Indian Remote Sensing Satellites

Resourcesat-2 Mission Status

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Presented by:
Deviprasad Karnik
Counsellor (SPACE)
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

1995/1997 IRS-1C/1D

LISS-3 at 23/70m,
PAN at 5.8m,
WiFS at 188m

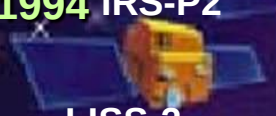
1999 INSAT-2E

1 km every 30 mins.

2003 IRS-P6
"Resourcesat-1"
LISS-3 at 23m,
LISS-4 at 5.8m,
AWiFS at 70m

1996 IRS-P3
WiFS

1994 IRS-P2



LISS-2

1999 IRS-P4
OCEANSAT-1

2005 IRS-P5
"Cartosat-1"

Stereo PAN at 2.5m,
30km swath

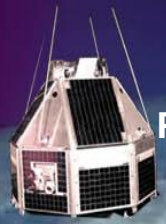
1988/91 IRS-1A/1B

LISS-1&2 at 73/36m

2007 IRS-P7
"Cartosat-2"

High-Res 1m PAN

1982 RS-D1



1979 BHASKARA
TV Cameras

BROAD PORTFOLIO OF IMAGING CAPABILITES:

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

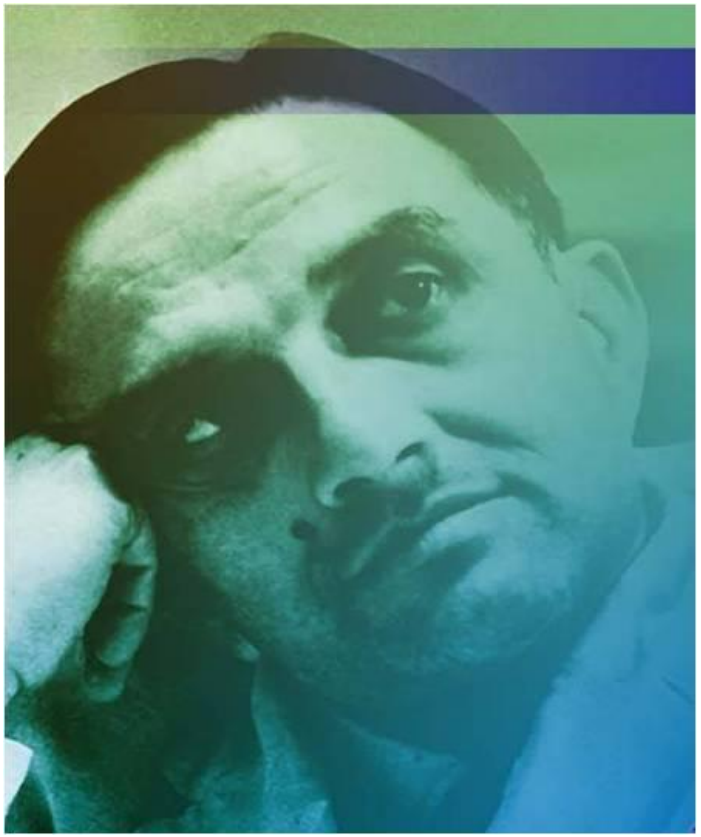
Future Missions:
MEGHA-TROPIQUES
SAPHIR, SCARAB,
MADRAS & RISAT

ISRO Launchers

	PSLV-Std PSLV-CA & PSLV-XL	GSLV	GSLV MkIII
Weight (T)	294	400	629
Payload (Kgs)	1,500 SSO	2,250 GTO	4,000 to 4,500 GTO
Launches	15 (1994 – 2009)	5 (2001-2007)	--

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.***

SPACECRAFT

Orbit :	Circular Polar Sun Synchronous
Orbit Height :	821 km (same as Resourcesat-1)
Orbit Inclination :	98.731
Orbit Period :	101.35 min
Number of Orbits per Day :	14
Equatorial Crossing Time :	10.30 a.m.
Repetivity (LISS-3) :	24 days (341 orbits)
Repetivity (AWiFS) :	5 days
Lift-off Mass :	1,200 kg (lighter than Resourcesat-1)
Distance Between Paths :	117.5 Km
Ground Track Velocity :	6.65km/sec.
Attitude and Orbit Control :	3-axis body stabilized using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters
Mission Life :	5-10 years
Launch Date :	Resourcesat-2 scheduled for Q3 2010 launch

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° (3δ)
  - Roll: $\pm$ 0.05° (3δ)
  - Yaw: $\pm$ 0.05° (3δ)
- Platform Stability
  - 5×10^{-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

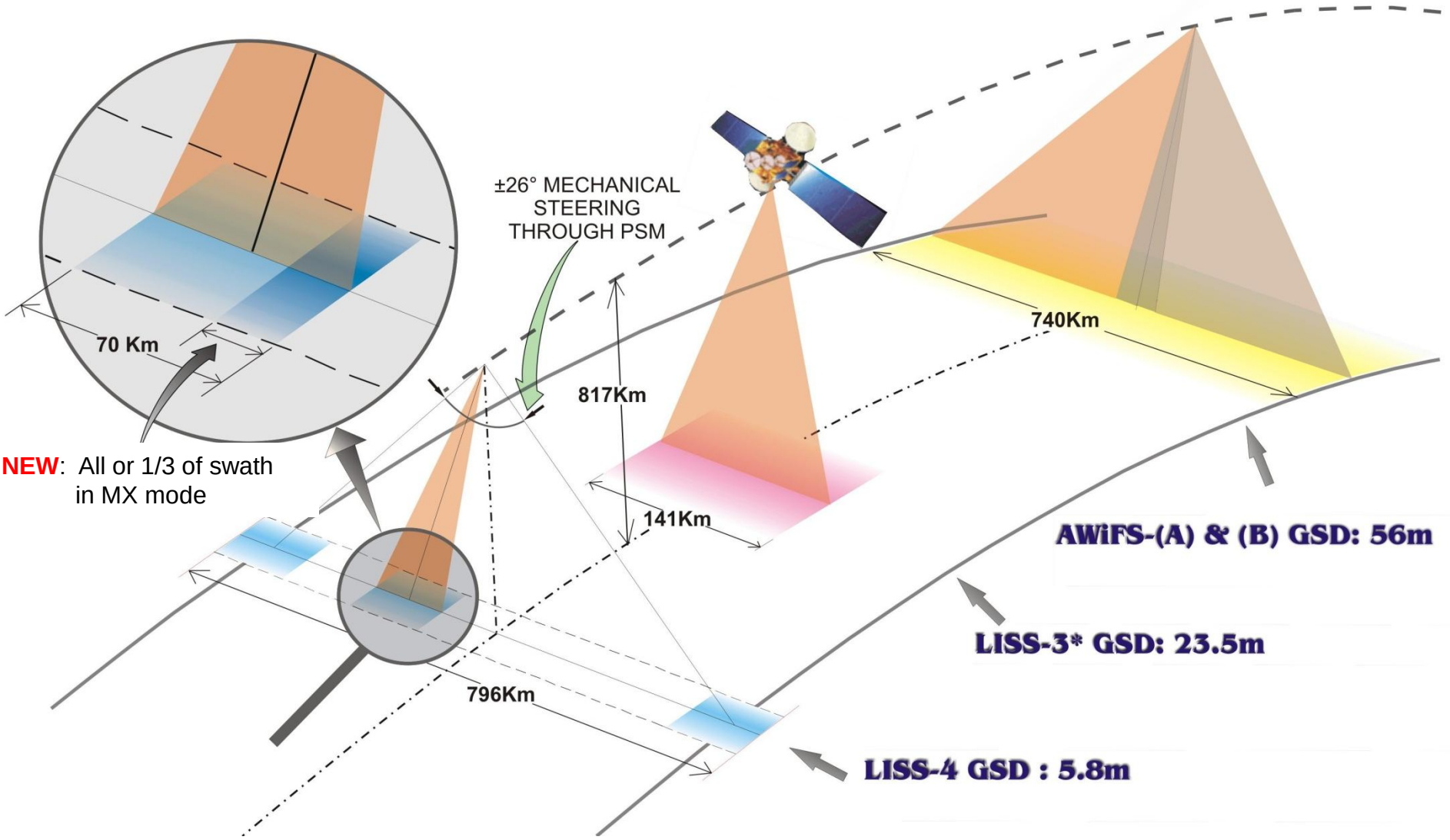
DPCM

	P1	P3	P5	P7	Total Bits
Original Bits	10	10	10	10	40
Output	(P1-P3)	P3	(P3-P5)	(P5-P7)	
Bits after DPCM	6	10	6	6	28
Bits Tx after Packing	7	7	7	7	28

SENSORS

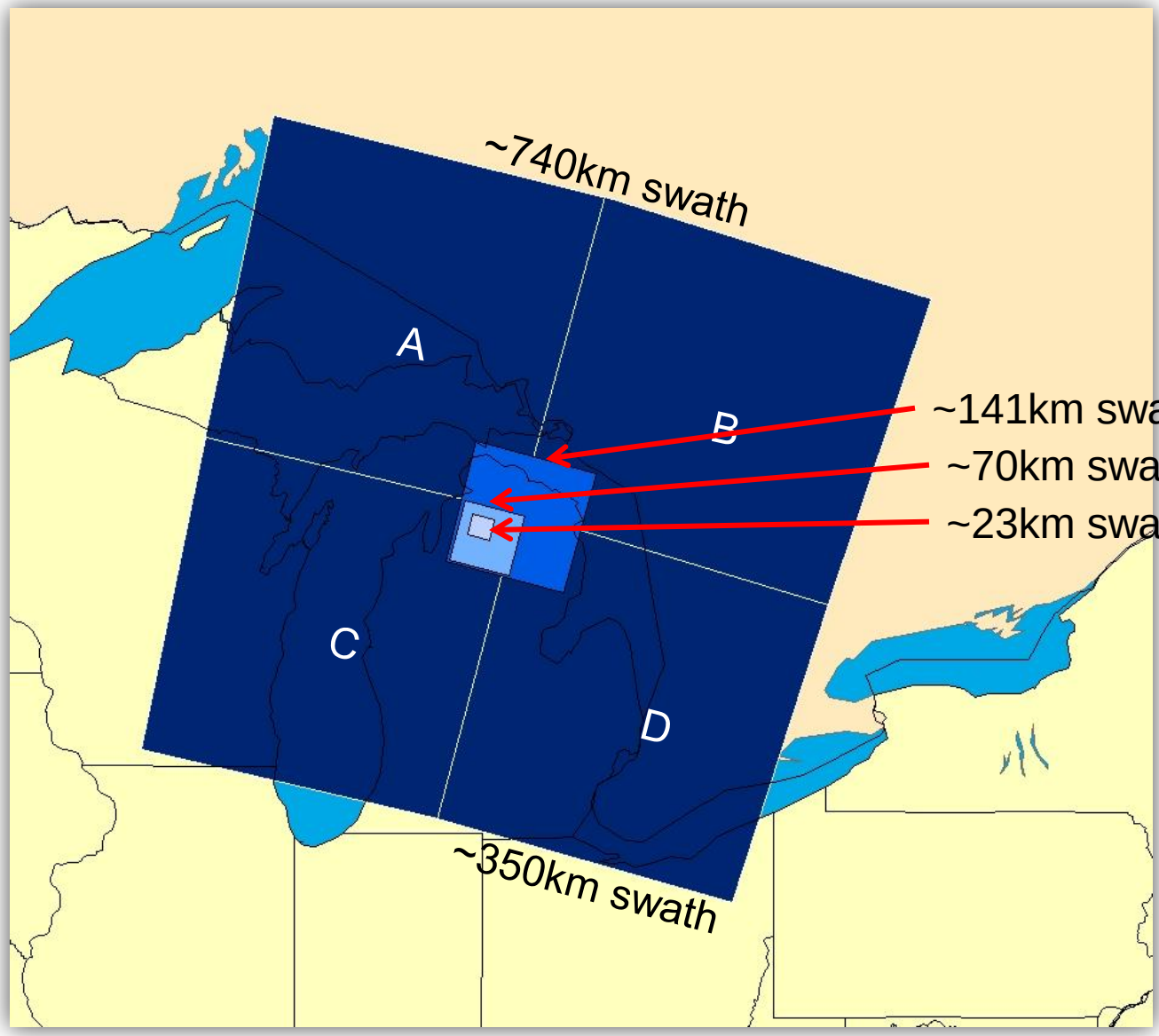
- Resourcesat-2 Carries 3 Sensors:
  - Same as Resourcesat-1
  - Advanced Wide Field Sensor (**AWiFS**)
  - Medium Resolution Linear Imaging Self-Scanner (**LISS-III**)
  - High-Resolution Linear Imaging Self-Scanner (**LISS-IV**)
    - Wider swath for MX mode (from 23Km x 70Km)
- All Sensors are “push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



AWiFS Sensor

AWiFS Cameras

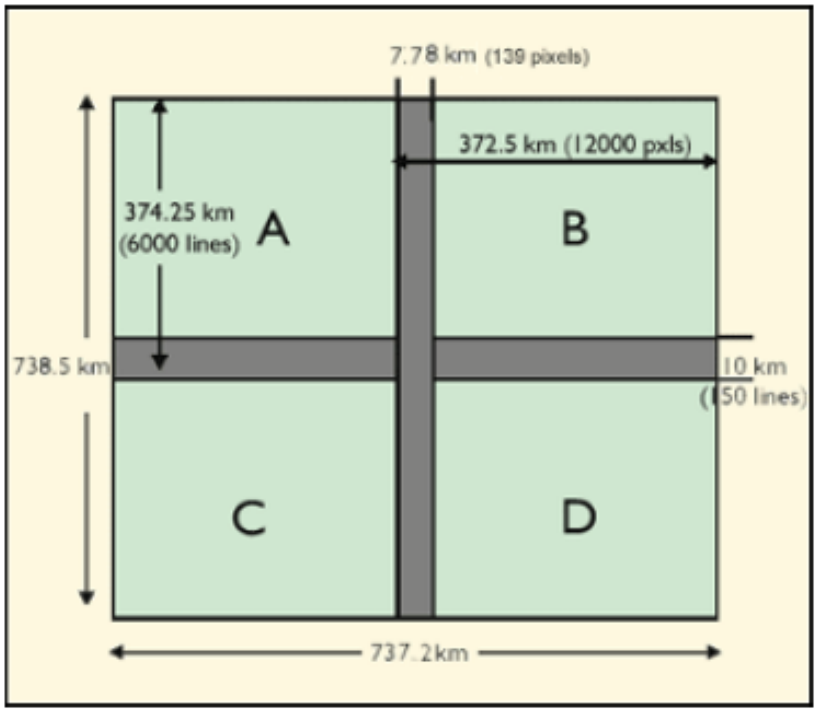
- The twin cameras of AWiFS provide medium-resolution multi-spectral data at 56m resolution (at nadir)
- Quantization: 10 bits
- Combined swath width: 740km with 5-day repeat cycle
- Operates in 4 spectral bands (Red, Green, NIR, SWIR)

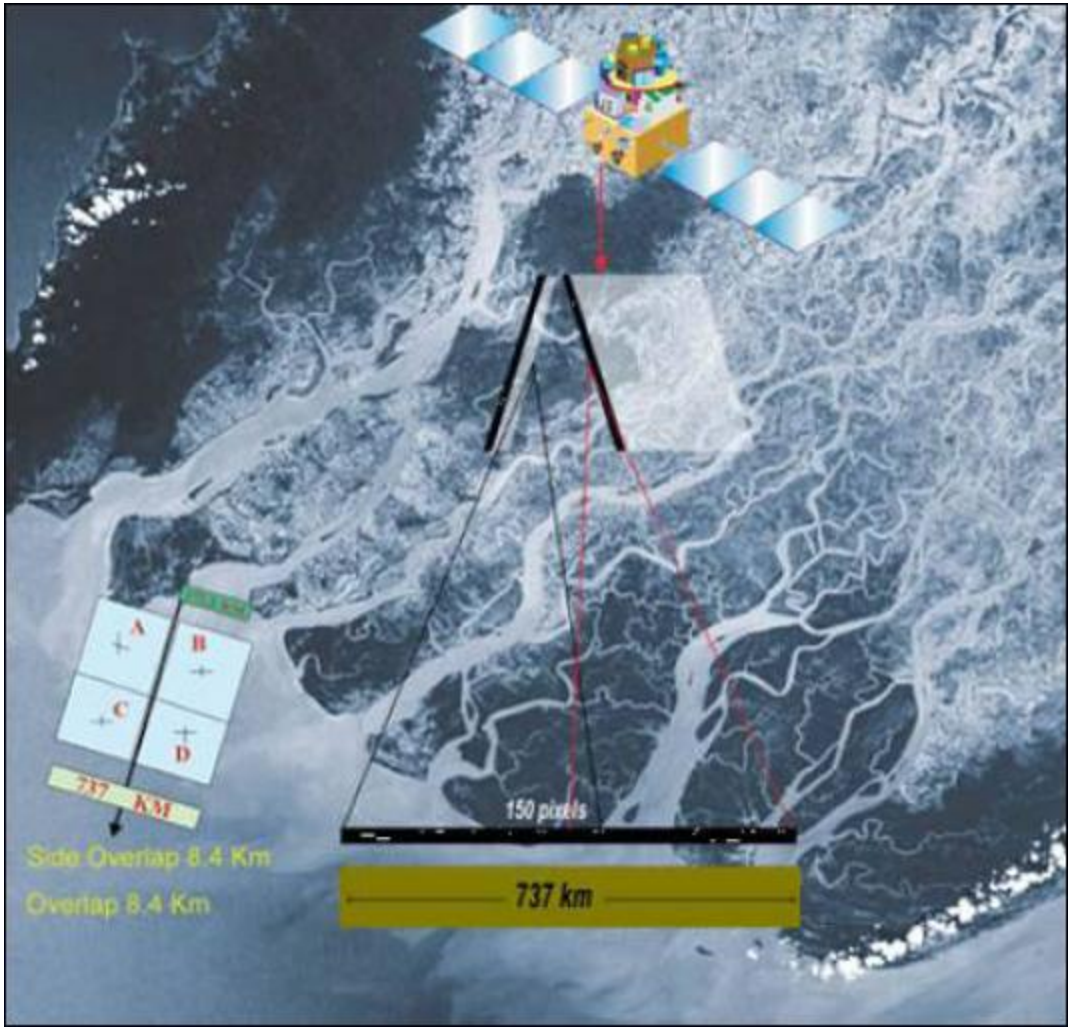
Key Features (Same as R1):

- **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

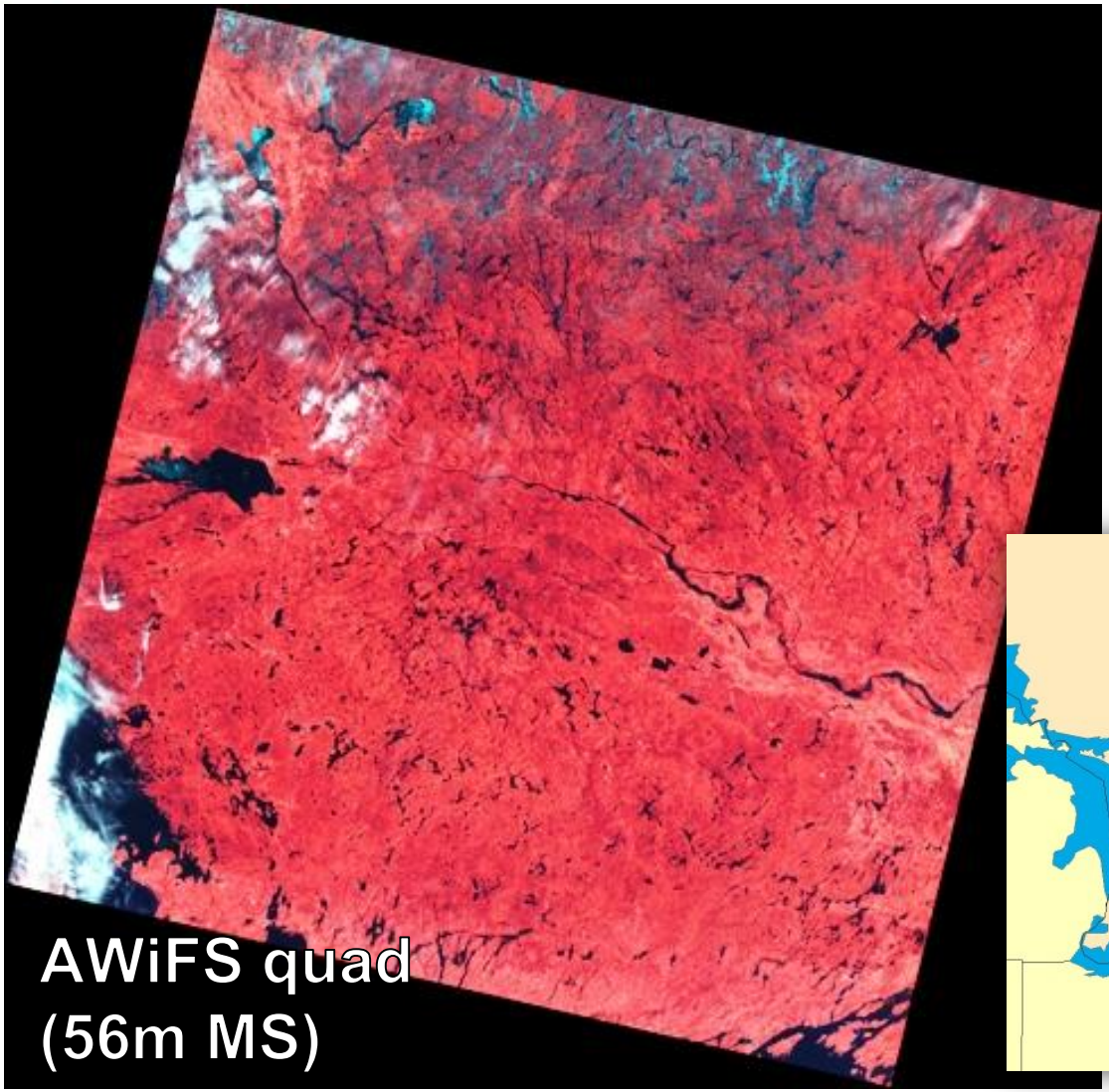
AWiFS Collection Mode

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



4/27/2009

287/37/Quad A - Ottawa, Ontario, CA

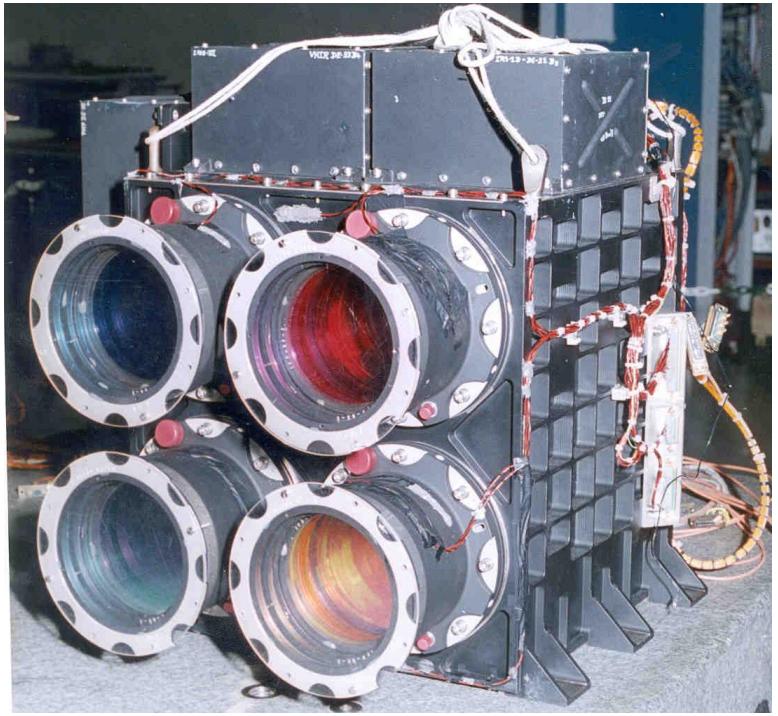
LISS-III Sensor

LISS-III Camera

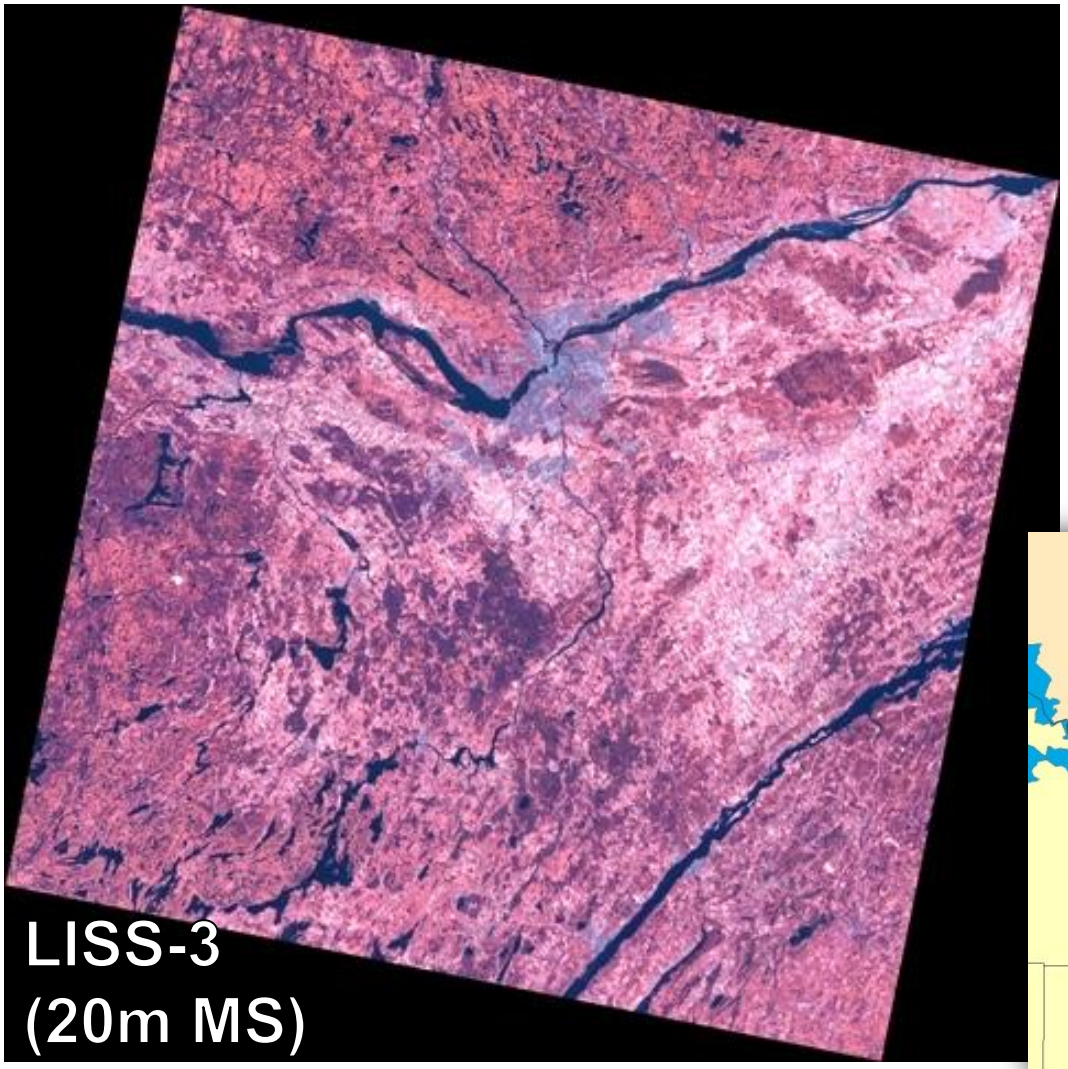
- LISS-III is a medium resolution camera offering GSD at 23.5m
- Quantization: 10 bits (7 bits transmitted with DPCM)
- Swath: 141 km with 24-day repeat cycle
- Four spectral bands: Red, Green, NIR, SWIR
- Each band consists of a separate lens assembly and linear array CCD

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



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287/37 Ottawa, Ontario, CA

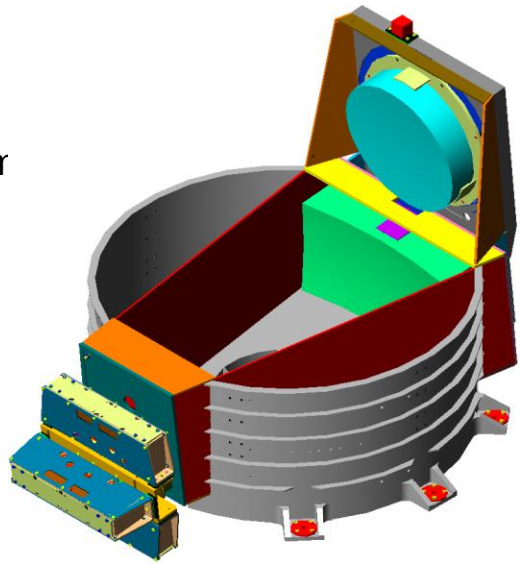
LISS-IV Sensor

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

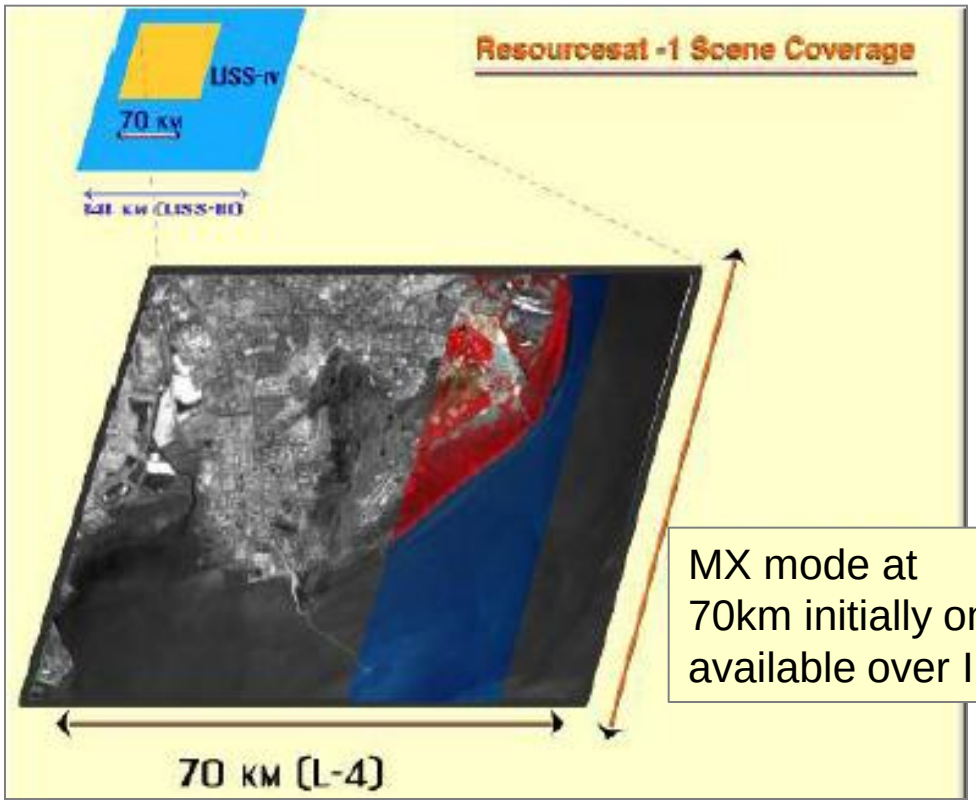
Key Features (Same as R1):

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



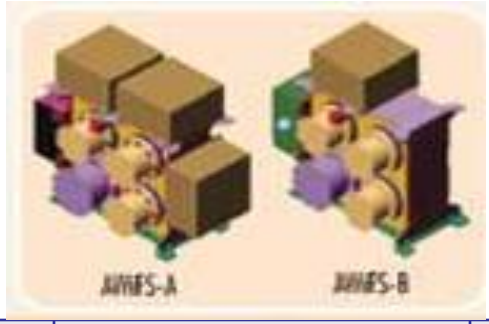
LISS-IV Collection Modes

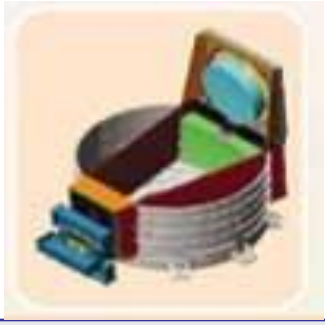
- LISS-IV can be operated in either of two modes
  - Mono Mode – 70km swath covered by band 3 (Red)
  - MX Mode – 70km swath covered by all 3 VNIR bands
    - Improvement over Resourcesat-1



MX mode at 70km initially only available over India

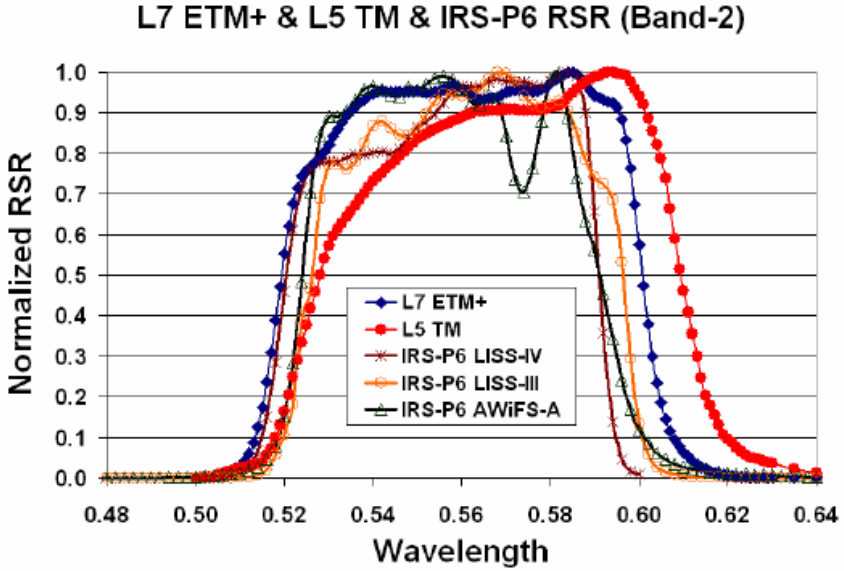
Summary of R2 Payloads

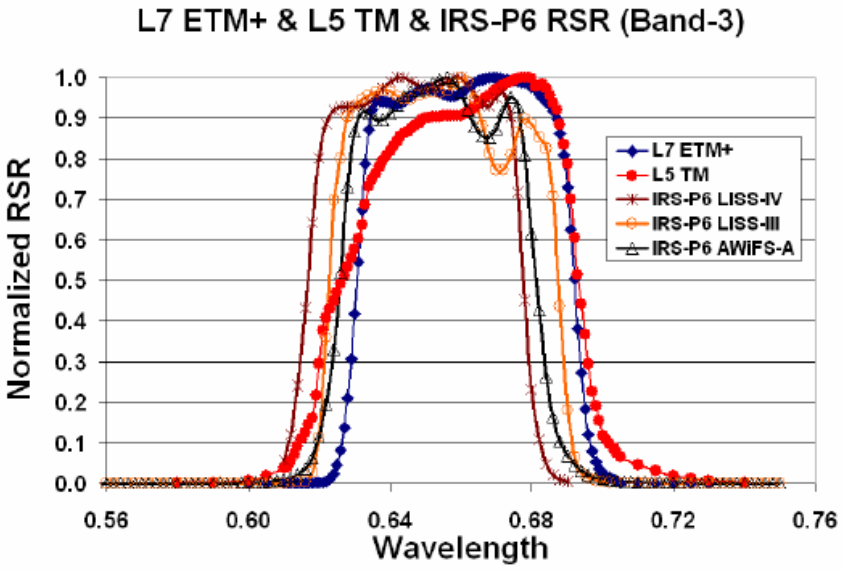


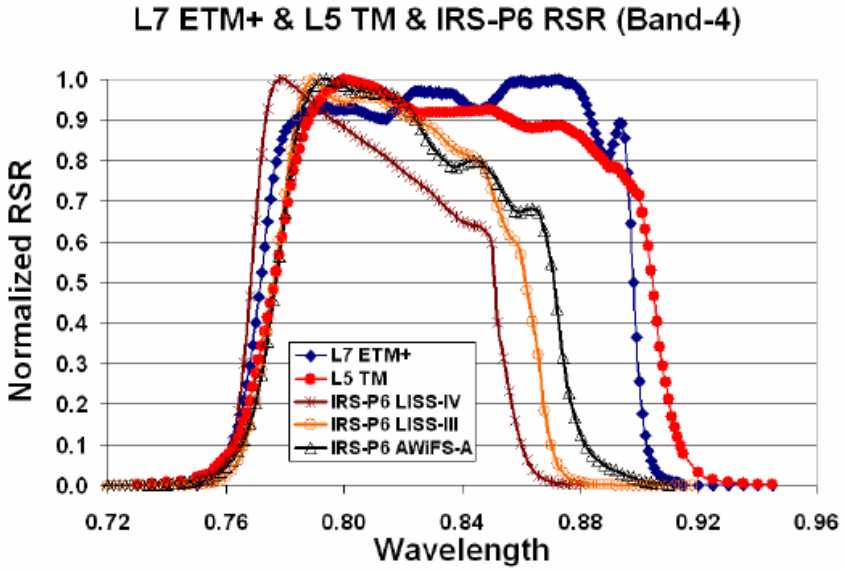


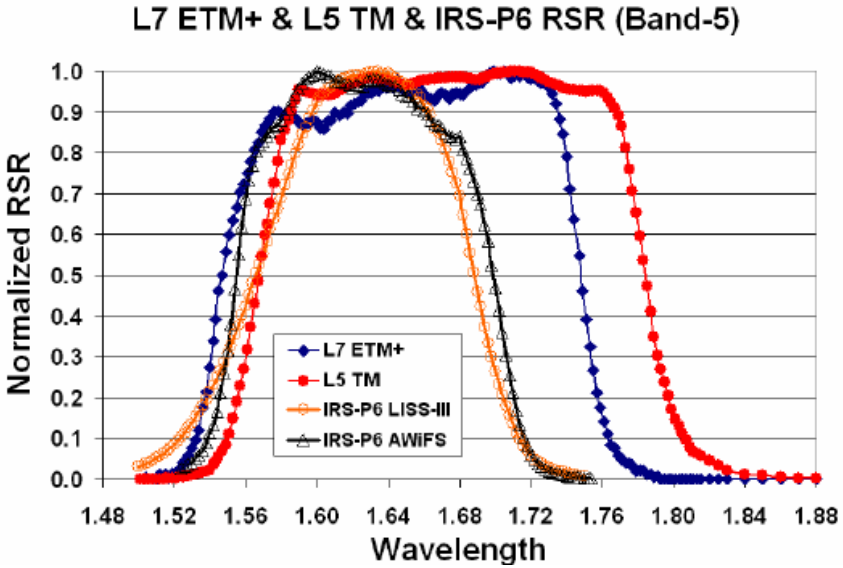
PAYLOADS		AWiFS	LISS-III	LISS-IV
Resolution (at nadir)		56m	23.5m	5.8m
Swath		740 km	141 km	70.3 km (MX mode) 70.3 km (PAN mode)
Spectral Bands	Band 2 (Green)	520-590 nm	520-590 nm	520-590 nm
	Band 3 (Red)	620-680 nm	620-680 nm	620-680 nm
	Band 4 (NIR)	770-860 nm	770-860 nm	770-860 nm
	Band 5 (SWIR)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

Comparison to Landsat









Data Collection Rates

Imagery Collection Rates:

Satellite	Sensor	Km^2 Per Second	Km^2 Per Minute	Scenes/Day (@ 8 mins/day)
Resourcesat-2	LISS-IV	~ 462 km^2	~ 27,720 km^2	~ 221,760 km^2
	LISS-III	~ 931 km^2	~ 55,836 km^2	~ 446,688 km^2
	AWiFS	~ 4,884 km^2	~ 293,040 km^2	~ 2,344,320 km^2

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

	Standard Products	Value Added Products
1	Path/Row Based	Ortho Products
2	Shift Along Track	
3	Quadrant Products	
4	Georeferenced Products	

Level	Type of Correction Applied
Level 0	No correction (not available for sale)
Level 1	Radiometric Correction only
Level 2 (Standard)	Radiometric and Geometric Correction
Level 3	Precision Correction (using GCPs)

Resampling Options	Map Projections	Earth Ellipsoids	Data Formats
Cubic Convolution	Polyconic	Clark 1866	LGSOWG Superstructure Format
Nearest Neighbor	Lambert Conformal Conical	Int'l 1909	Fast Format
Bilinear	Universal Transverse Mercator	GRS 1980	GeoTIFF (Gray Scale)
16 Point Sinc	Space Oblique Mercator	Everest	GeoTIFF (RGB)
Kaiser -16		WGS 84	HDF
4 Point Sinc		Bessel	
		Krassovsky	

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

Data Quality and Calibration

- 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!

ISRO CONTACT INFORMATION:
Mr. Deviprasad Karnik
Counsellor (Space)
ISRO Technical Liaison Unit
Embassy of India
2536 Massachusetts Ave., NW
Washington, DC 20008
TEL: 202-939-9811
Email: dpkarnik@indiagov.org

ANTRIX CONTACT INFORMATION:
Dr. K. Shridara Murthi
Managing Director
Antrix Corporation Limited
Antariksh Bhavan Complex
Near New BEL Road
Bangalore - 560 094 India
TEL: +1-91-80-23415241
Email: krs@antrix.gov.in

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-IV*n* at 2.5m, 3-4 bands, 5 day revisit
    - LISS-V*n* at 1.25m PAN, 5 day revisit
    - HSI*n* 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

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

Single Polarization	VV/HH/HV/VH
Dual Polarization	HH & VV/VV & VH
Polarimetric	HH & VV & HV & VH