Indian Remote Sensing Satellites

*Resourcesat-2 Mission Status*

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Presented by:
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Embassy of India
Presentation Topics

- Brief Heritage of the IRS Satellite Program
- Resourcesat-2 Overview
  - Mission Objectives
  - Payload and Orbit
  - Sensors
  - Collection Rates
  - Products Overview
  - Applications
  - Program Status
3+ DECADES OF INDIAN IMAGING SYSTEMS

BROAD PORTFOLIO OF IMAGING CAPABILITIES:

- Low, Medium and High Resolution
- Land and Ocean Monitoring
- PAN, MS and Stereo Sensors
- Optical and Radar System
- Repeat Coverage every 5 days

Future Missions:
- MEGHA-TROPIQUES
- SAPHIR, SCARAB,
- MADRAS & RISAT
# ISRO Launchers

<table>
<thead>
<tr>
<th></th>
<th>PSLV-Std</th>
<th>PSLV-CA &amp; PSLV-XL</th>
<th>GSLV</th>
<th>GSLV MkIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (T)</td>
<td></td>
<td>294</td>
<td>400</td>
<td>629</td>
</tr>
<tr>
<td>Payload (Kgs)</td>
<td>1,500 SSO</td>
<td></td>
<td>2,250 GTO</td>
<td>4,000 to 4,500 GTO</td>
</tr>
</tbody>
</table>
Why Such Investments?

● Why has India invested so much in Earth Observation and other space technologies?
● To understand why, we have to look at India’s history
  ♦ Vikram Sarabhai’s vision
    ○ “India must use technology whenever possible to solve the problems of man and society and to expand the national economy of India”
  ♦ Since their independence India has had a lot of “down-to-earth” problems of development
  ♦ To assure its development, India views science and space technology as a crucial apparatus for its socio-economic development - not a display of its might
● Each IRS satellite built by India is designed to meet a national need first
  ♦ Commercial and other objectives are second place
● Our history explains why India’s space program is so deeply rooted in Indian society

Dr. Vikram A. Sarabhai
Father of India’s Space Program
Resourcesat-2
Mission Objectives

- To provide continued remote sensing data services of Resourcesat-1 on an operational basis for integrated land at micro level with enhanced multi-spectral/spatial coverage.

- To further carry out studies in advanced areas of user applications such as improved crop discrimination, crop yield, crop stress, pest/disease surveillance and disaster management.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>Circular Polar Sun Synchronous</td>
</tr>
<tr>
<td>Orbit Height</td>
<td>821 km (same as Resourcesat-1)</td>
</tr>
<tr>
<td>Orbit Inclination</td>
<td>98.731</td>
</tr>
<tr>
<td>Orbit Period</td>
<td>101.35 min</td>
</tr>
<tr>
<td>Number of Orbits per Day</td>
<td>14</td>
</tr>
<tr>
<td>Equatorial Crossing Time</td>
<td>10.30 a.m.</td>
</tr>
<tr>
<td>Repetivity (LISS-3)</td>
<td>24 days (341 orbits)</td>
</tr>
<tr>
<td>Repetivity (AWiFS)</td>
<td>5 days</td>
</tr>
<tr>
<td>Lift-off Mass</td>
<td>1,200 kg (lighter than Resourcesat-1)</td>
</tr>
<tr>
<td>Distance Between Paths</td>
<td>117.5 Km</td>
</tr>
<tr>
<td>Ground Track Velocity</td>
<td>6.65km/sec.</td>
</tr>
<tr>
<td>Attitude and Orbit Control</td>
<td>3-axis body stabilized using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters</td>
</tr>
<tr>
<td>Mission Life</td>
<td>5-10 years</td>
</tr>
<tr>
<td>Launch Date</td>
<td>Resourcesat-2 scheduled for Q3 2010 launch</td>
</tr>
</tbody>
</table>
Attitude and Orbit Control

- The Resourcesat-1 and 2 spacecrafts are virtually identical
  - Both are 3-axis stabilized spacecraft using star sensors, earth sensors, gyros and sun sensors for attitude errors
  - Reaction wheels, magnetic torquer coils and thrusters are used as actuators for attitude control

- Point Accuracy
  - Pitch: $\pm 0.05^\circ$ (3δ)
  - Roll: $\pm 0.05^\circ$ (3δ)
  - Yaw: $\pm 0.05^\circ$ (3δ)

- Platform Stability
  - $5 \times 10^{-5}$ degrees/second (3δ)

- Mono-Propellant hydrazine fuel
  - 100 Kg for at least 5 year mission life
R2 Configuration Highlights

- LISS-IV swath in the MX mode is increased from 23Km to 70Km
  - Wider swath currently restricted for use over India

- Payload Data Handling (PLDH) design is new
  - To cater to above change in MX swath and larger On-board Solid State Recorders (OBSSR)

- New miniaturized payload electronics and power modules for payloads
  - Improved star sensor with MIL 1553B I/F with AOCE
  - Improved 8 channel GPS receiver and 10 channel SPS

- Solar Panel fabrication process changes were qualified on Cartosat-2 and Oceansat-2
  - Solar panel failures have occurred on Resourcesat-1

- Overall Spacecraft mass reduced from 1360 Kg to 1200 Kg
  - Less weight generally increases mission life
Improvements in Radiometry

DPCM (on LISS-III & IV)
- On Resourcesat-1, only 7 bits were transmitted through the payload, not all 10 bits (due to data rate constraints)
- On Resourcesat-2, Delta Pulse Code Modulation (DPCM) is employed for the LISS-III & IV sensors to circumvent such constraints
  ♦ In a block of 4 adjacent pixels of a port, the differential counts will be quantized w.r.t. a reference pixel for which full 10 bit data is transmitted
- DPCM will be separate for each band
- The difference among consecutive pixels is re-quantized to 6 bit
  ♦ 10 bit information is regenerated on ground

Multi Linear Gain (MLG)
- The gain of each pixel is adjusted depending on the input signal using a multi linear gain approach for AWiFS
# DPCM

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P3</th>
<th>P5</th>
<th>P7</th>
<th>Total Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original Bits</strong></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>(P1-P3)</td>
<td>P3</td>
<td>(P3-P5)</td>
<td>(P5-P7)</td>
<td></td>
</tr>
<tr>
<td><strong>Bits after DPCM</strong></td>
<td>6</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>28</td>
</tr>
<tr>
<td><strong>Bits Tx after Packing</strong></td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>28</td>
</tr>
</tbody>
</table>
SENORS

● Resourcesat-2 Carries 3 Sensors:
  ♦ Same as Resourcesat-1
  ♦ Advanced Wide Field Sensor (AWiFS)
  ♦ Medium Resolution Linear Imaging Self-Scanner (LISS-III)
  ♦ High-Resolution Linear Imaging Self-Scanner (LISS-IV)
    □ Wider swath for MX mode (from 23Km x 70Km)

● All Sensors are “push broom” scanners using linear arrays of CCDs
  ♦ Same as Resourcesat-1

● Resourcesat-2 also carries a larger On-Board Solid State Recorder (OBSSR)
  ♦ 400 Gigabits Capacity
    □ 280 Gigabits more than Resourcesat-1
    □ More capacity for wider swath of LISS-IV MX mode
Acquisition Modes

NEW: All or 1/3 of swath in MX mode
Swath of All Sensors

~740km swath

~350km swath

~141km swath LISS-III

~70km swath LISS-IV

~23km swath LISS-IV
AWiFS Sensor
AWiFS Cameras

- The twin cameras of AWiFS provide medium-resolution multi-spectral data at 56m resolution (at nadir)
- Quantization: 10 bits
- Combined swath width: 740km with 5-day repeat cycle
- Operates in 4 spectral bands (Red, Green, NIR, SWIR)

**Key Features (Same as R1):**
- **Bands:** Green at 520-590 nm; Red at 620-680 nm; NIR at 770-860 nm; SWIR at 1550-1700 nm
- **Gain:** Single
- **SNR:** 512
- **Calibration:** LEDs (16 levels)
- **Repeat Time:** 5 days
AWiFS Collection Mode

The AWiFS camera is split into two separate electro-optical modules (AWiFS-”A” and AWiFS-”B”) tilted by 11.94° with respect to nadir.
AWiFS Quad of Ottawa

AWiFS quad (56m MS)
LISS-III Sensor
LISS-III Camera

- LISS-III is a medium resolution camera offering GSD at 23.5m
- Quantization: 10 bits (7 bits transmitted with DPCM)
- Swath: 141 km with 24-day repeat cycle
- Four spectral bands: Red, Green, NIR, SWIR
- Each band consists of a separate lens assembly and linear array CCD

Key Features (Same as R1):
- **Bands**: Green at 520-590 nm; Red at 620-680 nm; NIR at 770-860 nm; SWIR at 1550-1700 nm
- **Gain**: Single
- **SNR**: 128
- **Calibration**: LEDs (6 levels)
- **Repeat Time**: 24 days
LISS-III Scene of Ottawa

LISS-3
(20m MS)

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LISS-IV Camera

- LISS-IV is the highest-resolution sensor offering GSD at 5.8m at nadir
- Quantization: 10 bits (7 bits transmitted with DPCM)
- Swath: 70km
- Acquisition Modes: MX and MONO
- Three (3) spectral VNIR bands
  - A single telescope and lens assemble is used for all bands
  - Band 3 (red) is placed closest to nadir, while band 2 looks ahead and band 4 looks behind the satellite velocity vector
- The 12,000 pixel CCD array for each band is separated into odd and even pixels, arranged in two rows with a distance of 35 microns (5 scan lines) between them

**Key Features (Same as R1):**

- **Bands:**
  - Green at 520-590 nm
  - Red at 620-680 nm
  - NIR at 770-860 nm
- **Gain:** Single
- **SNR:** 128
- **Calibration:** LEDs (16 levels)
LISS-IV Collection Modes

- LISS-IV can be operated in either of two modes
  - Mono Mode – 70km swath covered by band 3 (Red)
  - MX Mode – 70km swath covered by all 3 VNIR bands
    - Improvement over Resourcesat-1

MX mode at 70km initially only available over India
## Summary of R2 Payloads

<table>
<thead>
<tr>
<th>PAYLOADS</th>
<th>AWiFS</th>
<th>LISS-III</th>
<th>LISS-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (at nadir)</td>
<td>56m</td>
<td>23.5m</td>
<td>5.8m</td>
</tr>
<tr>
<td>Swath</td>
<td>740 km</td>
<td>141 km</td>
<td>70.3 km (MX mode) 70.3 km (PAN mode)</td>
</tr>
<tr>
<td>Spectral Bands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Band 2 (Green)</td>
<td>520-590 nm</td>
<td>520-590 nm</td>
<td>520-590 nm</td>
</tr>
<tr>
<td>Band 3 (Red)</td>
<td>620-680 nm</td>
<td>620-680 nm</td>
<td>620-680 nm</td>
</tr>
<tr>
<td>Band 4 (NIR)</td>
<td>770-860 nm</td>
<td>770-860 nm</td>
<td>770-860 nm</td>
</tr>
<tr>
<td>Band 5 (SWIR)</td>
<td>1550-1700 nm</td>
<td>1550-1700 nm</td>
<td></td>
</tr>
<tr>
<td>Quantization / After DPCM</td>
<td>12/10 bit</td>
<td>10/7 bit</td>
<td>10/7 bit</td>
</tr>
<tr>
<td>Array Width</td>
<td>6,000 pixels/band</td>
<td>6,000 pixels/band</td>
<td>12,000 pixels/band</td>
</tr>
</tbody>
</table>
Comparison to Landsat

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-2)

Normalized RSR

Wavelength

0.48 0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-3)

Normalized RSR

Wavelength

0.56 0.60 0.64 0.68 0.72 0.76

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-4)

Normalized RSR

Wavelength

0.72 0.76 0.80 0.84 0.88 0.92 0.96

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-5)

Normalized RSR

Wavelength

1.48 1.52 1.56 1.60 1.64 1.68 1.72 1.76 1.80 1.84 1.89
### Imagery Collection Rates:

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Sensor</th>
<th>Km² Per Second</th>
<th>Km² Per Minute</th>
<th>Scenes/Day (@ 8 mins/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resourcesat-2</td>
<td>LISS-IV</td>
<td>~ 462 km²</td>
<td>~ 27,720 km²</td>
<td>~ 221,760 km²</td>
</tr>
<tr>
<td></td>
<td>LISS-III</td>
<td>~ 931 km²</td>
<td>~ 55,836 km²</td>
<td>~ 446,688 km²</td>
</tr>
<tr>
<td></td>
<td>AWiFS</td>
<td>~ 4,884 km²</td>
<td>~ 293,040 km²</td>
<td>~ 2,344,320 km²</td>
</tr>
</tbody>
</table>
IRS Products Overview
Resourcesat Products

- **Standard Products**
  - **Path/Row Based Products**
    - Users have to specify the path/row, sensor, sub-scene, date of pass and band number as inputs
  - **Shift Along-Track Products**
    - If a user’s area of interest falls in between two successive scenes of the same path, the data can be supplied by sliding the scene center by 10% increments
  - **Quadrant Products**
    - These products are applicable only to AWiFS and LISS-III sensor. The full scene is divided into four nominal quadrants.
  - **Geo-referenced Products**
    - These are satellite path oriented products (i.e., Path Oriented) or true north oriented products (i.e., Map Oriented). The locational accuracy of these products is same as other standard products.

- **Value Added Products**
  - **Ortho Products**
    - An orthoimage shows ground objects in their true map or so called orthographic projection
    - The basic inputs required for orthoimage generation are (i) Digital Elevation Model (DEM), (ii) Ground Control Points (GCP) (iii) Satellite ephemeris (orbit, attitude information) and (iv) Radiometrically corrected image data
Accuracy of Ortho Products

- Accuracy levels of ortho products (from EOTec for USA):
  - AWiFS = 75m CE90
  - LISS-III = 35m CE90
  - LISS-IV = 20m CE90

- What reference data is used by EOTec’s ortho products?
  - EOTec uses both USGS’ DOQs (digital orthorectified quads) and Landsat GeoCover (Landsat orthos).

- All EOTec ortho products generally fall within 1 pixel of the reference imagery
# Product Options

<table>
<thead>
<tr>
<th>Standard Products</th>
<th>Value Added Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Path/Row Based</td>
</tr>
<tr>
<td>2</td>
<td>Shift Along Track</td>
</tr>
<tr>
<td>3</td>
<td>Quadrant Products</td>
</tr>
<tr>
<td>4</td>
<td>Georeferenced Products</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of Correction Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>No correction (not available for sale)</td>
</tr>
<tr>
<td>Level 1</td>
<td>Radiometric Correction only</td>
</tr>
<tr>
<td>Level 2 (Standard)</td>
<td>Radiometric and Geometric Correction</td>
</tr>
<tr>
<td>Level 3</td>
<td>Precision Correction (using GCPs)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resampling Options</th>
<th>Map Projections</th>
<th>Earth Ellipsoids</th>
<th>Data Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic Convolution</td>
<td>Polyconic</td>
<td>Clark 1866</td>
<td>LGSOWG Superstructure Format</td>
</tr>
<tr>
<td>Nearest Neighbor</td>
<td>Lambert Conformal Conical</td>
<td>Int'l 1909</td>
<td>Fast Format</td>
</tr>
<tr>
<td>Bilinear</td>
<td>Universal Transverse Mercator</td>
<td>GRS 1980</td>
<td>GeoTIFF (Gray Scale)</td>
</tr>
<tr>
<td>16 Point Sinc</td>
<td>Space Oblique Mercator</td>
<td>Everest</td>
<td>GeoTIFF (RGB)</td>
</tr>
<tr>
<td>Kaiser -16</td>
<td>WGS 84</td>
<td>Bessel</td>
<td>HDF</td>
</tr>
<tr>
<td>4 Point Sinc</td>
<td></td>
<td>Krassovskv</td>
<td></td>
</tr>
</tbody>
</table>
Applied Corrections

- Raw data suffers from both geometric and radiometric distortions which must be corrected
- The steps for performing the radiometric correction:
  - Detector normalization
  - Failed/degraded detector correction
  - Stagger correction for LISS-IV and SWIR bands of LISS-III & AWIFS
  - Line loss correction
  - Framing of required scene
Possible Applications

- **Agriculture**
  - Crop monitoring and condition assessment
  - Crop canopy water stress
  - Crop yield estimates
  - Damage assessment

- **Forestry**
  - Inventory and updating
  - Encroachment
  - Habitat analysis
  - Fire damage

- **Environmental Monitoring**
  - Land use
  - Soil contamination
  - Desertification analysis
  - Oil Spills and disaster monitoring
  - Environmental impact assessments

- **Geology and Exploration**
  - Rock type mapping
  - Mining pollution assessments
  - Coal fire analysis
  - Landslide vulnerability / risk

- **Infrastructure and Utilities**
  - Road networks
  - 3D city models
  - Structural and hydrological inventory
  - Utility corridor mapping
  - Change detection

- **Cartography / Mapping**

- **National Security**
Program Status
R2 Schedule Overview

Tasks to be completed before launch:

- Integrated spacecraft testing (IST)
  - Dis-assembled mode testing
  - Assembled mode testing
- Thermal Vacuum Testing
  - Simulates in-flight orbit conditions
  - Results determine flight worthiness
- Deployment Testing
- Vibration & Acoustic Testing
- Pre-Shipment Review
- Ship to Launch Site
  - Integrate Satellite with PSLV rocket & checks
- Launch and post launch operations
NRSC’s Data Quality Evaluation (DQE) system will be used to characterize R2’s payload and platform performance and its impact on radiometric and geometric accuracies.

- Same system was used on Resourcesat-1

The DQE system monitors accuracies and compares them with design specification during the operational phase of the mission.

To learn more about the DQE system, please refer to the following paper:

- Resourcesat-1 Data Quality Evaluation System, Data Quality Evaluation Division, RESIPA, Space Application Center, ISRO, Ahmedabad 15, India
  - Available on-line
Thank you!

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Back Up Slides
Future IRS Missions

Resourcesat-$n$
Cartosat-$n$
Radar
HSI
Future IRS Missions

● Resourcesat-2
  ♦ Launch currently scheduled for end of Q2 to early Q3- 2010
  ♦ Virtually identical to Resourcesat-1 (with miniaturization)
    ○ Improved solar array and power handling system
    ○ Radiometric resolution of LISS-III and LISS-IV will be improved from 7 bits to 10 bits
    ○ AWiFS will have improved multi-linear gains
    ○ OBSSR will be increased in size (2 each at 200 GB)
  ♦ Resourcesat-2 has a 7-10 year design life which assures data continuity through at least 2016

● Cartosat Series:
  ♦ Increased resolution and more spectral bands:
    ○ PAN at 0.5m resolution
    ○ MSI at 2-4m, 4 bands
    ○ HSI at 8m, ~200 bands
      – Swath at 8-10km
Future Missions (continued)

- **Resourcesat-3 series**
  - Increased resolution and more spectral bands to existing sensors:
    - AWIFS (A & B) improved to 25m resolution, 600km swath
    - LISS-III will remain at 23.5m resolution with 2 additional bands
      - Thermal at 70m resolution under consideration
    - LISS-IV will remain at 5.8m resolution, but swath will be increased
  - Possible addition of new sensors with 25km swath:
    - LISS-V (PAN) at 2.5m resolution
    - Hyperspectral at 25m resolution (~200 Bands)

- **Resourcesat-4 series**
  - Addition of new sensors with 12.5km swath based on 500mm optics:
    - LISS-IVn at 2.5m, 3-4 bands, 5 day revisit
    - LISS-Vn at 1.25m PAN, 5 day revisit
    - HSIn at 12.5m, 200 bands, 5 day revisit
Future Missions (continued)

- **RISAT – First IRS SAR system**
  - C-Band SAR
  - 10km swath in Spot mode, 240km swath in Scan mode
  - Resolution at 1m to 50m
  - Single/Dual polarization
  - Schedule for launch late 2009 or early 2010

<table>
<thead>
<tr>
<th>Mode</th>
<th>Look</th>
<th>Resolution</th>
<th>Swath</th>
<th>Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Resolution Mode</td>
<td>2-4</td>
<td>50m</td>
<td>240km</td>
<td>Single or Dual</td>
</tr>
<tr>
<td>Medium Resolution Mode (MRS)</td>
<td>1-2</td>
<td>25m</td>
<td>120km</td>
<td>Single or Dual</td>
</tr>
<tr>
<td>Fine Resolution Striping Single Mode (FRS-2)</td>
<td>9-12</td>
<td>30m</td>
<td>Quad</td>
<td></td>
</tr>
<tr>
<td>Fine Resolution Strip Map (FRS-1)</td>
<td>Single</td>
<td>3-6m</td>
<td>30km</td>
<td>Single or Dual</td>
</tr>
<tr>
<td>High Resolution Spot Mode (HRS)</td>
<td>Single</td>
<td>1-2</td>
<td>10 x 10km</td>
<td>Single or Dual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polarization Type</th>
<th>Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Polarization</td>
<td>VV/HH/HV/VH</td>
</tr>
<tr>
<td>Dual Polarization</td>
<td>HH &amp; VV/VV &amp; VH</td>
</tr>
<tr>
<td>Polarimetric</td>
<td>HH &amp; VV &amp; HV &amp; VH</td>
</tr>
</tbody>
</table>