event Monitor System

6.3 Ancillary Data Processing (ADP)

ADP System is a totally automated system to generate level-0 outputs namely, ADIF, OAT, FRED Files, Port wise Histogram files. ADP system takes acquired video data from the Direct Ingest System and Work Order from SWFM (Station Work Flow Manager).

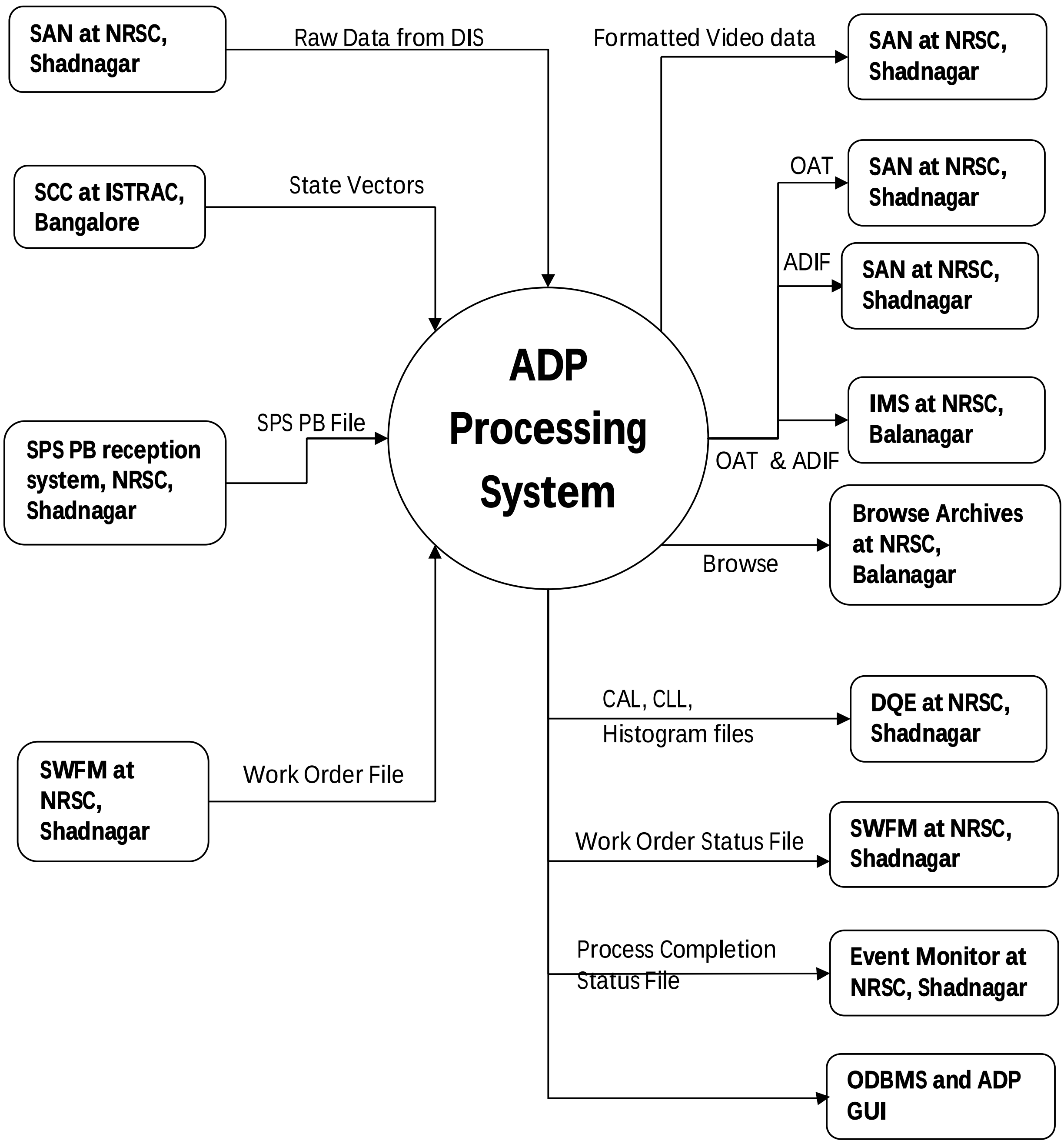


Fig. 6.5 Overview of ADP Processing System

The main functions are

- Automatic triggering of chains for processing based on work order file
- Display of progress/status of various chains
- Provide status to Work Flow Manager
- Reading work order and generating necessary inputs for further processing
- Determining good start and end times, identification of pass type and other pass related information
- Identification of session and strips in the data
- Time stamping and extraction of LBT, AOCS and gyro fine rate data from LBT data
- Generation of pass data quality report
- Processing of SPS RT data and generation of state vectors
- Processing of SPS-PB data and generation of state vectors
- Automatic state vector updation
- Ephemeris generation using S-band state vector / SPS-PB state vector
- Orbit information generation using the suitable state vector
- Attitude determination using earth sensor data
- Attitude determination using star sensor data
- Attitude fusion using earth sensor, star sensor and gyro data
- Orbit, attitude and time file (OAT) Validation
- Scene framing and foot print computation using orbit and attitude information
- Estimation of residual attitude bias using the scene information
- Scene framing and foot print computation using the orbit, attitude and the estimated residual attitude bias
- Ancillary data information file (ADIF) generation and validation
- Updation of status in work order Status file
- Generation of calibration information file

6.4 Enterprise Control and Monitor (EMC)

The whole facility work flow is automated and driven by events. When multitude number of systems work in collaboration to deliver the data driven by the requests/planning, there is a need to monitor the work-flows and performance of the enterprise and take management decisions in case of problems and failures. Enterprise Monitor and Control (EMC) package is a single window application enabling monitoring of the events and thus the progress of satellite data acquisition and processing operations. EMC is a HTTP protocol service. It interfaces with the processing systems in the enterprise like satellite Direct Ingest system, Data Pre-processing systems, Quality evaluation systems and User order processing systems. The centralized monitor accumulates processing status from various sub-systems, processes these messages and prepares appropriate enterprise views which can be accessed by managers over the network. Its main functional features are:

- Shows the Automation in production
- Displays satellite data images during real time acquisition of the passes .
- Accumulation of execution status from various sub-systems in the enterprise.
- Interpreting and processing various received execution status.
- Generating enterprise views for monitoring processing chains.
- Maintains archive of various execution statuses for future trend analysis reporting.
- Monitoring various enterprise resources like critical servers (like application server, database server etc), critical processes, network availability, CPU and memory usage for various processing system, network firewall status.
- Provides various views (like product wise view, individual processing node wise view, summarized view, resource specific usage views etc)
- Provide query based views for historic events
- Generates statistical reports

Fig. 6.6 Overview of EMC

6.5 Product Quality Check (PQC)

Product Quality check is the application package which provides an interactive facility to a client to check quality of the digital products generated by DPGS and VADS for data quality and media related errors. This procedure ensures the correctness of the products before supply to the users. The user interaction is eased through pop-up & pop-down menus of graphical user interface.

PQC package consists of two components namely PQC Scheduler and PQC worker node. There will be always one Scheduler running on the PQC server and there can be multiple PQC workers. PQC Scheduler provides the centralized control for the PQC package. It handles all the communications with DPWFM system and also provides the overall picture of PQC package. PQC client does the quality check based on work orders assigned to them. PQC package is built on client server model with Scheduler as the server and the worker as the client. Product formats supported are Geotiff (TIFF 6.0), Orthokit, and HDF5 for Resourcesat-2.

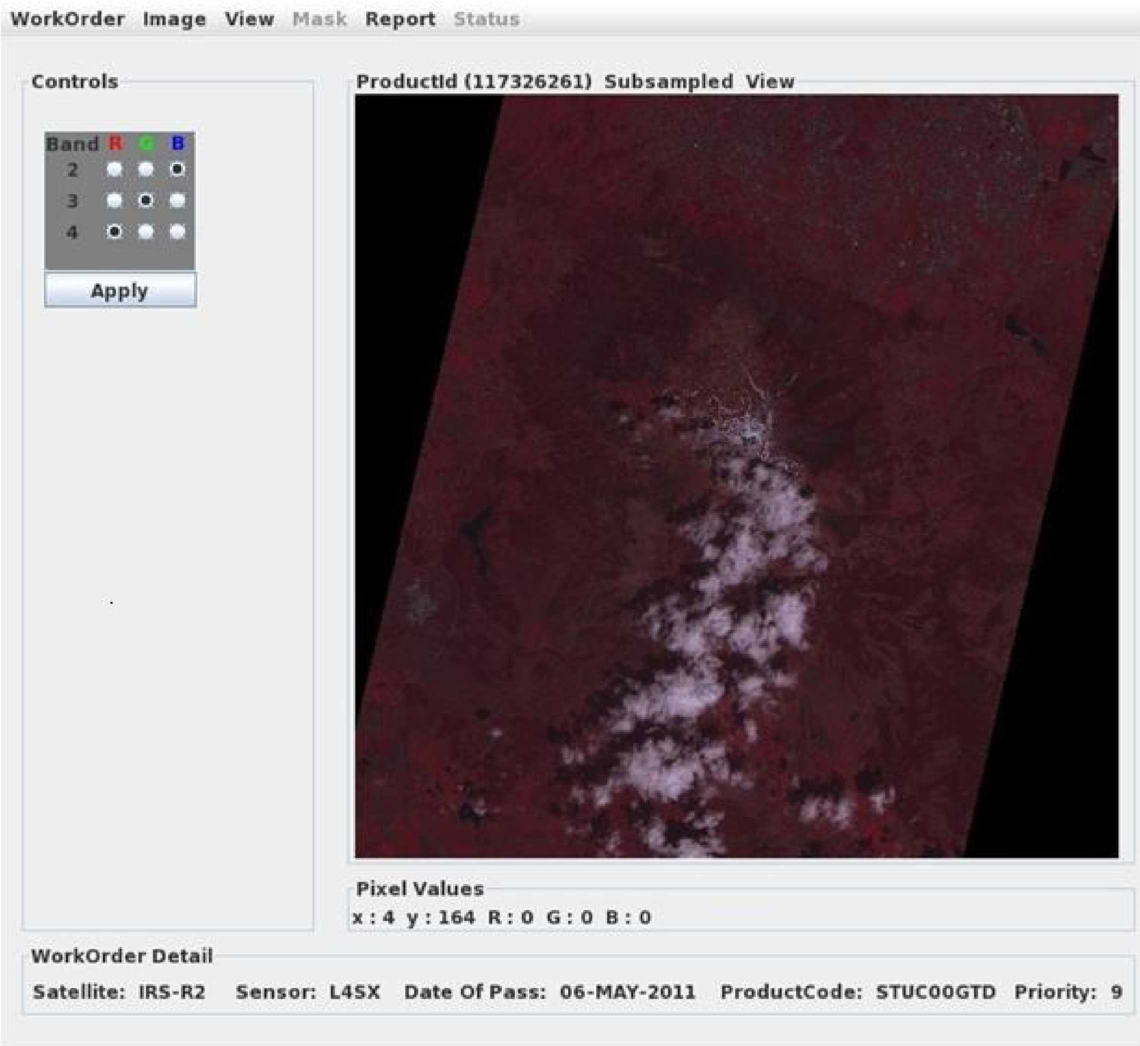


Fig. 6.7 PQC Check

6.6 Data Exchange Gateway (DEG)

Data Exchange gateway is a application package which establishes connectivity between networks to exchange data without compromising the security requirements in order to enable seamless workflow leading to realization of automated mode of operations. The networks can be categorized as

- Extranet which basically connects to external public internet.
- Intranet which is connected to extranet through a proxy firewall and hosts the 'User Services' application servers.
- 'User Services Backend' network where critical back end systems of user services are configured.
- 'Processing' network where all internal data processing nodes are configured.
- Storage Area Network where the three tier storage systems are configured.
- ISRONET where inter-centre connectivity is provided to exchange data for operational use.
- Maintenance network to which all the centers are provided access for maintenance purpose.
- The workflow of data production (driven by demand and the activity) is carried out at different systems. They are user services for selection, programming and delivery of data, data acquisition and level 0 processing, data qualification, data product generation etc. Even though these work blocks serve different purposes, they are interdependent for their functioning. These work blocks require input from each other to reach the end goal.
- 'User Services' interface with users to arrive at job order files for acquisition, data product generation and off the shelf delivery. Level-0 processing uses 'Pass Schedule' file as input from 'Programming Service' to acquire satellite data. Similarly, data processing requires 'Work Order' file as input from 'User Services' to process raw data generated by 'Level-0' processing. 'Ordering Service' takes 'Dispatch' files to complete processing of user order. Also to accomplish off the shelf data products delivery, 'Data Delivery Service' takes data products from storage system to post it on FTP server for user access. Apart from this there are many more supporting activities which make the work flow in data processing chain to function as expected. To perform these tasks automatically the systems on one network needs to exchange data with other.

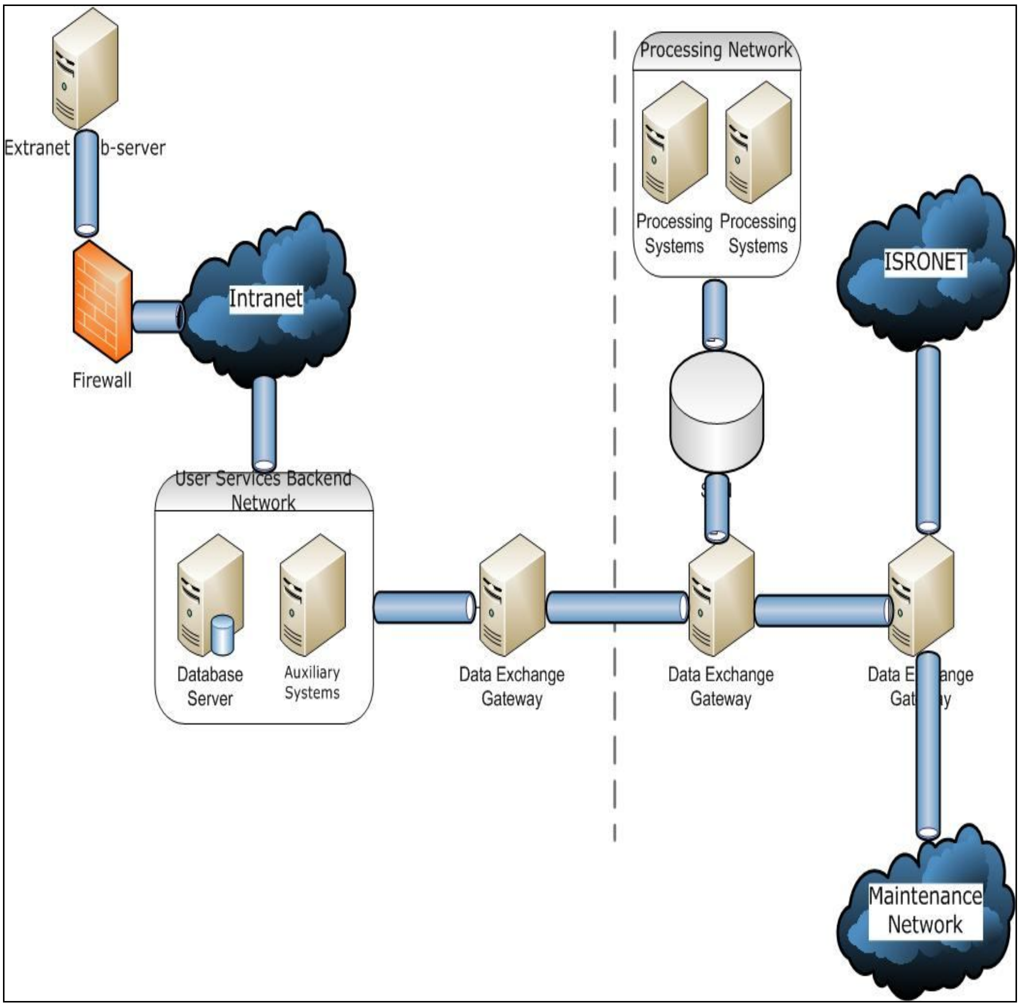


Fig. 6.8 Overview of DEG and Networks

6.7 Data products workflow Manager (DPWFM)

This system automates the entire workflow of the data products generation chain. With large amounts of acquired data and wide variety of data products where manual methods are not feasible, automation of user order processing and data product information flow to the data processing system is done by data products generation workflow processing software. The data product generation activities require many interfaces with various nodes involved in the production chain like User order processing, data processing, quality control, quality evaluation, value addition, etc .The level of integration and automation envisaged to attain large volume of data products generation, reduction in turnaround time, consistency in data products quality and repeatability in making the products.

The products generation is based on a token known as work order which is moved from one work center to another work center based on a set of rules. To develop an automaton for the production chain a push mechanism is required where the work orders are automatically posted to a local database for each work center node based on the load. This will totally eliminate the interactive component to get the work order. The product workflow is based on a set of predefined rules which are maintained in the database. The designer intervention is required for any change in the workflow or defining a new workflow. A graphical workflow would enable one to visualize the production chain or define new chain with ease. The data product chain and status visualization is provided at EMC.

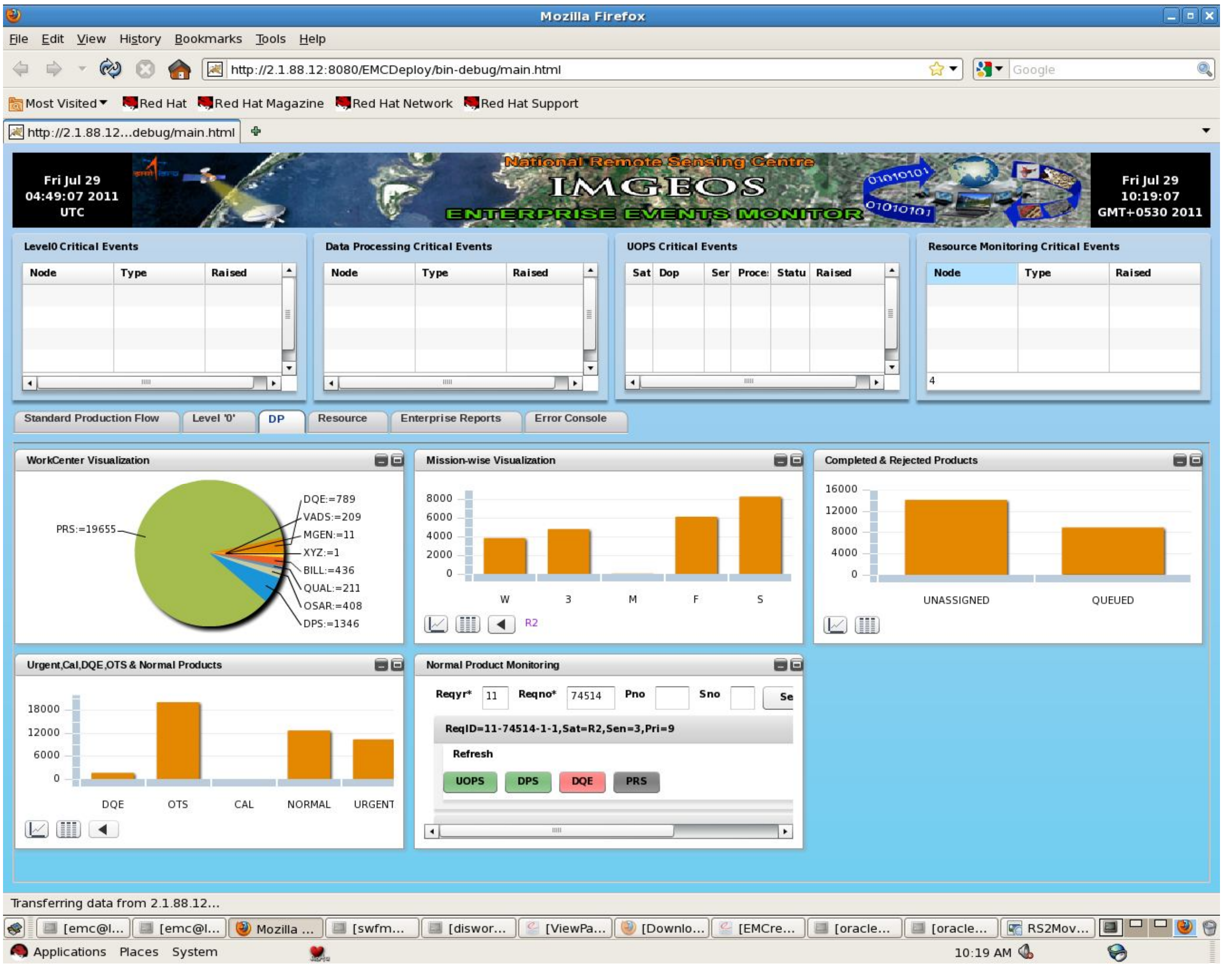


Fig. 6.9 Product status monitoring through EMC

6.8 Standard Data Products Generation System

6.8.1 Introduction

The concept and design of Resourcesat-2 Data Products Generation System has evolved from the

- Experience of design, development and operationalization of software for IRS –1C/1D/P6 data products in Indian and various International Ground Stations (IGS)
- Design and development of software for Digital Elevation Model (DEM) and Orthoimage (OI) for SPOT and IRS – 1C/1D stereo data and Carto-DEM.

- ❖ Study of software packages for satellite data processing developed by other agencies with global presence.
- ❖ Study of value added data products provided by global vendors.

Definition of mission modes was used in deriving levels of data products in terms of radiometric and geometric accuracy. Payload parameters were used in arriving at the definition of data products for Data Products Generation System.

6.8.2 Objectives

Keeping in view the overall objectives of the mission, the objectives of the software system for Resourcesat-2 data products are as follows.

- ❖ To conceptualize, design and develop necessary software for realization of data products System with user requirements in Indian Ground Stations, and International Ground Stations.
- ❖ To carry out necessary R & D for development of new techniques such as band to band registration in the case of LISS-IV, template-registered products and AWiFS heads Mosaicing.
- ❖ Use of DEM specially Carto-DEM with staging of coarser resolution DEMs in the entire processing of Data Products.

6.8.3 New elements in Resourcesat-2

Data Processing and changes as compared to Resourcesat-1 DPGS ; Impact of Payload configuration

- ❖ Staggered array of LISS-IV
- ❖ Co-registration of LISS-IV Mx bands
- ❖ Yaw steering specific changes in the geometric correction model.
- ❖ AWiFS camera A & B (split configuration) mosaic.
- ❖ AWiFS's 12 bit raw data processing and LISS-III and LISS-IV 10 bit raw data processing. Increased data volume for AWiFS as well as for LISS-III and LISS-IV.
- ❖ First time handling of Mx with 70km in addition to 23 km as in Resourcesat-I. Necessity of using Elevation Model in geometric processing to achieve co-registration of bands of LISS-IV Mx.

6.8.4 Changes in Processing Methodology

- ❖ On ground BBR for AWiFS/LISS-III/LISS-IV in automatised manner
- ❖ Archival mode or Full Pass processing for AWiFS and LISS-III sensors
- ❖ Single process based data product generation as a result of unification of several inline processes and new concept of pre-processing, sensor modeling and product generation
- ❖ Fully parameterized geometric correction and sensor model.
- ❖ Incorporating Digital Elevation Model for detector look angle intersection with earth surface.

- Introduction of multi-resolution DEM staging for automatic selection of finer to coarser resolution DEM from DEM stack.
- Introduction of RPC based Geo orthokit products.
- Usage of XML based product context generation.

6.8.5 New techniques incorporated

- Integrated thread-safe component-based dynamic sharable core pre-processing library for image data handling, radiometric correction, image processing filters, sensor modeling, map projection and datum conversion, elevation data management and image data formatting.
- Sensor model optimization and estimation of sensor interior and exterior orientation parameters based on non-linear optimization technique.
- Harris Corner detector based feature extraction and Random Sample Consensus (RANSAC) Algorithm for outlier rejection for image match points generation to be used for co-registration of LISS-IV Mx bands.
- Curvature preserving PDE (Partial Differential Equation) based Anisotropic filter for noise removal.
- Thread enabled processing of different sensors with optimized usage of CPU resources which is integrated in unified process which carries out radiometric correction, geometric correction and generates products after resampling.
- Packaging of data products in HDF5
- Usage of several new image processing filters and algorithms for image pre-processing
- Use of XML based workfile for interfaces in processing chain
- Use of hierarchally staged DEMs from higher to coarser resolution for better product accuracy

6.8.6 Software Design

This being first inline mission with IMGEOS scenario an entirely new image preprocessing frame work has been developed to cater to multi-mission requirements. This frame work is used in unification of processes for data processing of Resourcesat-1 (existing and operationalized at NRSC, Balanagar) and Resourcesat-2. A new interface of XML based work files is introduced to cater to porting issues and enhancing readability of Meta data with compatibility to various missions in IMGEOS environment. All elements and sub-systems of Resourcesat-2 DPGS are completely designed with object-oriented analysis and design approach using this preprocessing engine library. Coding language is chosen to be C++ and Java.

6.8.7 Radiometric Correction

Each of the three sensors of Resourcesat-2 consists of Linear arrays with different number of detector elements. The response of the different elements of any of the arrays will not be exactly uniform. Radiometric correction is the process, which normalizes these responses on the basis of the Laboratory measured Radiometric Calibration values. Radiometric Correction is mainly towards removing these distortions to correct an image, for consistency for the following reasons:

- Within an image (speckle or striping)
- Between adjacent or overlapping images (for mosaicing)
- Between bands (for some multispectral techniques)
- Between image dates (temporal data) and sensors

The steps for performing Radiometric Correction are:

- Detector normalization
- Framing of required scene
- Failed detector correction
- Line loss correction
- Stagger Corrections

6.8.7.1 Detector Normalization

All the sensors of RESOURCESAT-2 consist of linear arrays of a fixed number of detectors. The responses of these detectors for the same intensity of light falling on them are not identical. This non-uniform response, which leads to striping in the image data over uniform areas, is characterized in the laboratory in terms of a Radiometric Calibration Slope-Offset Look-up Table (RADLUT) or polynomial coefficients. Using this RADLUT, the RadCor process corrects the response non-uniformity of individual detector elements. Thus, this correction is a mapping from the input gray value to an output gray value for each detector, and over the entire range of the input gray levels.

6.8.7.2 Framing of the required scene

Data products provide the user data corresponding to his area of interest in terms of parameters like Path/Row/Subsecene/Map Sheet/Latitude-Longitude/Scene corners. Framing involves extracting the user area in both scan line and pixel direction. Each video data record is associated with line count information and Ground Receiving Time (GRT). Framing involves finding the start scan line needed for generating a particular product, and extracting the required number of scan lines for the product generation. Image framing is carried out in the following approach:

- Line Count based
- GRT (Ground receive time)/OBT(On-board time) based
- Default framing option is line count. In case where line count is not usable, GRT based framing is invoked.

6.8.7.3 Failed/Degraded detector Correction

Some of the detectors in any of the CCD arrays can fail or degrade over a period of time. In such cases, the response of that particular detector is estimated from the response of the neigh boring detectors. This estimation is, however, possible only if the failed detectors do not exceed two consecutive CCD elements. Besides, during the mission life of the satellite, the detectors show varying degrees of degradation. This uneven degradation again leads to anomalies like striping in the image data. Such degradations are also corrected. Some of the detectors in any of the linear arrays can be dead over the period of time. In such cases, the response of that particular detector is estimated.

6.8.7.4 Line loss correction

A line loss, in the transmission (assuming one sync corresponds to the integration time), will affect all detectors of the CCD array. This lost line can be identified and reconstructed. In case of loss of one line, the lost line is replaced by averaging the two neighbouring lines. If two lines are lost, the first line lost is recovered by repeating the previous line while the second line lost is recovered by repeating the next line. In case of three consecutive lines lost, the first line lost is recovered by repeating the previous line and the third line lost is recovered by repeating the next line. The second line is replaced by the average of the first and third line. The lost lines are not recovered in the case of more than three consecutive line losses.

6.8.7.5 Stagger Correction

The payload design of LISS-IV camera and SWIR band of LISS-III and AWiFS is such that the odd and even detectors are staggered by 5 scan lines and 2 scan lines respectively in the focal plane. However, this stagger does not translate into a constant stagger in the image data. In fact, the stagger in the image data depends on the tilt of the payload, velocity of the satellite and the integration time of the sensor. Correction is performed to remove this stagger effect. One-dimensional resampling (vertical direction) will be performed to construct the staggered pixels. Cubic Convolution technique will be used to reconstruct the staggered image.

6.8.7.6 Anisotropic Filter for Noise removal

This Radcor process also supports to addition process (Anisotropic filter) which are useful for noise removal (salt and pepper noise). The bands of LISS-IV are more prone to quantization noise because of the less coverage of full dynamic range. Hence, the enhancement is done for better visual appearance which amplifies the noise components and makes it visible in the image. Noise reduction without losing scene and feature information is the prime objective of the implementation of the anisotropic filter. In any image analysis, smoothening is required before any other tasks could be conducted. Gaussian low-pass filtering is known to be an efficient and simple way for image smoothening. However, it is well known that Gaussian filtering blurs the image features at edges while smoothing image noise. The reason is that Gaussian filters are isotropic in the sense that all surrounding pixels affect the centre pixel in a similar fashion regardless of their intensity variations. Hence, the edges and the noise are treated in the same way, which yields noise reduction but introduces edge blurring. To rectify the problem of traditional Gaussian filtering, we have proposed a method trying to achieve the goal of feature-preserving by smoothing. This is called as anisotropic filtering. This is a PDE-based regularization technique. In this, on an edge, smoothing is performed only along the edge direction, which is called Anisotropic Smoothing and in homogeneous regions, smoothing is performed equally in all directions, which is isotropic Smoothing.

6.8.8 Geometric Correction

The data acquired by the satellite, will have the following distortions –

- Distortion due to the relative motion of the satellite with respect to the earth
- Distortion due to Earth curvature
- Panoramic distortion arising out of the tilt angles
- Distortions arising out of the continuous yaw steering
- Distortions due the staggered array of LISS-IV

The corrections needed for removing the above mentioned distortions and projecting onto the user specified map projection plane in the desired datum is achieved by a process called IMGProc which also is responsible for filling geometrically corrected image using given resmapling kernel. In view of the payload configuration the different bands of LISS-4 are not registered on-board. In fact, the two extreme bands are separated on the ground by a distance equivalent to 2.1 seconds in terms of imaging time. This calls for ground based registration, which is also effected in the Geometric Correction software. A unified process call as IMGProc will carry out this pre-processing for all sensors handing radiometric as well as geometric correction for all standard products.

The distortions in the data from the satellite are corrected in two steps :

- By establishing a mapping between the output space, as defined by the user.
- By transforming the input data into this defined output space

The user can request any of the different types of products supported. The output space for the product under consideration is defined and then a map is established from the 'output space' to the 'input space' (the scene under consideration). Resampling is the technique of generating an image on a system of coordinates, taking the input image from a different set of coordinates. This is needed, because, the satellite imaging is done at fixed time intervals, whereas the final product generation depends on the image being generated at regular spatial intervals. Hence, there is a need to shift the original samples of the image or interpolate between the input values, to get the image samples at the output locations. This process is known as Resampling. More precisely, given the image intensities at a set of grid points, obtaining the same at a different set of grid points is known as Resampling.

6.8.9 Product Formatting

The corrected products containing the video data and the supporting ancillary information which are organised in a user specified formats identified as geotiff and HDF5 for Resourcesat-2 and written onto the disk. The design of the system should be flexible enough to accept any future requirements without much effort. Besides, the system should be portable to operate in various

UNIX clones, and range of Workstations, including PC. The archival of the disk based product on the output media is done by the Media Generation package.

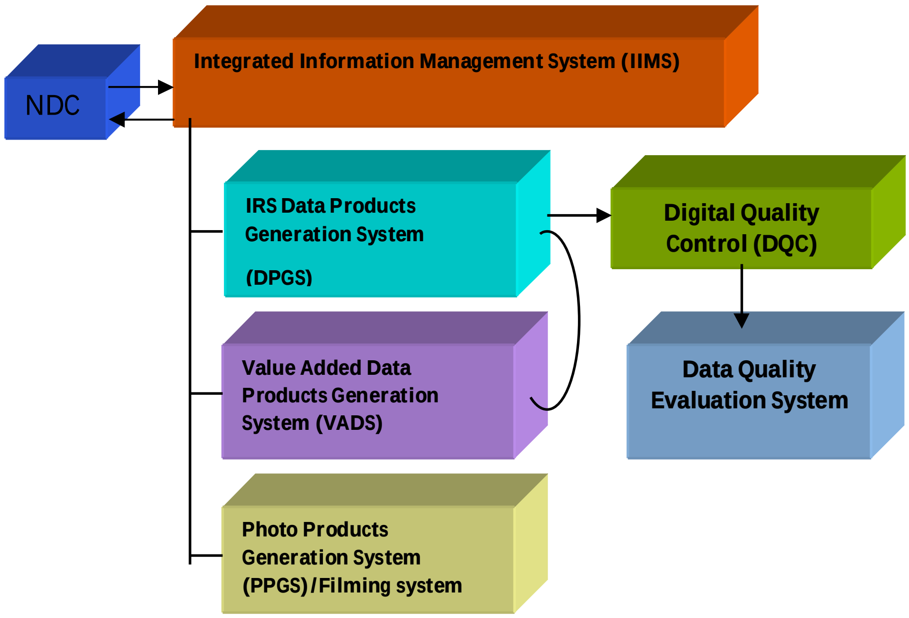


Fig. 6.10 Overview of Data Products Generation System

6.8.10 Products Specifications

Data products can be categorized as Standard products and Value Added products. In IMGEOS scenario, the Data Products Generation System and Value Added Products Generation Systems are two separate entities for generating two types of products – standard corrected products and value added products respectively. The primary difference between these two systems is the way products are generated. The DPGS generates those products which are subjected to standard set of corrections with no human interaction i.e. through automatic process, whereas VADS system generates next level of products which needs human interaction , for example GCP identification, visual inspection etc. for value addition in standard products which are generated by DPGS. DPGS will use Digital Elevation Model(DEM) for terrain height correction along with standard sensor model based geometric correction and geo-location accuracy improvement by automatic attitude bias estimation using ortho-corrected references.

Product Types:

Standard Products	Path/Row based Georeferenced Product
Value Added Products	Precision Geocoded Products
	Template registered products
	Precision Ortho corrected products

Levels of Corrections supported:

Level	**Type of Correction**
LEVEL-0	No correction (RAW)
LEVEL-1	Radiometric correction (RAD)
LEVEL-2	Radiometric and Geometric correction (STANDARD)

Map Projections supported:

User will be able to define any of the following map projections for the product type LEVEL 2.

Polyconic (POL)
Lambert Conformal Conical (LCC)
Universal Transverse Mercator (UTM)

For AWiFS products, only Lambert Conformal Conical (LCC) Projection will be supported whereas LISS-3 and LISS-4 products can be generated in Polyconic and UTM projections. However, for IGS installations, all map projections currently available for IRS-1C/1D/P6 will be supported.

Earth Ellipsoids supported:

Data Products system will support the following ellipsoids for geometrically corrected products.

Clarke 1866 (C6)
International 1909 (I9)
GRS 1980 (GR)
Everest (EV)
WGS – 84 (W4)
Bessel (BL)
Krassovsky (KW)

By default, when Everest ellipsoid is used associated datum to be used is Indian 1975 and WGS-84 datum will be used for WGS-84 ellipsoid. For other ellipsoids, corresponding appropriate datum will be used by default. For IGS installations, all ellipsoids currently available for IRS-1C/1D/P6 will be supported.

Resampling Options supported:

Following resampling options will be available for geometrically corrected products. For full pass processing mode (Archive Mode), Cubic Convolution resampling option will be used. For user products, however, the specified resampling option in the workorder will be used.

Cubic Convolution
Nearest Neighbor
16 Point Sinc

Output Resolutions supported:

Data Products System has the capability to generate geometrically corrected products with different output resolutions. However, operationally standard output resolutions will be used for product generation.

LISS – 4	5.0 meters to 6.25 meters
LISS – 3	12.5 meters to 25 meters
AWiFS	50.0 meters to 75 meters

Output Media supported:

Data Products System will always generate products on Disk. The media generation system will have capability to package this disk based product on CDROM/DVD.

Digital Data Product formats supported:

Digital Data from Data Products System will be supplied in the following two formats.

Band Separated GeoTiff
HDF5

6.8.11 Product Details

The details on product level specifications for all types of products from LISS-3, LISS-4 & AWiFS processed in DPGS are given in Tables 6.1 to 6.4.

Product Type	Level Of Correction	Projection	Sampling	Output Format	Internal Dist	Accuracy RMSE
Path-row based 141 km x 141 km	Raw	NA	NA	HDF5		
	Rad corrected	NA	NA	HDF5		
	Geo-Referenced	UTM/ POL	CC/NN	GeoTiff	<=3 +-0.25	<=150m
	Geo RPC	UTM/POL	CC/NN	GeoTiff Metadata	- +-0.25	

Table 6.1 LISS-3 Products

Product Type	Level Of Correction	Projection	Sampling	Output Format	ID/ BBR	Accuracy RMSE
Path-row based 70 x 70 km or 23 x 23 km	Raw	NA	NA	HDF5		
	Rad corrected	NA	NA	HDF5		
	Geo-Referenced	UTM /POL	CC/NN/ sinc 16	GeoTiff	<=3 +-0.25	<=100m
	Geo RPC	UTM/POL	CC/NN/ Sinc16	GeoTiff Metadata	- -	

Table 6.2 LISS-4 MX Products

Product Type	Level Of Correction	Projection	Sampling	Output Format	ID	Accuracy RMSE
Path row based 70 km x 70 km	Raw	NA	NA	HDF5		
	Rad corrected	NA	NA	HDF5		
	Geo-Referenced	UTM/ POL	CC/NN/ sinc 16	GeoTiff	<=3	<=100m
	Geo RPC	UTM/ POL	CC/NN/ Sinc16	GeoTiff + Metadata		

Table 6.3 LISS-4 Mono Products

Product Type	Level Of Correction	Projection	Sampling	Output Format	ID/ BBR	Accuracy RMSE
Path-row based 370 km x 370 km	Raw	NA	NA	HDF5		
	Rad corrected	NA	NA	HDF5		
	Geo-Referenced	LCC	CC/NN	GeoTiff	<=3 +-0.25	<=200m
	Geo RPC	LCC	CC/NN	GeoTiff + Metadata		
740 km x 740 km	Geo-Referenced	LCC	CC/NN	GeoTiff	<=5 +-0.25	<=250m

Table 6.4 AWiFS Products

Notes :

- ID is Internal Distortion in pixels and BBR is Band to Band Registration in pixels for both directions
- All Path-row based scenes mentioned in the product list are North-oriented.
- Terrain correction and accuracy improvement using reference image to be done all sensors and product types.
- Default Earth Ellipsoid & Datum to be supported : WGS-84
- Band separated GeoTIFF format only will be supported.
- Raw and Rad products are for internal/DOS users only.
- Raw product for LISS-4 will not have stagger correction, whereas Rad product will be provided with stagger correction.
- First and last scene will not be shifted to make full scene data.
- Metadata for RPC will be provided in IKONOS format.
- Extra Image data to be used in top and bottom (if available) to fill-in the scene bounding rectangle (similar to IC/1D/P6/O2).
- Default Projection, Sampling Option and Datum for full pass processing will be UTM/LCC (for AWIFS), CC and WGS-84 respectively.
- DP to support 22 map projections, three sampling options (CC, NN, Sinc16), and all available Datum options for user products.

6.8.12 Product Radiometric Accuracy

This is defined by signal-to-noise ratio (SNR) of the payload, measured as the standard deviation products for a uniform homogeneous terrain feature. Radiometric accuracy is specified in terms of the following parameters:

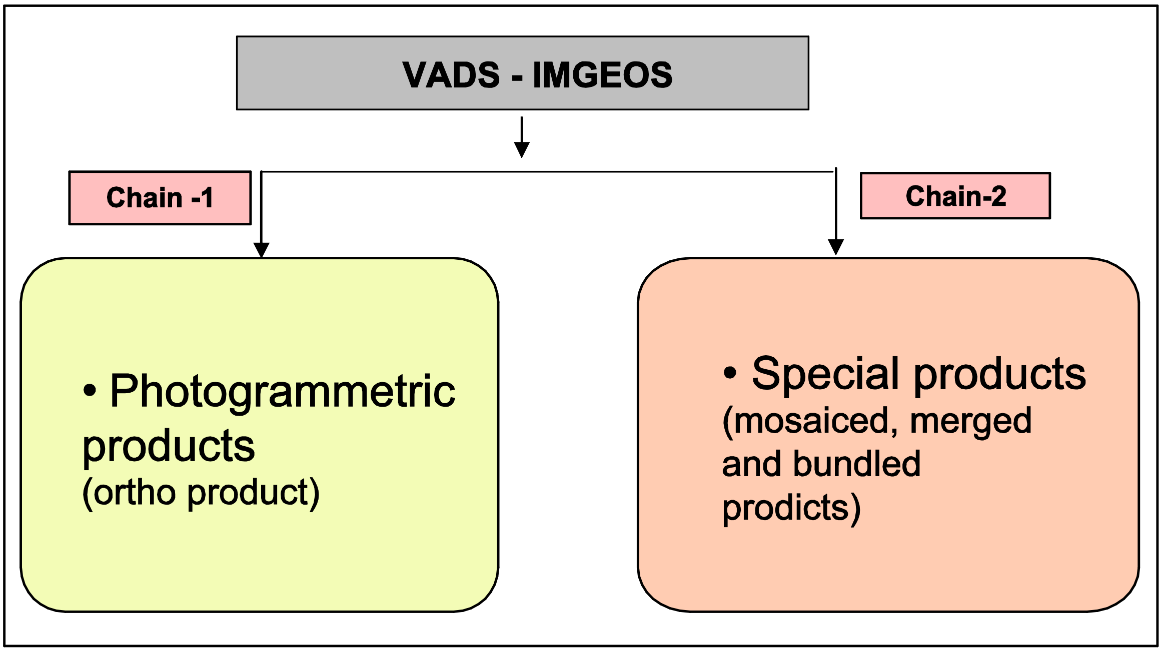
- Relative Radiometry
  SNR across the uniform scene SNR local for any 16 x 16 pixel sub-image
  Spectral Response of the detectors across CCD array
- Absolute Radiometry
  Verification with in-situ ground truth data

6.8.13 Location Accuracy for System corrected Products

- Star sensor attitude and Satellite Position system (Prime Mode): 150 m (1s)
- Earth sensor attitude and Satellite Position system (Backup Mode) : 450 m (1s).

6.9 Value Added Data Services (VADS) System of IMGEOS

VADS is precision and special product generation work center in IMGEOS with all required interfaces. In the interactive chain, the products will be generated as per the work-order and will have interfaces with workflow manager. These systems will be used to generate value added products in a semi- automatic mode. Two chains of VADS system are shown in figure6.11.



. **Fig. 6.11 Two chains of operations for VADS**

Following are the important features of the VADS system.

- Generates ortho products for given ROI
- Supports all sensors from Resourcesat-1/2
- Product specification
  - 2 Datums (WGS-84 and Everest) are supported
  - 4 projections (UTM, LCC, Geographic, Grauss Kruger) are supported
  - Output resolution from 0.5 pixel to 5 times input resolution
  - Map-based products (1:25,000, 1:50,000 and 1:250,000 scales) are supported. Apart from this open series map index is also supported along with SOI index. Open series maps with 2000 to 1,000,000 scales are supported
  - 3 resampling options (Cubic Convolution, Nearest neighborhood and Sync 16) are supported
- Bundled (co-registered) products generation
- Mosaic of products (along and across track)
- PAN sharpening
- Access to the reference data base (GCP library and DEMs for ortho product generation)

As shown in figure 6.11, here are two chains of operations for VADS. One is image-based value addition and other is satellite photogrammetric products. Ortho/standard products are the inputs for image-based value addition where as geometrically raw form of input data is required as input for satellite photogrammetric product generation.

6.9.1 Special Products

Inputs for image-based products are standard or ortho products for further value addition, mosaicing or merging. Special products generation chain is shown in figure 6.12.

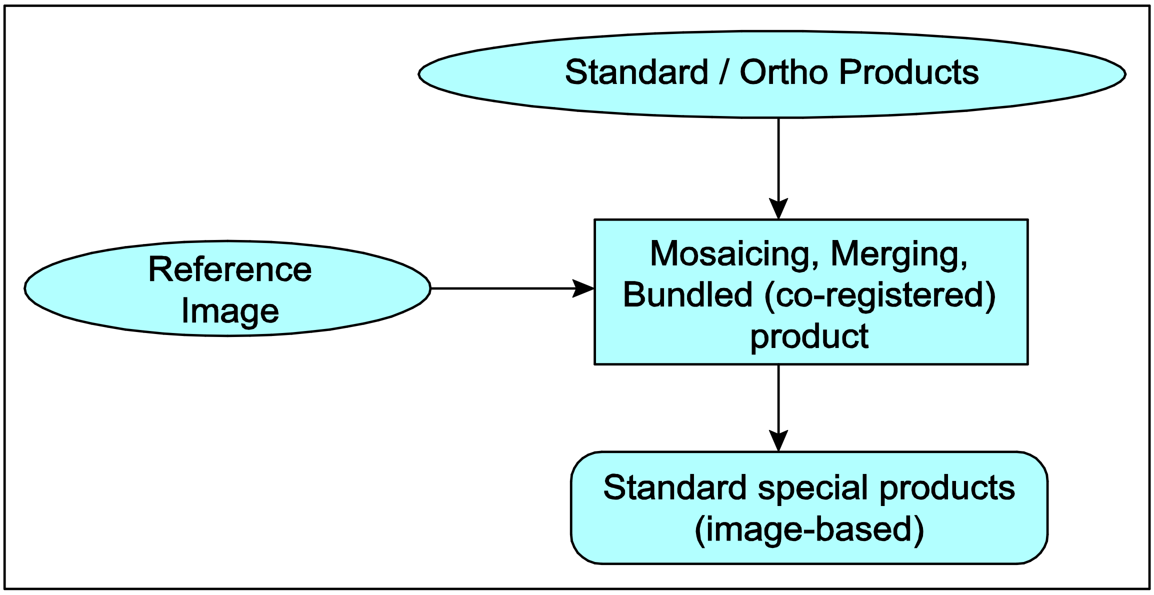


Figure 6.12 Special products generation

6.9.1.1 Bundled Products

Input options supported
1. Standard products in geo-tiff format
2. Photogrammetric Ortho products (Geotiff)

Data for processing
1. Work-order
2. Target and Reference images

Outputs supported
1. Geotiff format for scene and Specifications & Quality report

Bundled products are supported for the combinations of following satellite/sensors.
1. Resourcesat-1 – all sensors
2. Cartosat-1
3. Cartosat-2
4. Resourcesat-2 – all sensors

6.9.1.2 Merged Products

Input options supported
1. Standard products in geo-tiff format
2. Photogrammetric Ortho products (Geotiff)

Data for processing
1. Work-order
2. Target image, Reference image

Outputs to be supported
1. Geotiff format for scene and Specifications & Quality report

Merged products supported for the following combinations.
1. IRS-1C/1D --- PAN + L3
2. Resourcesat-1 – L4 + C1
3. Resourcesat-1 --L4 +C2
4. Resourcesat-2— L4 (23 kms and 70 kms) + C1
5. Resourcesat2— L4 (23 kms and 70 kms) + C2

6.9.1.3 Mosaic products

Inputs to be supported
1. Standard products in geo-tiff format
2. Photogrammetric Ortho products (Geotiff)

Data for processing
1. Work-order
2. Target image, Reference image etc

Outputs to be supported
1. Geotiff format and Quality report
2. Geotiff format for more than a scene and Specifications& Quality report

Mosaic products generation support
1. Resourcesat-2 – all sensors
2. Resourcesat-1 – all sensors
3. Cartosat -1
4. Cartosat -2

6.9.2 Photogrammetric Products

Inputs for satellite photogrammetric based products require geometrically raw image. Processes outline is shown in figure 6.10.

Geocoded / Ortho Products (Photogrammetric product)
1. Input options supported
2. Geometrically raw data

Data for processing
1. Work-order
2. GCP, TCP, MAP, Reference image, DEM etc
3. Raw data (HDF-5)
4. ADIF DB

Outputs to be supported
1. Geotiff format for scene and Specifications & Quality report

Geocoded / Ortho products support.

1. Resourcesat-2 – all sensors

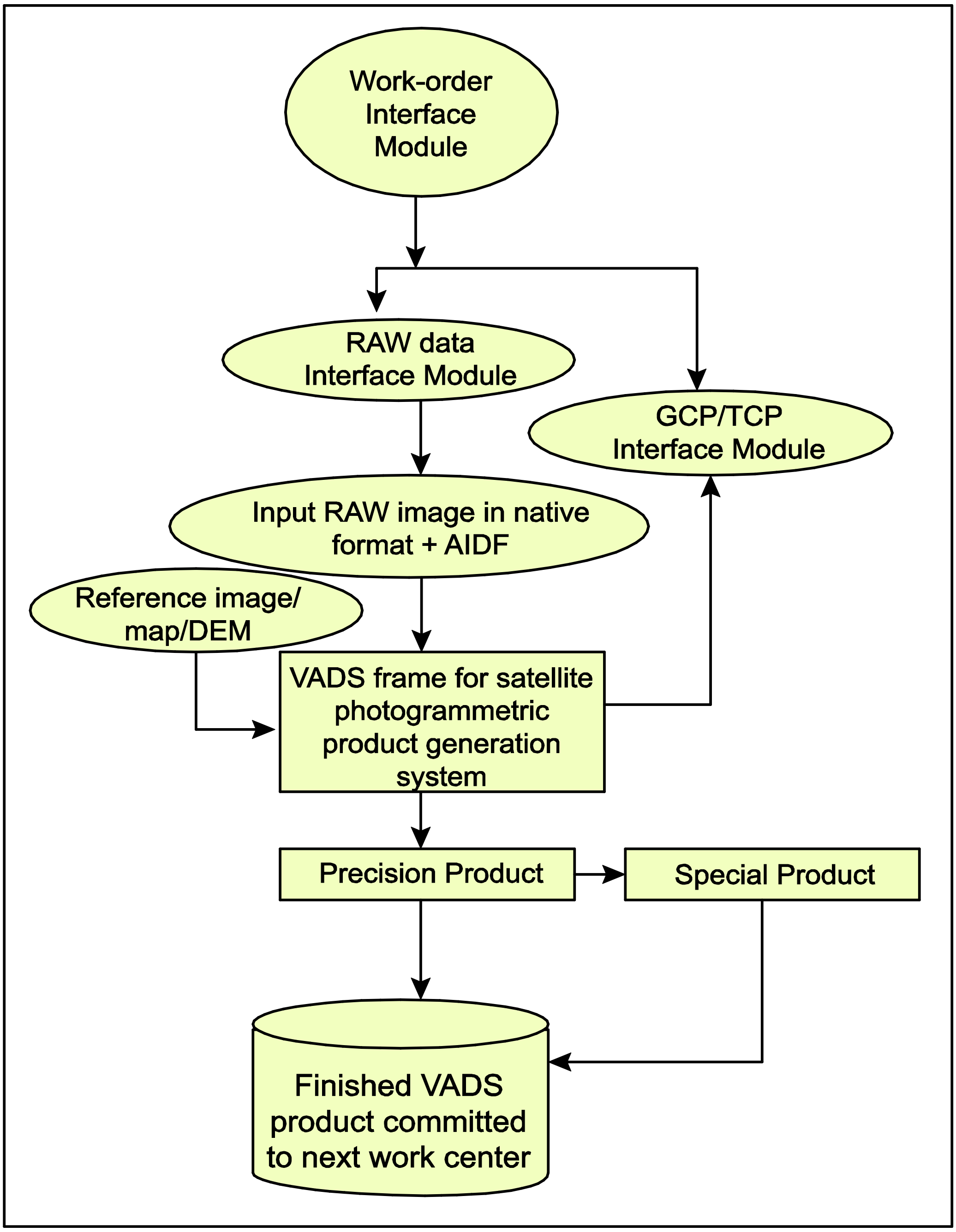


Figure 6.13 Satellite Photogrammetric products generation

	Ortho Rectified Products	LISS3	AWIFS	Liss-4
1.	Across Track RMSE_X	< = 50 Mt	< =100 Mt	< = 25 Mt
2.	Along Track RMSE_Y	< = 50 Mt	< =100 Mt	< = 25 Mt
3.	RMSE_XY	< = 70 Mt	< =140 Mt	< = 35 Mt
4.	Residual BBR	<=0.25	<= 0.25	<= 0.5
5.	Internal Distortion	< =1 pixels	< =2 pixels	< 1 pixels
6.	Scale variation (Pixel resolution)	< 0.1175 mt (0.5%)	< =0.28 mt (0.5%)	<= 0.029 mt (0.5%)
7.	Residual stagger	0.2 pixels- B5	<=0.2 pixels- B5	0.2 pixels
	Mosaic / Merged / Co-registered Products	**LISS3**	**AWIFS**	**Liss-4**
1.	Across Track RMSE_X	< = 50 Mt	< =100 Mt	< = 25 Mt
2.	Along Track RMSE_Y	< = 50 Mt	< =100 Mt	< = 25 Mt
3.	RMSE_XY	< = 70 Mt	< =140 Mt	< = 35 Mt
4.	Residual BBR	<= 0.25	<= 0.25	<= 0.5
5.	Internal Distortion	< =1 pixels	< =2 pixels	< 1 pixels
6.	Scale variation (Pixel resolution)	< 0.1175 mt (0.5%)	< 0.28 mt (0.5%)	<= 0.029 mt (0.5%)
7.	Radiometry (seam line etc)	Visual Inspection	Visual Inspection	Visual Inspection

Table 6.5 VADS Product Specifications

Chapter 7

PRODUCT QUALITY EVALUATION AND CONTROL – PROCEDURES AND CRITEREA

7.1 DQE Parameters and detailed procedures

Data quality evaluation is the quality check for the user defined digital products against mission specifications. This activity is intended to monitor the performance of the payloads and the stability of the platform by evaluating various parameters. Analysis on computed DQE parameters is the main source for feed back to the mission to maintain payload and platform specifications in order to meet the goals during operational life of the Mission. Geometric quality parameters, the location accuracy and sidelap/overlap are useful to NDC in selecting the data sets for the end user. Data Quality Evaluation can be broadly classified into three types namely geometric, radiometric and on-board Calibration data quality. The functional block diagram of DQE system is shown below.

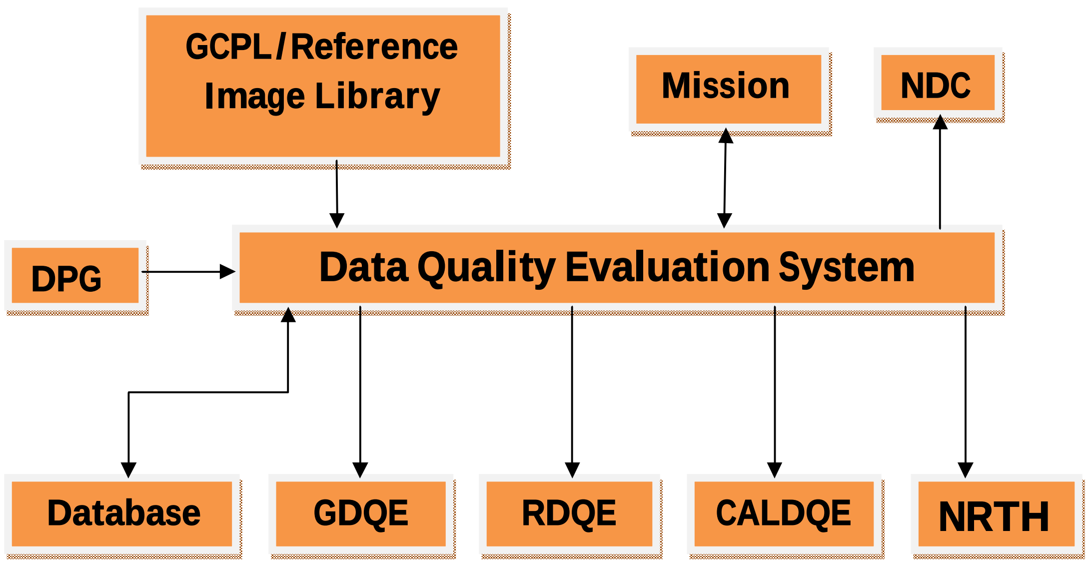


Fig. 7.1 Block Diagram of Data Quality Evaluation System

7.1.1 Geometric Data Quality Evaluation (GDQE)

Geometric data quality evaluation is carried out to certify the product for its geometry like positional accuracy, scale and internal distortion on Level-2 products. GDQE performs mapping of image data to exact location on Earth using Ground Control Points (GCPs). Having multiple spatial resolution sensors onboard, different references are used with accuracies better than a meter to better than 100m for the evaluation. Residual Roll, Pitch and Yaw values are also computed to monitor platform pointing accuracy by regular evaluation.

All sensors in Resourcesat-2 are of multispectral, except for L-4 mono mode operation. Standard products are evaluated for their co-registration of spectral bands. Band to Band misregistration (BBR) after geometric corrections is computed either by mean bias correlation method or by Sequential Similarity Detection Algorithm for image matching.

Satellite data is expected to have overlaps between scenes (with in a satellite trace and in between multiple traces) to facilitate the user requests for large area coverage Ex. District/State/Full India mosaic products. Since overlap/sidelap change because of orbit perturbations, these parameters are periodically monitored. Common area in across track direction between two consecutive adjacent pass data is the sidelap and in along track direction is the overlap.

7.1.1.1 New Elements with respect to Resourcesat-1

Odd and Even detectors of Resourcesat-2 Liss-IV sensor are staggered with 5.2 pixels in along track direction. On stagger corrected (Level-1) product residual stagger will be computed. The image matching approach has been adopted for the estimation of residual stagger. Rational Polynomial Coefficients (RPCs) provided with Ortho-Kit products are also evaluated .These two parameters are the new elements with respect to Resourcesat-1.

In nutshell, GDQE is performed to certify the location accuracy, internal distortion, scale, residual Roll, Pitch and Yaw (RPY), BBR, sidelap/overlap for each sensor and residual stagger estimation for Liss-4.

7.1.2 Radiometric Data Quality Evaluation (RDQE)

Radiometric evaluation of image data confirms the detector performance in terms of sensitivity to the lab measurements. Basic parameters that can be evaluated are scene-based parameters such as scene-dynamic range, histogram generation and target-based parameters such as mean, standard deviation, signal-to-noise ratio, radiance value and apparent reflectance values are computed on stable targets and various Calibration/Validation (CALVAL) sites to characterize the stability of the payload sensors. These parameters are evaluated on both level-0 and level-1 products for Look-Up-Table (LUT) verification and analysis. Conventional radiometric evaluation will be done on Level-1 product. Data saturation, noise levels, artifacts and bad/degraded detectors are monitored and provided as feedback to Data Product Generation System (DPGS) for updating LUT.

7.1.3 In-Flight Calibration Data Quality Evaluation (CAL DQE)

In-Flight Calibration data quality evaluation is used to monitor the individual detector performance throughout the mission life. Using internal light source to illuminate the sensors calibration data will be transmitted. Two different onboard calibration schemes were adopted in this mission namely variable exposure based and cal pulse based. Middle infrared (MIR) band of Liss-3 and AWiFS sensors are calibrated in cal pulse based scheme, visible and near infrared (NIR) bands of Liss-3,Liss-4 and AWiFS cameras are calibrated in 16 level variable exposure scheme. Same calibration mechanism was followed in Resourcesat-1. Onboard Calibration data will be transmitted with onboard compression include mode only. Unlike Resourcesat-1, calibration data will not be available in onboard compression by-pass mode.

First-day In-Flight Calibration data will be compared with Ground Check Out (GCO) and Thermovac data recorded in the laboratory during LTC (Light Transfer Characteristic) for the operating temperature to ensure validation of onboard data with reference to ground measured data. In the operational period, first-day calibration data is made as Ground Reference for the future data sets for that temperature.

Data quality evaluation software generates two kinds of validation parameters called Global parameters and Cycle parameters. Global parameters like total number of cycles, Low Bit rate Telemetry (LBT) data sample temperatures, Start Ground Receive Time (GRT), Sync status, Start line count and cycle quality tag are computed for total CALIBRATION pass.

In operational scenario, cycle parameters are computed for the array level and detector level mean, standard deviation, signal-to-noise ratio, standard error and relative error for each exposure. Deviation of mean value from first-day data is considered as standard error. Deviation from previous orbit data is considered as relative error.

Chi-Square analysis is performed on each detector to certify the performance. If the Chi-Square value is less than the threshold value, the performance of the detector is said to be same as observed on ground or with previous set of data otherwise, reported as flagged/ degraded detector.

7.1.4 Near Real Time Histogram Analysis (NRTHA)

The basic purpose of this analysis is to start the quality-check at the time of the data reception itself, so that an early alarm about any kind of anomaly can be generated in advance to the processing of the data to generate the end product. This package is integrated in data-processing chain and is a fully automatic approach. Basic steps involved are histogram file collector, histogram file analyzer, report generation and database updation.

All parameters evaluated during GDQE, RDQE, CALDQE and NRTHA are stored in oracle database and maintained even after mission life time. DQE is responsible for generating daily, monthly reports and sent to mission. To analyze the sensor behavior statistically, DQE results will be retrieved, periodic and special reports will be generated using trend analysis. CAL ground references and radiometric reference images will be made available in DQE data base for regular use.

7.2 Product Quality Control

All data products are subject to stringent quality measures before dispatch to users. Only good quality products – both digital data and photographic prints – are supplied to the users after ensuring that they meet a set of predefined quality criteria. All imagery is inspected for acquisition and data processing related issues. Photo products are also verified for adherence to engineering parameters and other photo processing related issues.

7.2.1 QC Criteria for User products

General Criteria

- Ensure that the correct product has been generated (scene details, projection, datum, resampling, resolution, format, etc)
- Good radiometric quality (products should be free from severe vertical striping, noise,
- Artifacts, jitter, radiometric imbalances, etc)
- Scattered pixel dropouts should not affect more than 5% of the total area
- Data loss should not exceed one scan line
- There should not be any image distortions or breaks affecting the continuity of data
- Geometric quality should be as per specifications
- BBR (for color images) should be within specifications

7.2.1.1 QC Criteria for Photo Products

By default, B/W and Colour photo products are generated by the LPP (Laser Photo Printer) facility. All the photo products are visually inspected and graded as accepted or rejected. The rejected products are either reprinted or put back to DPS for regeneration. Certain uncorrectable cases are routed to NDC for an alternate date. All photo products should conform to the following criteria:

- The engineering parameters (Dmax, Dmin, Colour Balance, etc) should be within specifications
- Correct annotation Details, Grid, Tick Marks and Scale
- Photo processing defects such as roller marks, scratches, fog, dust, finger prints, etc., should not affect the interpretability and aesthetic quality of the image.
- There should be sufficient image contrast and density so that the photographic products can be interpreted easily.

7.2.1.2 Specifications for Photo Products

Parameter	B/W	Color
D Max	≥1.90	≥2.30
D Min	≤0.15	≤0.15
Color Balance	-	- ≤ 0.1D at 1.0 D
Scale	as specified for the particular product type and sensor	

7.2.1.3 QC Criteria for Digital Products

All Digital images are displayed in full resolution and a 100% visual check is carried out. In addition to the general criteria mentioned above, digital products should conform to the following:

- Radiometric quality specifications
- Area coverage, mosaicing problems (for special products)
- Geometric Quality specifications: to ensure the location accuracy of the products.

7.2.2 Photo QC Procedures

All Photo paper prints are dispatched to the users after being duly certified by QC. Each paper print is accompanied with the corresponding digital data. QC carries out the following checks in order to ensure that the photo products are of good quality:

7.2.2.1 Engineering Parameters check

Photo products are checked for Density maximum (D_{max}), minimum (D_{min}) and linearity of gray scale (10% of total prints received) using a calibrated Photographic Reflection Densitometer.

7.2.2.2 Radiometric & Visual Check

All photo products are inspected visually for:

- Presence of Artefacts, image distortion, striping, noise
- Check for mosaicing problems, resampling
- Check for any sensor and data processing related problems
- Contrast, brightness
- Tone reproduction
- Aesthetic / interpretable quality
- Fog, Scratches, roller marks, chemical marks, water scale marks, etc.,
- Any other photo processing / photo writing problems

7.2.2.3 Geometric Check

All Photo products are checked for area coverage (in terms of Lat./Long.), location accuracy and photographic enlargement.

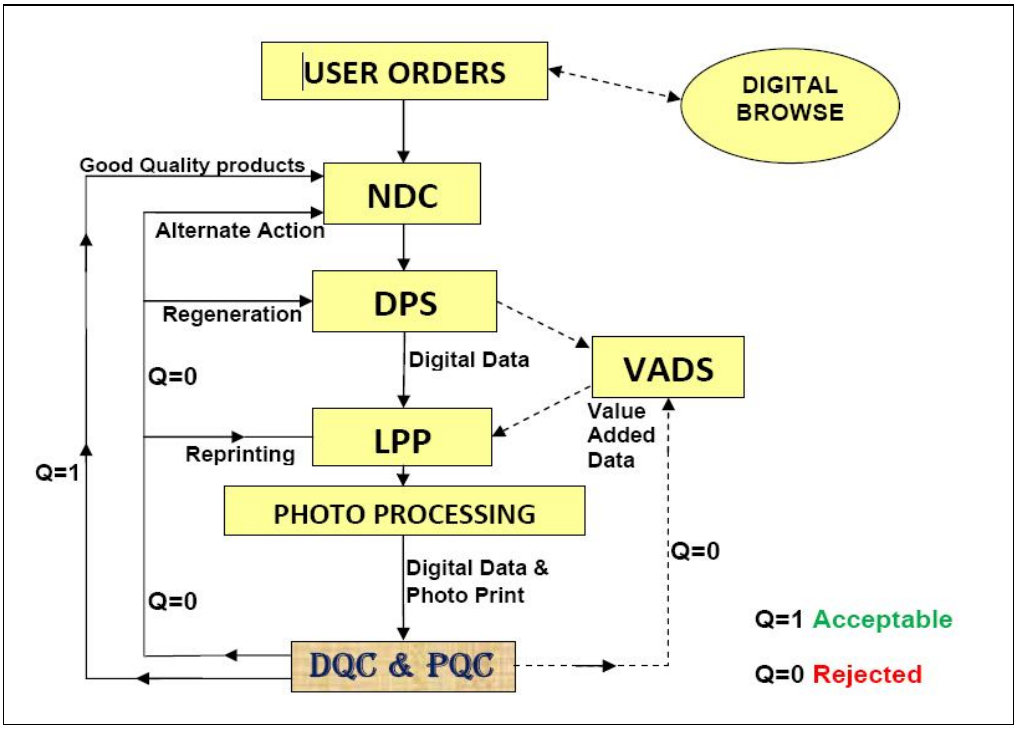


Fig. 7.2 Flow Chart for QC of photo products

7.2.3. Digital QC Procedures

All data generated at data processing (DPS) and Special Products (VADS) work centers are routed to DQC for certification.

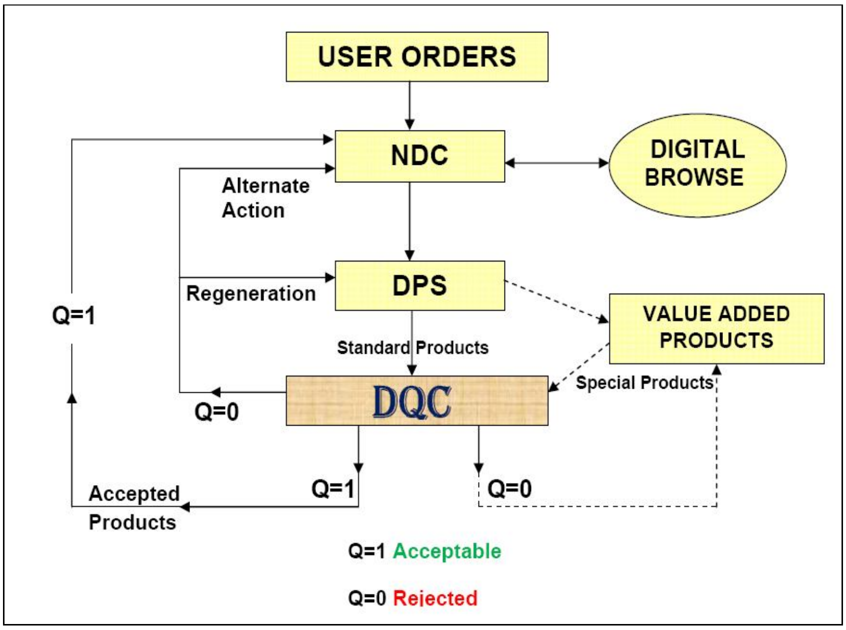


Fig. 7.3 Flow Chart for Generation of Digital products

The following parameters are checked for all types of products:

7.2.3.1 Product Correctness

Format, readability (media) & completeness (header file contents, scene details, length of records)

7.2.3.2 Radiometric Check

100% visual check is done to ensure good radiometric quality of each product. Every part of the images is actually displayed and viewed in full resolution (1:1 display) with options to roam and zoom wherever required. Most commonly checked parameters include:

- Presence of artefacts, line/pixel dropouts, sync losses, distortions/breaks
- Striping, noise, staggering, jitter
- Radiometric imbalances
- Mosaicing-related problems (value-added images)
- Other sensor and data processing related problems

7.2.3.3 Geometric Check

All digital products are checked for correctness of datum, projection, resampling, resolution, scene centre, area coverage (in terms of Lat./Long.),etc.

7.2.3.4 BBR

QC ensures that the bands of a colour image are well registered. The Specifications are:

- < 0.25 pixels between bands 2 and 3
- <0.40 pixels between bands 2 and 4

7.2.4. QC Certificate

All accepted products are supplied to the users with a QC certificate. The certificate contains details of the scene and data quality rating along with remarks.

NATIONAL REMOTE SENSING CENTRE

PRODUCT QUALITY CONTROL CERTIFICATE

Request No.   Account No.   Product Type:

Format:

Scene Details:

Geometric Accuracy:

QC Rating: Accepted/Rejected   Reasons, if Rejected:

Remarks:

QC Date: QC by:

Chapter 8

DATA ACCESS AND DISTRIBUTION

8.1 Introduction

User **O**rder **P**rocessing **S**ystem (UOPS) which is an integrated web based application enables the user to register, browse and select the satellite images, perform account related transactions, place orders and monitor the order status. After browsing the images using the various queries and selecting the scenes, users can place the orders using the ordering tolls. Facility to obtain the status of user accounts and the orders placed is also available online. Registered users can also change their details like address and their login password and send general queries through e-mail.

Upon connecting to the NRSC User order processing system site, the user is presented with a page with various links which enable the user to navigate through the application. If the user is new, he has to register himself for the ordering service to be enabled. While registering, the user has to agree to the terms and conditions displayed. A registration form is displayed in which he has to provide details like name, user identification (uid), password, user category, mailing address etc.,. The uid and password can be used as shown in Figure 8.2 for future logins.

If the user is a registered user, he can sign in with his uid and password and enable the services.

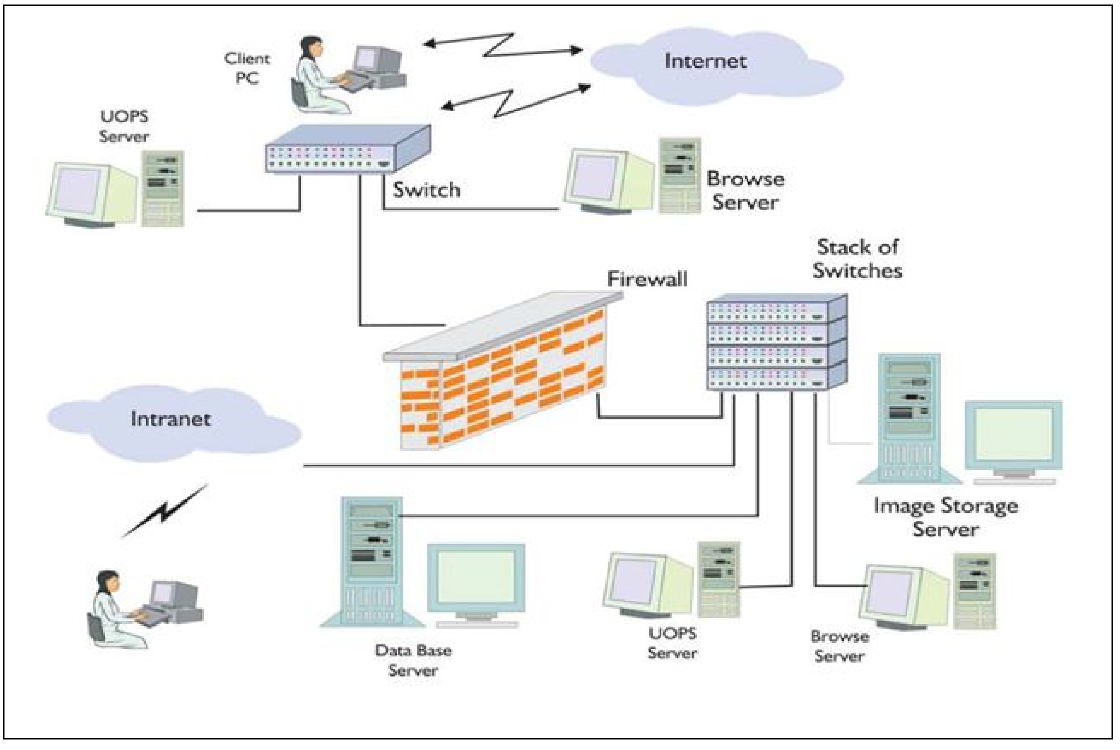


Fig. 8.1 Block diagram of User Order Processing System

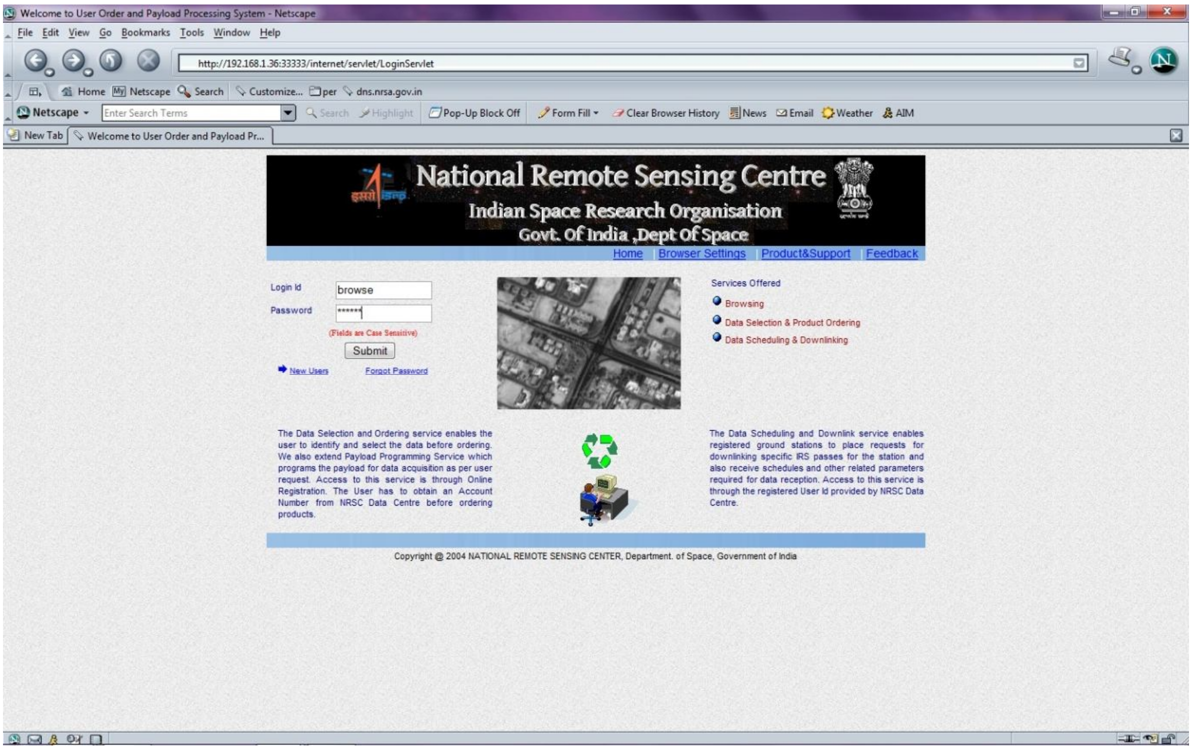


Figure 8.2 UOPS opening page

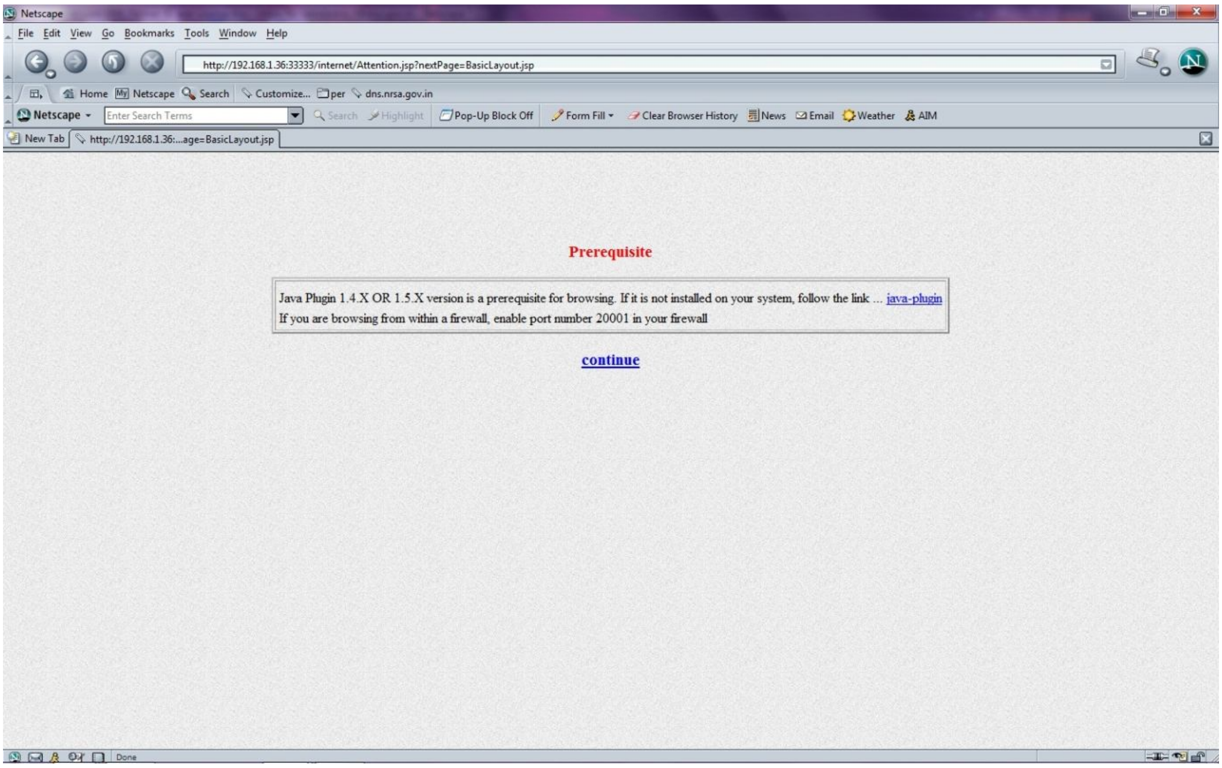


Figure 8.3 Pre-requisites

8.2 Browsing Services

Browsing services is a pre-requisite information provided to the users for converting the required area of interest into scenes and checking the data availability for the required area of interest. Before placing an order for data, the users need to browse through the data, to check for cloud and quality of the data. To meet this requirement, NRSC generates sub-sampled and compressed browse images along with necessary ancillary information. This facility is made available to users through Internet. The Browse facility has been integrated with data ordering and payload programming systems. Data can be browsed online and suitable scenes can be selected and converted into and data request by registered users who have an account with NDC. The different means of searching the image catalogue are :

- Polygon
- Mapsheet
- Location
- Point
- Shape file.
- Date
- Path

Any one of these means can be selected as per the user convenience.

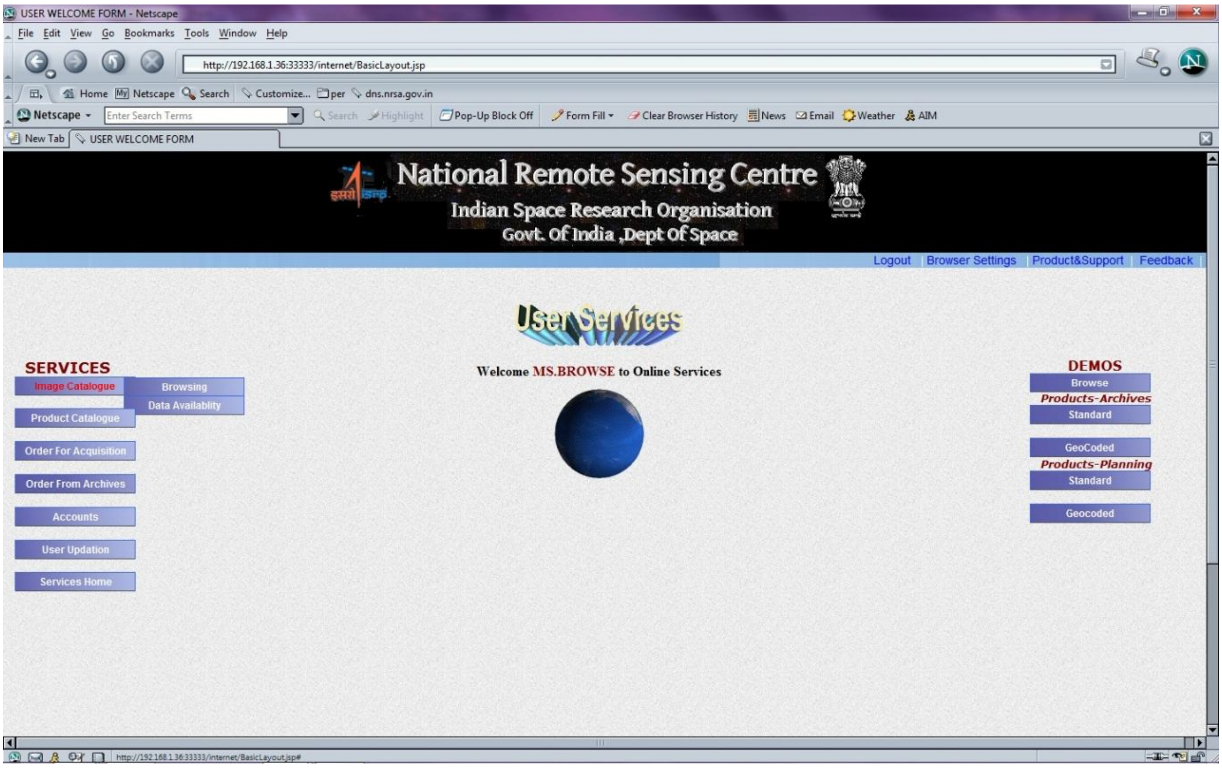


Figure 8.4 Browsing services

8.2.1 Polygon based query

This option is useful to browse the images for a given geographical area. Users can input their area of interest either in terms of latitude/longitude in degrees, minutes, seconds or degrees decimal format of top left and bottom right corners as shown in figure 8.5 or draw the area on a map with the help of mouse. On submitting the query, a form requesting the user to enter the period of interest is displayed. Sub- sequently, a list of scenes covering the user's area of interest during the desired period, along with a graphical plot is displayed as shown in figure 8.6. The user can then, view the images selected along with the layout of the scenes overlaid on the given area using the plot option.

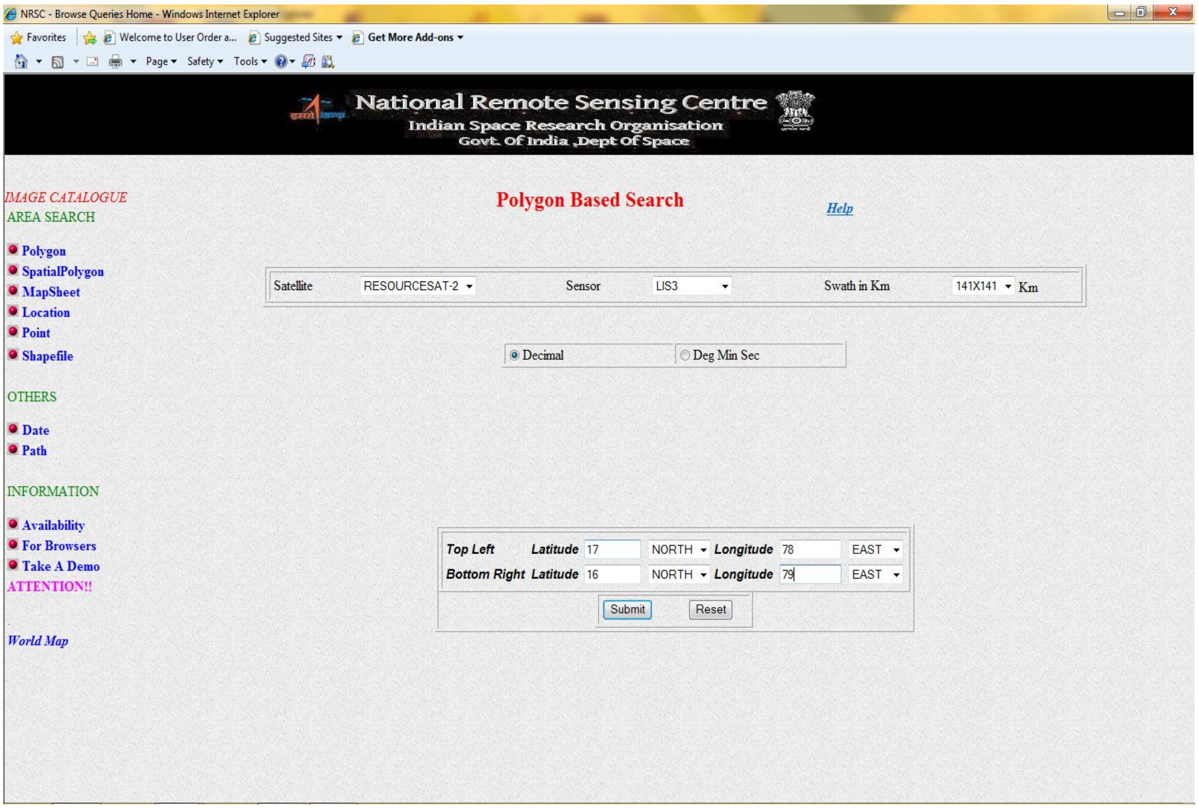


Figure 8.5 Polygon based search

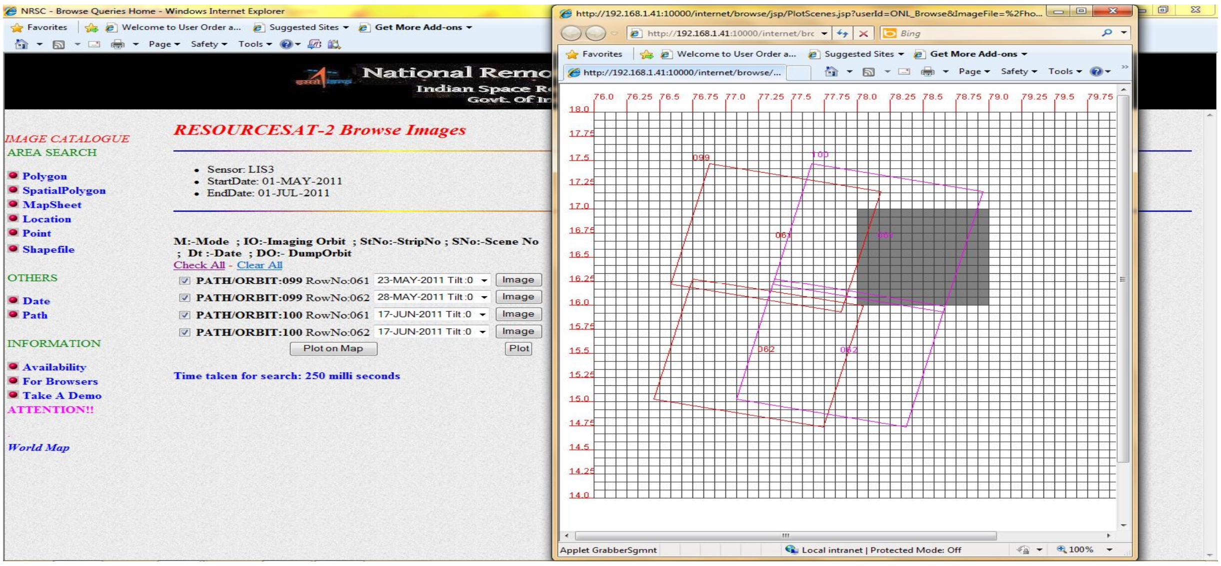


Figure 8.6 Layout of scenes over the area of interest

8.2.2 Mapsheet based query

Map sheet based products are one of the most popular products. So provision to query by map sheet number has been provided to facilitate easy querying by the user. In this case, apart from satellite, sensor, user has to select the map sheet number, either in open series map or as per the old SOI mapsheet numbers as shown in figure 8.7. On submitting the query, a form asking for the desired period is presented. On submitting, a list of scenes covering the map sheet, during the desired period, along with a graphical plot, is displayed. The user can then view the images and select.

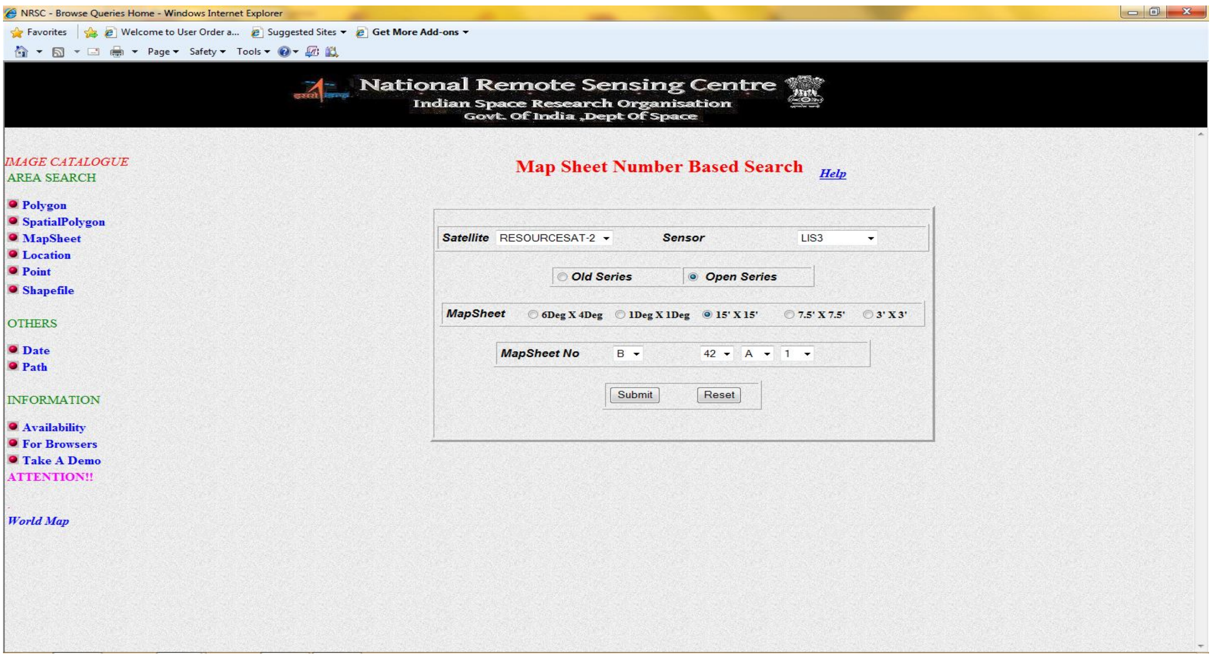


Figure 8.7 Mapsheet based search

8.2.3 Location based query

In case the user does not know anything other than the name of the location, he can use this query to browse the images covering the place during the desired period as represented in the figure 8.8. The inputs to be provided by the user are satellite, sensor and the name of the place. The user is presented with the details of the scene covering his place and on what dates it was covered. The user can then, view the images along with the graphical plot and select.

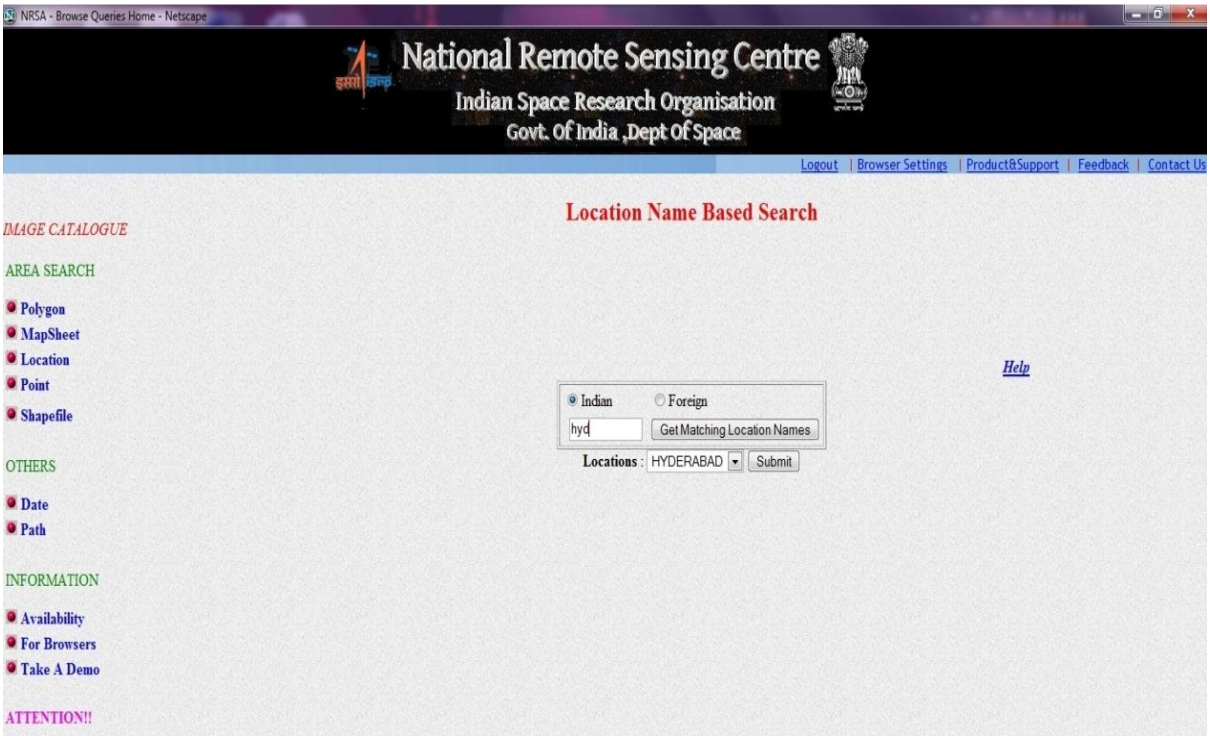


Figure 8.8 Location name based search

8.2.4. Point (Lat-Long) based query

This query takes latitude and longitude of a single point and it maps to a square based on the extent chosen. This query is useful if particular area around a point is to be viewed as in the figure 8.9. User has to select the satellite, sensor, enter latitude and longitude of the point in degrees minutes seconds or degrees decimal format and choose the extent of region desired. The extent of the region varies w.r.t. the sensor. On submitting the query, a form asking for the desired period is presented. On submitting, a list of scenes covering the extent with the point as center, during the desired period, along with a graphical plot, is displayed. The users can then, view the images and select

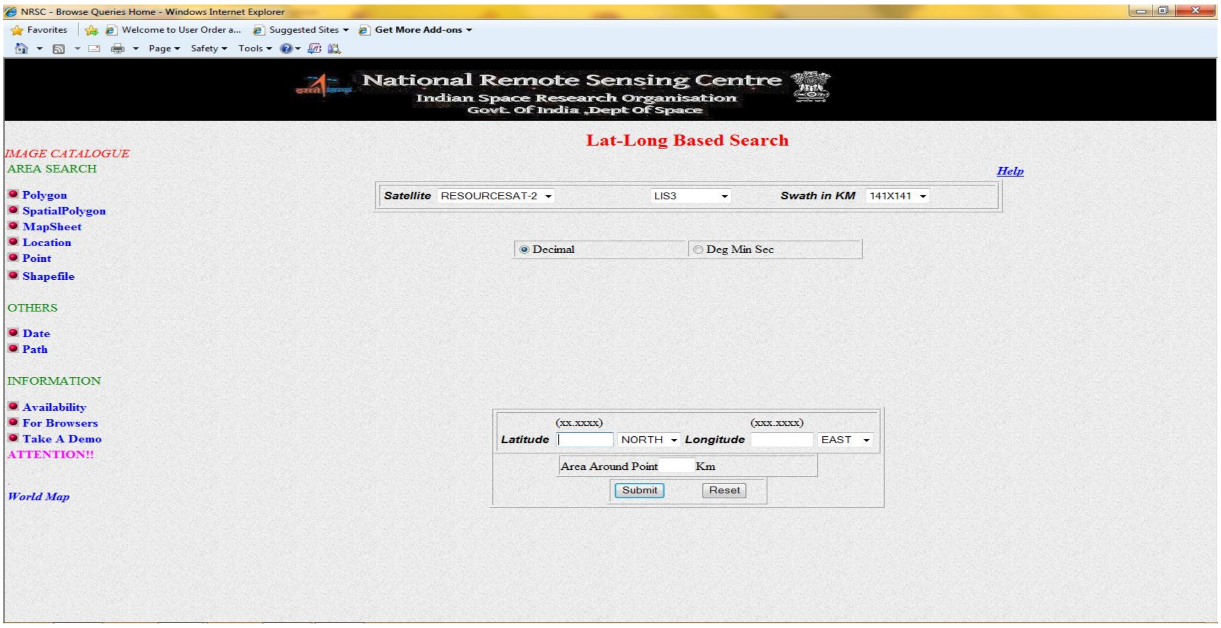


Figure 8.9 Point based search

8.2.5 Shape file based query

This query as shown in the figure 8.10 is useful for viewing the images dates when the input is in the form of a shape file generated in arcview format with geographic co-ordinates. The maximum number of points required in constructing the shape file should not exceed 10,000 . Users have to choose the satellite and sensor and submit along with the shape file in WGS 1984 Geographic /UTM projection only. On submitting, a list of scenes covering the shape file is displayed. Provision for viewing the selected scenes plotted on the shape file is also provided. The users can then view the images and select.

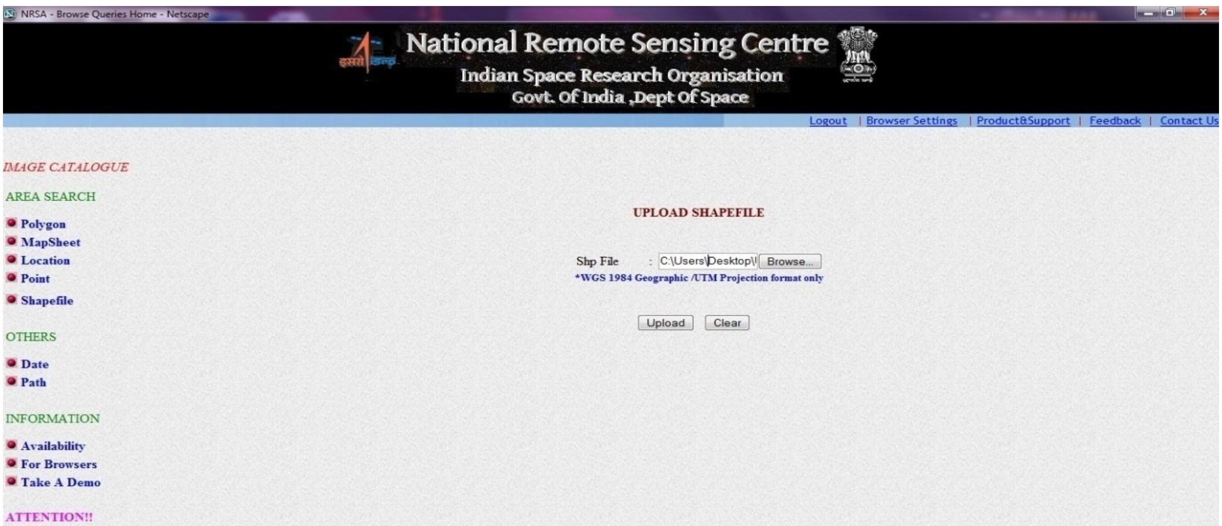


Figure 8.10 Shapefile based search

8.2.6 Date of pass based query

This query is useful if the user wants to browse the images for a specific date. Users have to choose the satellite, sensor and the date of pass in dd-mm-yyyy format. On clicking the path guide, the list of paths acquired for that day, satellite and sensor are displayed. Users have to select the desired path and enter the number of rows for which he would like to browse the scenes as shown in figure 8.11 and then submit. On submitting the desired scene details, the image along with meta information is displayed.

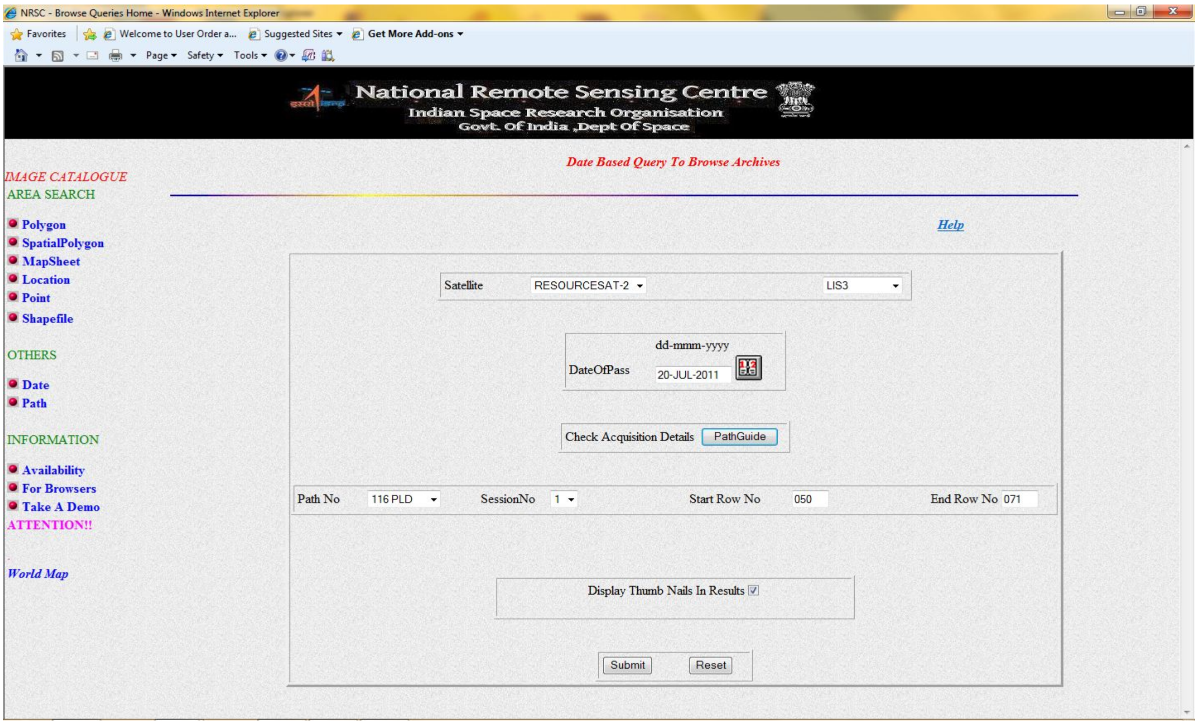


Figure 8.11 Date based search

8.2.7 Path based query

This Query is useful for viewing the images pertaining to a given path acquired on different dates. Users have to choose the satellite and sensor, enter path, start row, number of rows and date range (Start-date and End-date) in dd-mmm-yyyy format as shown in figure 8.12. On submitting the query, a list of dates on which the desired path and rows have been acquired, are displayed. On selecting a date, details of the scenes are displayed.

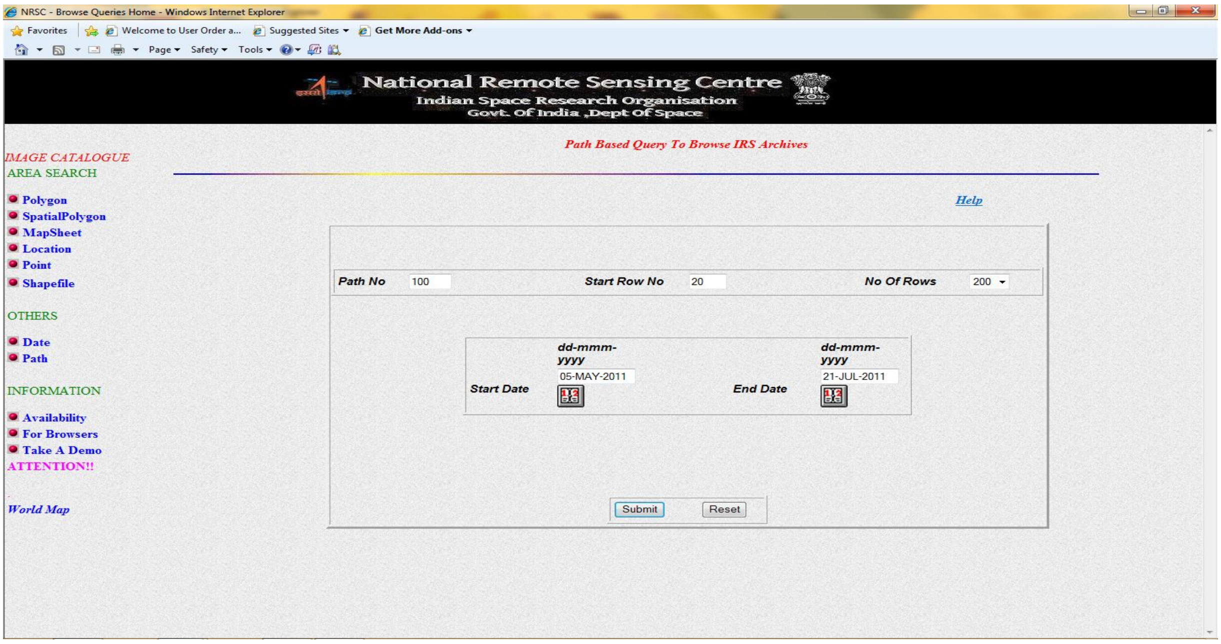


Figure 8.12 Path based search

8.3 Data Ordering

Existing users can place their data orders online either from the archives or for the fresh acquisitions. The data thus selected using any of the services described above available for browsing can now be converted into an order by selecting "Order from Archives". In case if the data is required for the fresh acquisitions, then "Order for Acquisition" has to be selected as demonstrated in figure 8.13.

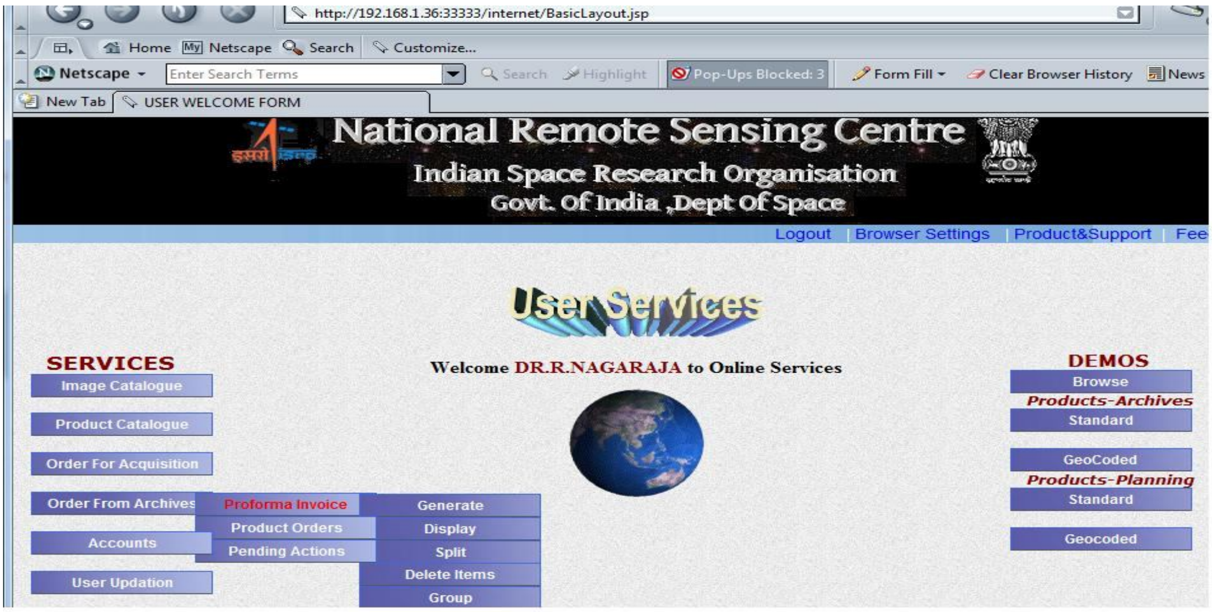


Figure 8.13 Online Services

All the scene details thus derived from the browsing can be created into a proforma invoice. An online ordering is provided to guide the users. The following steps are involved for proforma invoice creation.

❖ After selecting the proforma invoice and then the generate option, submit the appropriate inputs regarding the order type, satellite, scene type, sensor, selection type and product type.

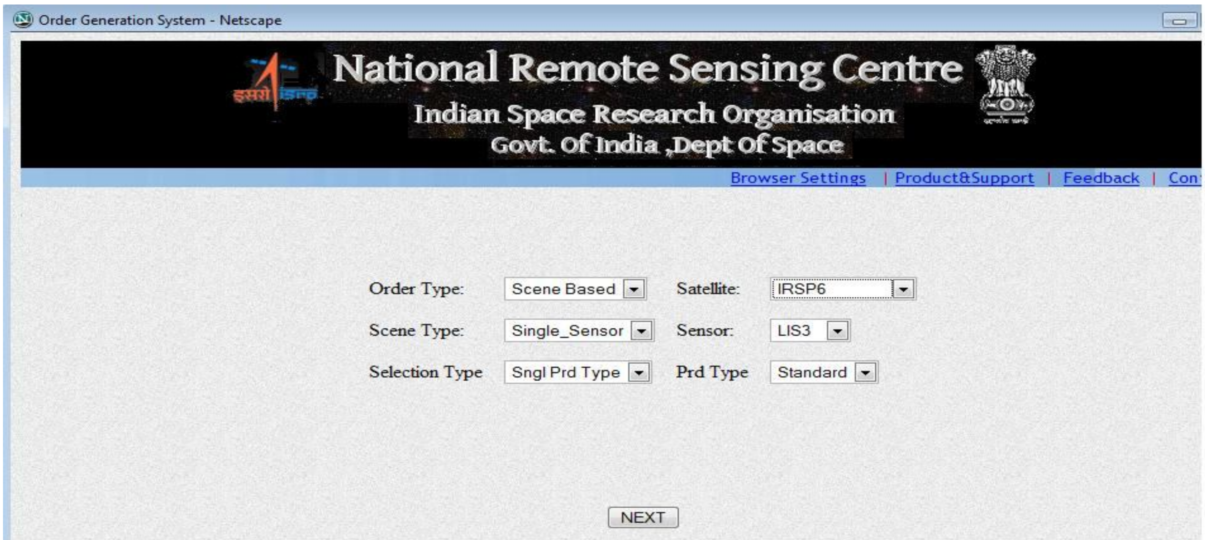


Figure 8.14 Submission of product details

❖ Choose the required option for data selection and provide the necessary inputs corresponding to the data option selected. The various options are similar to that of the options presented in the browsing tools. The details of which are presented in figure in 8.15.

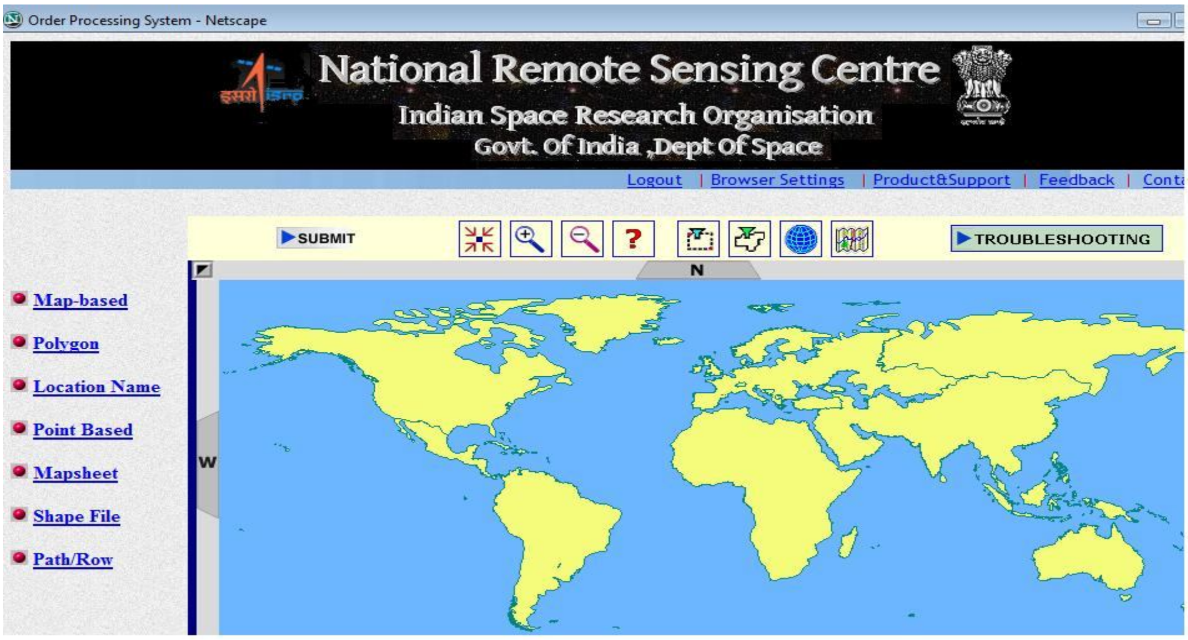


Figure 8.15 Different modes of submitting the area of interest

- A screen with the valid scenes as input will be provided as shown in figure 8.16. The scenes can be viewed for cloud and the plot either with or without out map overlay can be selected to verify the coverage of the selected scenes over the required area.

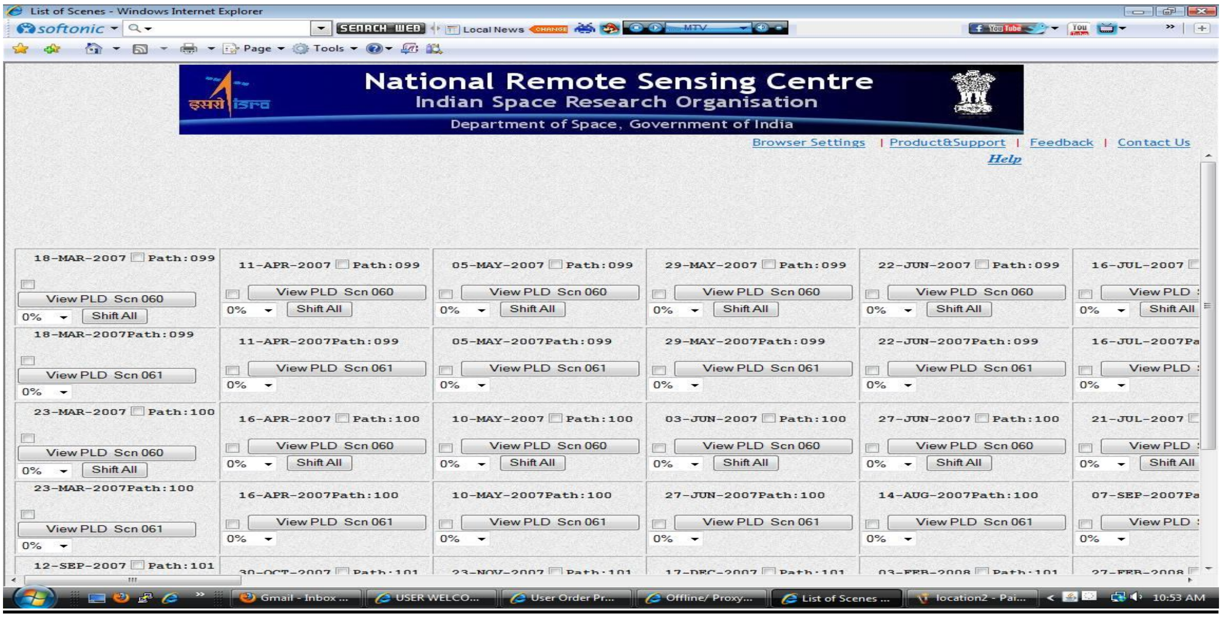


Figure 8.16 List of scenes

- The selected scenes are then displayed for order placing. There is an option to delete if any of the selected scenes are not required as shown in figure 8.17.

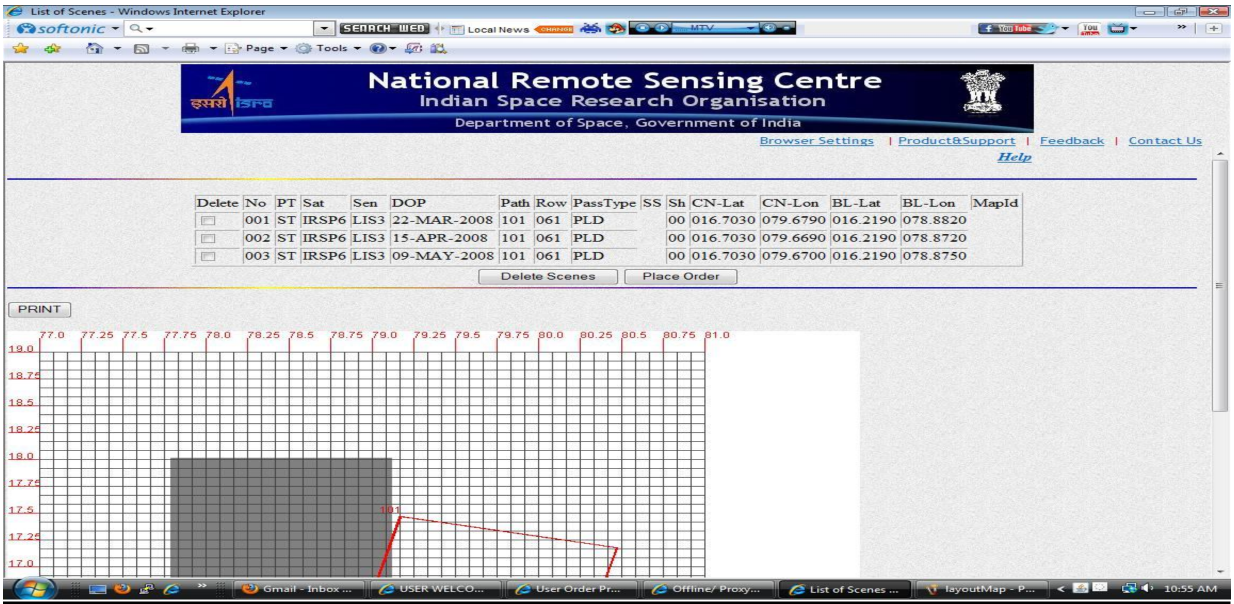


Figure 8.17 Option for product deletion

❖ Upon submission of the scenes, a form as shown in figure 8.18 appears requesting for the product type, projection, sampling, correction level, enhancement (for photo products), format (for digital products), media, datum, dispatch mode, priority and the quantity.

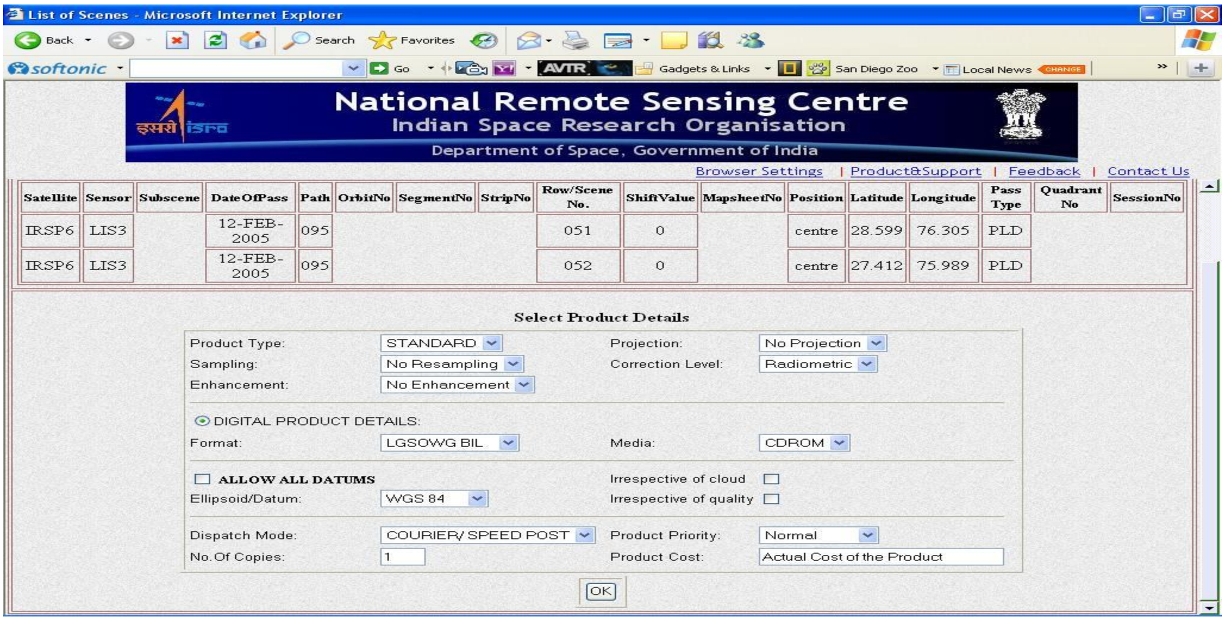


Figure 8.18 Selection of product details

❖ After confirming the above details, the user needs to generate the PI (proforma invoice) as shown in figure 8.19. Provision to append some more products in the PI also exists. User can update the order reference in the PI created. After storing all the required products in the PI, then submit “generate Order” as in figure 8.20. It is mandatory that, for order placing, the user has to place the request through his account.

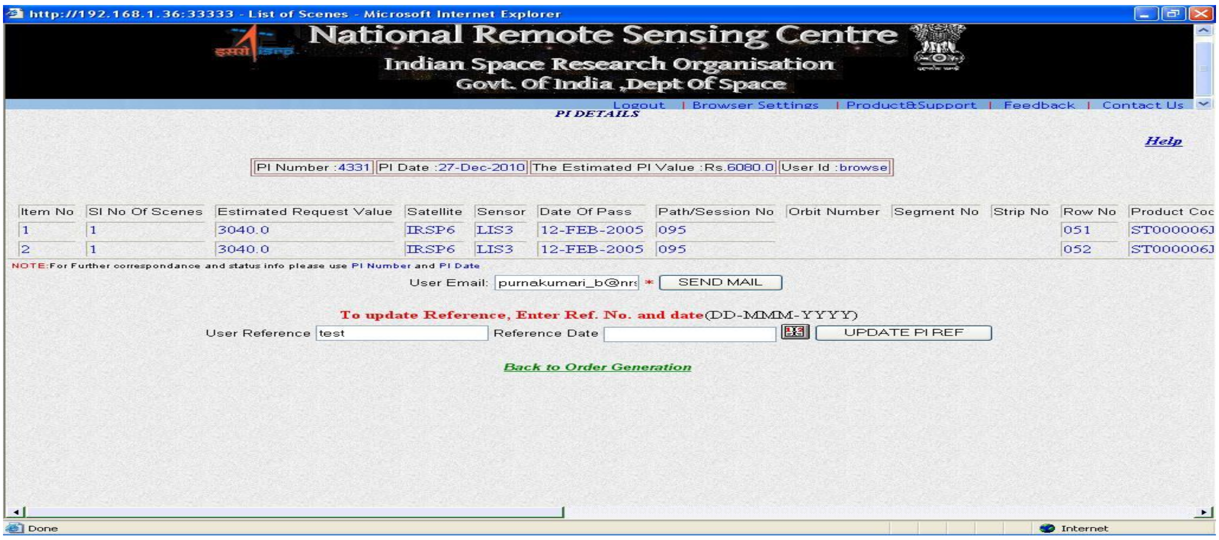


Figure 8.19 Proforma invoice details

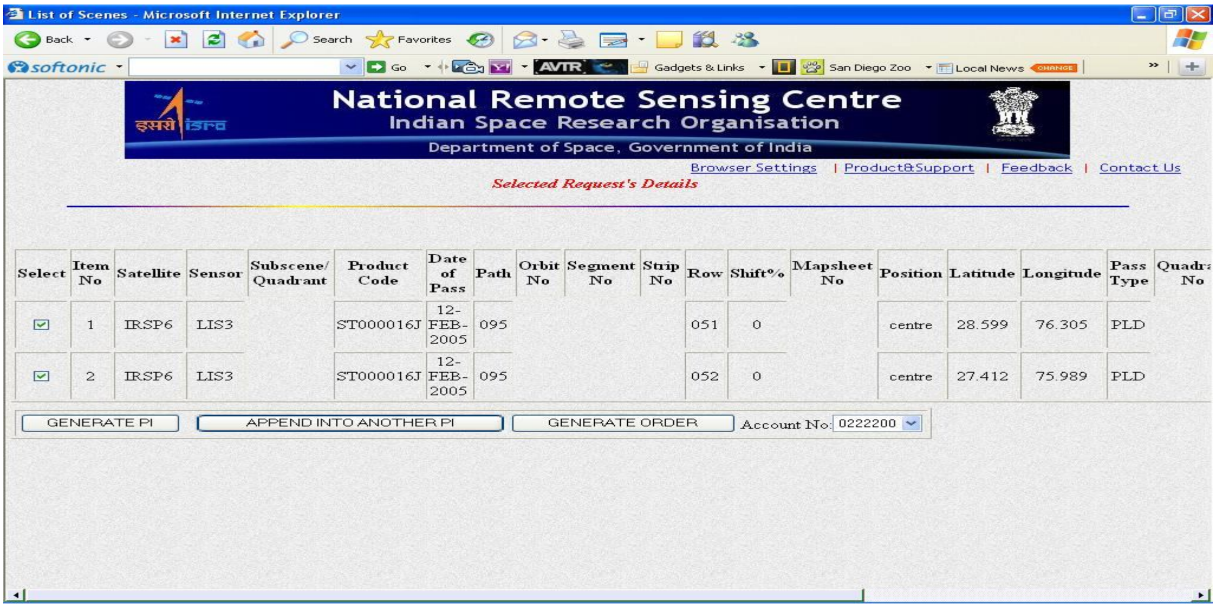


Figure 8.20 Selection of appropriate options

- After submitting the generate order, a unique request number will be generated as can be seen from the figure 8.21, by the system which helps in monitoring of the order status.

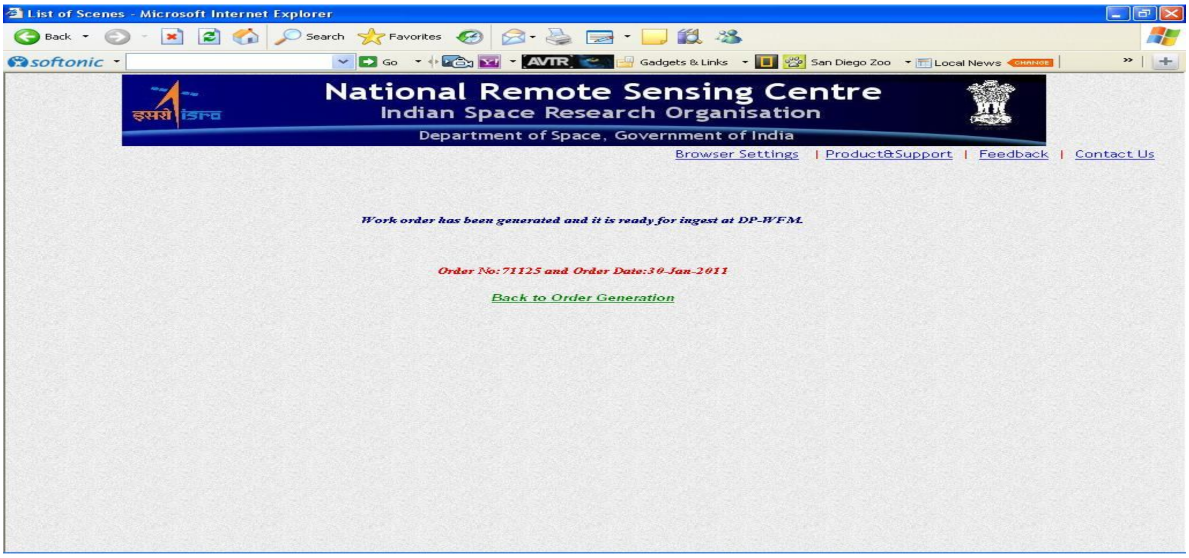


Figure 8.21 Workorder generation

- The other functionalities in the proforma invoice as shown in the figure 8.22 includes the display-which is useful to check the details of the proforma invoices created, split- a split an invoice if few products in that request are not required or are to be ordered at a later stage, delete items – to delete in any of the items in the proforma are not required and group – if multiple proformas needs to be grouped together.

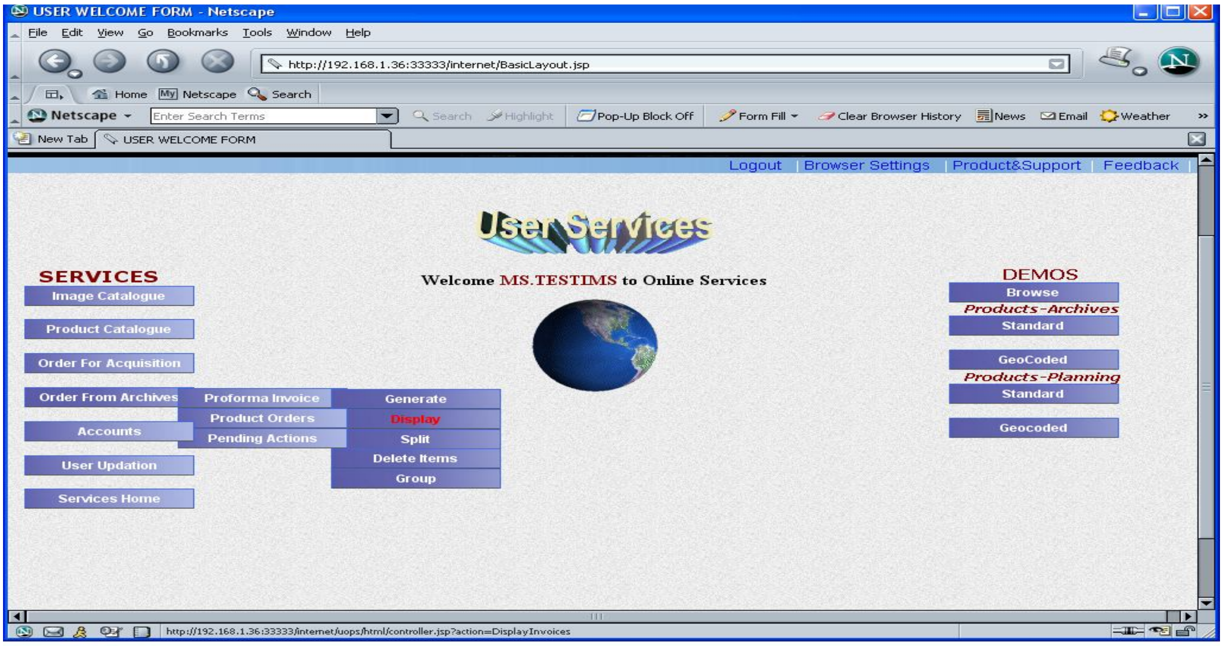


Figure 8.22 Functions related to proforma invoice

❖ Under the product orders, there are two utilities as in figure 8.23; convert PI to order – which is useful to convert the stored PIs into an order at a later time and the order status monitoring which helps the user to know the status of the order.

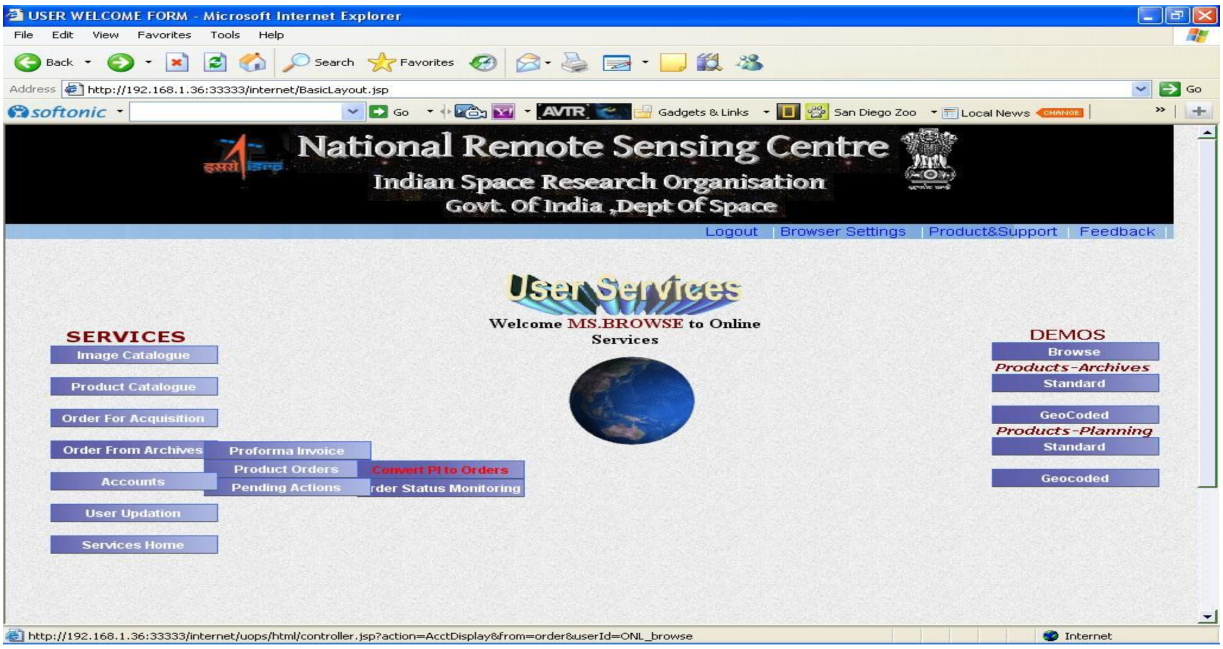


Figure 8.23 Product ordering

❖ In the order conversion, it is mandatory to have an online account through which the orders can be placed. The users having an online account can place their orders directly through their account for the stored PIs. New users can send their requests for online account to NDC using Accounts services as demonstrated in figures 8.24 & 8.25.

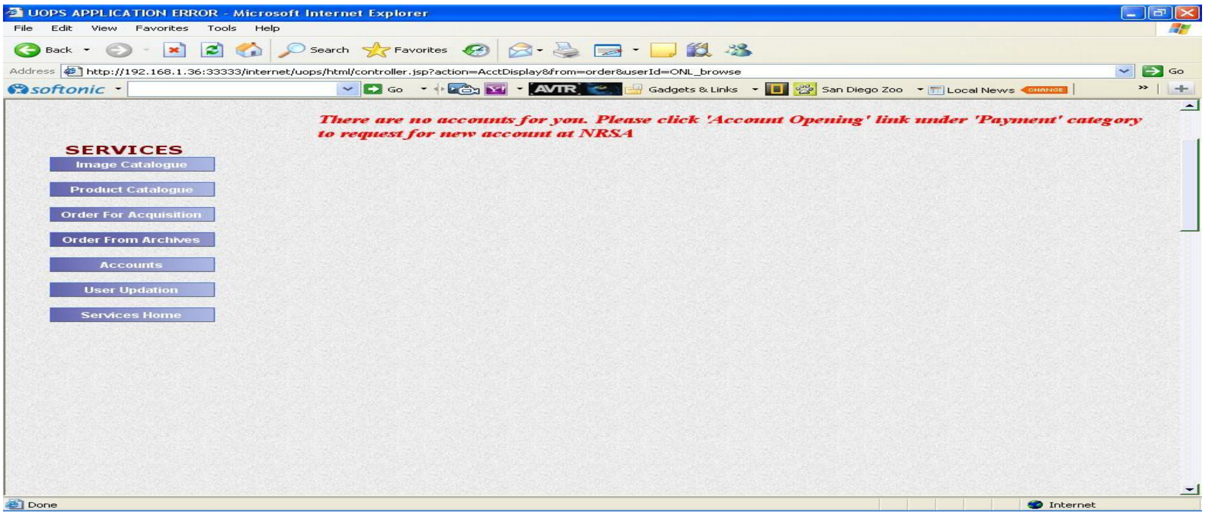


Figure 8.24 Account opening

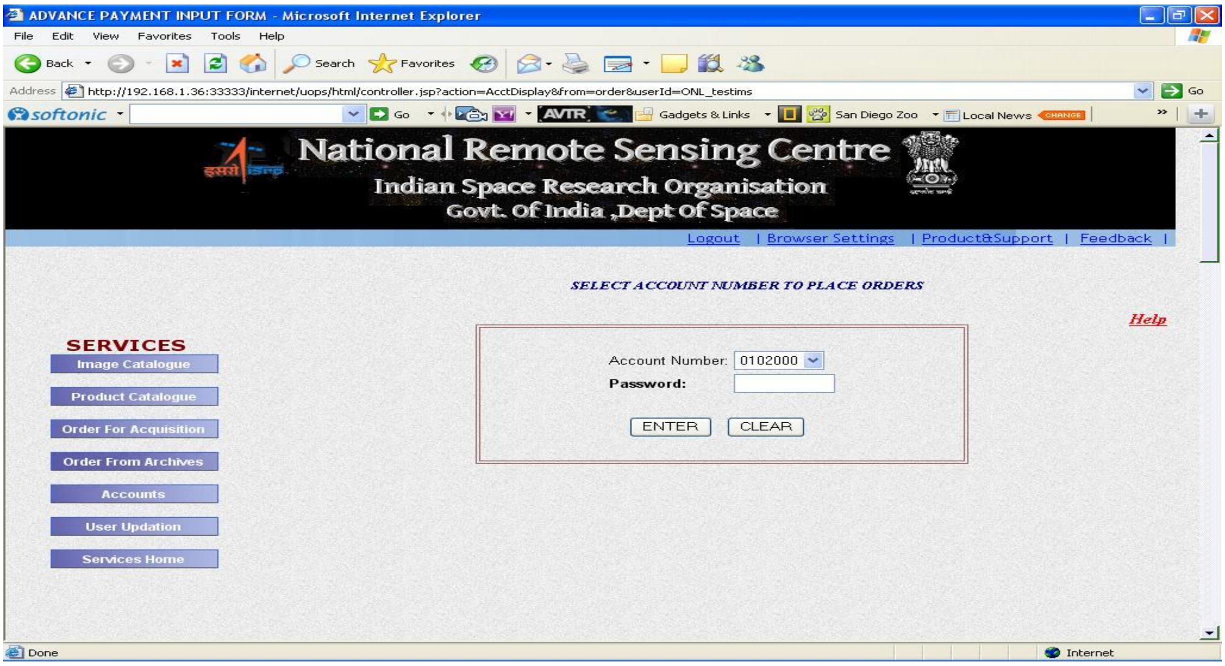


Figure 8.25 Account login for order placing

❖ After submitting the “convert PI to order” through the online account and before the order conversion, the shipping details are to be added as shown in figure 8.26. After the order generation, the request details, product details, etc., will be displayed as shown in figure 8.27.

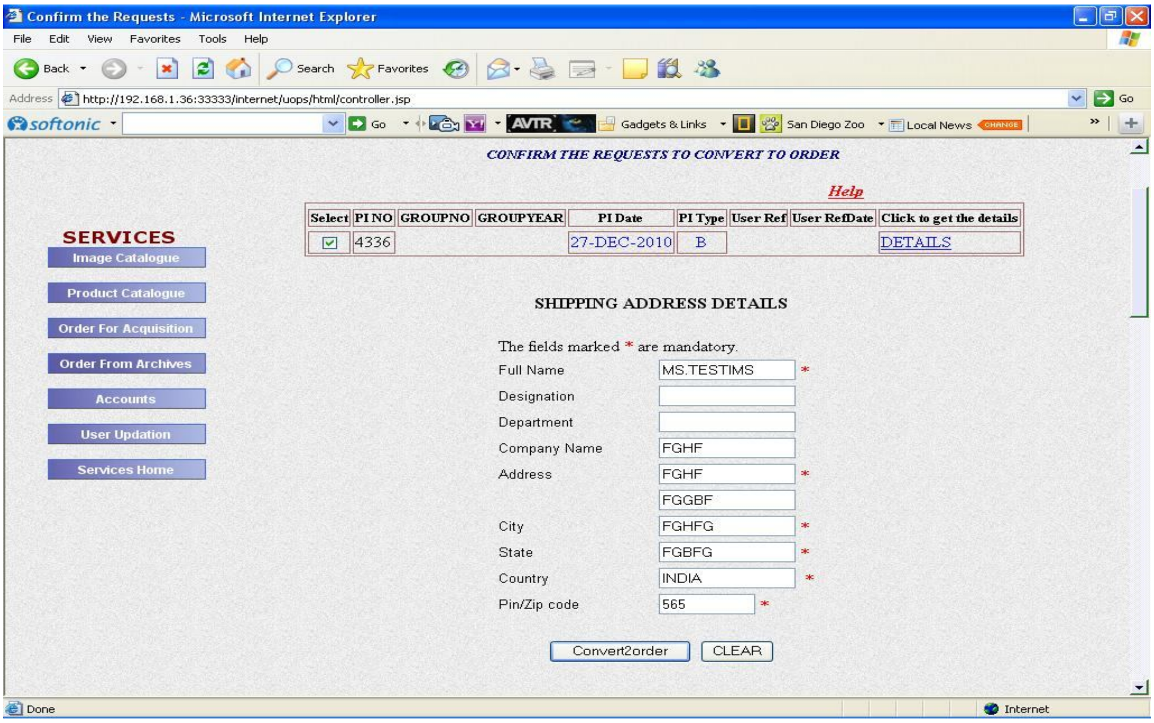


Figure 8.26 Addition of shipping address

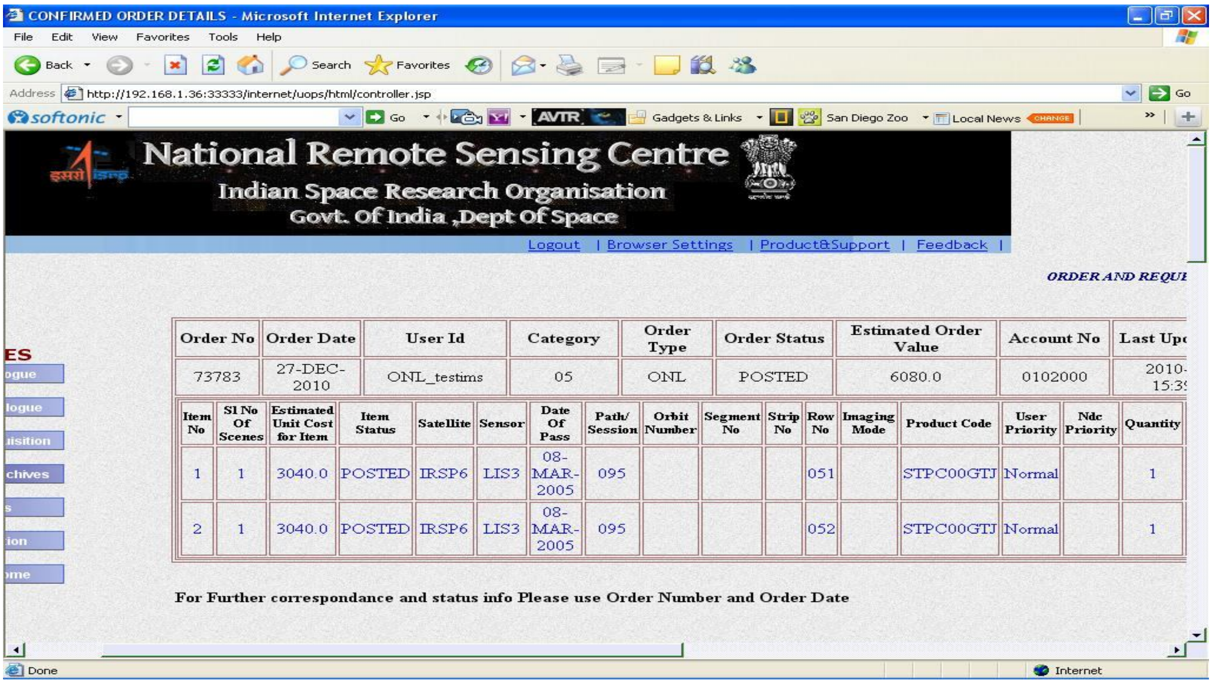


Figure 8.27 Order generation

❖ Using the order status monitoring tool, the status of the request can be viewed as shown in figure 8.28.

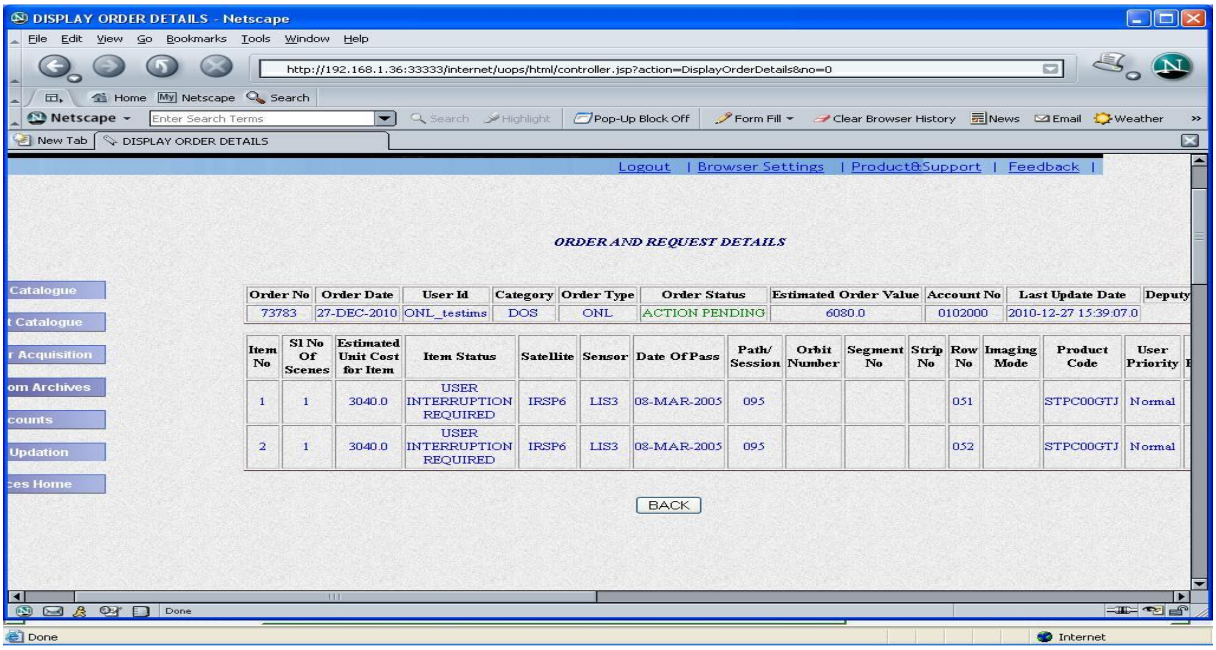


Figure 8.28 Order status monitoring

❖ After viewing the status of the products, in case if any of the product fails due to technical reasons, it can be re-generated by submitting a different date using the utility - Alternate date provided under pending actions as shown in figure 8.29.

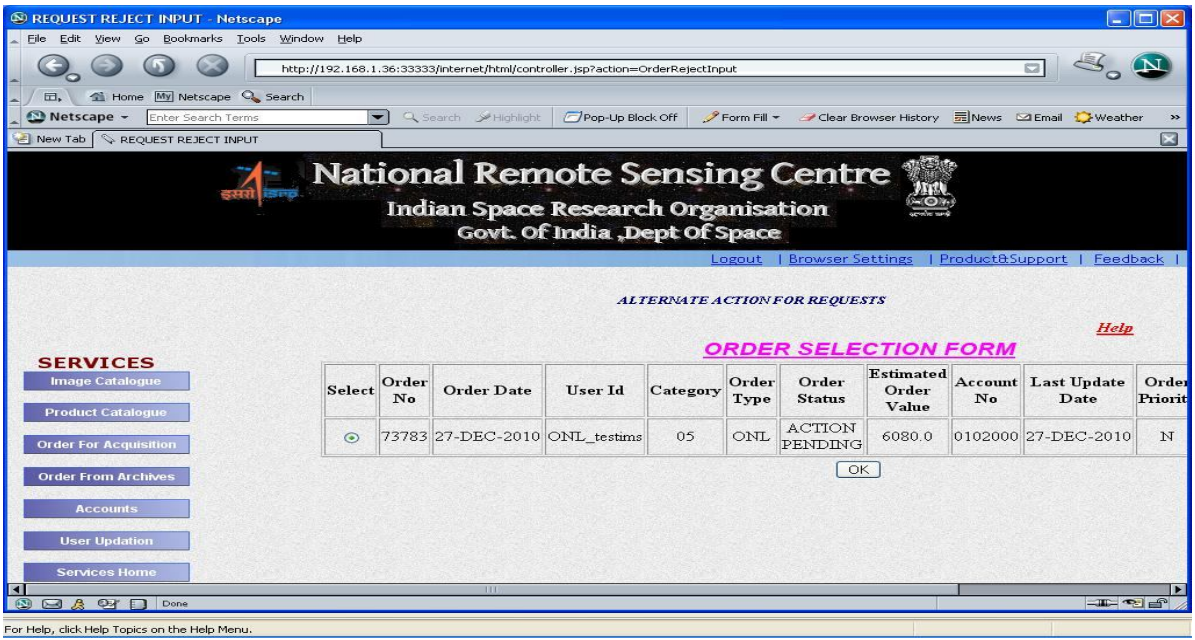


Figure 8.29 Requests for alternate date actions

8.3.1 Order Processing and monitoring on Intranet by NDC

An off-line user is one who has one or more account numbers with NDC but has been placing orders for data by filling the order form. Order processing facility on Intranet enables NDC to monitor, distribute, process and dispatch the generated products to the customers placed offline.

8.4 Payload Programming

8.4.1 Introduction

Resourcesat-2 Payload Programming System (PPS) accepts requests from Users and the several International Ground Stations (IGS) for their future requirements of Resourcesat-2 data acquisitions.

The satellite acquisition has to be programmed to meet

- ❖ The need for a systematic acquisition over the Indian Ground station at Shadnagar
- ❖ The data acquisition requirements of International Ground stations
- ❖ The User specific requirements which necessitates the tilting of Liss-IV camera or the use of the On-Board Solid State Recorder (OBSSR)
- ❖ The need for a systematic Global Archival of data

8.4.2. Resourcesat-2 coverage

The Resourcesat-2 orbit has a 24-day cycle, which means that LISS-III and AWiFS data is acquired over the same location every 24 days. LISS-III and AWiFS data over the Shadnagar ground station is collected regularly irrespective of user's request. LISS-IV Mx data over Indian landmass is acquired with 70 Km swath (Mx70) while all other areas globally is acquired with 23 Km swath (Mx23). LISS-IV camera is steered to about +2.1 and -2.1 in alternate cycles of 24 days to acquire LISS-IV A/C and B/D strips. LISS-IV acquisition over Indian landmass is completed once in 48 days. In the Mx70 acquisition mode, Band 3 data is transmitted in real-time to Shadnagar station. The corresponding Band 2 and Band 4 data of the 70 Mx are recorded on the OBSSR and are received at Shadnagar by one or more of the following ways

- ❖ Data is down linked immediately after the pass while the satellite moves over the ocean areas of Shadnagar visibility
- ❖ Data is transmitted to Mauritius ground station which is then transferred to Shadnagar by a 45 Mbps link
- ❖ Data is transmitted to Shadnagar during the night passes

Thus the complete acquisition of a LISS-IV 70 Mx pass can vary from a few minutes to about 12 hours.

LISS-IV camera can be steered up to ± 26^0 to provide a more frequent revisit cycle (Figure 8.30). This is particularly useful for acquisitions during emergencies (like disasters) or when the application is time sensitive or when acquiring an image on a specific date is important.

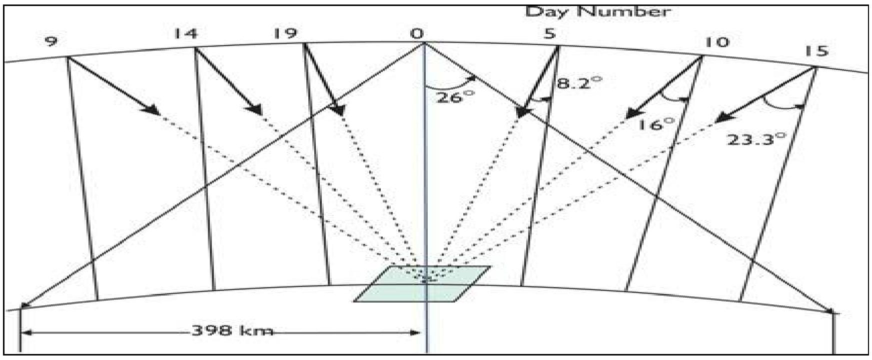


Figure 8.30 Steerability of LISS-IV camera

8.4.3. On Board Solid State Recorder (OBSSR)

Data over nearly any part of the world can be acquired by the OBSSR. There are two Solid State Recorders each having a capacity of 200 GB. One SSR of 200 GB caters to the recording of Band2 and Band4 data of 70 Mx data while the other SSR caters to the LISS-1V SMX, LISS-III and AWiFS requirements outside the visibility of the Shadnagar ground station.

8.4.4 Ground station requirements

In the Real-time mode, a Ground Station (GS) can acquire data of any/all of the three sensors viz. LISS-III, LISS-IVMx (23Km swath) and AWiFS.

8.4.5. Programming services

For future date acquisition, the satellite is programmed to collect data with a particular tilt, spectral mode and acquisition mode to service a user request. For many applications, the dates on which data is acquired are very important. For example in crop monitoring activities, acquiring data in specific times during crop growth cycle is essential. For such applications, it is advisable to plan data acquisition well in advance. However, if your turn around time is critical, we offer urgent programming, in which case the request is serviced at the earliest possible opportunity. Urgent Programming attracts an acquisition fee.

8.4.6. Programming Activities

Programming requests from Users and Ground Stations can be placed through the User Order Processing System (UOPS). These requests are consolidated at NDC and an optimal acquisition plan for every pass is planned. This plan is arrived at, depending on availability of satellite resources, on the priorities of the requests, and the constraints of the satellite.

- ❖ Daily schedules are generated one day before the date of pass and can accommodate any urgent requests.
- ❖ The command generation file is sent to Spacecraft Control Centre (SCC), ISTRAC at Bangalore one day before the pass, where the necessary commands for the satellite are generated.
- ❖ The schedules and the state vectors are sent to the Ground Stations every day, for acquisition of data.
- ❖ After acquisition of the pass, NDC informs the user on the status of acquisition. On successful acquisition, data is generated and supplied to the user.
- ❖ After acquisition of the pass, ground ststions inform NDC and SCC of anomalies if any.

An overall flowchart of the programming activities is shown in Figure 8.31

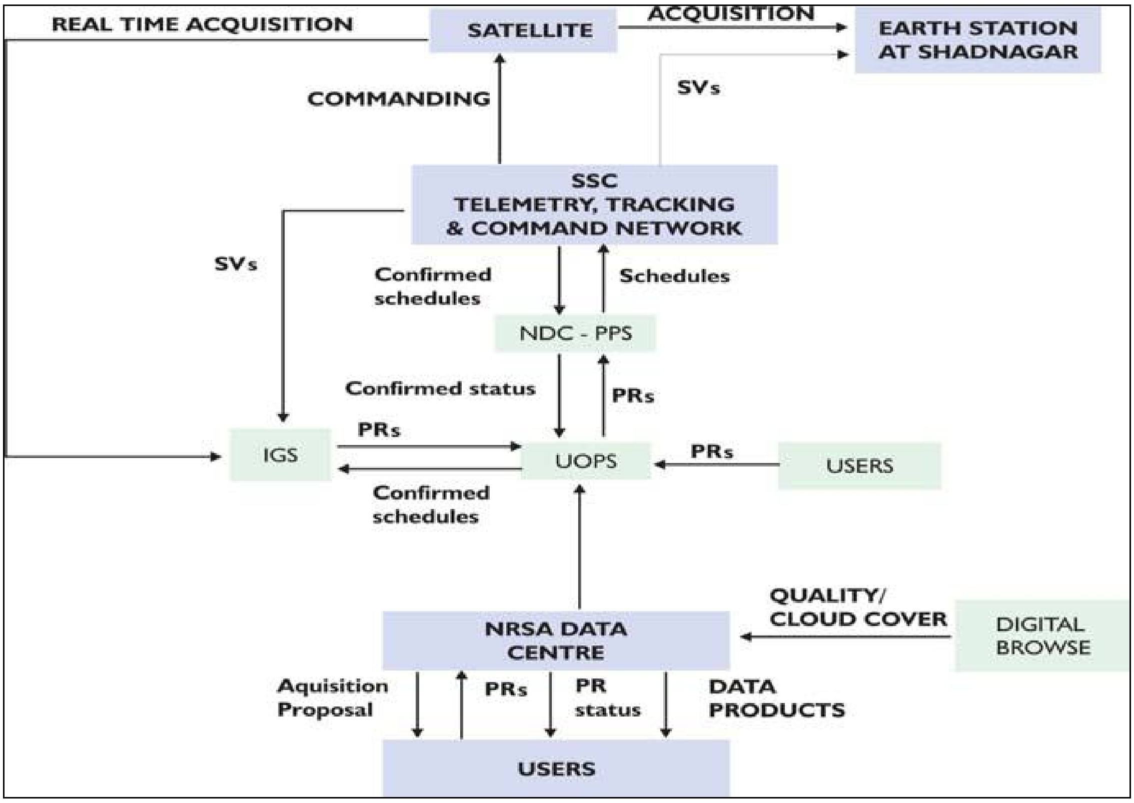


Figure 8.31 Flowchart of the programming activities

8.4.7 Programming Requests

8.4.7.1 General Users

Users need to provide the following information while placing a Programming request (PR)

8.4.7.2 Area of Interest (AOI)

The geographical location of your area can be mentioned in terms of

- Polygon(top-left and bottom-right corner coordinates)
- point latitude/longitude coordinate
- path/row (as per the Resourcesat-2 referencing scheme)
- Name of a location
- SOI map sheet number
- Shapefile

8.4.7.3 Period of interest

If data is required on a specific date because of simultaneous ground truth collection or other application requirements, it can be indicated by filling in the same date in the start and end date entries. Otherwise a range of dates can be specified during which data can be acquired.

8.4.7.4. Sensors required

The required sensors, LISS-III / LISS-IV or AWiFS have to be specified. In case of LISS-IV, the spectral mode Mono/Mx has to be additionally specified. In the LISS-IV Mx mode acquisition over Indian areas will be planned in the Mx70 mode and over non-Indian areas in the Mx23 mode

8.4.7.5. Type of service

Depending on the urgency of your requirement you may select between Normal and Urgent Programming Services. A typical PR form is shown in figure 8.33. Before placing a confirmed PR, the user will be shown online, the feasible dates of acquisition.

After the PR form is completed and confirmed, a request number is assigned to the request. The status of the request is set to 'Under-Process'. The request takes varying status in the process of getting successfully serviced. Users can check for the status of their requests online by keying in the request number. The sequence of steps involved in generating the order for fresh acquisitions are shown in figured 8.32 to 8.41.

The PRs from various users are carefully studied and priorities are assigned depending on the order in which the PR is received, acquisition mode, type of service etc. Best efforts are made (a maximum of three attempts) to acquire the data over the required area as per user specifications.

After the satellite is programmed, the data is collected in real-time or through OBSSR, as per the request. If the data is acquired successfully within the user-specified cloud limits and meets quality criteria set forth by NRSC, an acquisition report is sent to the user (online status for the request at this stage indicates 'completed'). The product is then generated and despatched to the user. Purchase of data products is mandatory.

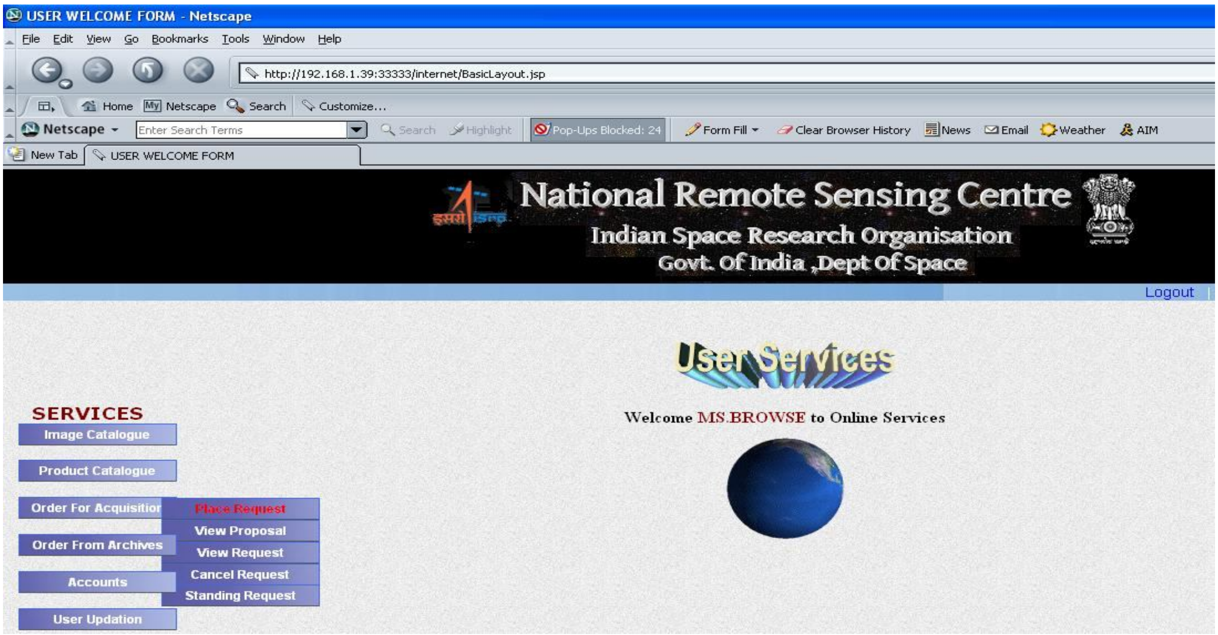


Figure 8.32 Order for fresh acquisitions

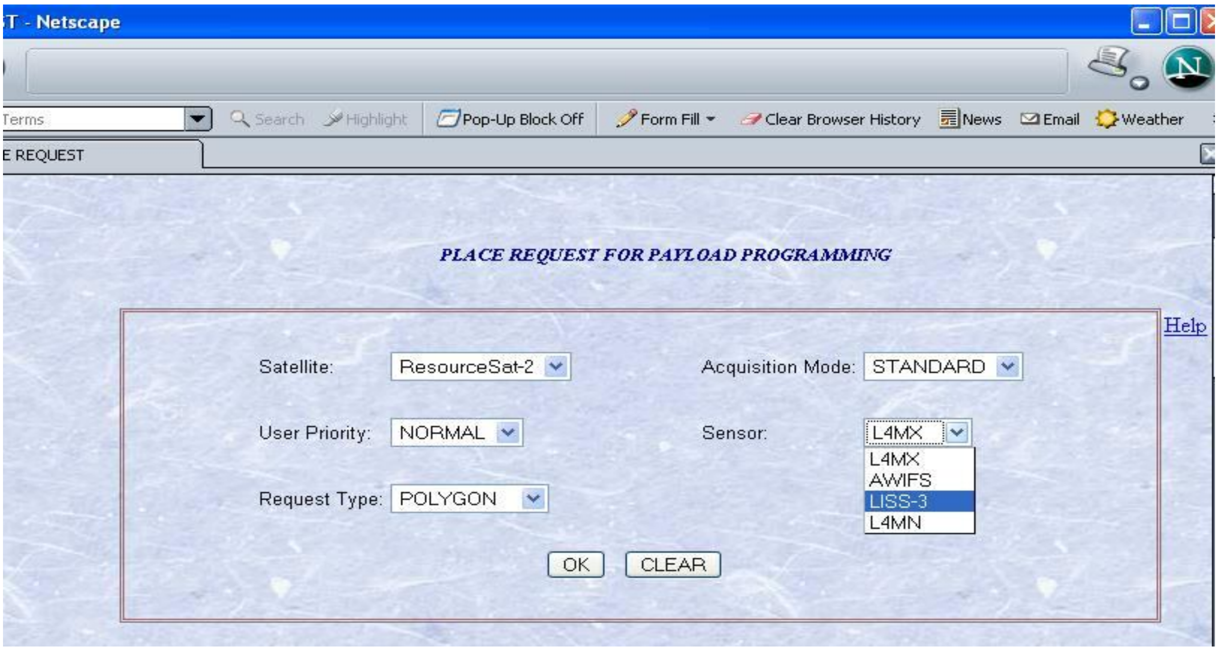


Figure 8.33 Programming request form

Figure 8.34 Submission of the details for the PR request

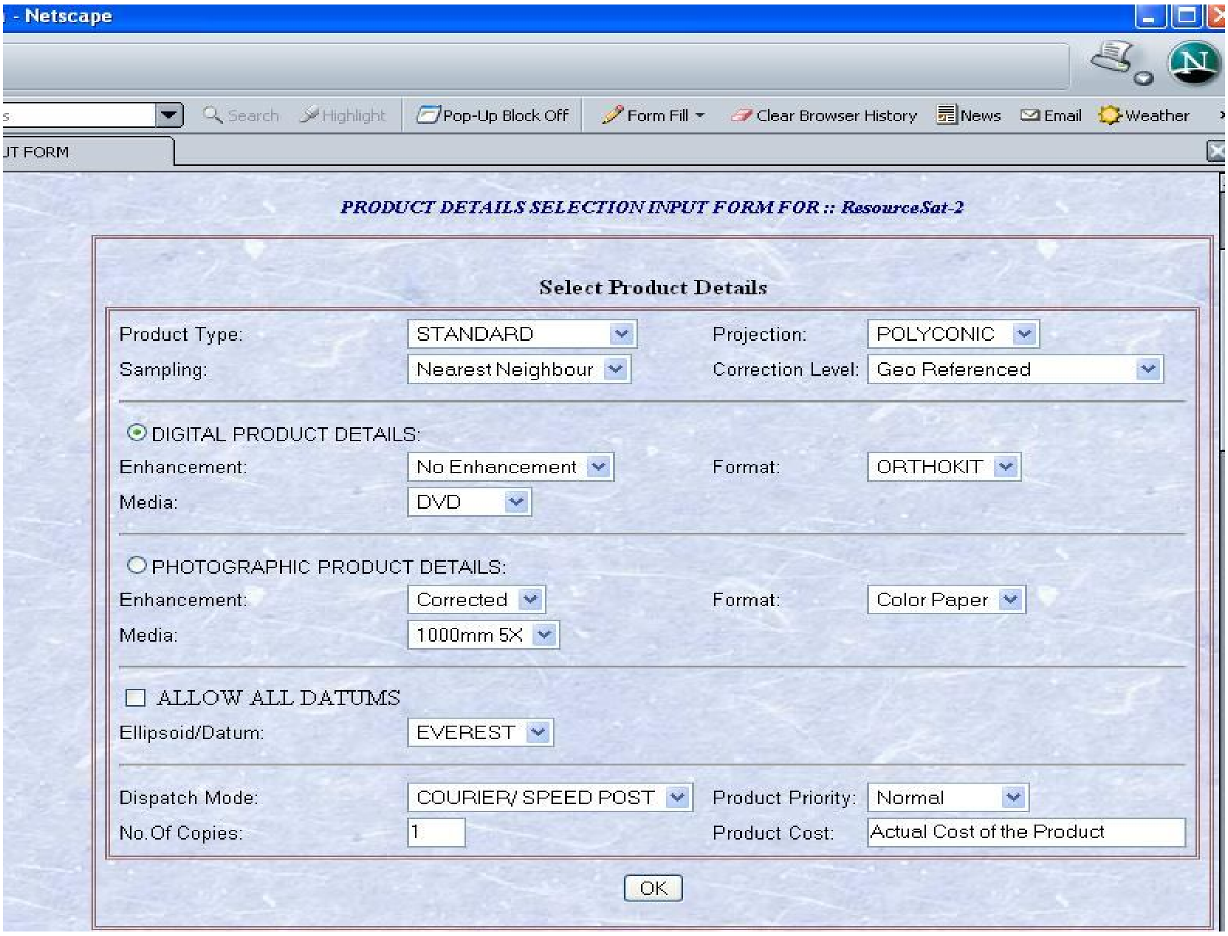
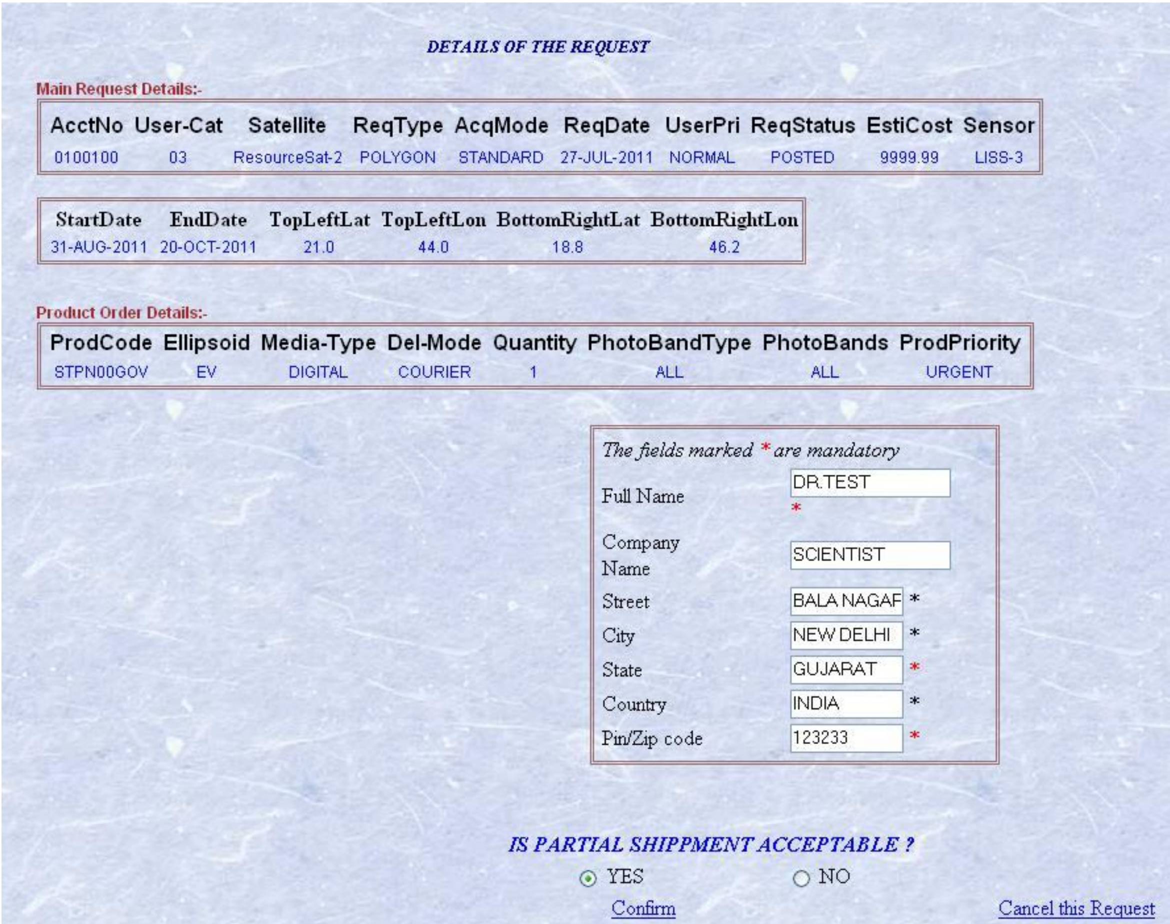


Figure 8.35 Submission of product details



DETAILS OF THE REQUEST

Main Request Details:-

AcctNo	User-Cat	Satellite	ReqType	AcqMode	ReqDate	UserPri	ReqStatus	EstiCost	Sensor
0100100	03	ResourceSat-2	POLYGON	STANDARD	27-JUL-2011	NORMAL	POSTED	9999.99	LISS-3

StartDate	EndDate	TopLeftLat	TopLeftLon	BottomRightLat	BottomRightLon
31-AUG-2011	20-OCT-2011	21.0	44.0	18.8	46.2

Product Order Details:-

ProdCode	Ellipsoid	Media-Type	Del-Mode	Quantity	PhotoBandType	PhotoBands	ProdPriority
STPN00GOV	EV	DIGITAL	COURIER	1	ALL	ALL	URGENT

*The fields marked * are mandatory*

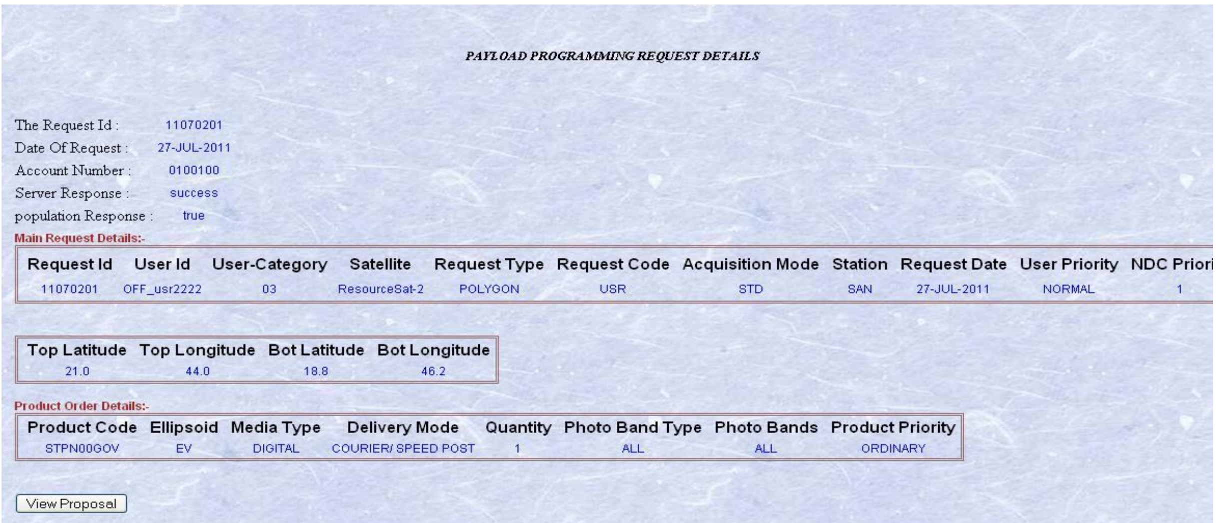
Full Name	DR.TEST *
Company Name	SCIENTIST
Street	BALA NAGAF *
City	NEW DELHI *
State	GUJARAT *
Country	INDIA *
Pin/Zip code	123233 *

IS PARTIAL SHIPPMENT ACCEPTABLE ?

YES NO

Confirm Cancel this Request

Figure 8.36 Submission of shipping details



PAYLOAD PROGRAMMING REQUEST DETAILS

The Request Id : 11070201
Date Of Request : 27-JUL-2011
Account Number : 0100100
Server Response : success
population Response : true

Main Request Details:-

Request Id	User Id	User-Category	Satellite	Request Type	Request Code	Acquisition Mode	Station	Request Date	User Priority	NDC Priori
11070201	OFF_usr2222	03	ResourceSat-2	POLYGON	USR	STD	SAN	27-JUL-2011	NORMAL	1

Top Latitude	Top Longitude	Bot Latitude	Bot Longitude
21.0	44.0	18.8	46.2

Product Order Details:-

Product Code	Ellipsoid	Media Type	Delivery Mode	Quantity	Photo Band Type	Photo Bands	Product Priority
STPN00GOV	EV	DIGITAL	COURIER/ SPEED POST	1	ALL	ALL	ORDINARY

View Proposal

Figure 8.37 Payload programming order details

Number of subrequests : 4

☑ Sub Request Id:1

Satellite : ResourceSat-2   Sensor : LISS3   SensorMode : NA

Path : 66   Start Row : 57   End Row : 58

Opp Id	Imaging Orbit	Imaging Date	Pass Type	Roll Tilt
1	1906	01-sep-2011	RC	0
2	2105	15-sep-2011	RC	0
3	2176	20-sep-2011	RC	0
4	2247	25-sep-2011	RC	0
5	2446	09-oct-2011	RC	0
6	2517	14-oct-2011	RC	0
7	2588	19-oct-2011	RC	0

☑ Sub Request Id:2

Satellite : ResourceSat-2   Sensor : LISS3   SensorMode : NA

Path : 67   Start Row : 57   End Row : 59

Opp Id	Imaging Orbit	Imaging Date	Pass Type	Roll Tilt
1	1906	01-sep-2011	RC	0
2	1977	06-sep-2011	RC	0
3	2176	20-sep-2011	RC	0
4	2247	25-sep-2011	RC	0
5	2318	30-sep-2011	RC	0
6	2517	14-oct-2011	RC	0

Figure 8.38 Display of feasible dates of acquisition

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Indian Space Research Organisation

Department of Space, Government of India

The Request Id: 11070201 has been confirmed by: OFF_USR2222

Figure 8.39 Order confirmation

Req Id	Satellite	Acq Mode	Req Type	Req Date	User Priority	Start Date	End Date	Req Status	Est Cost
11070171	RES-02	STD	POLYGON	27-JUL-2011	NORMAL	28-MAR-2012	20-MAY-2012	UNDER-PROCESS	10000.0

Top Latitude	Top Longitude	Bot Latitude	Bot Longitude
21.0	44.0	20.8	44.2

SUB REQUEST DETAILS:-

REQUESTID	SUBREQUESTID	SATELLITE	SENSOR	SENSORMODE	PATH	STARTROW	ENDROW	NWLAT	NWLON	NELAT	NELON	SWLAT
11070171	1	RES-02	LISS4	MX23	0	0	0	21.1802	44.0234	21.1445	44.2557	20.7477
11070171	2	RES-02	LISS4	MX23	0	0	0	20.9635	44.1813	20.9278	44.4132	20.7477
11070171	3	RES-02	LISS4	MX70	0	0	0	21.4715	43.8351	21.3678	44.501	20.2595
11070171	4	RES-02	LISS4	MX70	0	0	0	21.5654	43.864	21.4641	44.5308	20.3527

Product Order Details:-

Product Code	Ellipsoid	Media Type	Delivery Mode	Quantity	Photo Band Type	Photo Bands	Product Priority
G3PN00OEJ	EV	DIGITAL	COURIER/ SPEED POST	1	ALL	ALL	ORDINARY

Print

Figure 8.40 Status monitoring

8.4.7.6 International Ground Station request

Ground stations interested in acquiring Resourcesat-2 data over their station can place their programming requests either through a Nodal ground station or can directly place their requests with NDC. Nodal ground stations are responsible for the requests of all the ground stations handled by them. If there are any conflicting requests between ground station requests, the nodal ground station resolves conflicts before placing the requests of the ground stations to NDC. Individual International Ground stations are responsible for the requests planned over their respective ground stations.

All ground stations have to be registered by NDC. NDC provides the User id and password for users to place their requests online. A Ground station can change the password assigned to it. IGSs need to place, programming requests at least two days before the pass.

Nodal Ground Stations and other IGSs can use the 'Request placing' option of UOPS to place their Programming Requests. The Nodal ground station is provided with the list of station codes of the Stations handled by them. The PR of each ground station defines the following parameters:

- Station Id
- Date of pass
- Path number
- Sensor(LISS-III/LISS-IV/AWiFS)
- Mode (LISS-IV Mono/LISS-IV Mx)
- Tilt or latitude/longitude of the target
- Start time and end time of acquisition or start row and end row

The sequence of forms used by IGSs to place their request through UOPS as shown in figures 8.41 to 8.49.

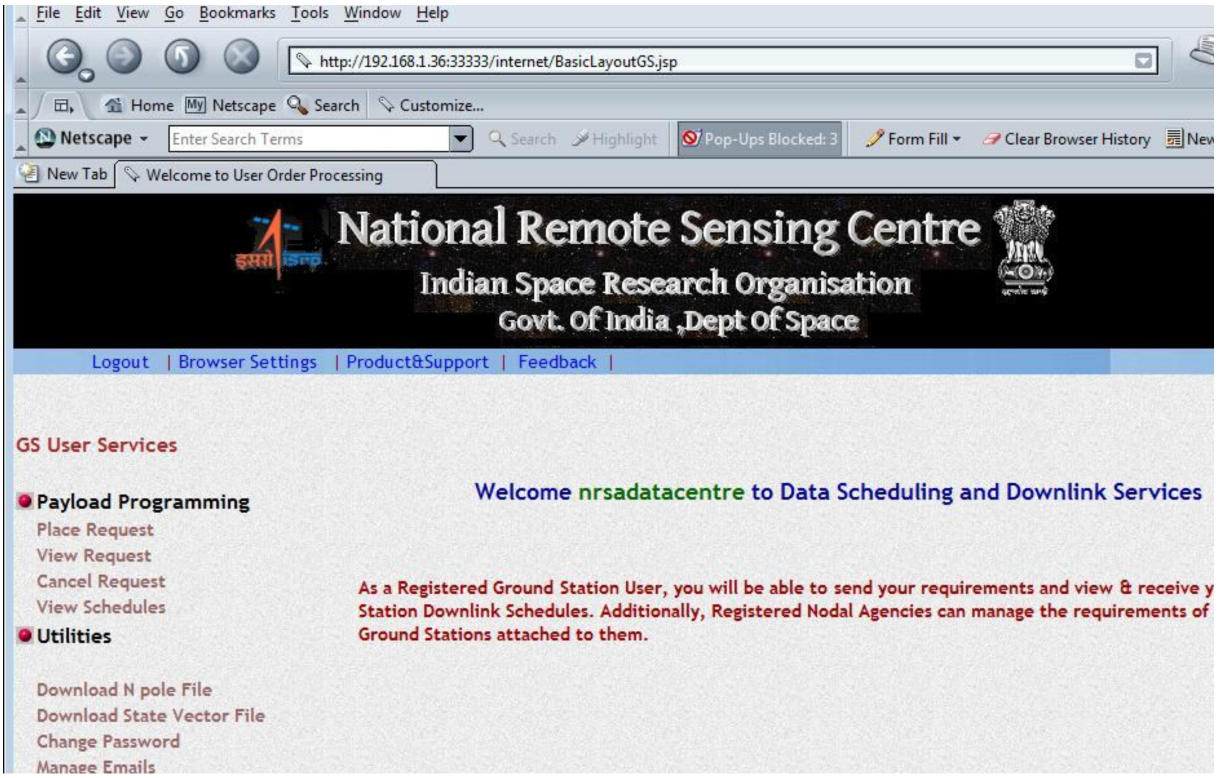


Figure 8.41 PR requests from IGS users

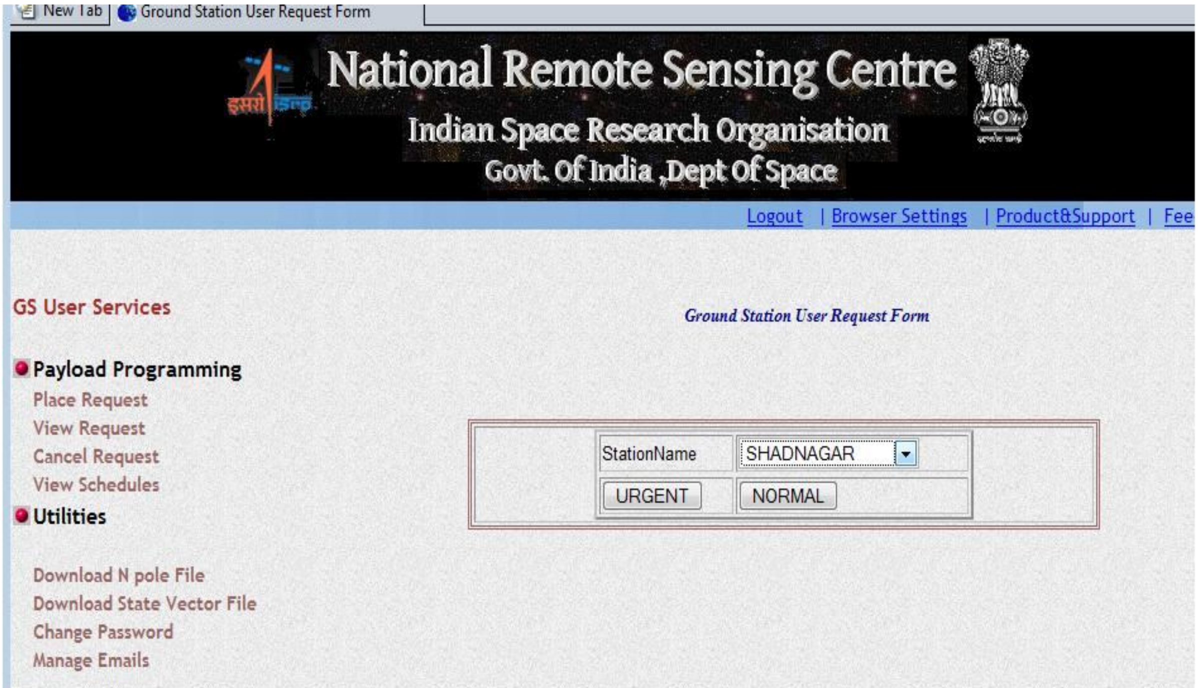


Figure 8.42 Ground station request form

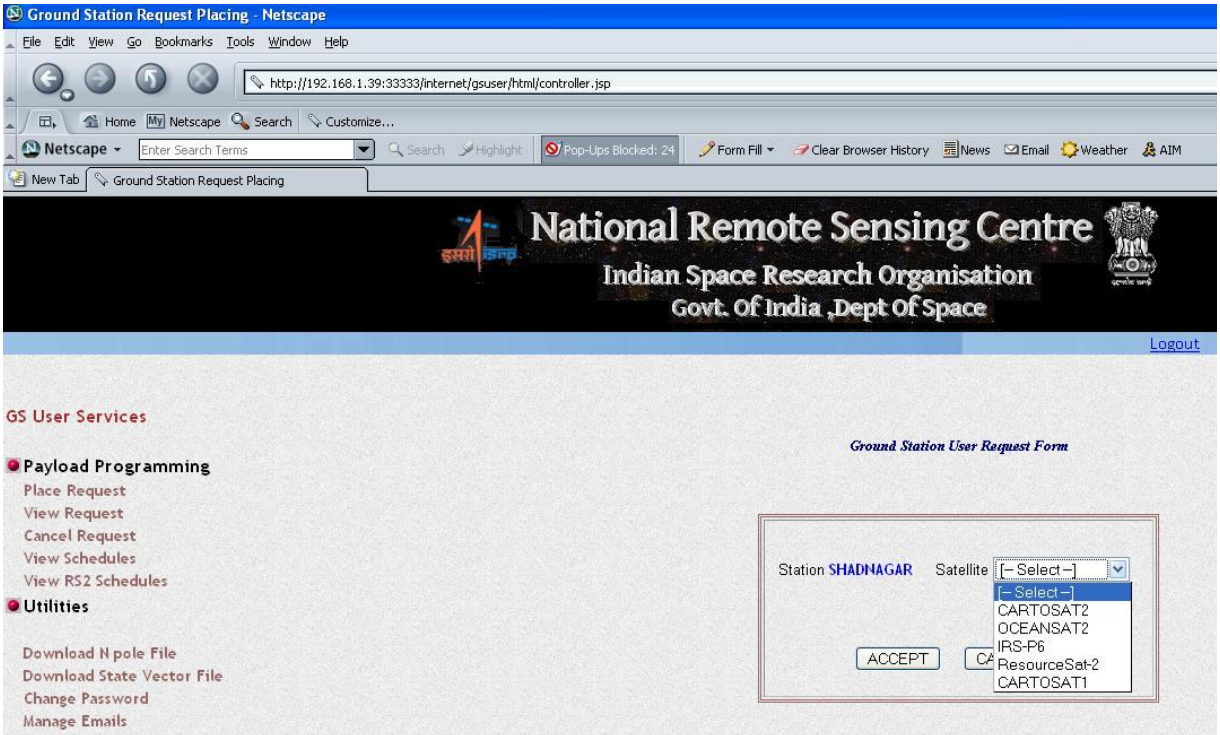


Figure 8.43 Satellite selection

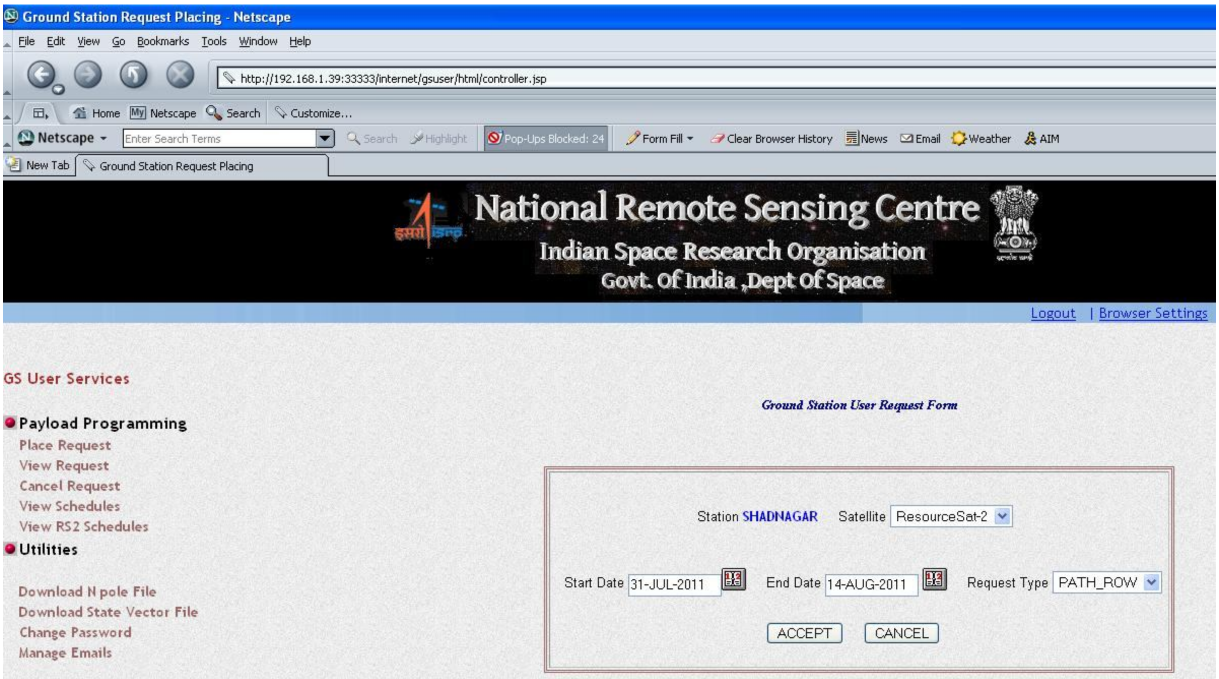


Figure 8.44 Submission of dates and area

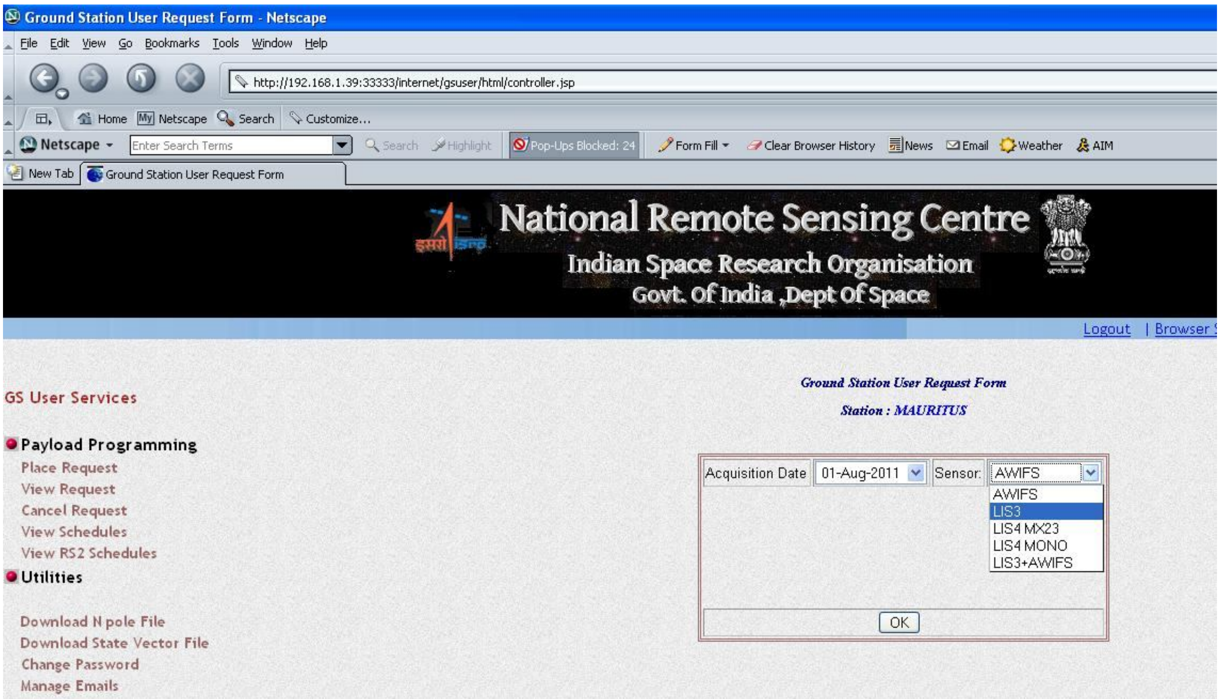


Figure 8.45 Submission of sensor

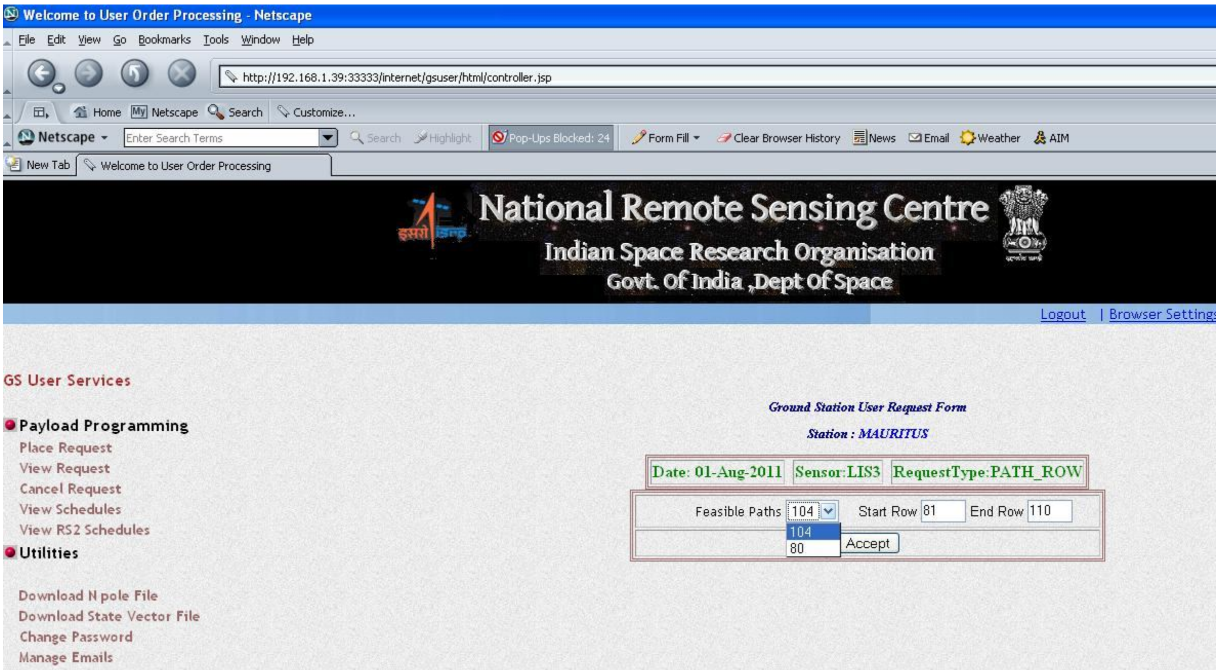


Figure 8.46 Submission of feasible scenes

The requests are verified for their correctness and the path number requested is validated against the Date of pass and the visibility of the ground station. Each request of a station for a day and Path is assigned a 'Request Number'.

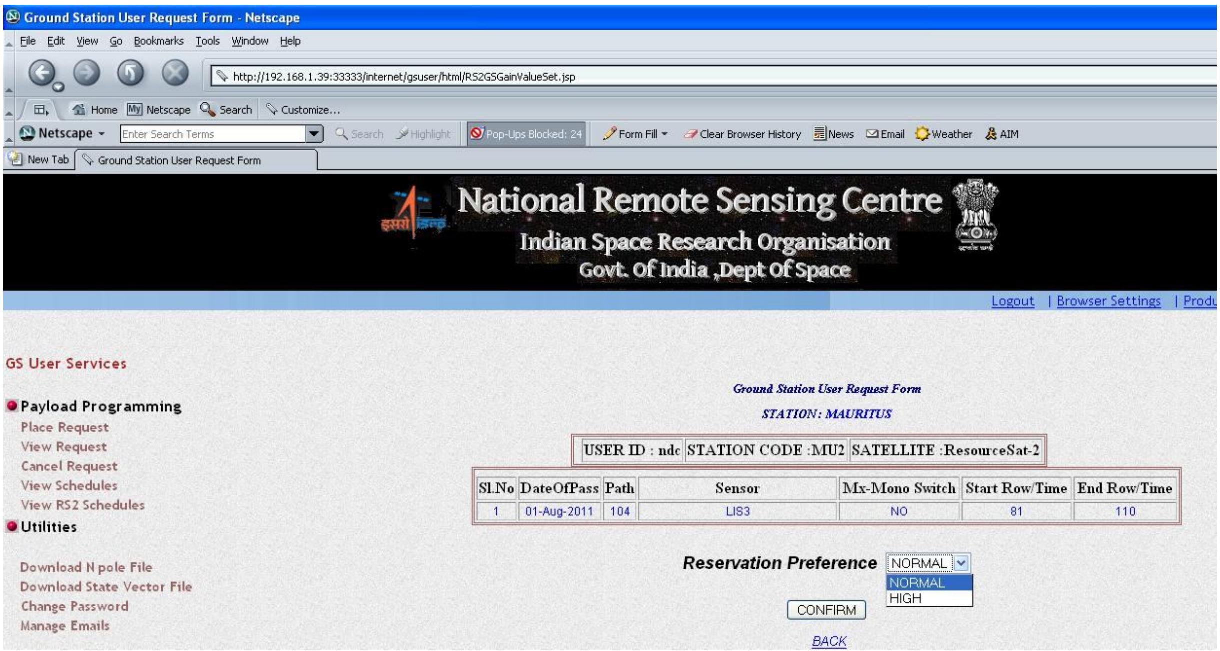


Figure 8.47 Request confirmation

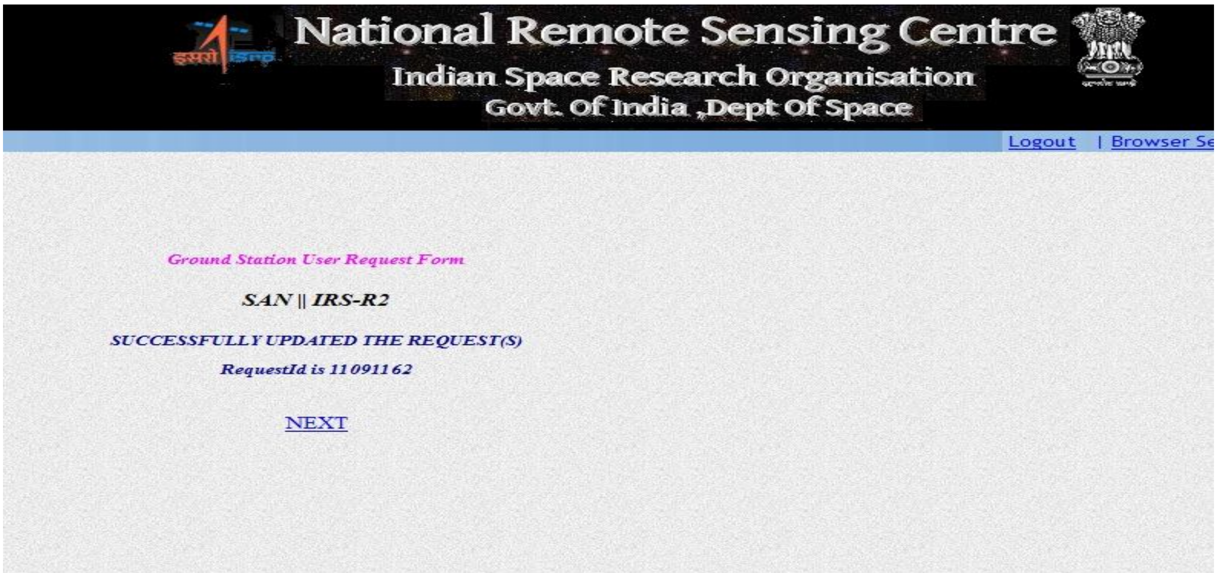
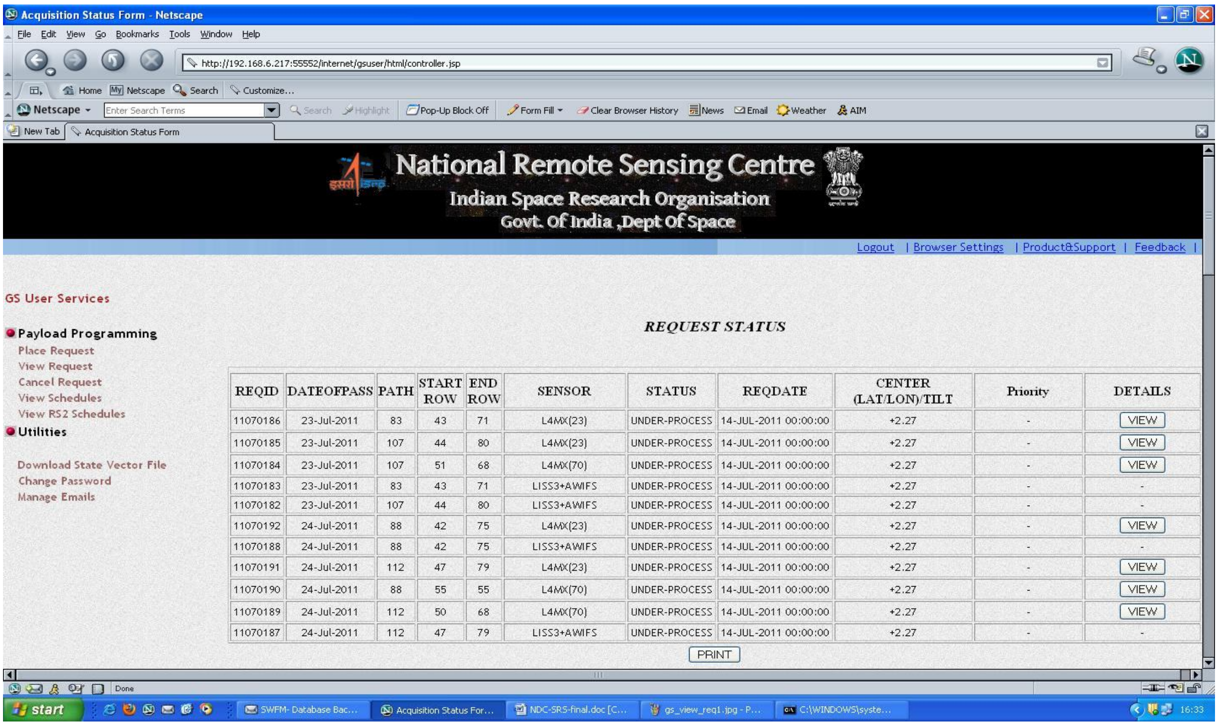


Figure 8.48 Request confirmation

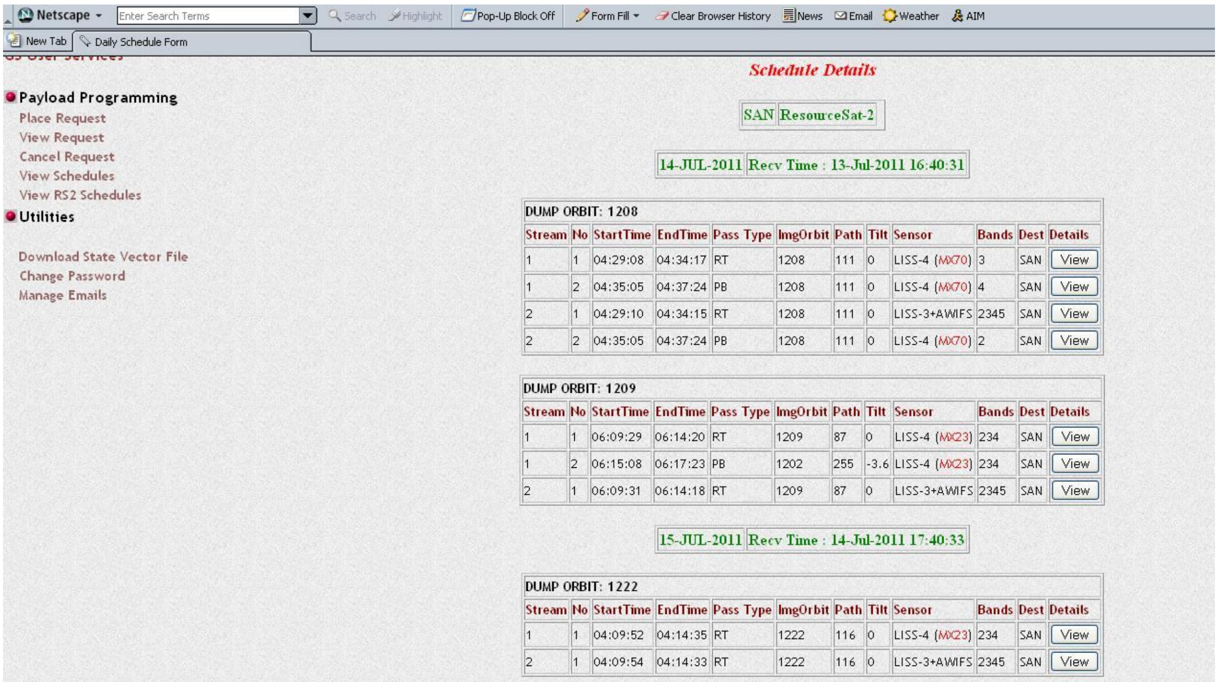
The status of the request at this stage is set as 'Under-Process'. IGSs can view the status of their requests online. While programming for a day, if a request is selected, the status changes to 'Scheduled'. A sample status is shown below.



REQID	DATEOFPASS	PATH	START ROW	END ROW	SENSOR	STATUS	REQDATE	CENTER (LAT/LON)/TILT	Priority	DETAILS
11070186	23-Jul-2011	83	43	71	L4MX(23)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070185	23-Jul-2011	107	44	80	L4MX(23)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070184	23-Jul-2011	107	51	68	L4MX(70)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070183	23-Jul-2011	83	43	71	LISS3+AWIFS	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	-
11070182	23-Jul-2011	107	44	80	LISS3+AWIFS	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	-
11070192	24-Jul-2011	88	42	75	L4MX(23)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070188	24-Jul-2011	88	42	75	LISS3+AWIFS	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	-
11070191	24-Jul-2011	112	47	79	L4MX(23)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070190	24-Jul-2011	88	55	55	L4MX(70)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070189	24-Jul-2011	112	50	68	L4MX(70)	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	VIEW
11070187	24-Jul-2011	112	47	79	LISS3+AWIFS	UNDER-PROCESS	14-JUL-2011 00:00:00	+2.27	-	-

Figure 8.49 IGS Request Status

NDC sends the schedules to the ground station, which indicates all the passes that have been planned for the station with the start and end times of acquisition. Schedules can be downloaded and viewed online. A sample schedule is in figure 8.50.


Netscape | Enter Search Terms | Search | Highlight | Pop-Up Block Off | Form Fill | Clear Browser History | News | Email | Weather | AIM

New Tab | Daily Schedule Form

Payload Programming
- Place Request
- View Request
- Cancel Request
- View Schedules
- View RS2 Schedules

Utilities
- Download State Vector File
- Change Password
- Manage Emails

Schedule Details

SAN | ResourceSat-2

14-JUL-2011 | Recv Time : 13-Jul-2011 16:40:31

DUMP ORBIT: 1208

Stream	No	StartTime	EndTime	Pass Type	ImgOrbit	Path	Tilt	Sensor	Bands	Dest	Details
1	1	04:29:08	04:34:17	RT	1208	111	0	LISS-4 (MX70)	3	SAN	View
1	2	04:35:05	04:37:24	PB	1208	111	0	LISS-4 (MX70)	4	SAN	View
2	1	04:29:10	04:34:15	RT	1208	111	0	LISS-3+AWIFS	2345	SAN	View
2	2	04:35:05	04:37:24	PB	1208	111	0	LISS-4 (MX70)	2	SAN	View

DUMP ORBIT: 1209

Stream	No	StartTime	EndTime	Pass Type	ImgOrbit	Path	Tilt	Sensor	Bands	Dest	Details
1	1	06:09:29	06:14:20	RT	1209	87	0	LISS-4 (MX23)	234	SAN	View
1	2	06:15:08	06:17:23	PB	1202	255	-3.6	LISS-4 (MX23)	234	SAN	View
2	1	06:09:31	06:14:18	RT	1209	87	0	LISS-3+AWIFS	2345	SAN	View

15-JUL-2011 | Recv Time : 14-Jul-2011 17:40:33

DUMP ORBIT: 1222

Stream	No	StartTime	EndTime	Pass Type	ImgOrbit	Path	Tilt	Sensor	Bands	Dest	Details
1	1	04:09:52	04:14:35	RT	1222	116	0	LISS-4 (MX23)	234	SAN	View
2	1	04:09:54	04:14:33	RT	1222	116	0	LISS-3+AWIFS	2345	SAN	View

Figure 8.50 IGS Schedule

IGSs can cancel a request two days before the date of pass. State vector information is sent by email to the ground stations on a daily basis. State vector can also be downloaded from the site. In the case of anomalies in acquisition, IGSs send the pass performance report to NDC within 24 hours of the acquisition of the pass.

ANNEXURE

LIST OF ACRONYMS

AC	Alternate Current
ACC	Antenna Control Computer
ADIF	Ancillary Data Information File
ADP	Ancillary Data Processing
AFEH	Advanced Frontend Hardware
AGC	Automatic Gain Control
A/D	Analog to Digital
AH	Ampere Hour
AOCE	Attitude Orbit Control Electronics
AOCS	Attitude and Orbit Control System
AOI	Area of Interest
AOS	Acquisition of Signal
AWiFS	Advanced Wide Field Sensor
BAS	Browse Archival System
BBR	Band to Band Registration
BDH	Base band Data Handling
BLR	Bangalore
BIK	Biak
BPSK	Bi-Phase Phase Shift Key
BSQ	Band Sequential
B/H	Base/Height
B/W	Black & White
CAL	Calibration
CC	Cubic Convolution
CCD	Charge Coupled Device
CCB	Configurable Command Block
CNDR	Carrier to Noise Density Ratio
DAQLB	Data Archival and Quick Look Browse
DBMS	Data Base Management Sysytem
DC	Direct Current
DD	Degree Decimal
DEG	Data Exchange Gateway