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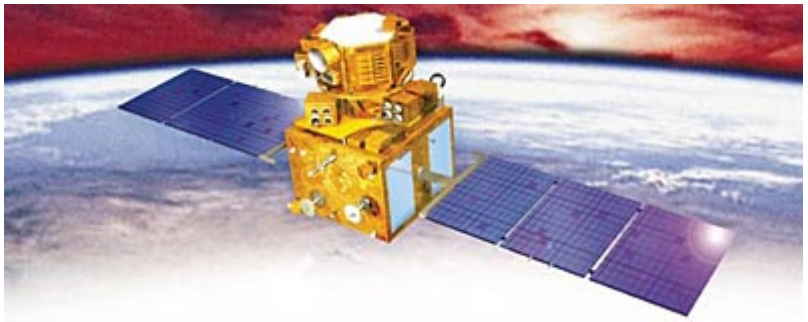
Overview of the Resourcesat-1 (IRS-P6)



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Contract employee under U.S. Geological Survey contract 03CRCN0001

U.S. Department of the Interior

U.S. Geological Survey

Outline

- Background
- Orbit and Payload
- Sensor Overview
- RSR Profiles comparison
- Data Products
- Conversion to Radiance
- References

IRS Missions

- **Bhaskara 1 and 2 : These were experimental remote sensing satellites launched in Jun 1979 and Nov 1981 respectively**
  - Payload consisted of TV cameras and radiometers
- **IRS-1A and 1B : Launched in Mar 1988 & Aug 1991 respectively, these were the first generation, operational remote sensing satellites**
  - The two identical satellites carried Linear Imaging and Self Scanning sensors (LISS-1 & LISS-II (2)) for providing data in four spectral bands with a resolution of 72.5m and 36.25m respectively with a receptivity of 22 days
- **IRS-P2 : Launched in Oct 1994 using the indigenously developed Polar Satellite Launch Vehicle (PSLV-D2)**
  - IRS-P2 carried a modified LISS camera
- **IRS-1C and IRS-1D : Launched in Dec 1995 & Sep 1997 respectively, are the second generation, operational remote sensing satellite missions with improved sensor and coverage characteristics**

IRS Missions

- **IRS-P3 : Launched in Apr 1996 by the PSLV-D3**
  - The payload consists of two imaging sensors & one non-imaging sensor
  - The Wide Field Sensor (WiFS) sensor is providing data with a spatial resolution of 188m in three spectral bands, in the VNIR regions, with a swath of 810 Km
  - The other two sensors on-board are a Modular Opto-electronic Scanner (MOS) and an X-ray astronomy payload
  - WiFS and MOS data products are being disseminated to users
- **OCEANSAT-1 (IRS-P4) : Launched in May 1999**
  - The payload consists of an Ocean Color Monitor (OCM) operating in eight spectral in the VNIR region and a Multi-frequency Scanning Microwave Radiometer (MSMR), operating in four frequencies namely 6.60, 10.61, 18 and 21 GHz
  - These sensors are providing data for measuring the physical and biological parameters of oceans

Resourcesat-1 (IRS P6)

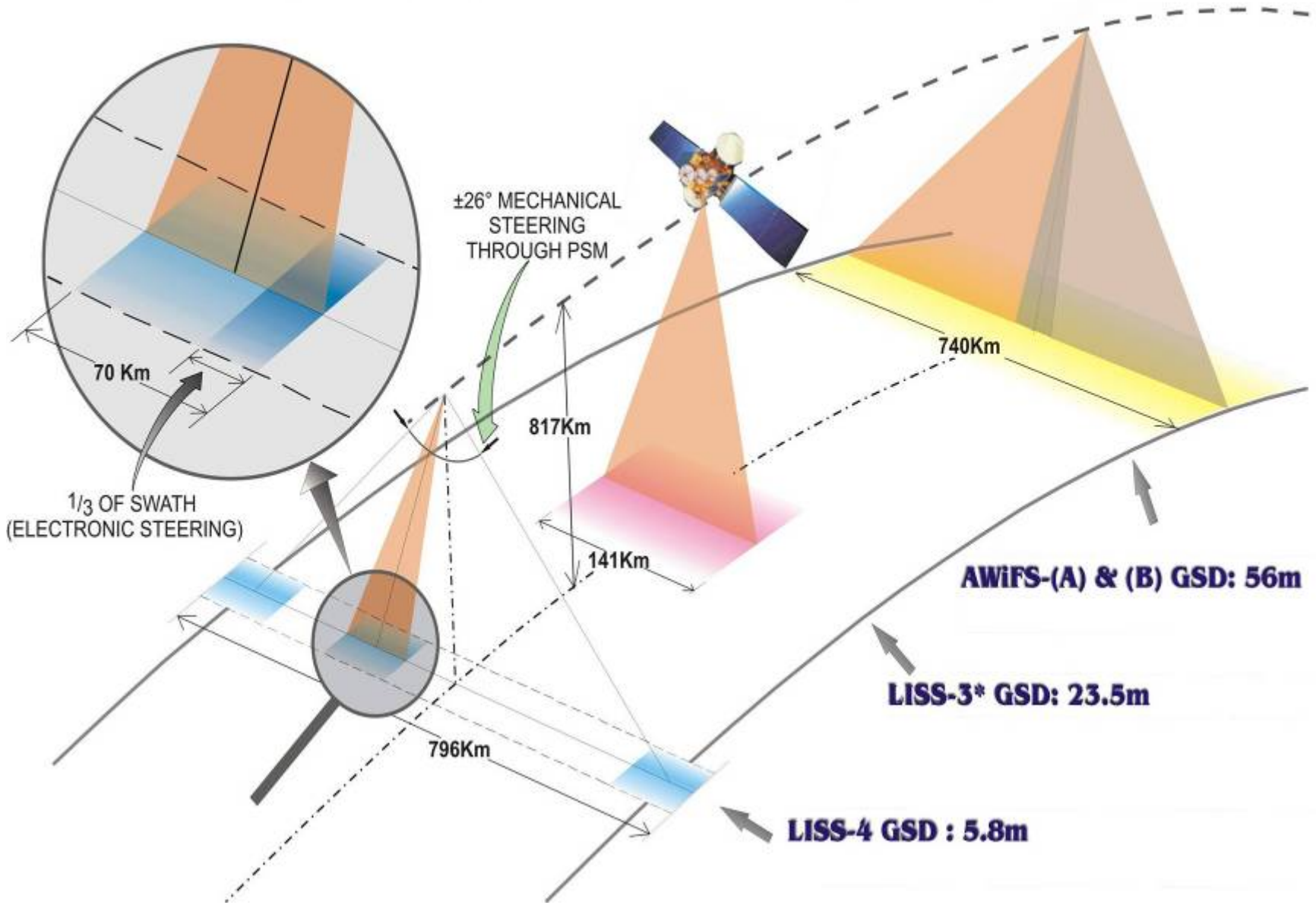
- **The RESOURCSAT-1 satellite was launched in to the polar sun-synchronous orbit (altitude of 817 km) by PSLV-C5 launch vehicle on October 17, 2003 with a design life of 5 years**
- **RESOURCSAT-1 is also called IRS-P6**
  - Most advanced Remote Sensing Satellite built by ISRO
  - Tenth satellite of ISRO in IRS series
  - Other ISRO operational satellites are IRS 1-C, IRS 1-D, IRS P-2, IRS P-3

Resourcesat-1 Orbit and Coverage Details	
Orbit Altitude	817 Km
Orbit Inclination	98.69 deg
Orbit period	101.35 min
Number of Orbits per day	14.2083
Equatorial crosing time	10.30 a.m.
Repetivity (LISS-3)	24 days
Repetivity (LISS-4)	5 days
Distance between adjacent paths	117.5 km
Distance between successive ground tracks	2,820 km
Lift-off Mass	1360 kg
Ground trace velocity	6.65 km/sec
Orbits/cycle	341
Semi major axis	7195.11
Eccentricity	0.001
Mission Life	5 years

ResourceSat-1 Overview

- **RESOURCESAT-1 carries three sensors**
  - High Resolution Linear Imaging Self-Scanner **(LISS-IV)**
  - Medium Resolution Linear Imaging Self-Scanner **(LISS-III)**
  - Advanced Wide Field Sensor **(AWiFS)**
- **All three cameras are "push broom" scanners using linear arrays of CCDs**
- **RESOURCESAT-1 also carries an On-board Solid State Recorder (OBSSR) with a capacity of 120 Giga-Bits to store the images**

IRS-P6 THREE TIER IMAGING



Advanced Wide Field Sensor (AWiFS)

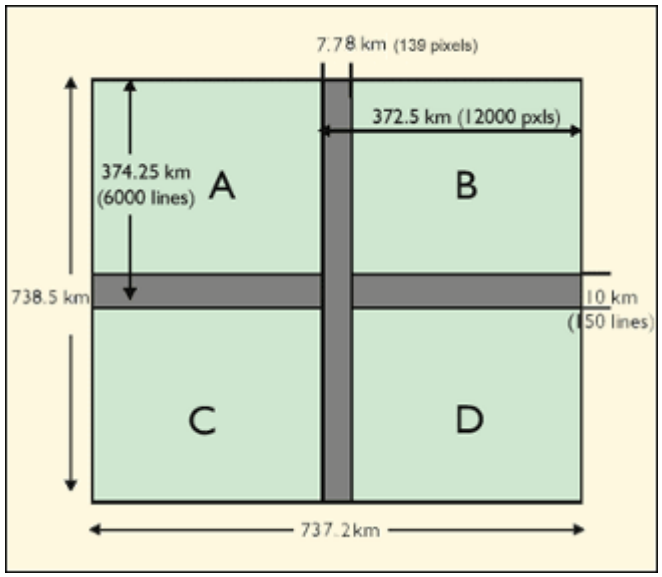
- The AWiFS with twin cameras is a moderate-resolution sensor offering a GSD of 56m at nadir
- Quantization: 10 bits
- Combined ground swath is 740km with five day repeat cycle
- Operates in four spectral bands – three VNIR one SWIR

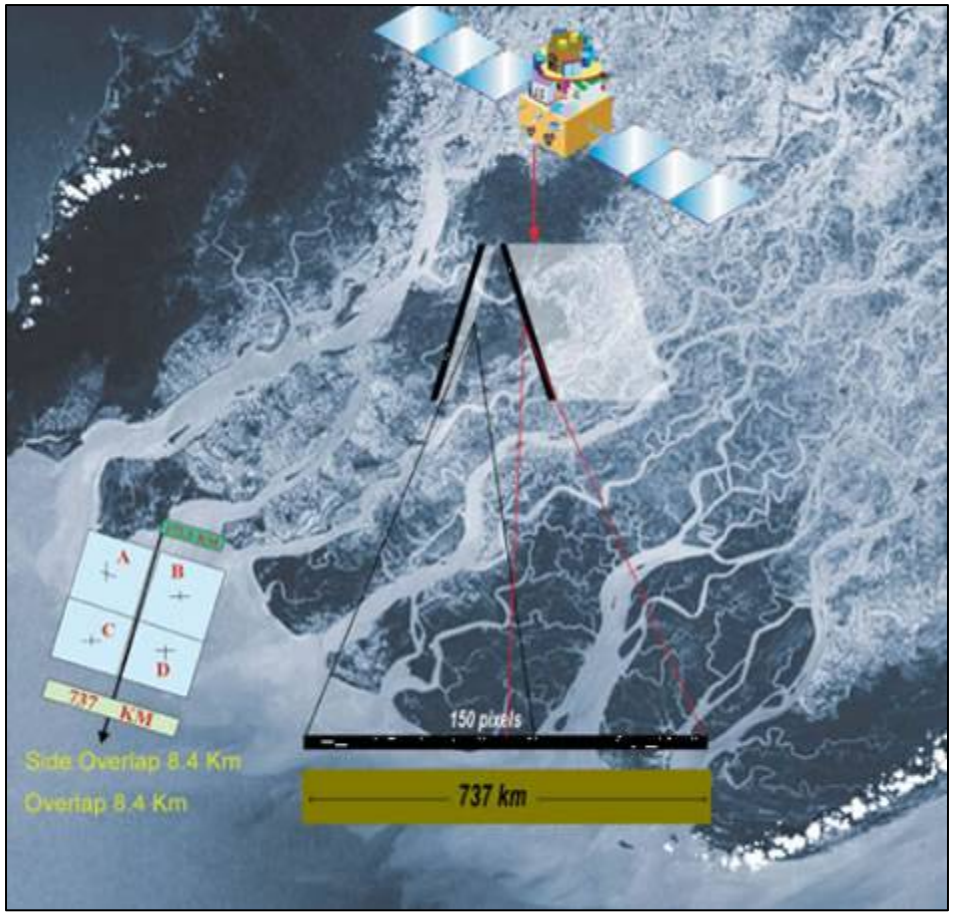
VITAL FACTS:

- Instrument: Pushbroom
- Bands (4): 0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70 µm
- Spatial Resolution: 56 m (near nadir), 70 m (near edge)
- Radiometric Resolution: 10 bit
- Swath: 740 km
- Repeat Time: 5 days
- Design Life: 5 years

AWiFS Sensor Collection Mode

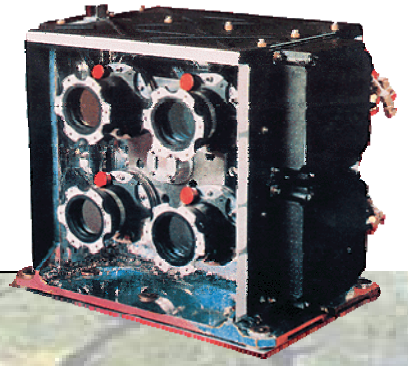
The AWiFS camera is split into two separate electro-optic modules (AWiFS-A and AWiFS-B) tilted by 11.94 degrees with respect to nadir





Medium Resolution Linear Imaging Self-Scanner (LISS-III)

- **The LISS-III is a medium resolution sensor offering a GSD of 23.5m**
- **Quantization: 7 bits (SWIR band 10 bits – selected 7 transmitted)**
- **Ground swath is 141 km with 24 day repeat cycle**
- **Operates in four spectral bands - three VNIR one SWIR**
- **Each band consists of a separate lens assembly & linear array CCD**
  - The VNIR bands use a 6000 element CCD with pixel size 10x7 microns
  - The SWIR band uses a 6000 element CCD with pixel size 13x13 microns
  - The data from the VNIR bands are digitized to 7 bits while the data from SWIR band are digitized to 10 bit
  - The VNIR bands could be operated in any one of the four selectable gains by command, while the SWIR band is configured with single gain setting covering the full dynamic range



LISS-III In-flight Calibration

- **The In-flight calibration of the LISS-III camera is carried out using four LEDs per CCD in VNIR bands and 6 LEDs for the SWIR band**
- **LEDs are operated in pulsed mode**
- **Pulse duration during which these LEDs are ON is varied in specific steps**
  - Each LED has a cylindrical lens to distribute the light intensity onto the CCD
  - Each 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

High Resolution Linear Imaging Self-Scanner (LISS-IV)

- **The LISS-IV is the highest-resolution sensor offering a GSD of 5.8m at nadir**
- **Quantization: 10 bits (selected 7 bits transmitted)**
- **Ground swath is 23 or 70 km with 5 days repeat cycle**
  - Steerable upto +/- 26^{o} across track to obtain stereoscopic imagery
- **Operates in three spectral VNIR bands**
  - A single telescope & lens assembly 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 12000 pixel CCD array for each band is separated into odd & even pixel, arranged in two rows with a distance of 35 microns (5 scan lines) between them**

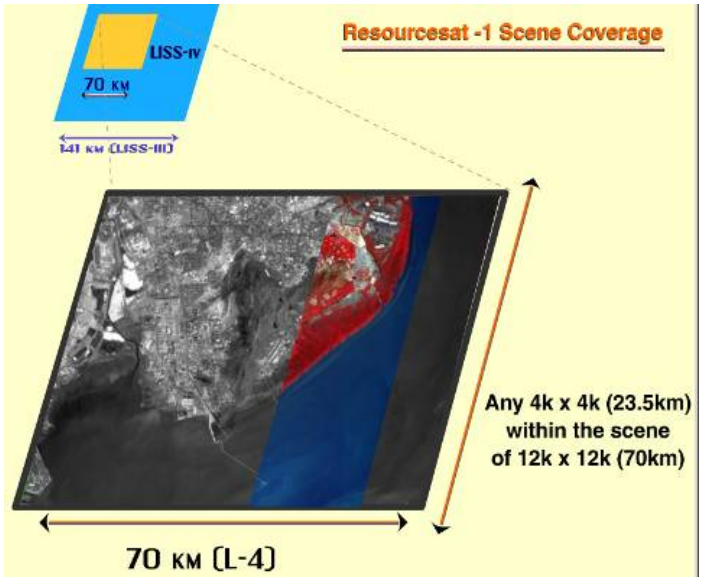
LISS-IV Quantization 7 bits

- **The image data is digitized to 10 bits onboard the satellite but only 7 bits are transferred from satellite to ground**
  - There is a fixed gain setting used to produce the original 10-bit signal
  - There is no dynamic decision-making on the part of the onboard data handling system
    - The selection of which 7 bits to transfer from the 10-bit signal is performed by the satellite operator during collection tasking
    - The ground operators select which 7 bits are extracted by specifying one of four 'gain' settings 0-6, 1-7, 2-8, or 3-9
  - Sensor metadata provided with the image product indicates what ‘gain’ setting (i.e., bit selection) was used for the scene
- **The product are delivered as 8-bit**
  - The ground processing system applies a 7-bit LUT for radiometric calibration of the 7 bit data, then they insert a zero bit at the least significant bit
  - This pushes the DN range from 0-127 to 2-254
  - The end-user still end up getting DNs of 1 and 255, however, because of cubic convolution resampling

LISS-IV Modes (Mono or Mx)

- **The LISS-IV sensor can be operated in either of two modes**
  - In mono mode (Mono), the full swath of 70 km will be covered in any one single band selectable by ground command
    - Nominally the red band (B3) is used because it is closest to nadir
    - The full 12000 pixel array of B3 is used to collect a 70km swath width
  - In multi-spectral mode (Mx), LISS-IV covers a swath of 23 km (selectable out of 70 km total swath) in all three bands

- In the Mx mode, 4000 pixels are collected from each of the three bands
- Any pixel number from 1 to 8000 can be chosen as the start of the 4000-pixel subset, meaning that the 23km wide multi-spectral scene can fall anywhere within the Mono 70km footprint

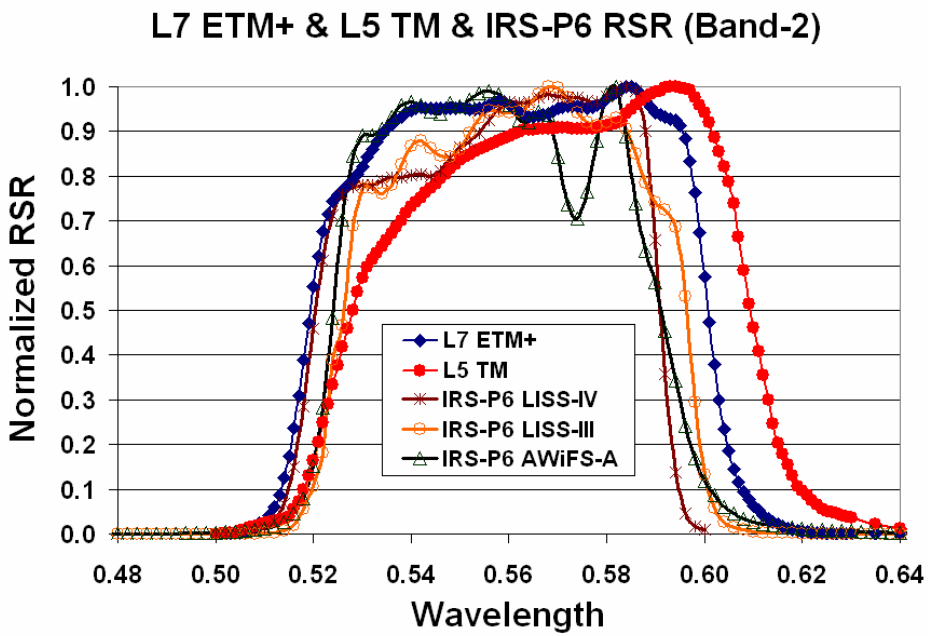


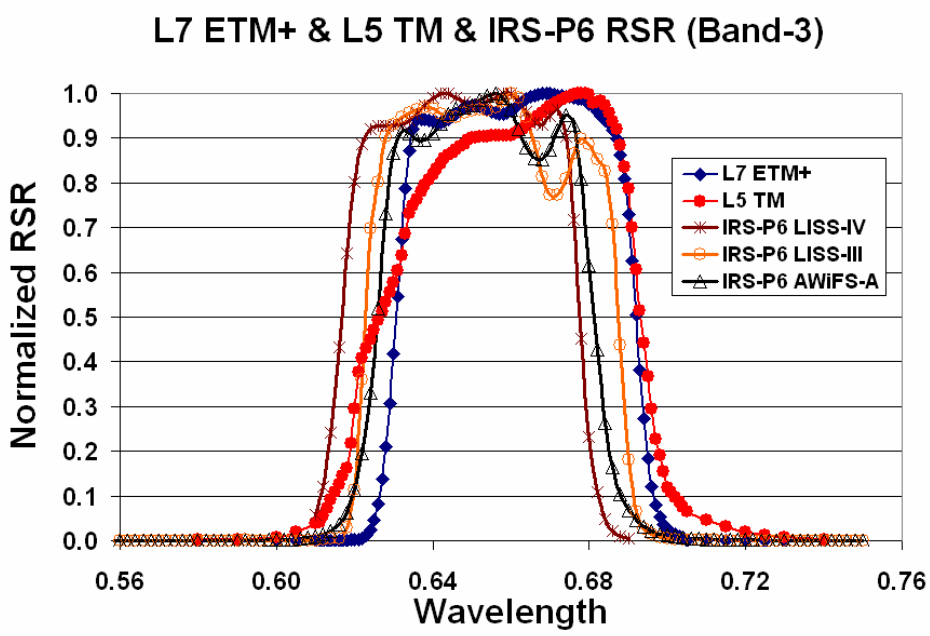
LISS-IV In-flight Calibration

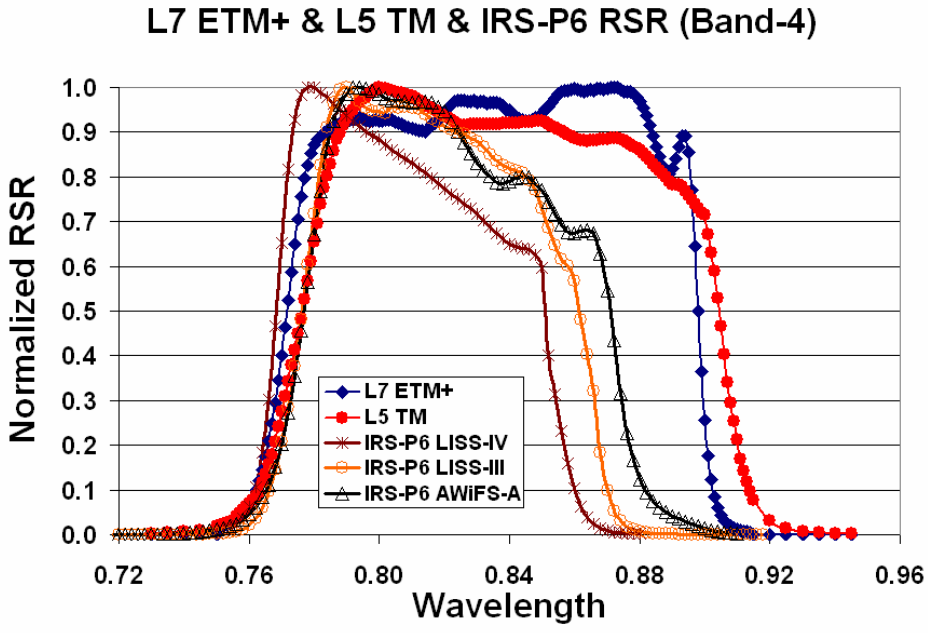
- **Pre-launch light transfer characteristics (LTC) of the overall Payload system are generated in the lab**
  - Performance parameters like spectral response, dark current, dynamic range, temperature and linearity are measured
  - LTC data is used for radiometric corrections of the image data
- **However, 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)

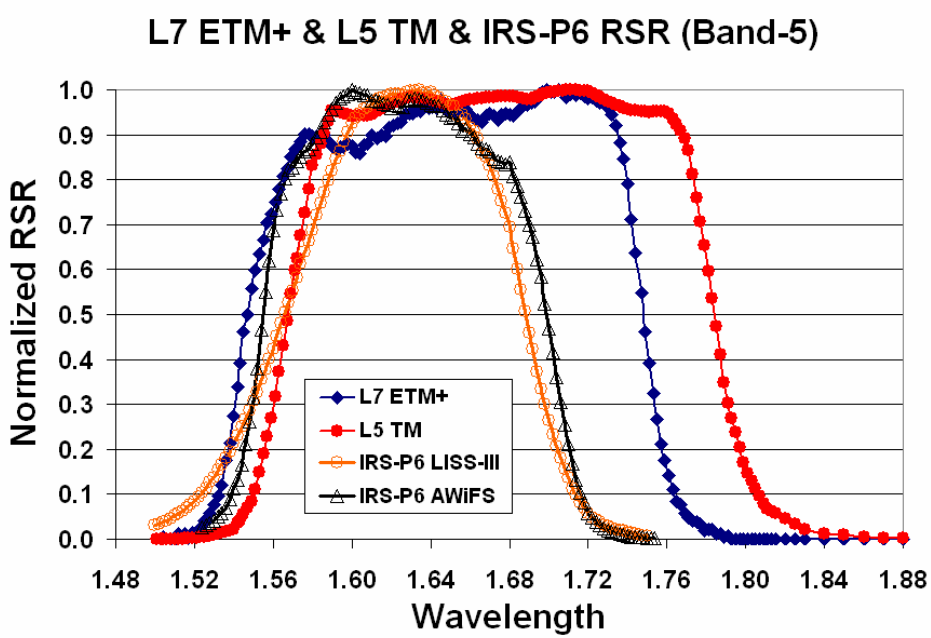
IRS-P6 Sensor Specifications

Resourcesat-1 Specifications			
	LISS IV	LISS III	AWiFS
Resolution (m)	5.8	23.5	56
Swath (km)	23.9 km (Mx)	141km	740 km
Spectral Bands (µm)	B2: 0.52-0.59	B2: 0.52-0.59	B2: 0.52-0.59
	B3: 0.62-0.68	B3: 0.62-0.68	B3: 0.62-0.68
	B4: 0.77-0.86	B4: 0.77-0.86	B4: 0.77-0.86
		B5: 1.55-1.70	B5: 1.55-1.70
Quantization (bits)	7	7	10
Integration Time (msec)	0.877714	3.32	9.96
No. of gains	Single gain	Four for B2,3,4	Single gain
Sensor	Pushbroom	Pushbroom	Pushbroom
CCD Arrays	1 * 12288	1 * 6000	2 * 6000
CCD Size (µm)	7 µm x 7 µm	10 µm x 7 µm	10 µm x 7 µm
Focal Length (mm)	982	347.5	139.5
Cross-track FOV for pixel (radiance)	0.0000071	0.0000288	0.0000717
Power (W)	216	70	114
Weight (kg)	169.5	106.1	103.6
Data Rate (MBPS)	105	52.5	52.5
Repeat Cycle (days)	5	24	5

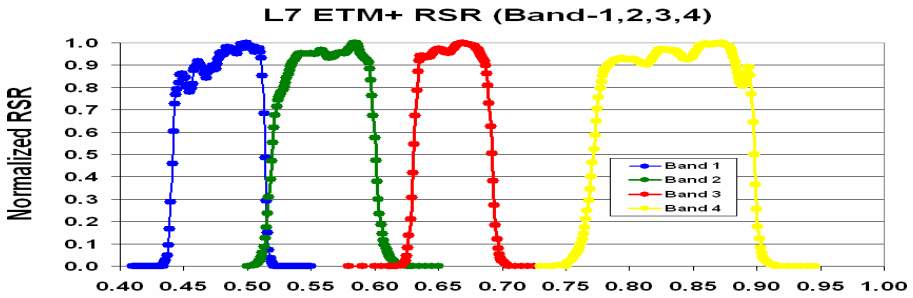

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-2)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
IRS-P6 LISS-IV
IRS-P6 LISS-III
IRS-P6 AWiFS-A

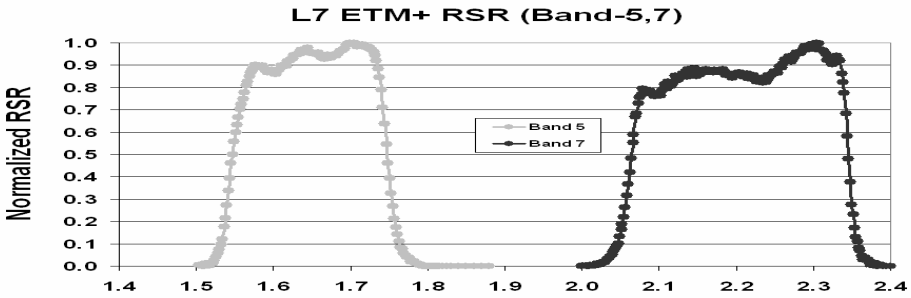

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-3)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
IRS-P6 LISS-IV
IRS-P6 LISS-III
IRS-P6 AWiFS-A

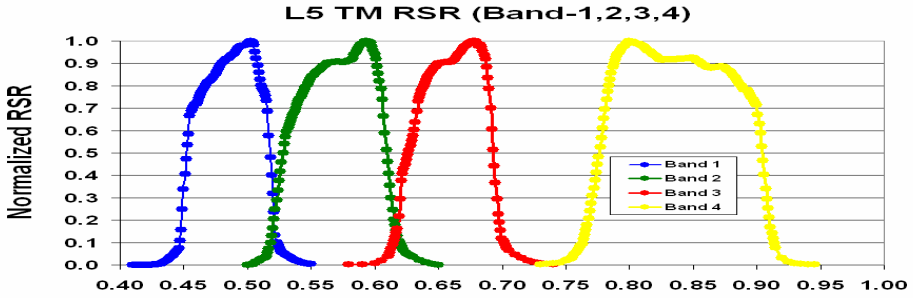

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-4)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
IRS-P6 LISS-IV
IRS-P6 LISS-III
IRS-P6 AWiFS-A

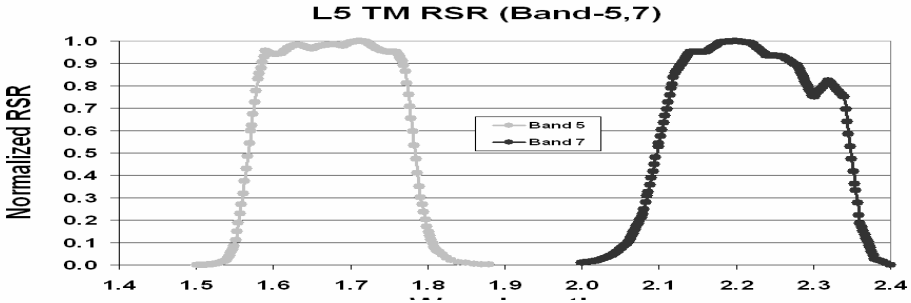

L7 ETM+ & L5 TM & IRS-P6 RSR (Band-5)
Normalized RSR
Wavelength
L7 ETM+
L5 TM
IRS-P6 LISS-III
IRS-P6 AWiFS

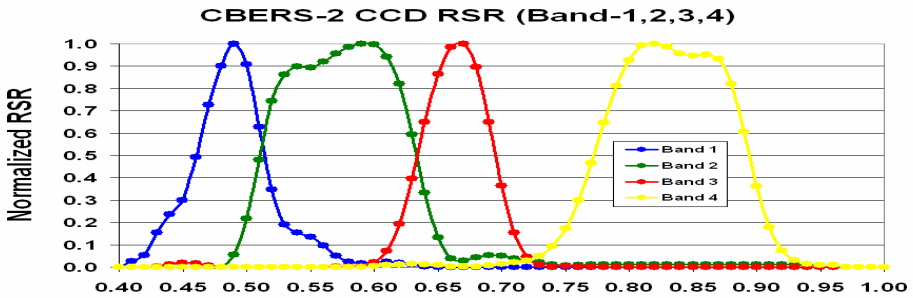
Relative Spectral Response (RSR) Profiles

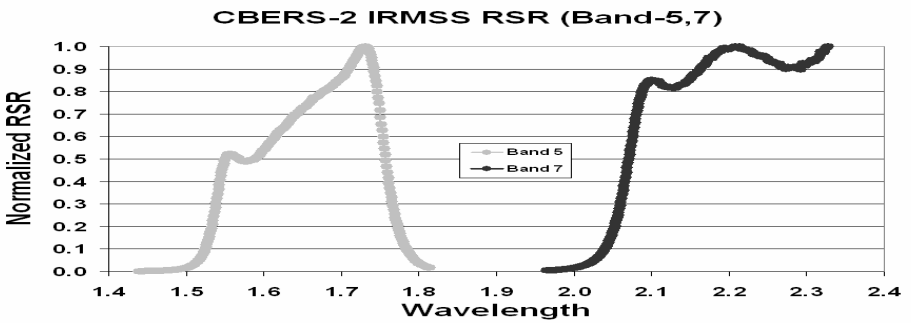


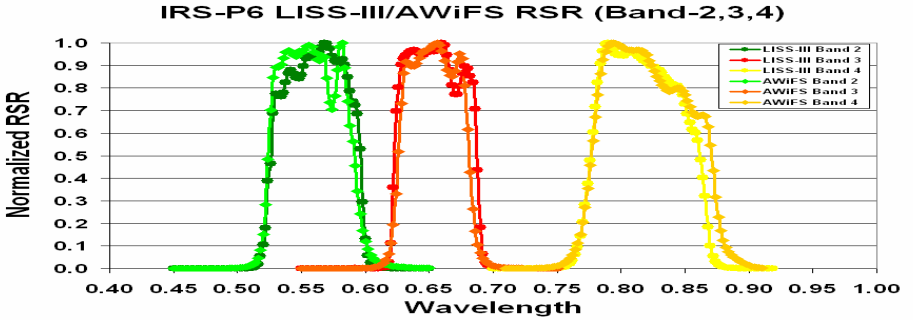


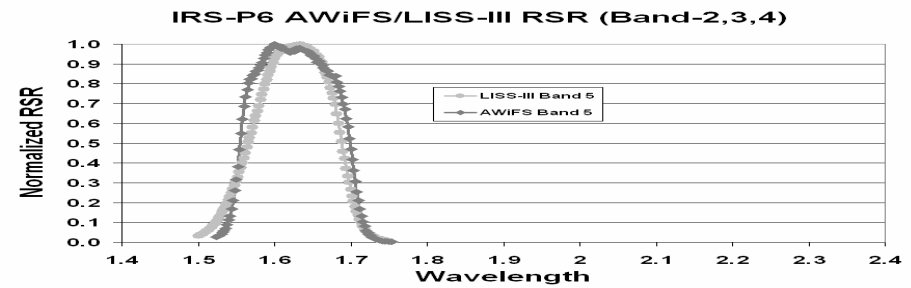












Data Products

	Standard Products	Value Added Products
1	Path/Row Based	Precision Geocoded Products
2	Shift Along Track Product	Template registered products
3	Quadrant Products	Merge Products
4	Georeferenced Products	Ortho products
5	Geocoded Products	
6	Basic Stereo Pair	

Level	Type of Correction
Level-0	No correction (Raw)
Level-1	Radiometric correction
Level-2	Radiometric and Geometric correction (Standard)
Level-3	Precision correction using GCPs

Resampling Options	Map Projections	Earth Ellipsoids	Digital Data Product formats
Cubic Convolution (C)	Polyconic (P)	Clarke 1866 (C6)	LGSOWG Superstructure Format
Nearest Neighbour (N)	Lambert Conformal Conical (L)	International 1909 (I9)	Fast Format
Bilinear (B)	Universal Transverse Mercator (U)	GRS 1980 (GR)	GeoTiff-Gray Scale
16 Point Sinc (S)	Space Oblique Mercator (S)	Everest (EV)	GeoTiff-RGB
Kaiser-16 (K)		WGS – 84 (W4)	HDF
4 Point Sinc (F)		Bessel (BL)	
		Krassovsky (KW)	

Space Imaging (now GeoEye) was granted a license to receive & distribute AWiFS imagery from their ground station in Oklahoma (Jan. 2005)

Corrections applied to IRS-P6 raw data

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

Conversion to Radiance

$$L^* = \frac{(Lmax - Lmin)}{Qcalmax} Qcal + Lmin$$

Where

- **L* = spectral radiance at the sensors aperture W/(m^2.sr.um)**
- **Qcal = Calibrated Digital Number**
- **Qcalmax = maximum possible DN value**
  - 255 for LISS-IV & LISS-III products,
  - 1023 for 10-bit AWiFS and 255 for 8-bit AWiFS products
- **Lmax & Lmin = scaled spectral radiance (provided in the header file)**
  - **For GeoTIFF products, these values are found in the Image Description field of the GeoTIFF header**
  - **For Fast Format products, values are in the HEADER.DAT**
  - **For LGSOWG products, values are in the leader file**

    Note that the values given for GAIN and BIAS in the header are not the GAIN and BIAS as expected. These values are L_min and L_max given in units of [mw/cm2/str/um] where BIAS is L_min and GAIN is L_max.

Header File Information (Lmax & Lmin)

LISS-IV Mono Band 3:

On board gain number for band 3 3
Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 9.92230

LISS-III:

On board gain number for band 2 3
On board gain number for band 3 3
On board gain number for band 4 3
On board gain number for band 5 2
Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 12.06400
Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 15.13100
Minimum / maximum radiance for band 4 [mw/cm2/str/um] ... 0.00000 15.75700
Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 3.39700

AWiFS-A camera (A&C quadrant scenes):

On board gain number for band 2 8
On board gain number for band 3 9
On board gain number for band 4 8
On board gain number for band 5 9
Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 52.34000
Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 40.75000
Minimum / maximum radiance for band 4 [mw/cm2/str/um] ... 0.00000 28.42500
Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 4.64500

AWiFS-B camera (B&D quadrant scenes):

On board gain number for band 2 8
On board gain number for band 3 9
On board gain number for band 4 8
On board gain number for band 5 9
Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 52.34000
Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 40.75000
Minimum / maximum radiance for band 4 [mw/cm2/str/um] ... 0.00000 28.42500
Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 4.64500

Ortho Generation: 10-to-8 bit rescaling

- **Ortho metadata provides DN-to-radiance scaling coefficients**

$$L_{rad} = \frac{DN_{10}}{1023} \cdot \left(L_{max} - L_{min}\right) + L_{min}$$

DN_{10} = 10-bit pixel value

L_{min} = Min radiance value provided in scene metadata

L_{max} = Max radiance value provided in scene metadata

- **10- to 8-bit rescaling maintains integrity of DN-to-radiance coefficients**

$$DN_8 = DN_{10} \cdot \frac{255}{1023}$$

$$L_{rad} = \frac{DN_8}{255} \cdot \left(L_{max} - L_{min}\right) + L_{min}$$

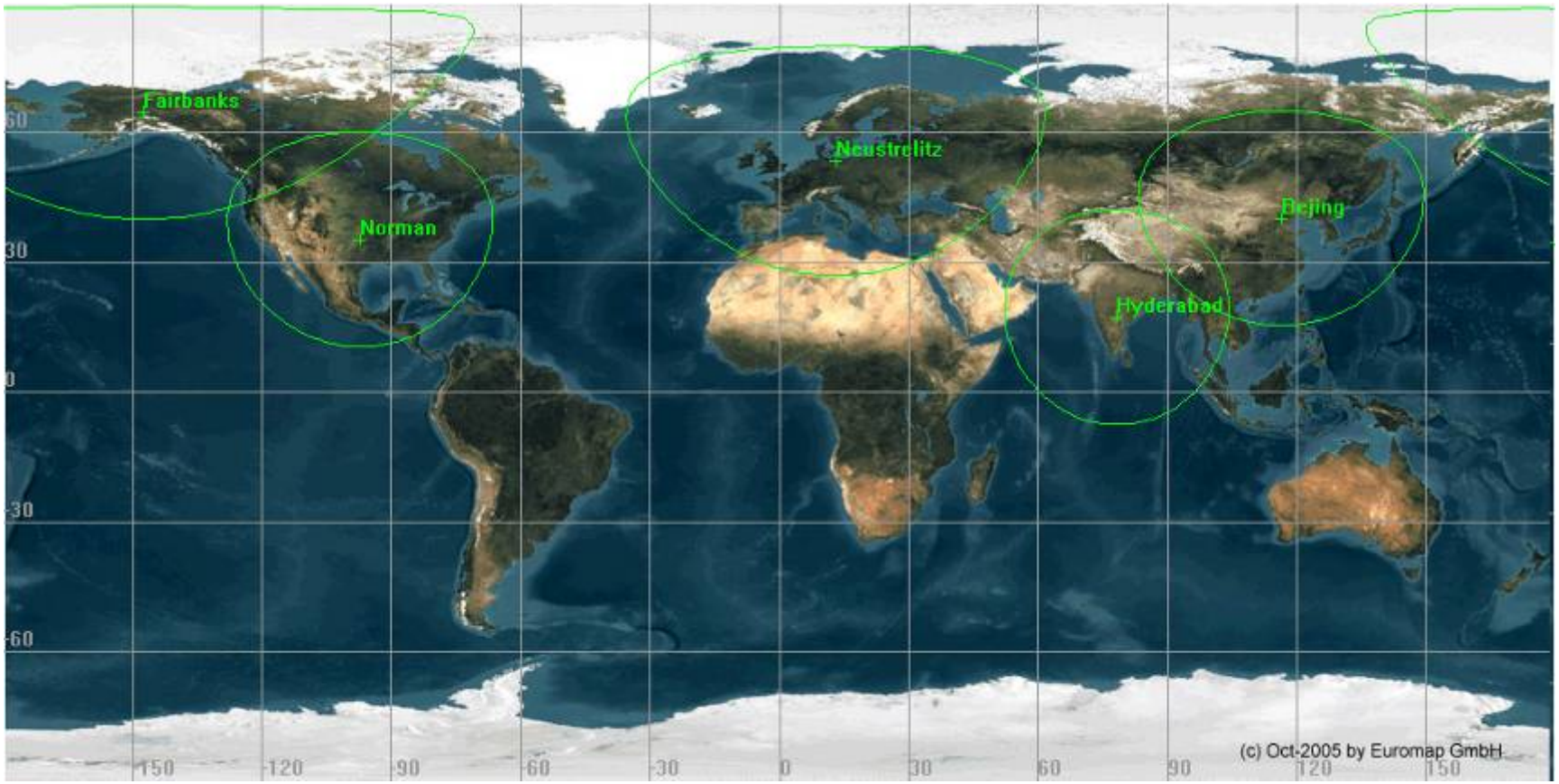
Radiance to TOA Reflectance

$$\rho_p = \frac{\prod \bullet L_\lambda \bullet d^2}{ESUN_\lambda \bullet \cos\theta_s}$$

ESUN Units = W/(m^2.um) from ISRO			
	LISS-IV	LISS-III	AWIFS
Band 2	1853.6	1849.5	1854.7
Band 3	1581.6	1553	1556.4
Band 4	1114.3	1092	1082.4
Band 5	--	239.52	239.84

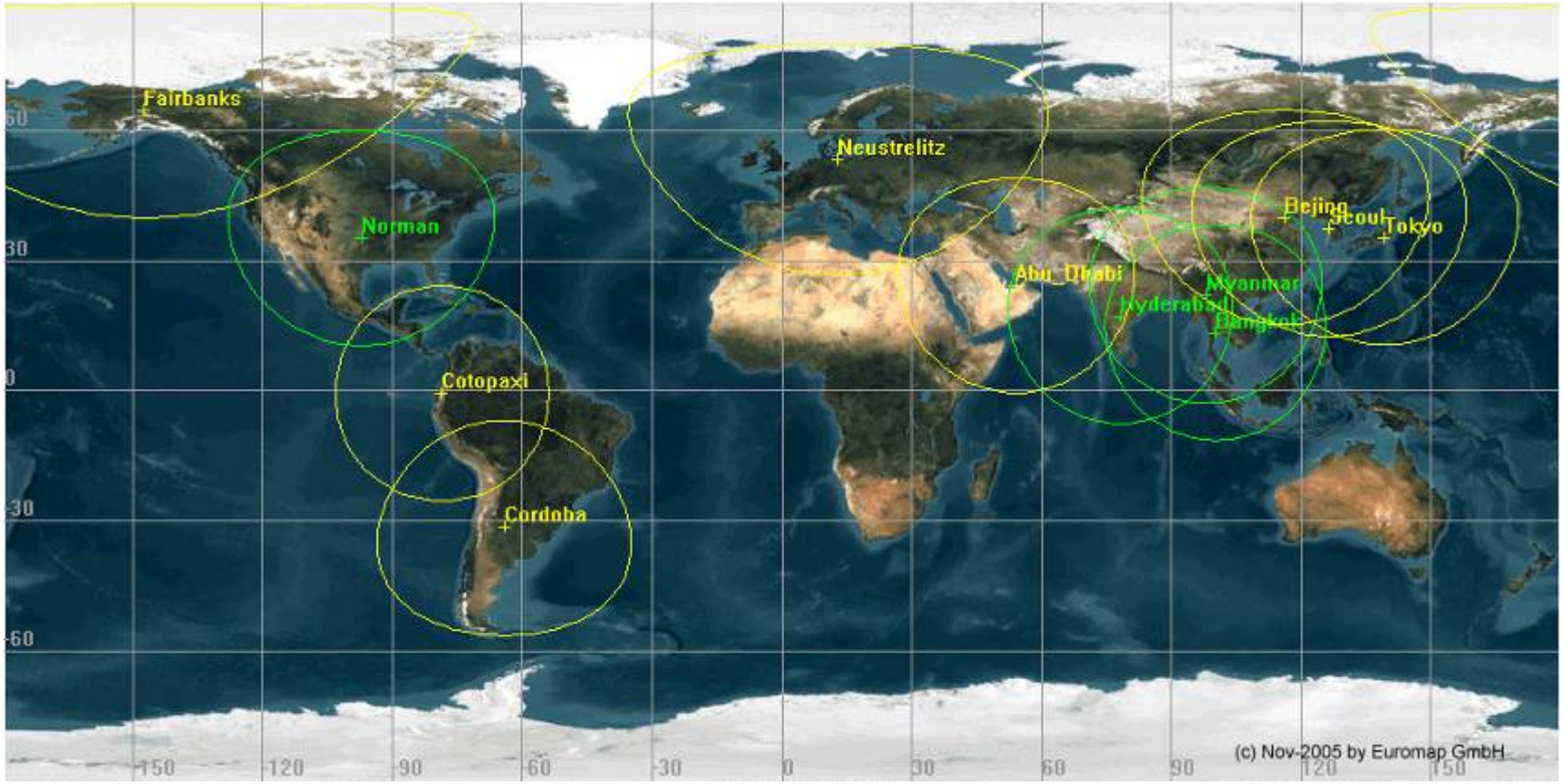
Solar Exoatmospheric Spectral Irradiances										
Units:	ESUN = W/(m^2.um)									
Model :	Neckel and Labs		Chance Spectrum CHKUR (MODTRAN 4.0)							
Band	L4 TM	L5 TM	L4 TM	L5 TM	L7 ETM+	E0-1 ALI	HRCCD	IRMSS	LISS-III	AWiFS
1	1958	1957	1957	1957	1969	1967.6	1928.18			
2	1828	1829	1825	1826	1840	1837.2	1799.51		1846.77	1849.82
3	1559	1557	1557	1554	1551	1551.47	1535.35		1575.50	1579.37
4	1045	1047	1033	1036	1044	1164.53	1053.38		1087.34	1075.11
5	219.1	219.3	214.9	215.0	225.7	230.03		220.11	236.65	235.83
7	74.57	74.52	80.72	80.67	82.07	79.61		83.3		
Pan					1368	1747.86				
1P						1851.8				
4P						957.46				
5P						451.37				

Resourcesat-1 IGSs



There is a new IRS-P6 ground station coming up in UAE

IRS-IC and ID IGS



References

- **World Wide Web (WWW)**
  - http://www.isro.org/
  - http://www.nrsa.gov.in/index.html/
  - http://www.spaceimaging.com/products/
- **Documents**
  - IRS-P6 Data User's Handbook
  - IRS-1D Data User's Handbook
  - IRS Program: An Overview