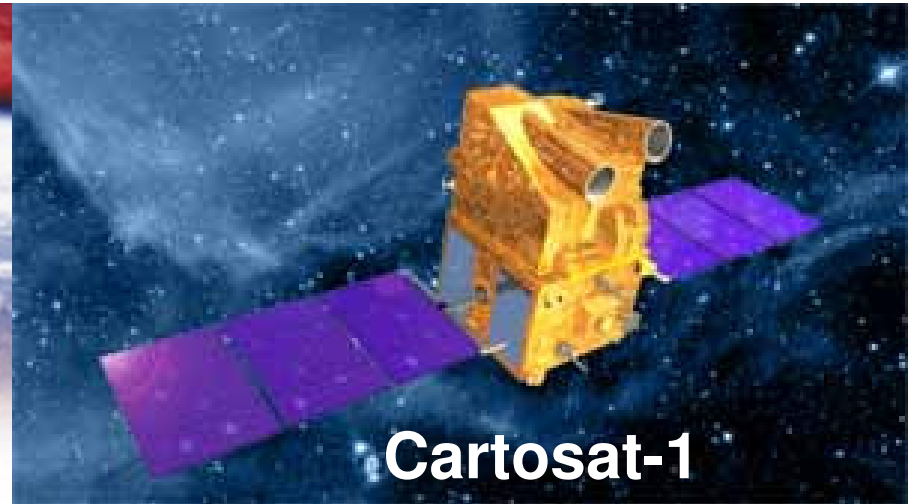




**Resourcesat-1**



**Cartosat-1**

## Indian Remote Sensing Satellites

*- Current & Future Missions -*

Presented by:  
Timothy J. Puckorius  
Chairman & CEO  
EOTec

- Who is EOTec
- India's Earth Observation Heritage
- Current IRS Satellite Missions
  - Resourcesat-1 (IRS-P6)
    - Multispectral broad area coverage
  - Cartosat-1 (IRS-P5)
    - Real-time Stereo mapping
  - Cartosat-2 (IRS-P7)
    - High-Resolution imaging at 0.81m
- Future IRS Satellite Missions
- Conclusions



## Who is EOTec

---

- Earth Observation Technologies LLC (EOTec) now serves as **Managing Agents** for ANTRIX Corporation Ltd.
  - ANTRIX is the commercial arm of Indian Space Research Organization (“ISRO”)
  - EOTec’s role is to help identify, qualify and conclude purchase agreements on behalf of ANTRIX with prospective customers and resellers worldwide for:
    - IRS Satellite Access
    - IRS Ground Station Equipment
    - IRS Data Sales
    - Launch Services
    - Manufacturing Services
    - Other Value-Added Services

1995/1997



IRS-1C/1D LISS-3 (23/70M,  
STEERABLE PAN (5.8 M);  
WiFS (188M)

1999



INSAT-2E CCD  
(1KM RESOLUTION;  
EVERY 30 MNUTESS)

2003



RESOURCESAT-1  
LISS3 - 23 M; 4 XS  
LISS4 - 5.8 M; 3-  
XS

1996



IRS-P3  
WiFS MOS  
X-Ray

1994



IRS-P2  
LISS-2

2005



CARTOSAT - 1  
PAN - 2.5M, 30 KM,  
F/A

1999



IRS-P4  
OCEANSAT OCM, MSMR

1988/91



IRS-1A/1B LISS-1&2 (72/36M,  
4 BANDS; VIS & NIR)

# INDIAN IMAGING SYSTEMS



CARTOSAT-2  
PAN - 1M

2007



MEGHA-  
TROPICUS  
SAPHIR  
SCARAB &  
MADRAS

1982



RS-D1

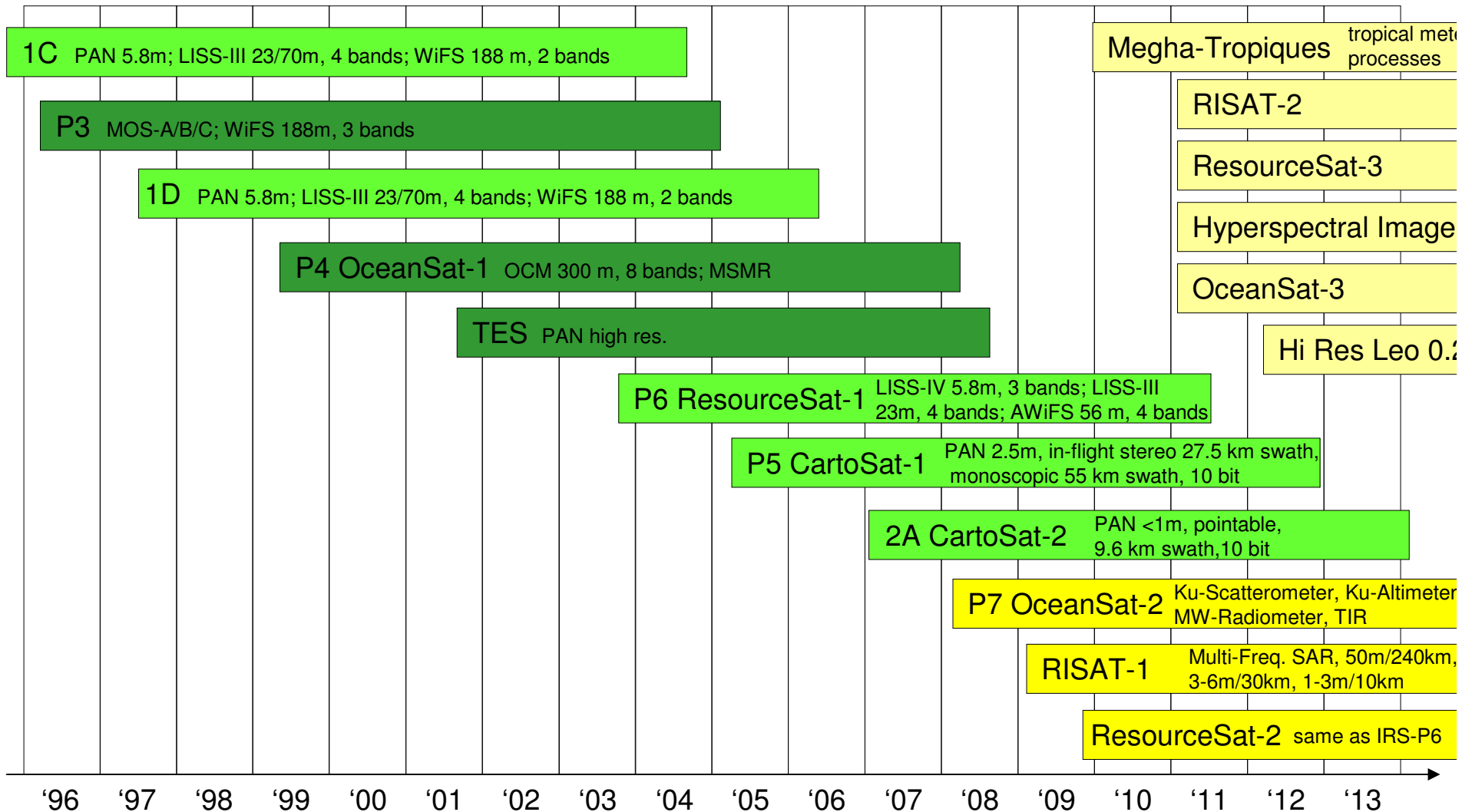
1979



BHASKARA

## IMAGING IMPROVEMENTS

- ◆ 1KM TO 0.81 M RESOLUTION
- ◆ GLOBAL COVERAGE
- ◆ APPLICATION-SPECIFIC





# Current IRS Missions

Resourcesat-1

Cartosat-1

Cartosat-2

# EOTec



Resourcesat-1  
(IRS-P6)

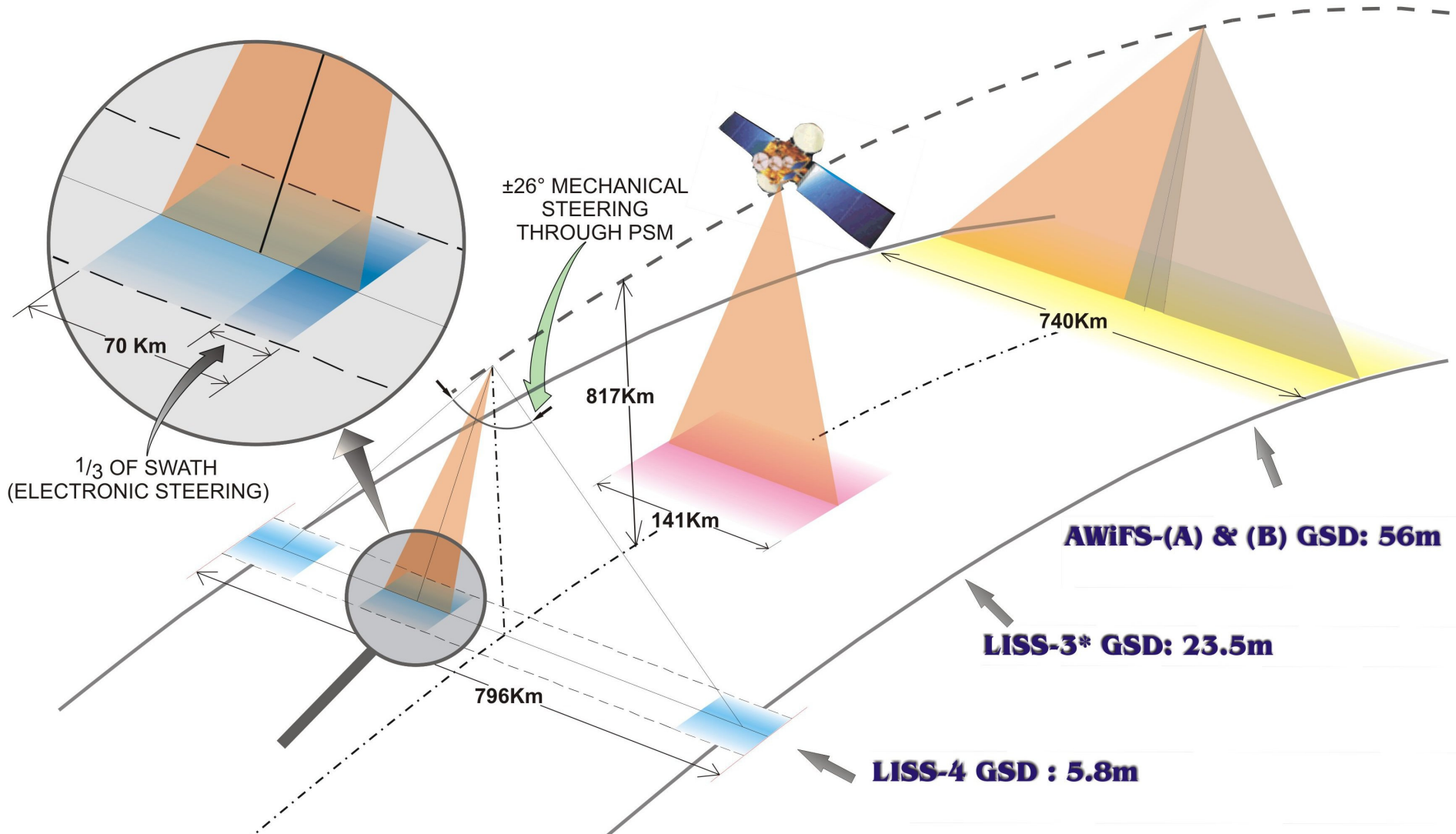
<b>Orbit :</b>	<b>Circular Polar Sun Synchronous</b>
<b>Orbit height :</b>	<b>821 km</b>
<b>Orbit inclination :</b>	<b>98.76°</b>
<b>Orbit period :</b>	<b>101.35 min</b>
<b>Number of Orbits per day :</b>	<b>14</b>
<b>Local Time of Equator crossing :</b>	<b>10.30 a.m.</b>
<b>Repetivity (LISS-3) :</b>	<b>24 days (341 orbits)</b>
<b>Revisit (AWiFS) :</b>	<b>5 days</b>
<b>Lift-off Mass :</b>	<b>1,360 kg</b>
<b>Attitude and Orbit Control :</b>	<b>3-axis body stabilized using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters</b>
<b>Power :</b>	<b>Solar Array generating 1250 W (at EOL), Two 24 Ah Ni-Cd batteries</b>
<b>Mission Life :</b>	<b>5-7 years</b>
<b>Launch Dates :</b>	<b>Resourcesat-1 launched on 10-17-03 Resourcesat-2 scheduled for <b>mid 2009</b></b>



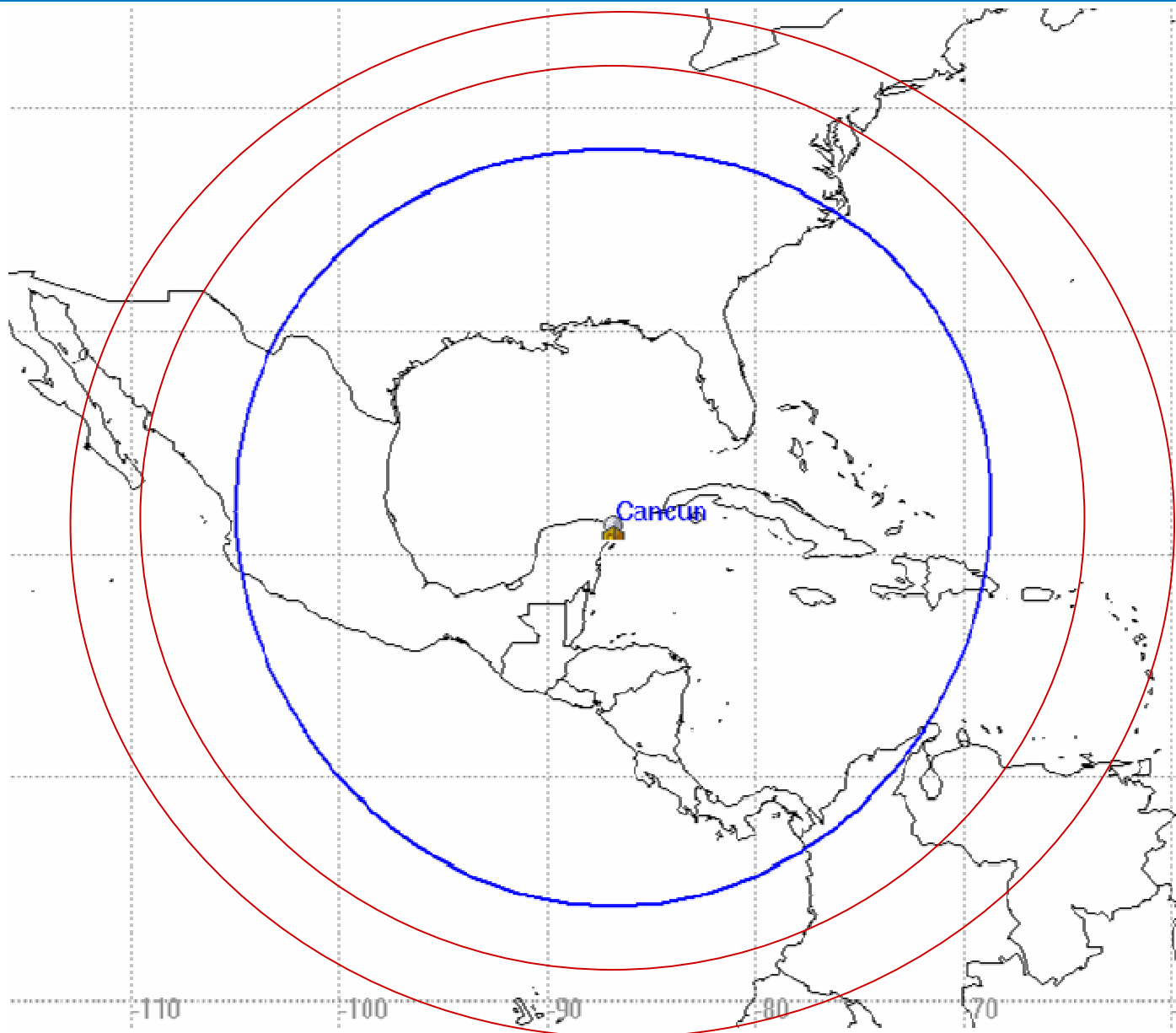


PAYLOADS	LISS-4	LISS-3	AWiFS
Spatial Resolution (m)	5.8	23.5	56
Swath (km)	23.9 (MX mode) 70.3 (PAN mode)	141	740
Spectral Bands (micron)	0.52-0.59 0.62-0.68 0.77-0.86	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70
Quantisation (bits)	7	7	10
Square Wave Response (at Nyquist)	>0.20	B2 > 0.40 B3 > 0.40 B4 > 0.35 B5 > 0.20	B2 > 0.40 B3 > 0.40 B4 > 0.35 B5 > 0.20
Power (W)	216	70	114
Weight (kg)	169.5	106.1	103.6
Data Rate (MBPS)	105	52.5	52.5

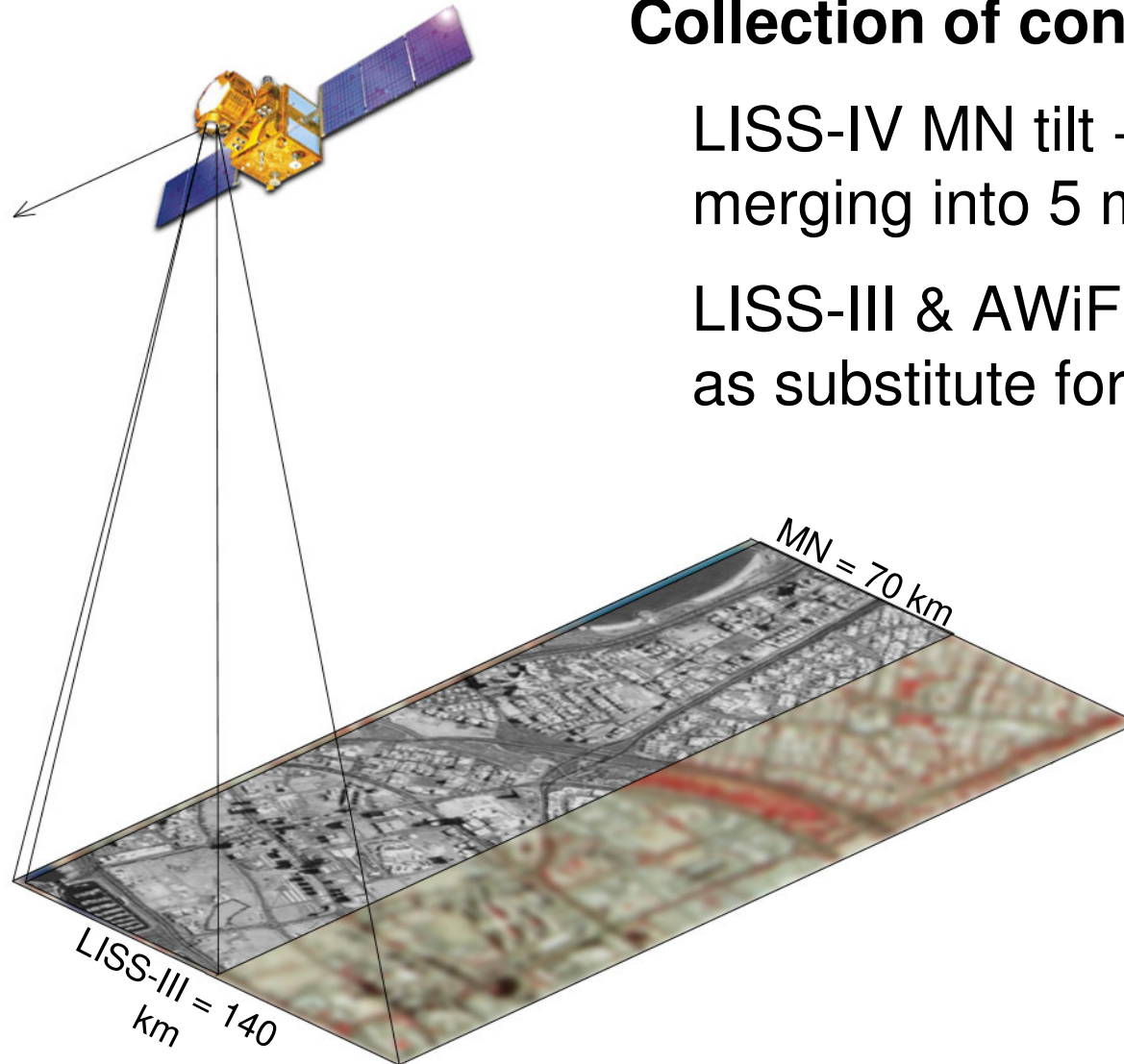
## IRS-P6 THREE TIER IMAGING



# EOtec Regional Coverage in Real-Time



Satellite	Sensor	Km <sup>2</sup> Per Second	Km <sup>2</sup> Per Minute	Scenes/Day (@ 8 mins/day)
<b>Resourcesat-1</b>	LISS-IV	~ 462 km <sup>2</sup>	~ 27,720 km <sup>2</sup>	~ 221,760 km <sup>2</sup>
	LISS-III	~ 931 km <sup>2</sup>	~ 55,836 km <sup>2</sup>	~ 446,688 km <sup>2</sup>
	AWiFS	~ 4,884 km <sup>2</sup>	~ 293,040 km <sup>2</sup>	~ 2,344,320 km <sup>2</sup>



### Collection of contiguous coverage

LISS-IV MN tilt +/- 2 deg allows merging into 5 m natural colour

LISS-III & AWiFS is being offered as substitute for Landsat TM

AWiFS-A & AWiFS-B with total swath of 740 km omitted

Sensor	IRS-1C/1D PAN	IRS-P6 LISS-IV
Mode		Mono
Spatial resolution	5.8 m	5.8 m
Swath-width	70 km	70 km
Radiometric Resolution, Quantisation	6 bit	7 bit
Spectral coverage	500 – 750 nm	620-680 nm
Number of CCD arrays	3	1

Better radiometric resolution

Red instead of pan-chromatic band

Only one array, leads to better internal geometry

Suitable for mapping, mobile phone cell planning

- The LISS-IV camera can be operated either in monochromatic or multi spectral mode.
- LISS-IV multi spectral mode acquisitions are not offered.

Sensor			LISS-IV		LISS-III	AWiFS
Mode			Mono	MX		
Spatial resolution	B2	green	5.8 m	5.8 m	23.5 m	56 m .. 70 m
	B3	red		5.8 m	23.5 m	56 m .. 70 m
	B4	NIR		5.8 m	23.5 m	56 m .. 70 m
	B5	SWIR			23.5 m	56 m .. 70 m
Swath-width			70 km	23.9 km	140 km	740 km
Radiometric Resolution, Quantisation	all Bands		7 bit	7 bit	7 bit	10 bit
Spectral coverage	B2	green	620-680 nm	520-590 nm	520-590 nm	520-590 nm
	B3	red		620-680 nm	620-680 nm	620-680 nm
	B4	NIR		770-860 nm	770-860 nm	770-860 nm
	B5	SWIR			1550-1700 nm	1550-1700 nm
CCD arrays (number of arrays * No. of elements)	B2	green	1 * 12000	1 * 12000	1 * 6000	2 * 6000
	B3	red		1 * 12000	1 * 6000	2 * 6000
	B4	NIR		1 * 12000	1 * 6000	2 * 6000
	B5	SWIR			1 * 6000	2 * 6000

- **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**

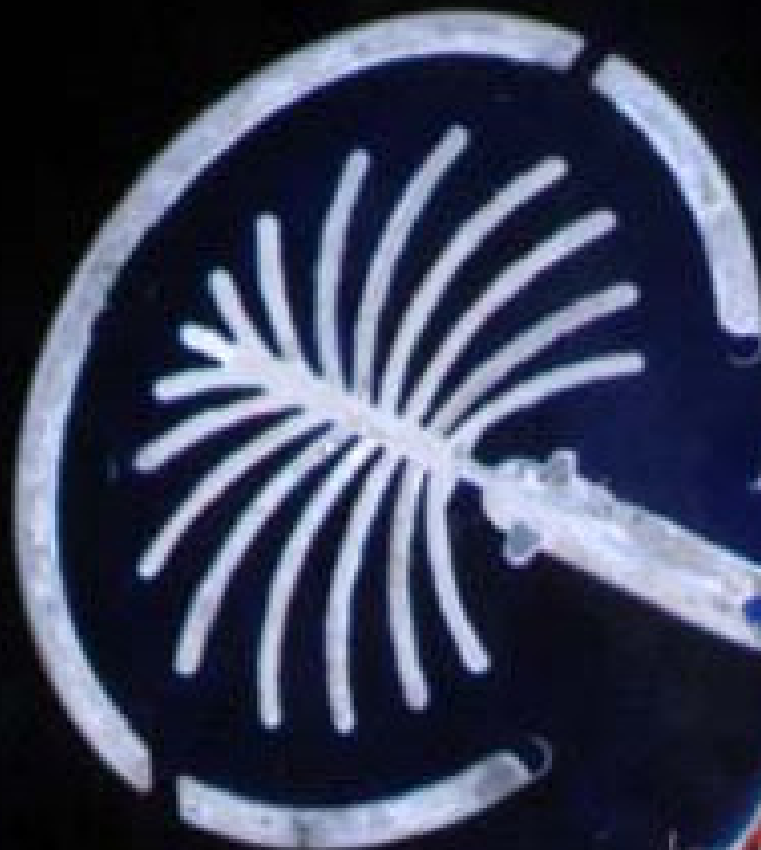


# Milan, Italy



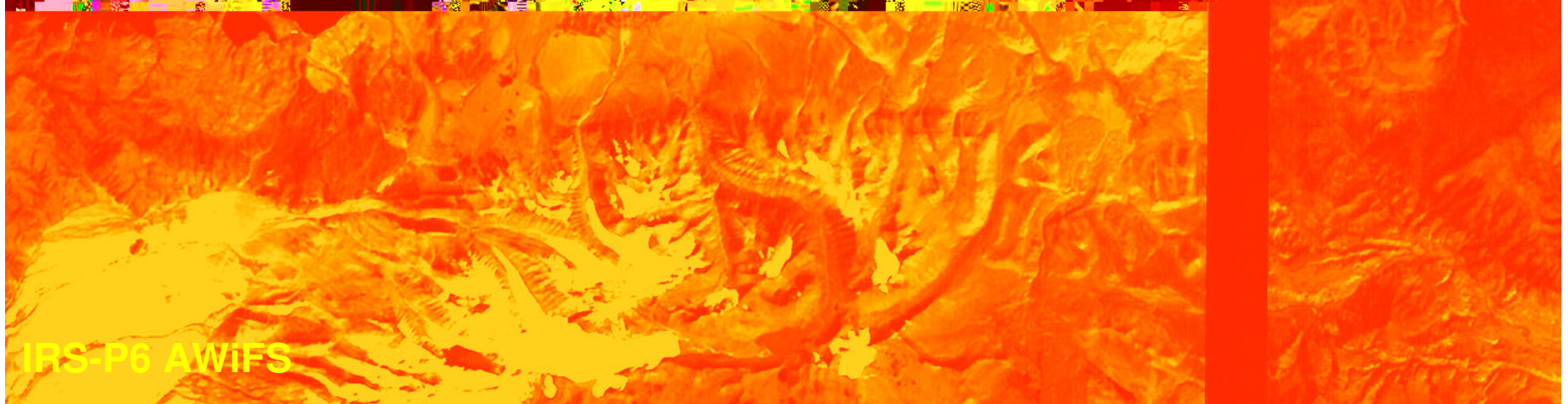
**IRS-P6 LISS-IV Mono Mode**  
**5.8m / 7 bit / 70km / Red band**

# Palm Island, Dubai



IRS-P6 LISS-IV  
5.8m / 7 bit / 70km

# Manasarovar Lake, Tibet



# Part of Myanmar coast



IRS-P6 LISS-III



# USDA Satellite Imagery Archive

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## Resourcesat-1 AWiFS Data at the USDA and Plans for 2007

Robert Tetrault

USDA Satellite Imagery Archive Manager

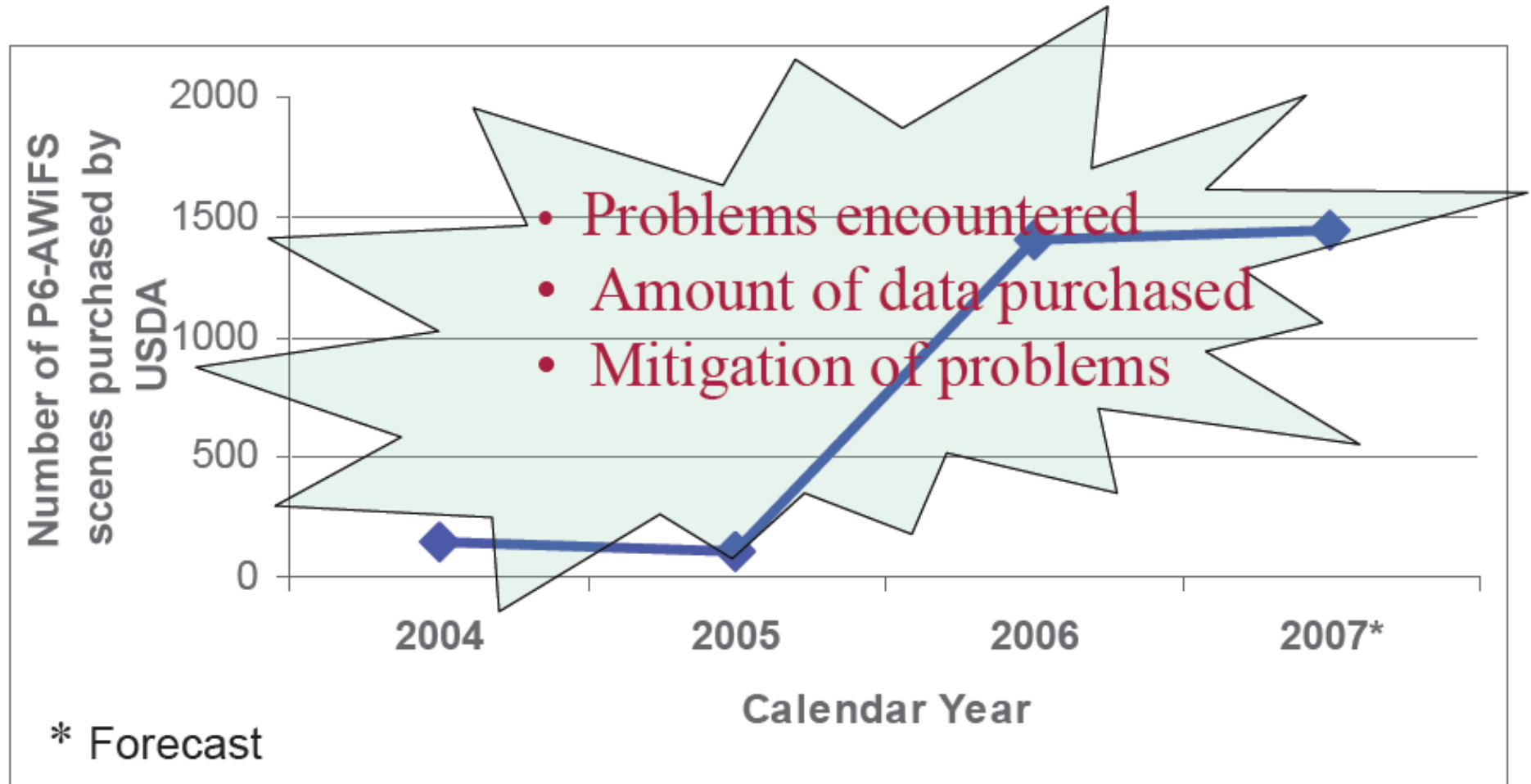
Civil Commercial Imagery Evaluation Workshop

March 2007

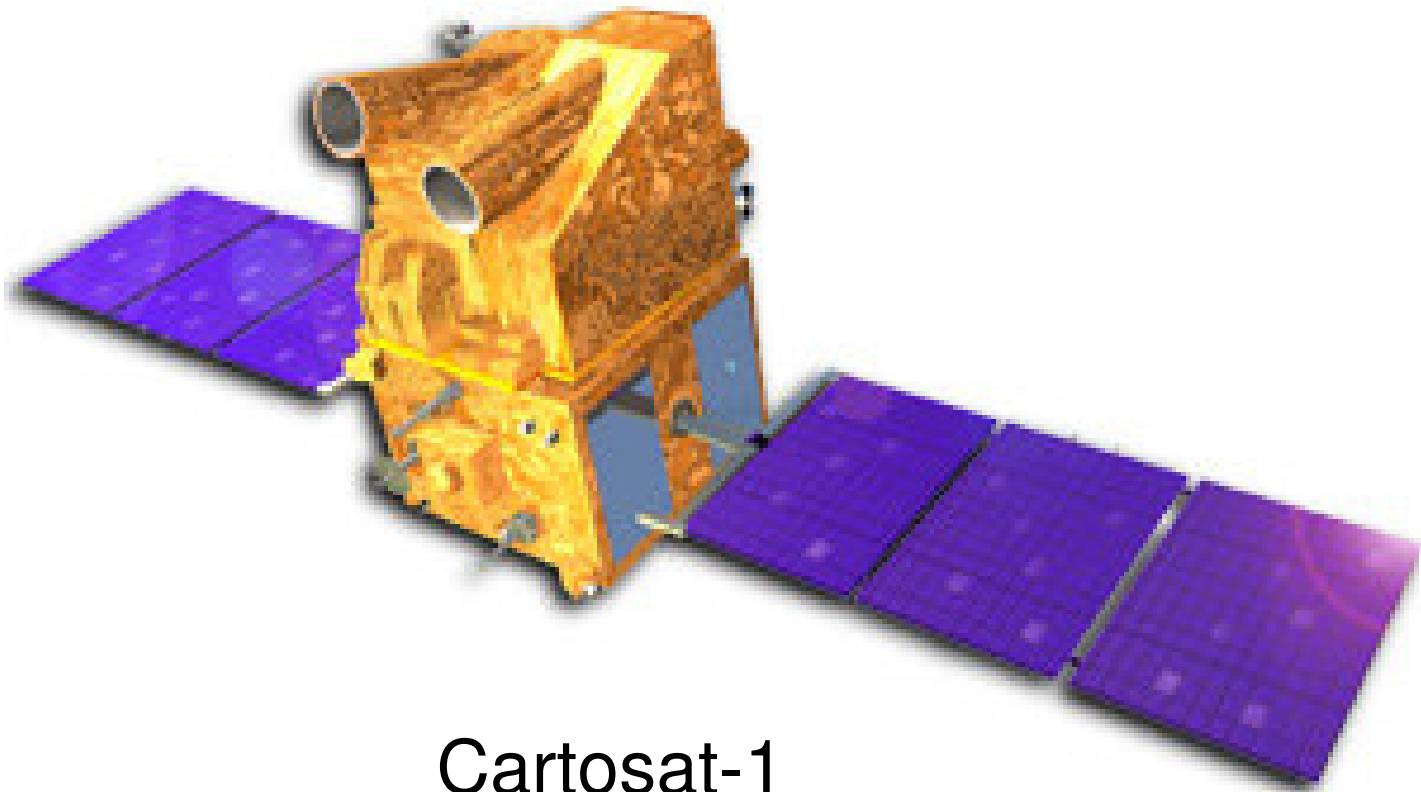




## How Did USDA Transition to P6-AWiFS?



# EOTec

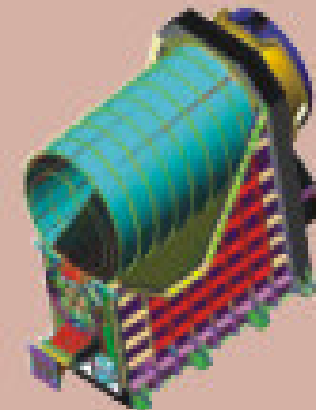


Cartosat-1  
(IRS-P5)

<b>Orbit :</b>	<b>Circular Polar Sun Synchronous</b>
<b>Orbit height :</b>	<b>~618 km</b>
<b>Orbit inclination :</b>	<b>98.87°</b>
<b>Orbit period :</b>	<b>97 min</b>
<b>Number of Orbits per day :</b>	<b>15</b>
<b>Local Time of Equator crossing :</b>	<b>10.30 a.m.</b>
<b>Orbital Repetivity Cycle :</b>	<b>126 days</b>
<b>Nominal Wait Time to Acquire Adjacent Path :</b>	<b>11 days</b>
<b>Max. Wait Time for Revisit :</b>	<b>5 days</b>
<b>Data Rate :</b>	<b>105 Mb/s</b>
<b>Solid state storage:</b>	<b>120GB</b>
<b>Lift-off Mass :</b>	<b>1,560 kg</b>
<b>Attitude and Orbit Control :</b>	<b>3-axis body stabilized using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters</b>
<b>Power :</b>	<b>5 sq m Solar Array generating 1100W (End Of Life) Two 24 Ah Ni-Cd batteries</b>
<b>Mission Life :</b>	<b>5 – 7 years (launched 05/05/05)</b>



Payloads	: Two PAN Cameras (PAN fore mounted with a tilt of +26 deg and PAN aft mounted with a tilt of – 5 deg from the yaw axis to generate stereoscopic imagery)
Instantaneous Geometric Field of View (IGFOV)	: < 2.5 m
Swath	: 30 km
Spectral Band	: 0.50-0.85 Micron
Data rate	: 105 Mbps for each camera
Solid State Recorder	: 120 GB capacity for image data storage



*CARTOSAT-1  
PAN camera*

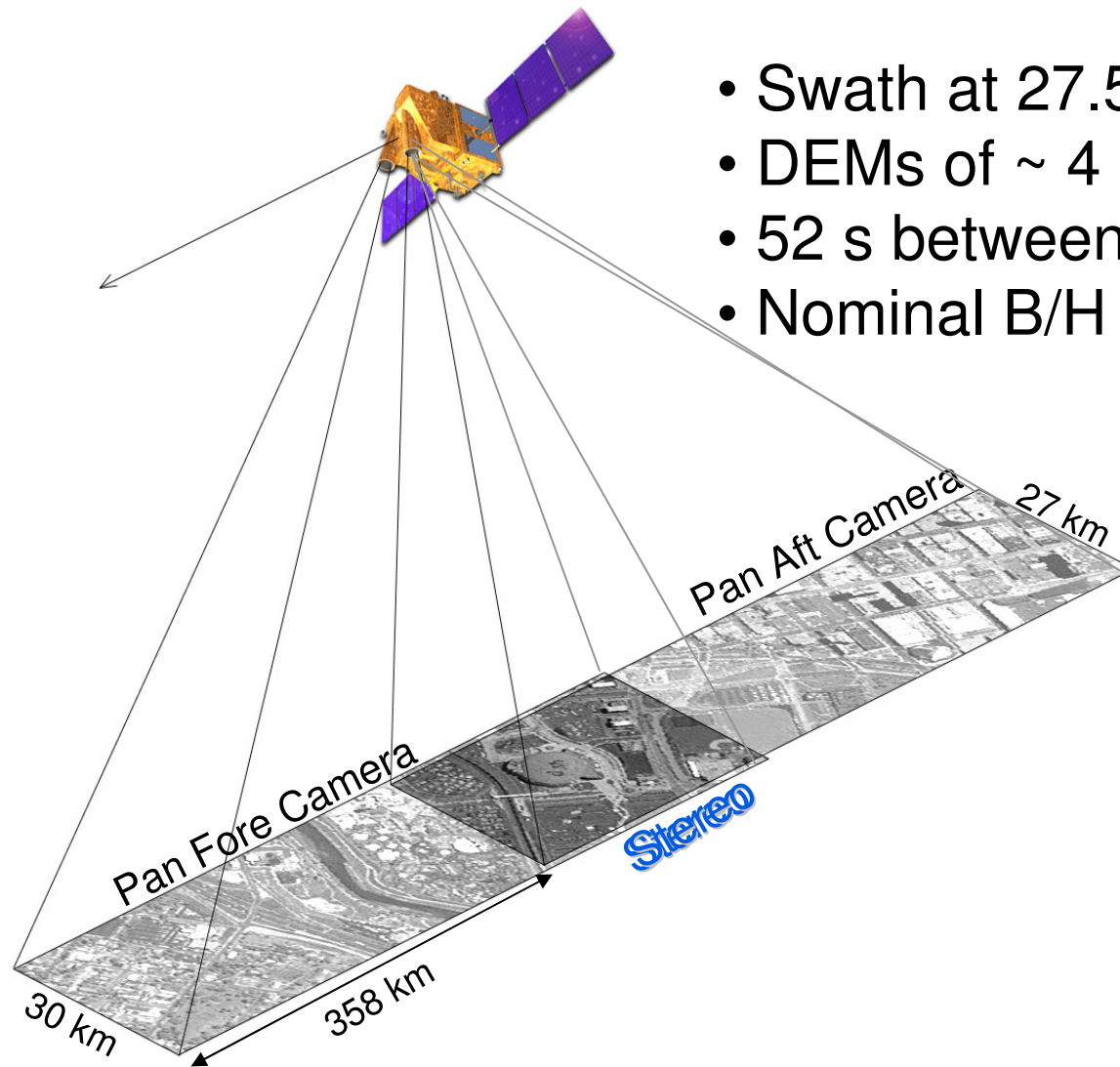
- Cartosat-1 has two (2) panchromatic cameras for in flight stereo viewing
- Stereo data is provide to ground stations in *Real-Time*

<b>Sensor</b>	<b>PAN Fore</b>	<b>PAN Aft</b>
<b>Tilt Along Track</b>	+26°	-5°
<b>Spatial Resolution</b>	2.5 m	2.5 m
<b>Swath-width</b>	30 km	27 km
<b>Radiometric Resolution, Quantisation</b>	10 bit	10 bit
<b>Spectral coverage</b>	500-850 nm	500-850 nm
<b>CCD arrays (number of arrays * No. of elements)</b>	1 * 12000	1 * 12000

- Revisit capability is 5 days (by rolling on axis  $\pm 23^\circ$ )

Satellite	Sensor	Km <sup>2</sup> Per Second	Km <sup>2</sup> Per Minute	Scenes/Day (@ 8 mins/day)
<b>Cartosat-1</b>	PAN Camera (Fore)	~ 190 km <sup>2</sup>	~ 11,385 km <sup>2</sup>	~ 91,080 km <sup>2</sup>
	PAN Camera (Aft)	~ 190 km <sup>2</sup>	~ 11,385 km <sup>2</sup>	~ 91,080 km <sup>2</sup>

# EO Tec IRS-P5 Stereo Collection Mode



- Swath at 27.5 km
- DEMs of ~ 4 m elevation accuracy
- 52 s between cameras ~ 358 km
- Nominal B/H ratio 0.62

# Denver, CO

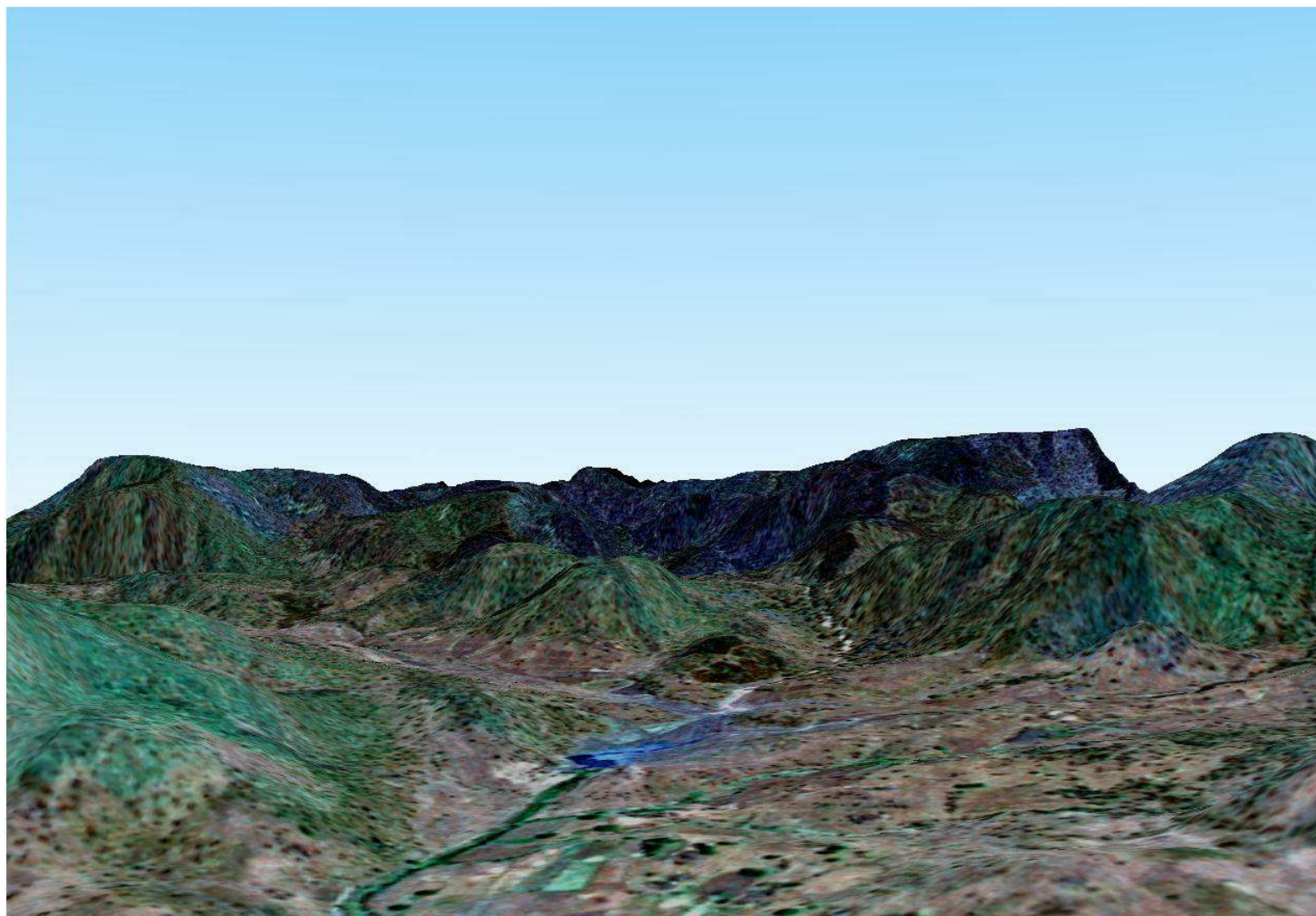


IRS-P5 / PAN-A / 2.5m / 10 bit



# INITIAL IMAGE OF CARTOSAT-1

## 3D PERSPECTIVE VIEWS OF KHED BRAHMA, GUJARAT



NATURAL COLOR COMPOSITE IMAGE OF  
CARTOSAT-1 PAN-AFT + IRS-P6 LISS-IV MX

ACQUIRED ON:

CARTOSAT-1 PAN : 08-MAY-2005  
IRS-P6 LISS-IV MX : 27-MAR-2004

BEST COMPLIMENTS FROM  
NRSA / DOS

# EOTec



Cartosat-2

# Cartosat-2 at a Glance



*CARTOSAT-2 Spacecraft with its solar panels in stowed condition*

Launched 1/10/07

Altitude	: 630 km
Inclination	: 97.91 deg
Period	: 97.4 min
Local time at descending node	: 9.30 am
Orbits/day	: 14
Revisit	: 4 days
Repetivity	: 310 days
Lift-off Mass	: 680 kg
Attitude and Orbit Control	: 3-axis body stabilised using high torque Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters
Power	: Solar Array Generating 900 W, Two 18 Ah Ni-Cd batteries
Payload	: Panchromatic camera (PAN)
Operational Life	: 5 years
<b>PAN specifications</b>	
Resolution	: <b>0.81m</b>
Swath	: About 9.6 km
Spectral Band	: 0.5 – 0.85 micrometre
Data rate	: 336 MBPS
Solid State Recorder	: 64 GB capacity for image data storage



### **Resolution/Swath:**

Panchromatic: 0.80m at 9.6km

### **Solid Stage Recorder:**

64 GB; 138 Images of 9.6km X 9.6km

### **10 Bit Detector Dynamic Range**

### **Max Data Rate:**

105 MBPS / X-Band Downlink

### **Maximum Area Imaged per 12 min Pass:**

0.82m GSD (Mono): 8832 km<sup>2</sup>

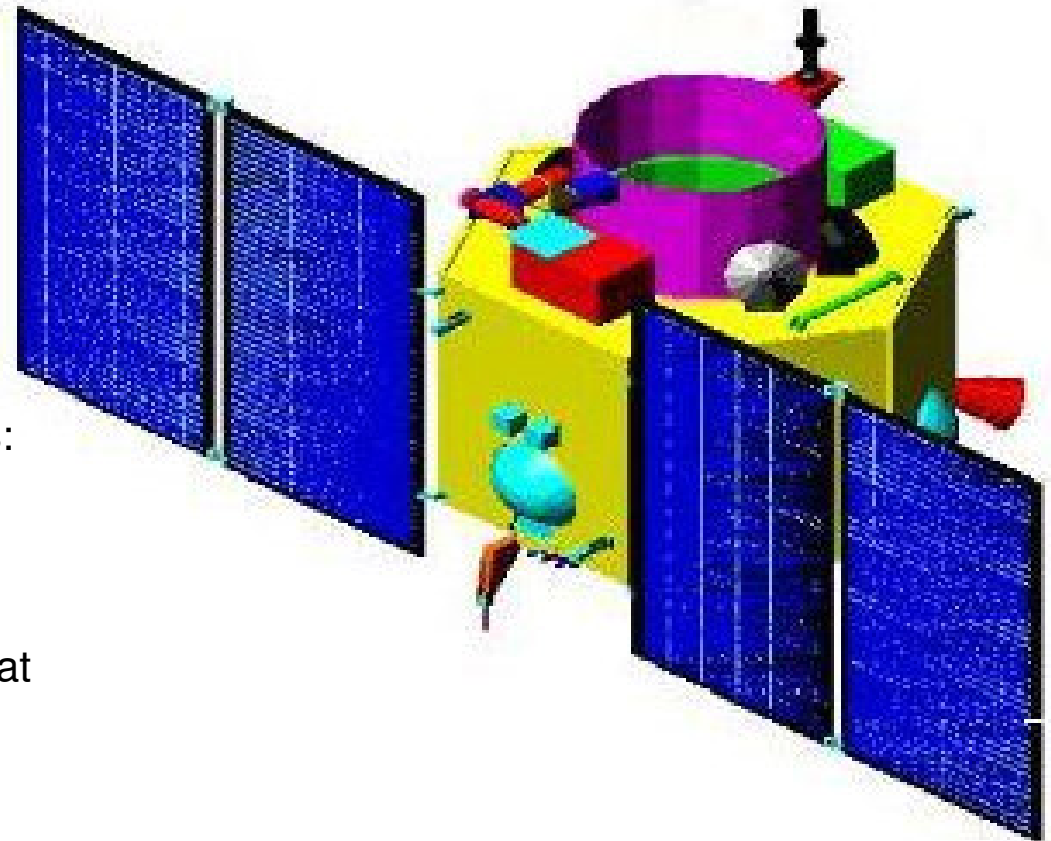
### **Revisit Time:** 4/5 days at equator

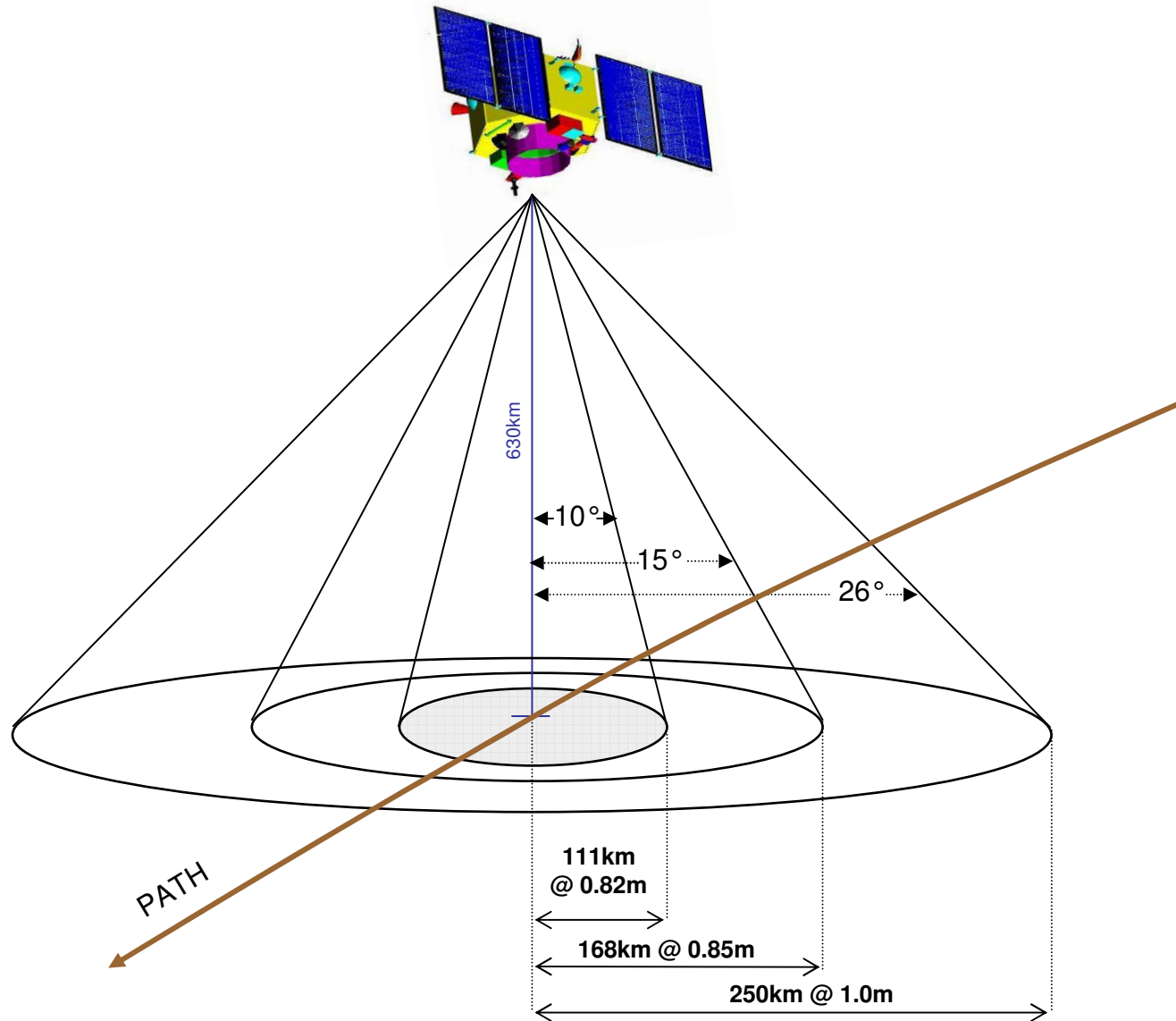
**Orbit:** 630km / 97.922° Sun Synchronous at  
9.30 A.M Local time

**Launch Mass:** 680 Kgs

**Launched Date:** January 10, 2007

**Design Life:** Minimum 5 years



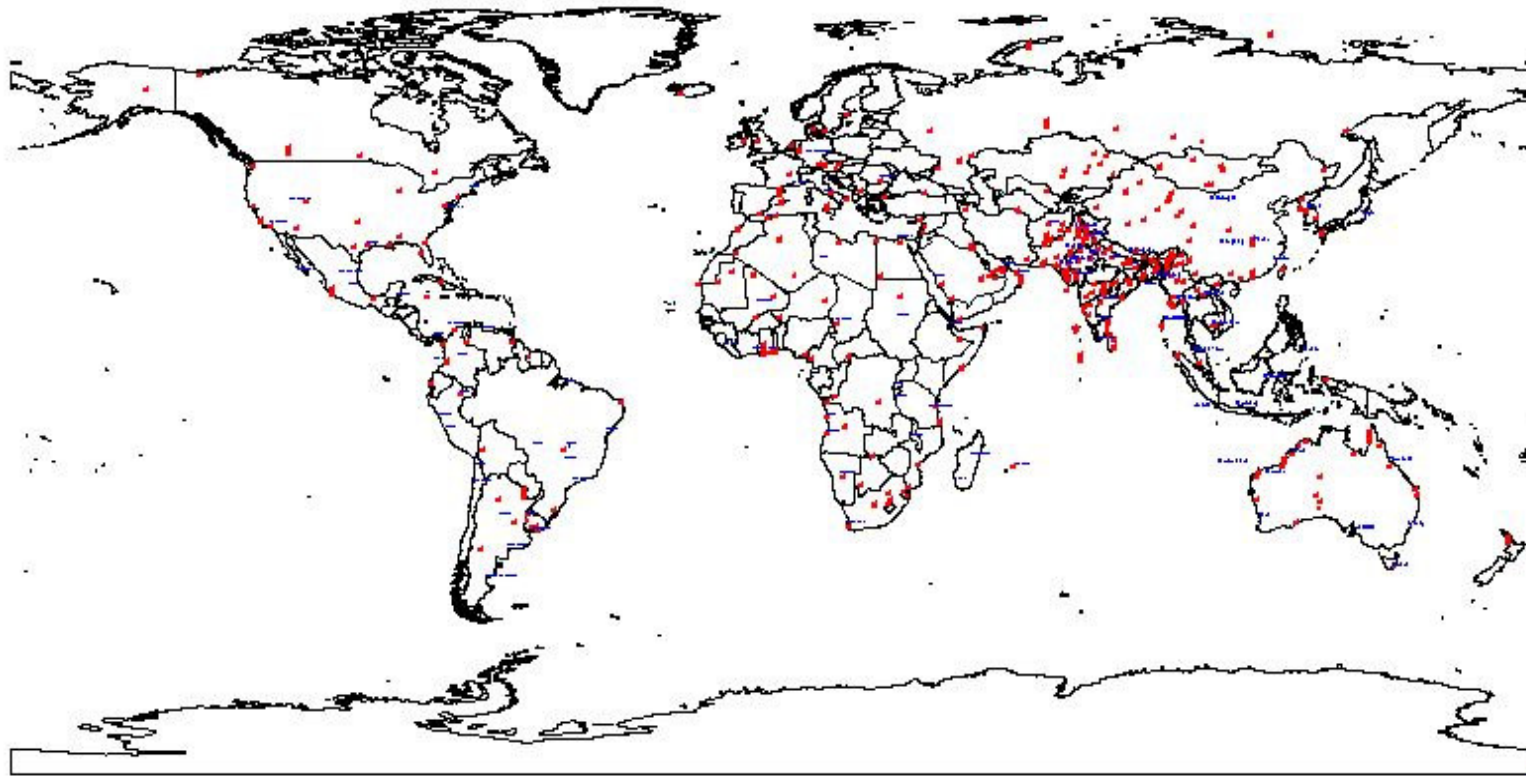




# EOTec C2 Sample Imagery (Bangalore)



### CARTOSAT 2 - GLOBAL COVERAGE



Total area acquired  
2,39,057.4 Sq. Km



# Future IRS Missions

Resourcesat-*n*

Cartosat-*n*

Radar

HSI

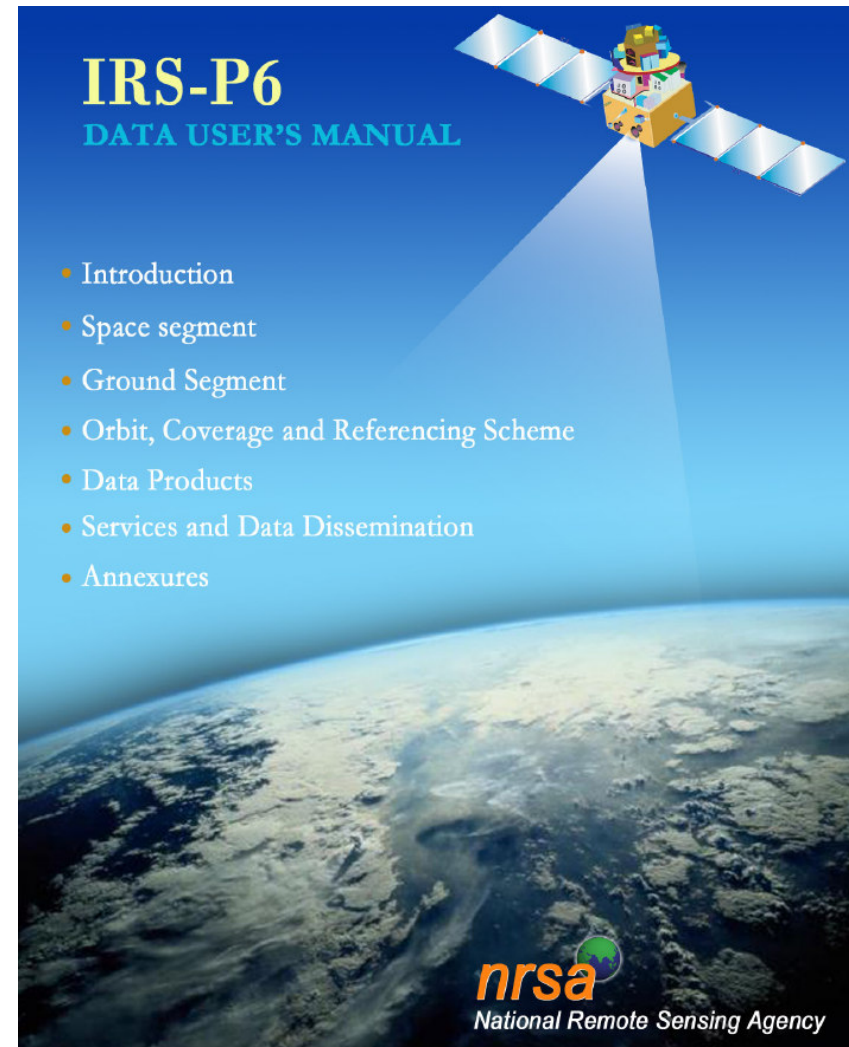
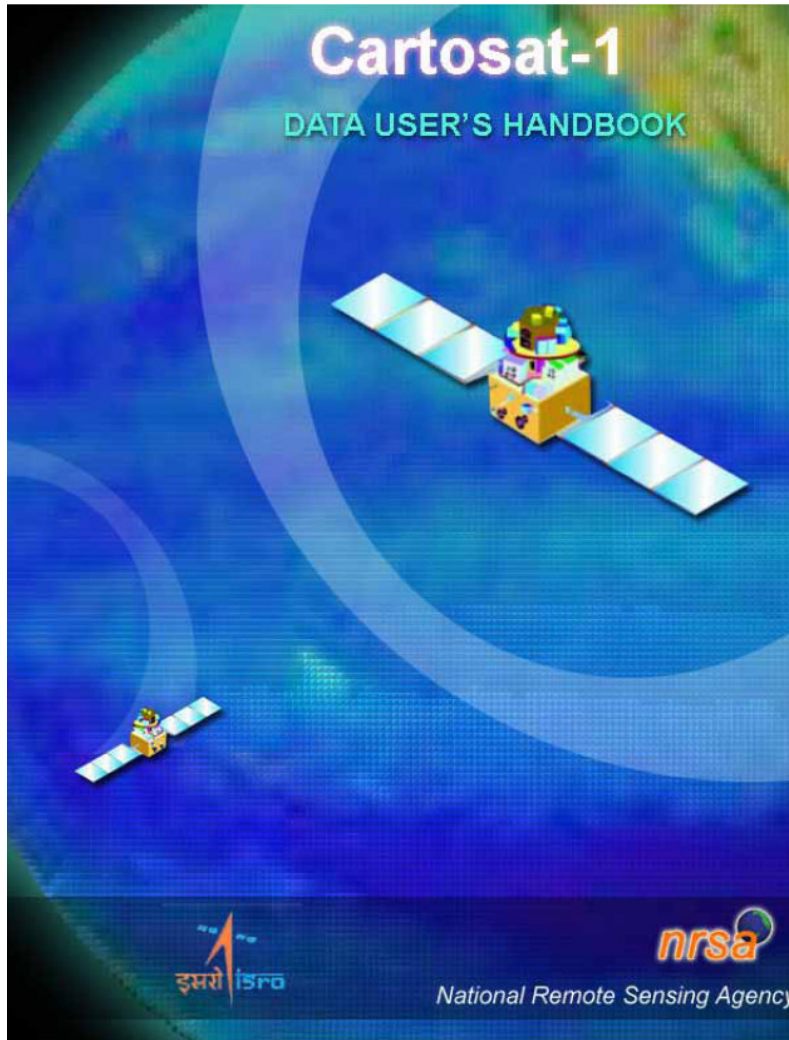
- **Resourcesat-2**
  - Identical to Resourcesat-1 (with miniaturization)
  - Launch scheduled for mid-2009
  - Assures data continuity through 2015
- **Cartosat Series:**
  - Increased resolution and more spectral bands:
    - PAN at 0.5m resolution
    - MSI at 2-4m, 4 bands
    - HSI at 8m, ~200 bands
      - Swath at 8-10km

- Resourcesat-3 series
  - Increased resolution and more spectral bands:
    - AWiFS (A & B) at 25m resolution, 600km swath
    - Liss-III at 23.5m resolution and 2 additional bands
      - Thermal at 70m resolution under consideration
    - Liss-IV at 5.8m with 1 additional band, 25km swath
  - Addition of new sensors with 25km swath:
    - Liss-V (PAN) at 2.5m resolution
    - Hyperspectral at 25m resolution (~200 Bands)
    - 5 day revisit cycle
- 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



- **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

- ISRO and Antrix are dedicated to providing IRS data through 2018
  - Current systems will be operational thru 2012
  - Next generation systems will carry into 2018
  - Data continuity is assured
- Resourcesat-1's improved cameras/sensors result in improved products
  - JACIE and USDA have published evaluation results
- Cartosat-1 provides high-resolution stereo data in real time
  - Competitors do not downlink their stereo data to any ground stations
  - Economically provides **millions** of km<sup>2</sup> of data per day
- Follow on systems are already under development



Available at NRSA's web site: [www.nrса.org.in](http://www.nrса.org.in)



Thank you!

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Email: [Timothy@eotec.com](mailto:Timothy@eotec.com)