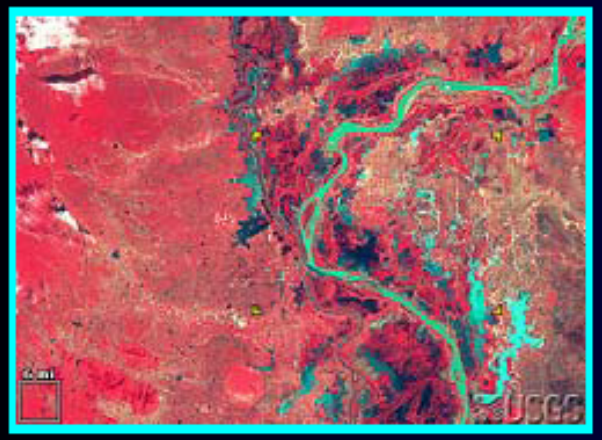
PLATEFORMS

Earth Observation Satellites

LANDSAT

3 January 1973, Landsat 1
MSS bands 4 2 1



14 December 1985,
Landsat 5 MSS bands 4 2 1

A number of sensors have been on board the Landsat series of satellites, including the Return Beam Vidicon (RBV) camera systems, the MultiSpectral Scanner (MSS) systems, and the Thematic Mapper (TM)

Phnom Penh, Cambodia
1973, 1985

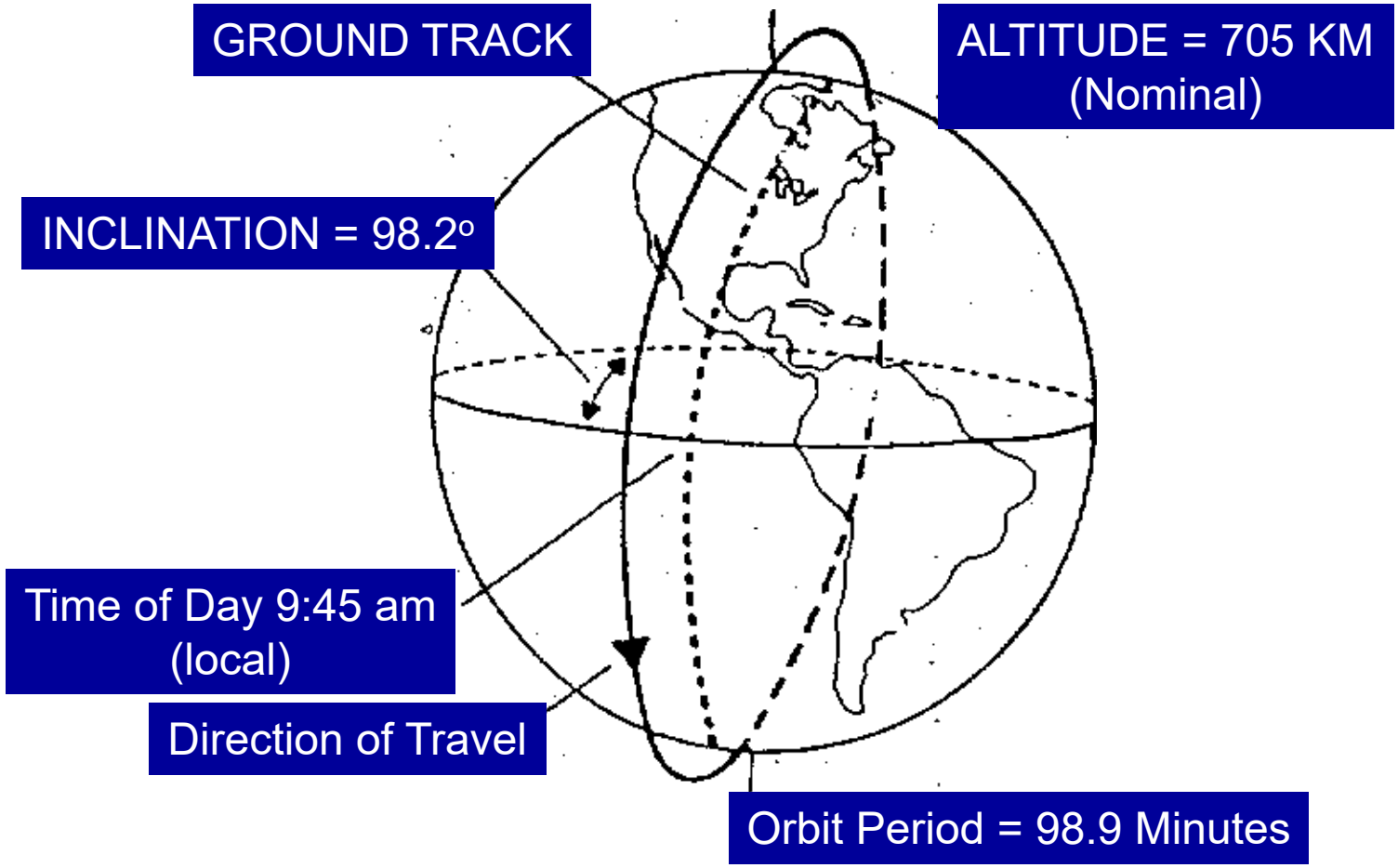
Phnom Penh (pronounced p-NOM PEN) is the
capital city of Cambodia. These images show
Phnom Penh, the Mekong River, and some irrigation works of the Khmer Rouge era. (Source information from USGS)

Landsat Thematic Mapper (TM)

Band No.	*Wavelength Interval (μ m)*	*Spectral Response*	*Resolution (m)*
1	0.45-0.52	Blue-Green	30
2	0.52-0.60	Green	30
3	0.63-0.69	Red	30
4	0.76-0.90	Near-IR	30
5	1.55-1.75	Mid-IR	30
6	10.40-12.50	Thermal-IR	120
7	2.08-2.35	Mid-IR	30

(TM) has been added to Landsats 4 (1982), 5 (1984), 6 (failed to attain orbit during launch and thus has never returned data) and 7 (1999).

Landsat Orbit

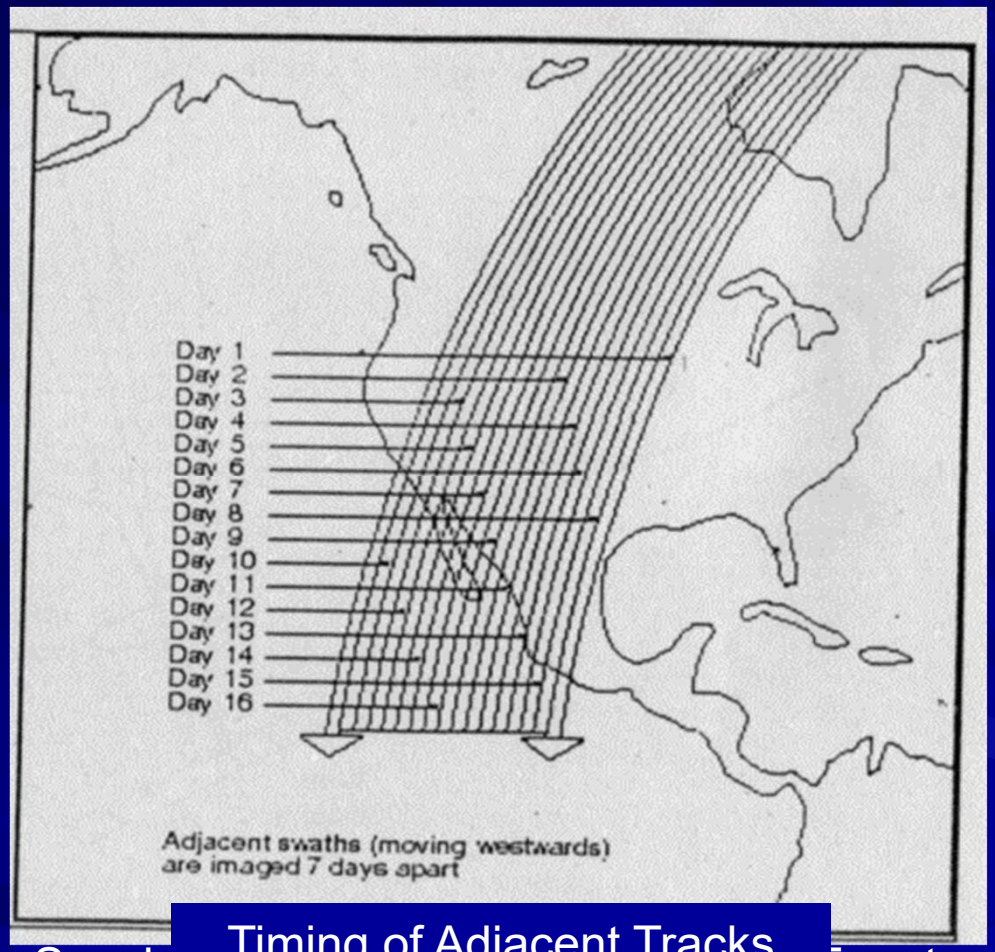


Sun Synchronized

- Sun-synchronous Satellites are those which cover each area of the world at a constant local time of day called local sun time.
- At any given latitude, the position of the sun in the sky as the satellite passes overhead will be the same within the same season. This ensures consistent illumination conditions when acquiring images in a specific season over successive years, or over a particular area over a series of days.
- This is an important factor for monitoring changes between images or for mosaicking adjacent images together, as they do not have to be corrected for different illumination conditions.

Ref: Fund. of RS by CCRS

LANDSAT 4/5 SWATHING PATTERN & ORBIT NO.



Timing of Adjacent Tracks

Spacing Between Adjacent Orbits at Equator

https://www.youtube.com/watch?v=xBhorGs8uy8

https://www.youtube.com/watch?v=1b1q3LHb6-8

Landsat 7 Spacecraft Status

≈ 18 years of on-orbit operations

Power Subsystem

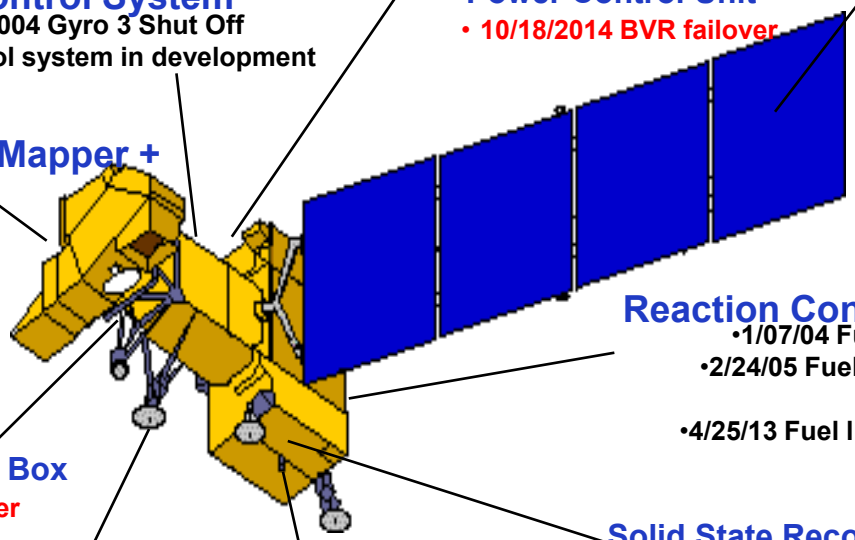
Batteries
Performance nominal

Solar Array
- 5/14/2002 Circuit #14 Failure
- 5/16/2005 Circuit # 6 Failure
- 8/13/2008 Circuit #14 partial recovery
- 14 circuits remain operating
- no impact to ops

Attitude Control System
- 05/05/2004 Gyro 3 Shut Off
- 1-gyro control system in development

Power Control Unit
- 10/18/2014 BVR failover

Enhanced Thematic Mapper +
- 5/31/2003 SLC Failure
- 4/01/2007 Bumper mode



Reaction Control System
- 1/07/04 Fuel line #4 thermostat #1a failure
- 2/24/05 Fuel line #4 thermostat failure; Primary heater circuit disabled
- 4/25/13 Fuel line #2 thermostat failure; Redundant heater circuit disabled

Remote Tlm Cmd (RTC) Box
- 09/27/2014 RTC A Failover

Solid State Recorder
- 11/15/1999 SSR PWA #23 Loss
- 02/11/2001 SSR PWA #12 Loss
- 12/07/2005 SSR PWA #02 Loss
- 08/02/2006 SSR PWA #13 Loss
- 03/28/2008 SSR PWA #22 Loss
- 09/03/2008 SSR PWA #23 Recovered
- 10/12/2013 SSR PWA #11 Loss
- Each PWA is 4% loss of launch capacity
- Boards are likely recoverable

X-band System
Performance nominal

S-band System
Performance nominal

Landsat 8 Spacecraft Status

≈ 4 years of on-orbit operations

Operational Land Imager

RF Communications

S-band System

Thermal Control System

Propulsion Subsystem

Attitude Control System

Electrical Power System

Batteries

Solar array

Thermal Infrared Sensor

- 10/1/2014 - Side-A SSM Encoder

X-band System

Command & Data Handling System

Solid State Recorder

Landsat 7

Orbit

- Sun-synchronous orbit at an altitude of 705 km (438 mi)
- 233 orbit cycle; covers the entire globe every 16 days (except for the highest polar latitudes)
- Inclined 98.2° (slightly retrograde)
- Circles the Earth every 98.9 minutes
- Equatorial crossing time: 10:00 a.m. +/- 15 minutes

Other Characteristics

•Scene size: 170 km x 185 km (106 mi x 115 mi)

•Landsat 7 data products and acquisition information: https://landsat.usgs.gov/landsat-7

Landsat 7

Sensors

- **Enhanced Thematic Mapper Plus (ETM+)**

Eight spectral bands, including a pan and thermal band:

- Band 1 Visible (0.45 - 0.52 µm) 30 m
- Band 2 Visible (0.52 - 0.60 µm) 30 m
- Band 3 Visible (0.63 - 0.69 µm) 30 m
- Band 4 Near-Infrared (0.77 - 0.90 µm) 30 m
- Band 5 Near-Infrared (1.55 - 1.75 µm) 30 m
- Band 6 Thermal (10.40 - 12.50 µm) 60 m Low Gain / High Gain
- Band 7 Mid-Infrared (2.08 - 2.35 µm) 30 m
- Band 8 Panchromatic (PAN) (0.52 - 0.90 µm) 15 m

LANDSAT 8 Info

- **Sensors**

Operational Land Imager (OLI)

Nine spectral bands, including a pan band:

- Band 1 Visible (0.43 - 0.45 µm) 30 m
- Band 2 Visible (0.450 - 0.51 µm) 30 m
- Band 3 Visible (0.53 - 0.59 µm) 30 m
- Band 4 Red (0.64 - 0.67 µm) 30 m
- Band 5 Near-Infrared (0.85 - 0.88 µm) 30 m
- Band 6 SWIR 1(1.57 - 1.65 µm) 30 m
- Band 7 SWIR 2 (2.11 - 2.29 µm) 30 m
- Band 8 Panchromatic (PAN) (0.50 - 0.68 µm) 15 m
- Band 9 Cirrus (1.36 - 1.38 µm) 30 m

Landsat 7 vs 8 bands

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and *TIRS* Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

LANDSAT 8 Info

- **Sensors**

Thermal Infrared Sensor (TIRS)

Two spectral bands:

- Band 10 TIRS 1 (10.6 - 11.19 µm) 100 m
- Band 11 TIRS 2 (11.5 - 12.51 µm) 100 m

Band	Wavelength	Description	Characteristics and Notes
1	.45-.52	Visible Blue	Maximum water penetration; vegetation vs soil; deciduos vs. conifers
2	.52-.60	Visible Green	Plant vigor (reflectance peak for plants)
3	.63-.69	Visible Red	Chloropyll absorption; vegetation discrimination
4	.76-.90	Near Infrared	Reflected IR; biomass and shoreline mapping
5	1.55-1.75	Middle Infrared	Reflected IR; moisture content of soil and vegetation; cloud/smoke penetration; vegetation mapping
7	2.08-2.35	Middle Infrared	Reflected IR; mineral mapping
6	10.4-12.5	Thermal Infrared	Thermal IR; soil moisture; thermal mapping

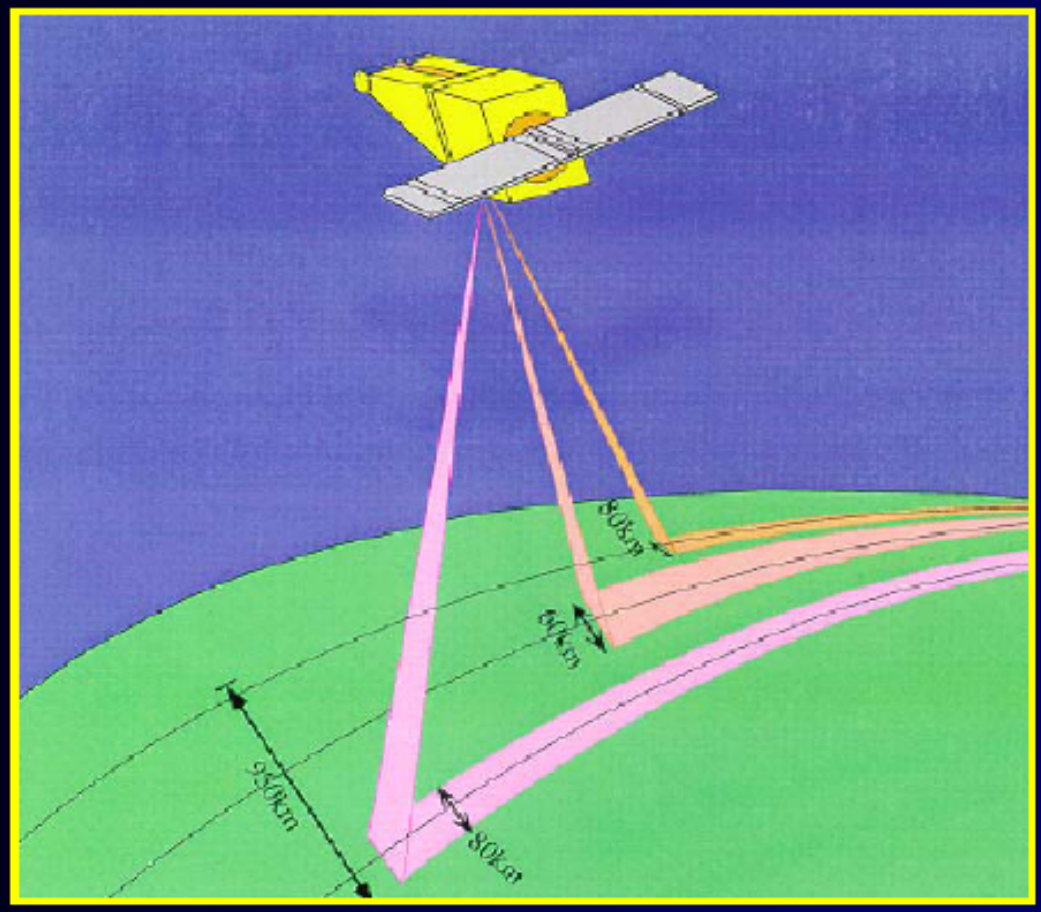
System Pour l'Observation de La Terra SPOT (System for Earth Observation)

SPOT

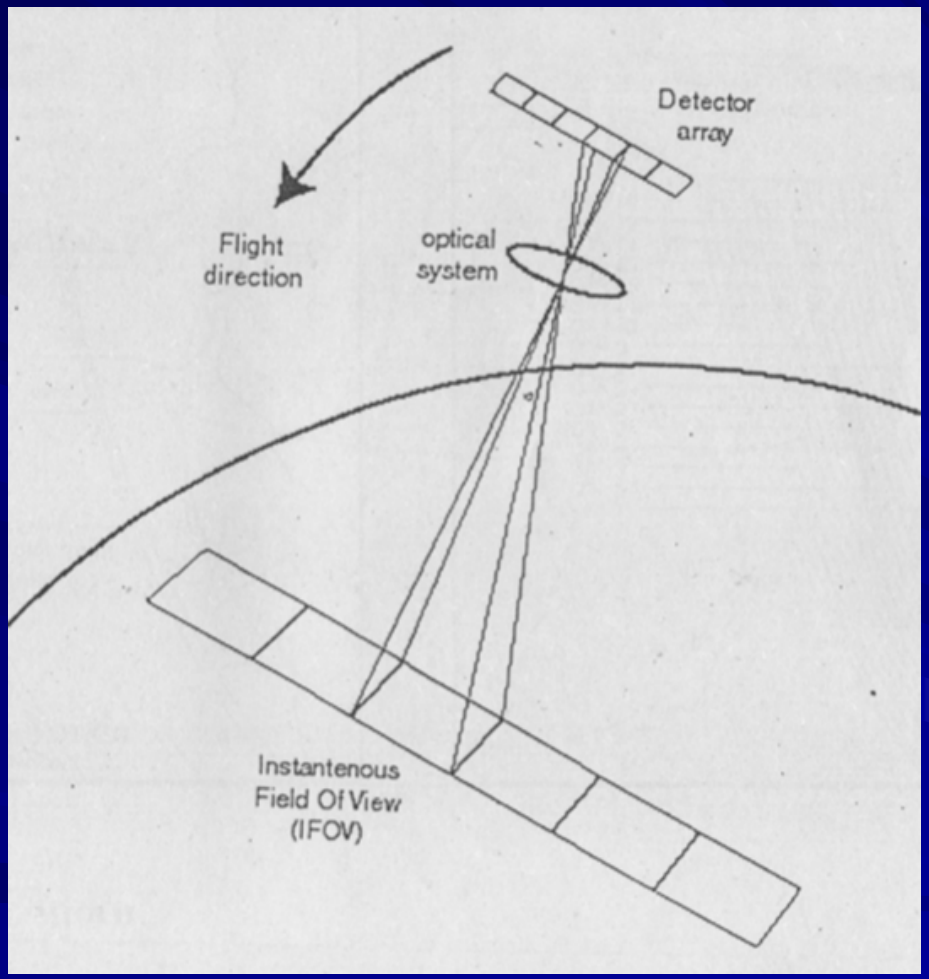
The SPOT satellites each have twin high resolution visible (HRV) imaging systems, which can be operated independently and simultaneously

The image shows the temple complex of Angkor. The large bluish-black rectangle is the Western Baray (reservoir), part of Angkor's famous irrigation system. The large square to its east is Angkor Thom, a fortified city. The brown spot at the centre of the square is the Bayon, a monumental structure. To its south is the fabled temple of Angkor Wat, surrounded by a wide moat. Other temples and the Eastern Baray are located round the complex. The road running south from Angkor Wat goes to the nearby town of Siem Reap. The wide bluish strip to the south is the flooded lake of Tonlé Sap.

SPOT Satellite System



Push Broom Scanner



Technical information Spot

SPOT satellite spectral bands and resolutions

Satellites	Spectral bands	Ground pixel size	Spectral range
Spot 5	Panchromatic B1: green B2: red B3: near infrared B4: short-wave infrared (SWIR)	2.5 m or 5 m 10 m 10 m 10 m 20 m	0.48 - 0.71 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm 1.58 - 1.75 µm
Spot 4	Monospectral (panchromatic) B1: green B2: red B3: near infrared B4: short-wave infrared (SWIR)	10 m 20 m 20 m 20 m 20 m	0.61 - 0.68 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm 1.58 - 1.75 µm
Spot 1 Spot 2 Spot 3	Panchromatic B1: green B2: red B3: near infrared	10 m 20 m 20 m 20 m	0.50 - 0.73 µm 0.50 - 0.59 µm 0.61 - 0.68 µm 0.78 - 0.89 µm

Enhancements in SPOT 5 in comparison to SPOT 4

- SPOT 5 – 2002-2015
- Two High Res. Geometric Instruments (HRG)--- 5m, and 2.5m (after combining 2.5 m images shifted along track)
- 10m for Visible(R+G+B), and 20m resolution, for SWIR (1.58-1.75 μm
- High Res. Stereoscopic (HRS) Instrument for DEM of 10 m resolution for the globe.

SPOT 6 & 7

SPOT 6 launched: 9 September 2012, while

SPOT 7 launched: 30 June 2014.

They form a constellation of Earth-imaging satellites designed to provide continuity of high-resolution, wide-swath data up to 2024.

EADS Astrium took the decision to build this constellation in 2009 on the basis of a perceived government need for this kind of data.

Spot Image, a subsidiary of Astrium, funded the satellites alone and owned the system (satellites and ground segments) at time of launch.

In December 2014, SPOT 7 was sold to Azerbaijan's space agency Azercosmos, who renamed it *Azersky*.

Ref: WIki

SPOT 6 & 7

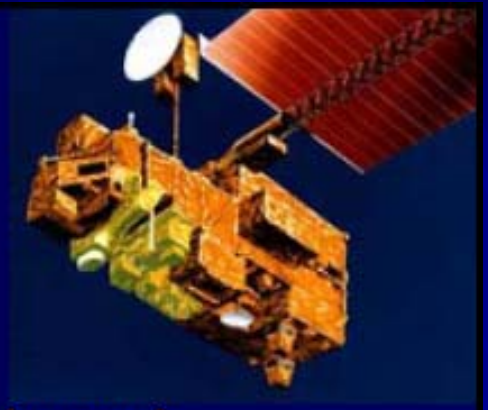
- SPOT 6 and SPOT 7 are phased in the same orbit as Pléiades Satellites, at an altitude of 694 km, forming a constellation of 2-by-2 satellites - 90° apart from one another.
- Image product resolution:
  - Panchromatic: 1.5 m
  - Colour merge: 1.5 m
  - **Multi-spectral: 6 m**

Spot 6 & 7

- Spectral bands, with simultaneous panchromatic and multi-spectral acquisitions:
  - Panchromatic (450 – 745 nm)
  - Blue (450 – 525 nm)
  - Green (530 – 590 nm)
  - Red (625 – 695 nm)
  - Near-infrared (760 – 890 nm)
- Footprint: 60 km × 60 km
- Responsive satellite tasking, with six tasking plans per day, per satellite

For price list:
http://www.infogeoafrica.com/infogeo-resources/docs/pricelists/pricelist_SPOT6_EN.pdf

ASTER



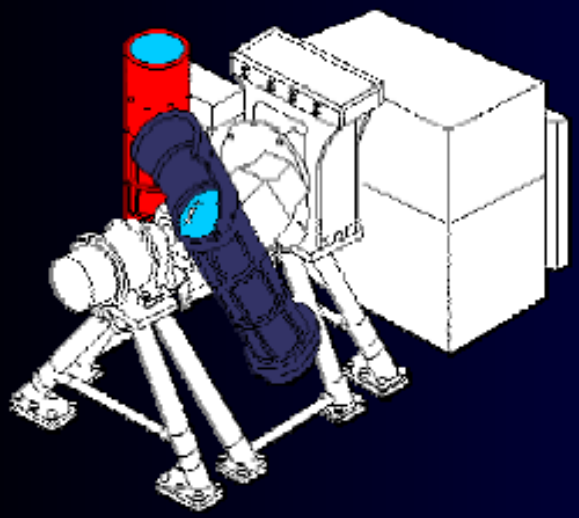
ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument that is flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS).

ASTER will be used to obtain detailed maps of land surface temperature, emissivity, reflectance and elevation. The EOS platforms are part of NASA's Earth Science Enterprise, whose goal is to obtain a better understanding of the interactions between the biosphere, hydrosphere, lithosphere and atmosphere.

ASTER Instrument Characteristics

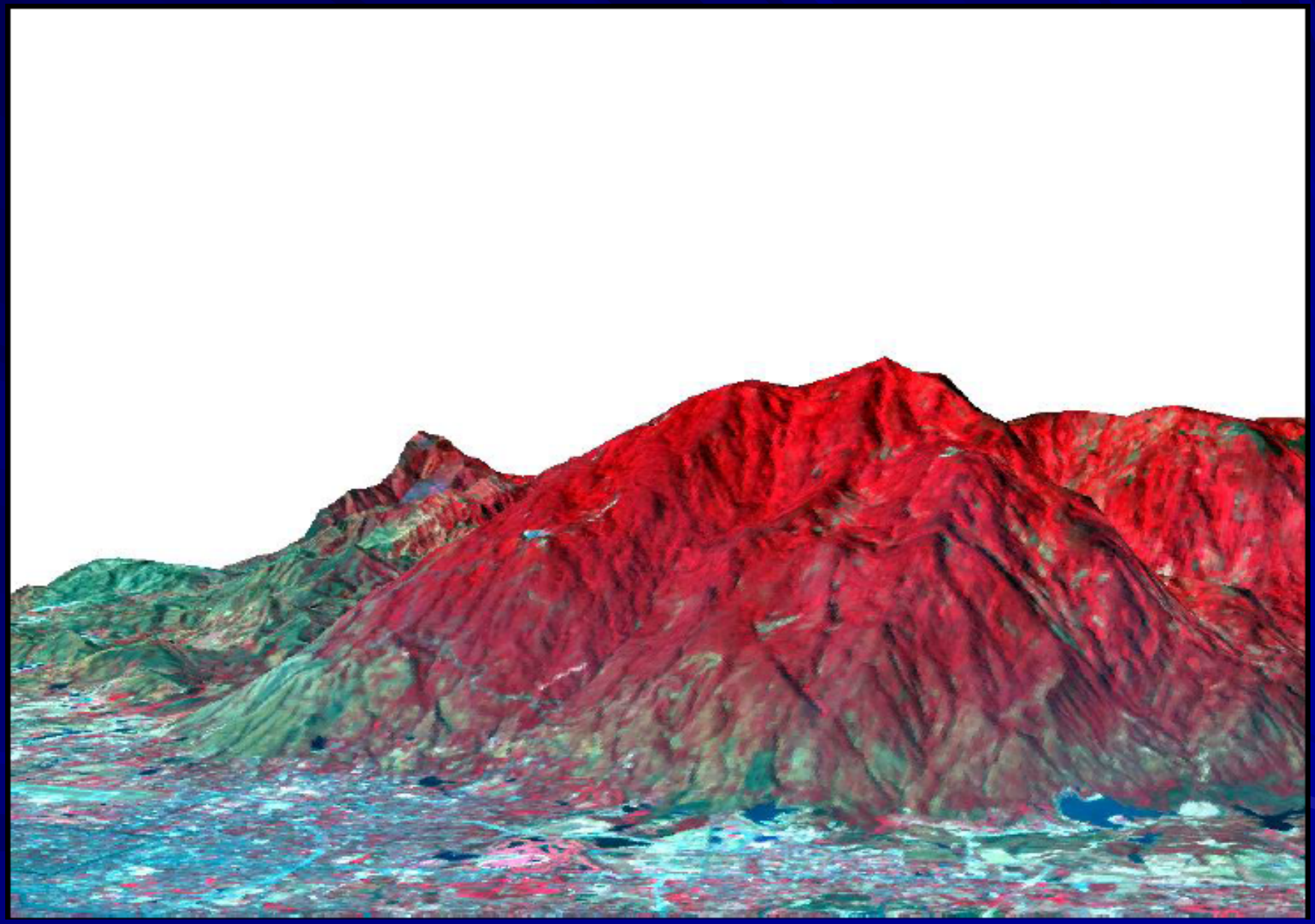
Characteristic	VNIR	SWIR	TIR
Ground Resolution	15 m	30m	90m
Data Rate (Mbits/sec)	62	23	4.2
Cross-track Pointing (deg.)	±24	±8.55	±8.55
Cross-track Pointing (km)	±31	±116	±116
Swath Width (km)	60	60	60
Detector Type	Si	PtSi-Si	HgCdTe
Quantization (bits)	8	8	12

ASTER Instrument



Nadir Looking Telescope - The **VNIR subsystem** nadir looking telescope is a reflecting-refracting improved Schmidt design. The focal plane of this telescope contains three 5000 silicon charge coupled detector line arrays. The nadir and backward looking telescope pair are used for same orbit stereo imaging and can be rotated as a unit +/- 24 degrees to provide extensive cross-track pointing capability

The VNIR subsystem produces by far the highest data rate of the three ASTER imaging subsystems. With all four bands operating (3 nadir and 1 backward) the data rate including image data, supplemental information and subsystem engineering data is 62 Mbps.



MODIS: Moderate Imaging Spectroradiometer (onboard Terra and Aqua)

- Ref: Modis Sensor onboard Terra, and Aqua:
- 36 bands, with spatial resolution of 250 to 500 m.
- Have onboard calibration facility (for radiometric, and geometric correction
- https://www.youtube.com/watch?v=kKHZq4WIBDc

MODIS File naming convention

MOD13A2.A2011129.h11v02.005.2011154120408.hdf

MODXXX.Ayyyyddd.hxxvxx.vvv.yyyydddhhmmss.hdf

MODXXX = product and level of product
MOD = Terra **MYD** =Aqua
yyyyddd = year and year day (001 – 366) for the start of the granule (2011, day 129)
hxxvxx = MODIS land tile (h11v02)
vvv = a three-digit version number (005)
yyyydddhhmmss = 4 digit year, 3 digit day, hr, min, and sec of the time (UTC)at which the granule is processed.

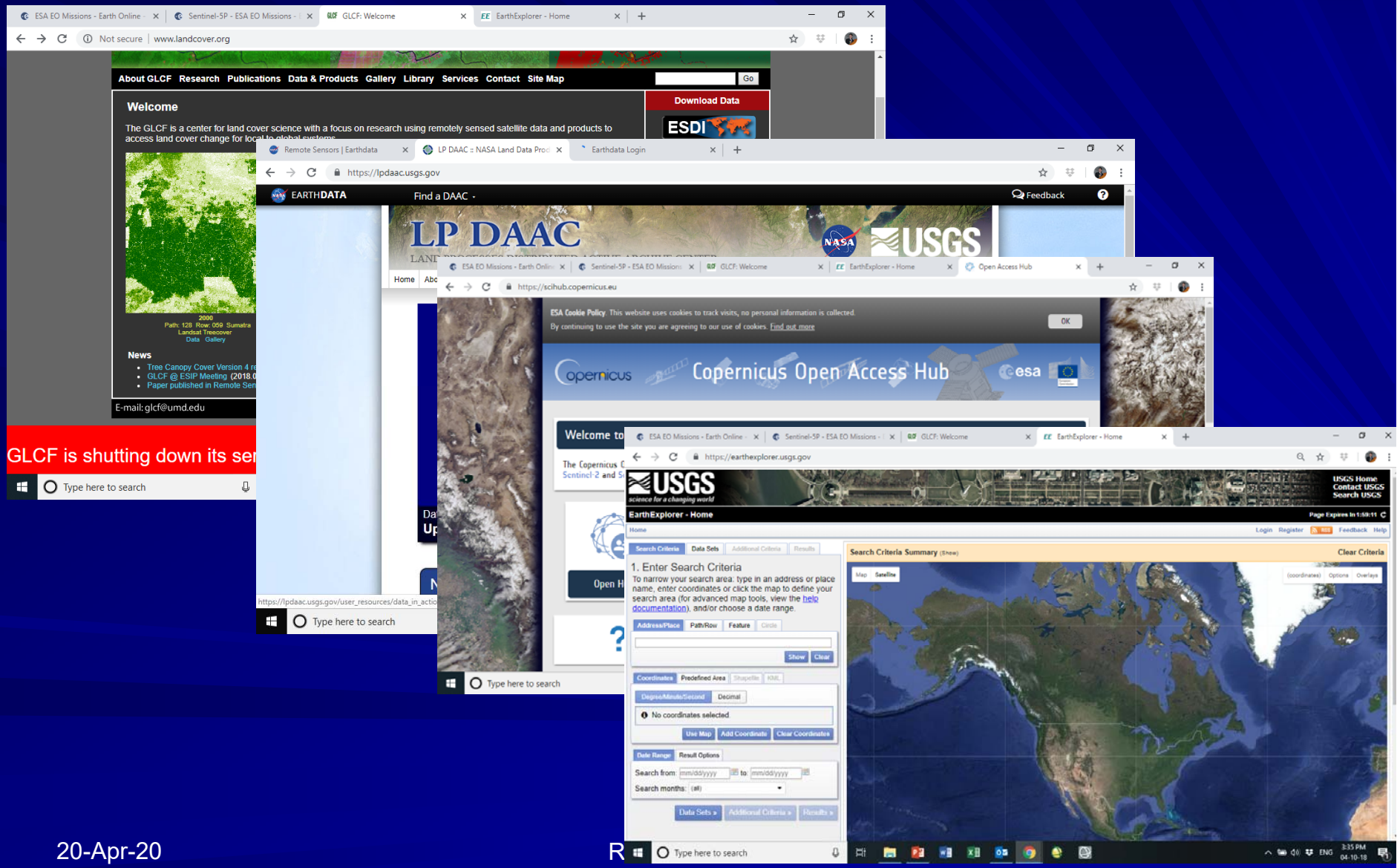
Quantization Levels

SENSOR	SATELLITE	LEVEL (bits)	DESCRIPTION
TM	LANDSAT	6	**8 bits after correction**
MSS	LANDSAT	8	
HRV	SPOT4,5	8	
HRV	SPOT4,5	6	
AVHRR	NOAA	10	**Both 10 & 16 bits data is available for distribution**
SAR	JERS-1	3	

Pakistan Remote Sensing Satellite: PRSS 1, PakTes 1A Launched 9 July 2018

- https://www.geo.tv/latest/202468-china-launches-rocket-carrying-two-pakistani-satellites
- 640km, 610 km

Data Availability



Data Download Portals

- USGS: https://earthexplorer.usgs.gov/
- ESA: https://scihub.copernicus.eu/
- USGS : https://glovis.usgs.gov/
- GLCF: http://www.landcover.org/

Price Indian RS Data

- https://nrsc.gov.in/sites/all/pdf/Satellite_Data_Price_List.pdf

IRS SATELLITE DATA PRODUCTS PRICE LIST

(Price in Rupees)

High Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
1.0	**PAN (1m) (Cartosat-2)**		
1.1	Mono Geo-referenced/Ortho kit 9.6 km x 9.6 km	100	2,440
1.2	Ortho Corrected 9.6 km x 9.6 km	15	2,890
2.0	**PAN - A/F (2.5m) (Cartosat-1)**		
2.1	Mono Geo-referenced/Ortho kit 27.5 km x 27.5 km	50	4,440
2.2	Stereo Ortho kit 27.5 km x 27.5 km	220	5,110
2.3	Ortho Corrected 27.5km X 27.5km	15	6,450
2.4	CartoDEM 14km X 14km	15	6,290
3.0	**LISS- 4 MX (5m) (Resourcesat-1,2)**		
3.1	Geo-referenced/Ortho kit 23.5 km x 23.5 km	50	1,540
3.2	Geo-referenced/Ortho kit 70 km x 70 km	50	4,170
3.3	Ortho rectified 70 km x 70 km	20	10,470
4.0	**MICROWAVE (1m - 50m) (RISAT-1)**		
4.1	Georeferenced SAR (FRS-1/FRS-2/MRS/CRS)	200	4,890

Medium Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
5.0	**LISS - III (24m) (Resourcesat-2)**		
5.1	Geo-referenced/Ortho kit 141 km x 141 km	100	3,520
5.2	Ortho rectified 141 km x 141 km	50	6,870
6.0	**AWiFS (56m) (Resourcesat-2)**		
6.1	Full Scene Geo-referenced 740 km X 740 km	150	7,420
6.2	Full Scene Ortho Rectified 740 km X 740 km	100	15,770
6.3	Quadrant Geo-referenced/ Ortho kit 370 km X 370 km	150	4,030
6.4	Quadrant Ortho rectified 370 km X 370 km	100	6,420

Low Resolution

S No	Product Type	Accuracy (CE90) in km	Price
7.0	**OCM (360m) (Oceansat-2)**		
7.1	Georeferenced 1420 km X 1420 km	1.5	3,050
7.2	Geo physical 1420 kmX1420 km	1.5	1,070

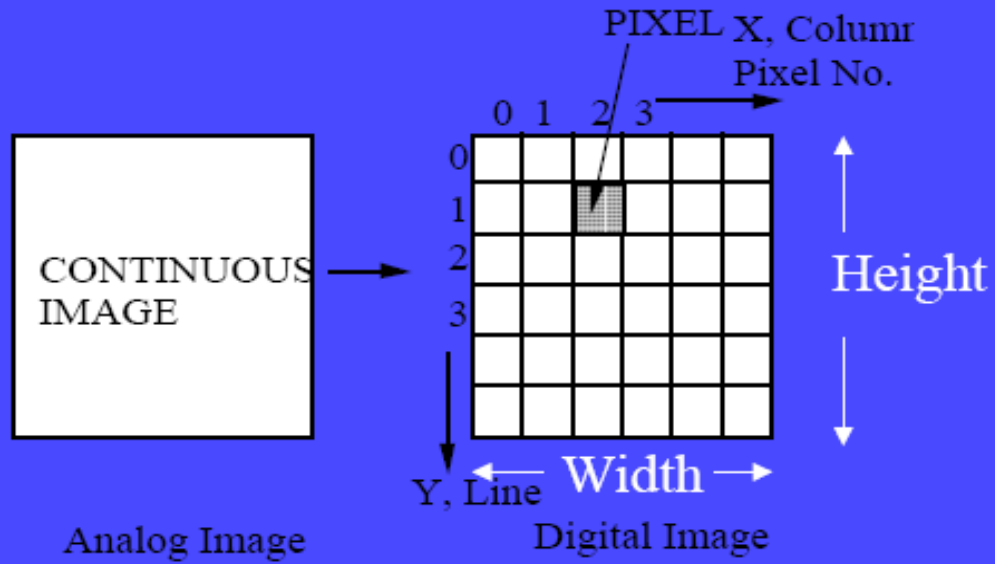
2. Digital Image Data
Pixel

Pixel (Picture Element)

pixel has a value f(x,y)

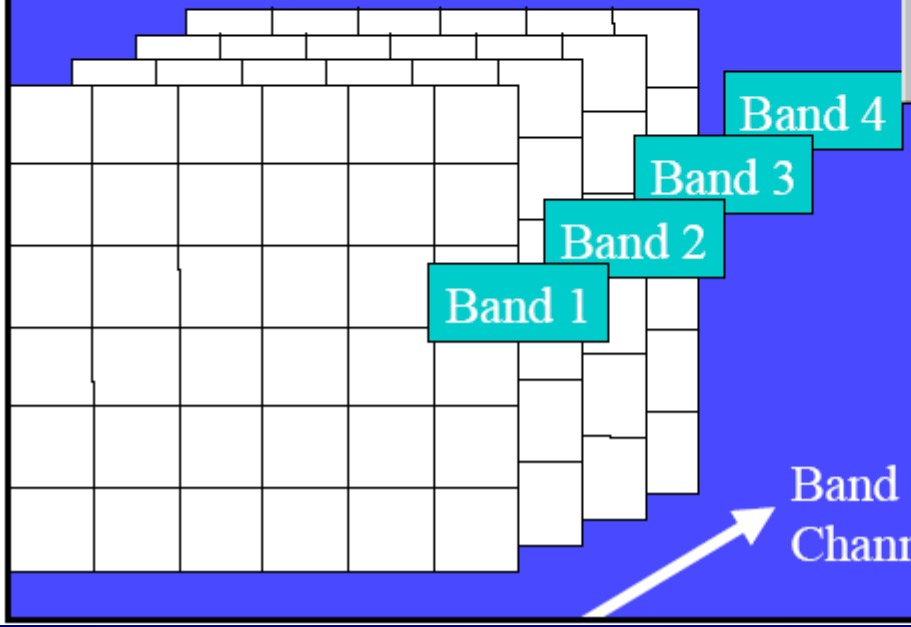
x,y:integer,

f: brightness in most case, integer



Multi Channel Image

Color Image: 3 channel for R,G,B
Landsat TM 7 Channel



Bit and Binary System

The gray level of each pixel is recorded and stored as a finite number of bits.

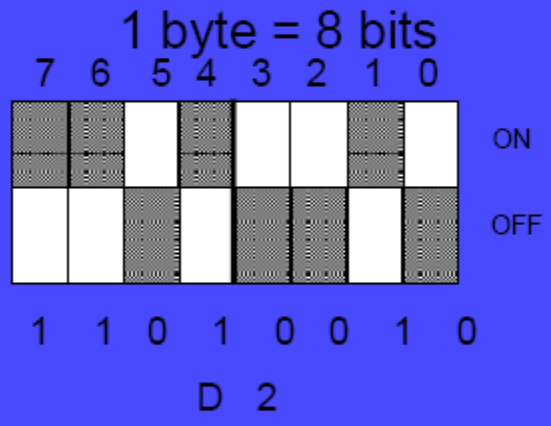
If there are k bits/pixel, total of 2^k gray levels over the range 0 to $2^k - 1$

Exmaple of 3 bits image

bit map			graylevel	bitmap		graylevel	
bit2	bit1	bit0		bit2	bit1	bit0	
0	0	0	0	1	0	0	4
0	0	1	1	1	0	1	5
0	1	0	2	1	1	0	6
0	1	1	3	1	1	1	7

if k equals 8, the group of bits is called byte.

Binary System in Computer Memory



13x16+2 = 210

binary system

hexadecimal system (0123456789ABCDEF)

decimal system

Pixel value is stored in limited space in a computer memory. 1unit = 1byte = 8bits

8 bits has 2^8=2*2*2*2*2*2*2*2 = 256 combinations of on/off at bits.

Thus k bits unsigned integer has 0 to 2^k-1 of data range.

8bits (1byte) / pixel 0 -> 255

16 bits (2bytes)/pixel 0-> 65535

1024 bytes = 1KB
1024 KB = 1MB
1024 MB = 1GB

Image Size in Bytes

1024 width *1024 height *7 bands / 1 byte/pixel -> 7M B

How to store numerical value in limited number of Bits

Typical Computer Word Length
8 bits, 16bits, 32bits, 64bits
We usually use 8,16,32,64bits to store pixel values.

8bits	unsigned integer	0-255	most common
16bits	unsigned integer	0-65535	Optical, radar image
32bits	unsigned integer	0-4,294,967,295	
8 bits	signed integer	-128 to +127	
16 bits	signed integer	-32768 to 32767	

IEEE format floating point value

32bits	float	significant figures	7
64bits	float complex		
64bits	double	significant figures	15
128bits	double complex		

Sampling

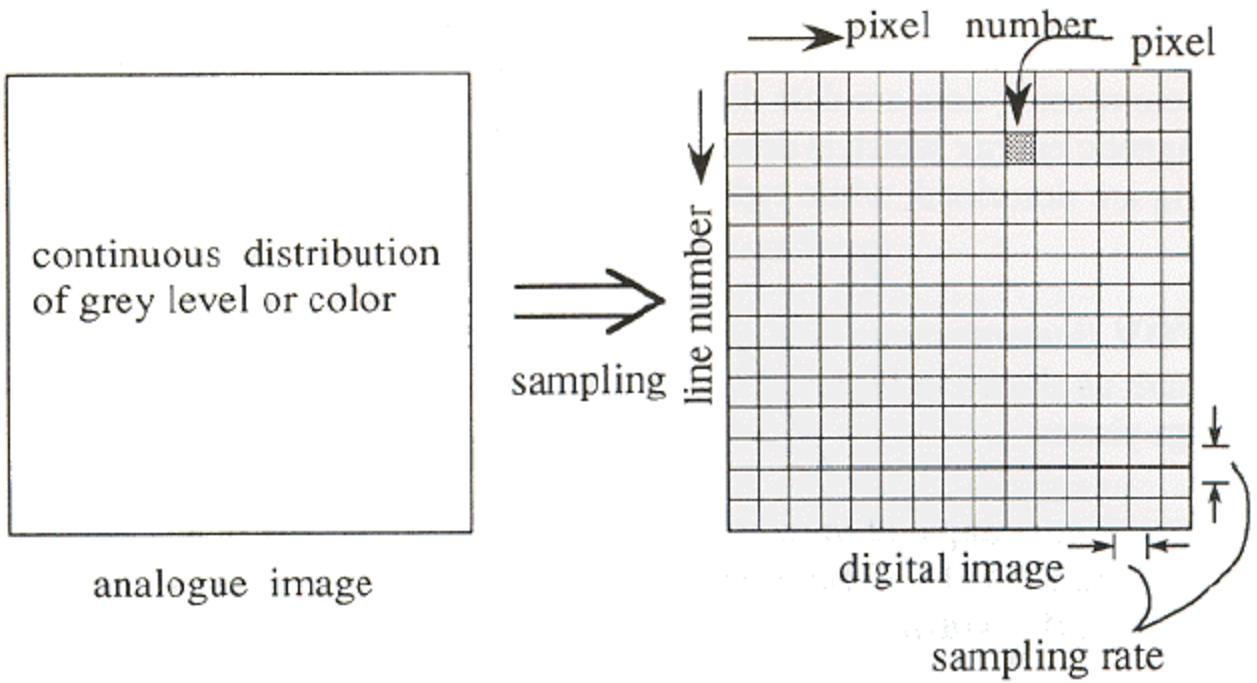


Figure 6.1.1 Concept of sampling

FOV and IFOV

FOV: Field of View

IFOV: Instantaneous Field of View for 1 pixel

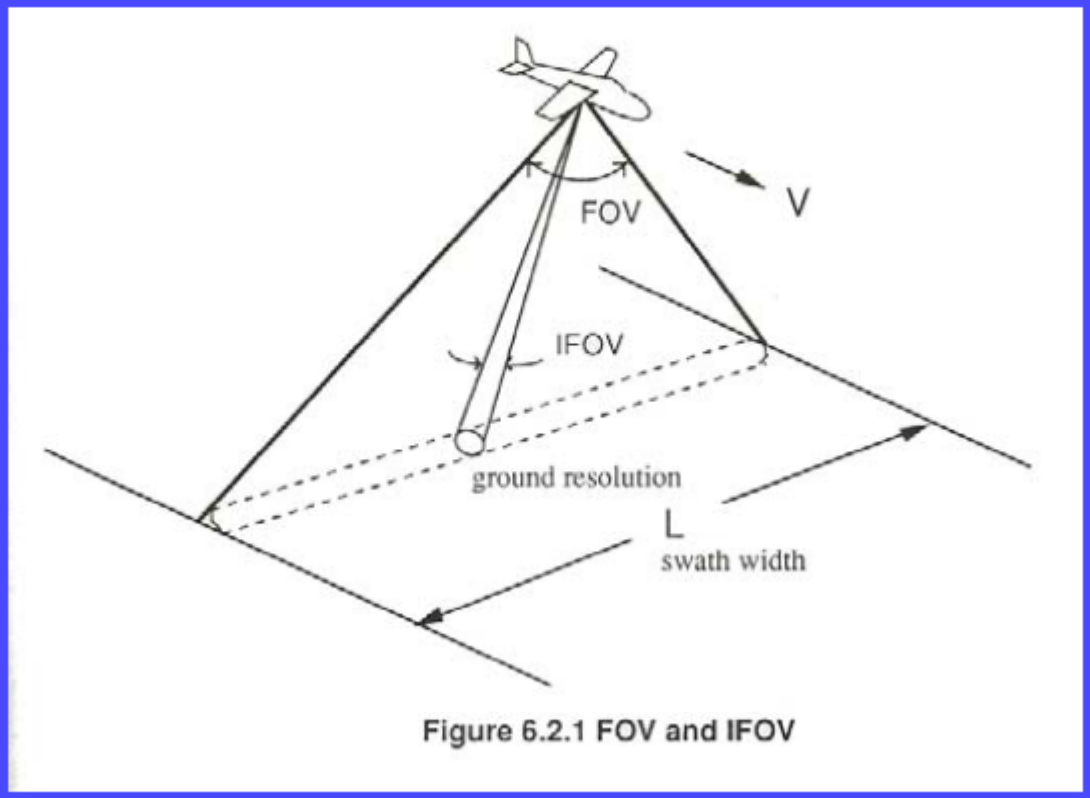


Figure 6.2.1 FOV and IFOV

Quantization

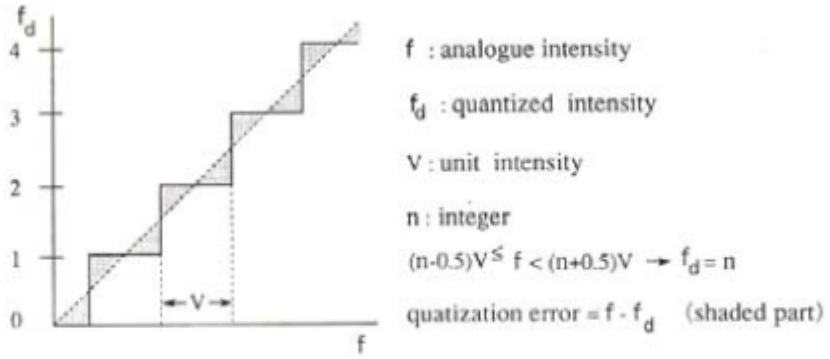


Figure 6.1.2 Concept of quantization

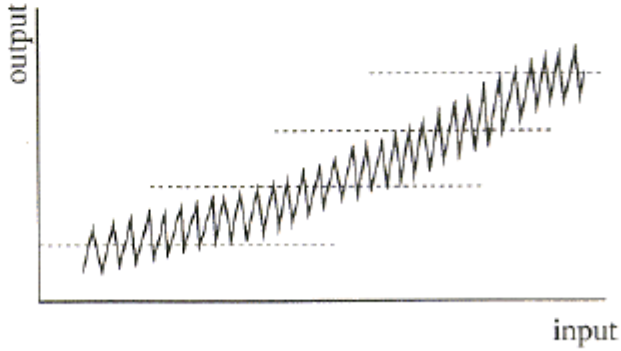


Figure 6.1.3 Quantization in the case of a signal containing a noise

Records and Files

Image data is stored in secondary memory(Floppy, Hard Disks, Many types of removable disks, Tape, etc.)

Each line of image pixels is usually stored as a logical record, which is implemented on physical records on media.
The total set of records which constructing an image is called file.

In case of tape media, only sequential access can be done, and logical record is same as physical record
Gap separates physical record. TM(tape mark) separates files

File Format

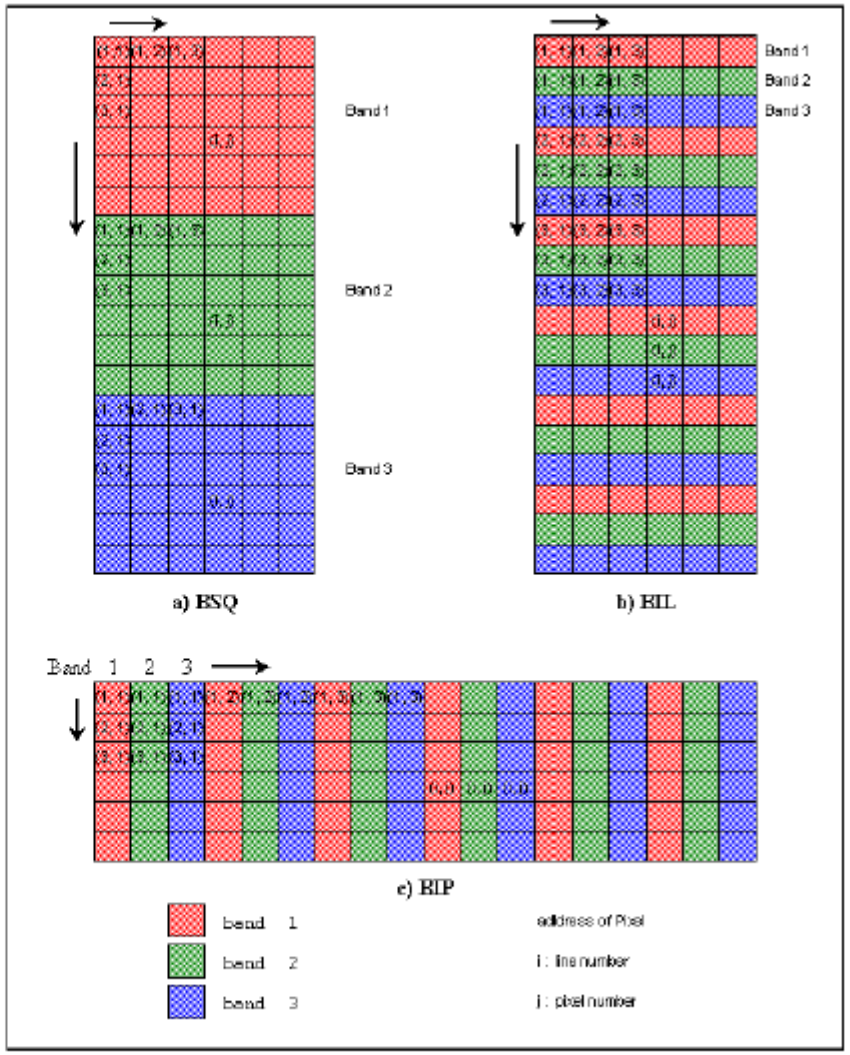


Figure 6.4.1 Image data format (in the case of 3 separate bands)

File Format

(1) Band-Sequential (BSQ)
(2) Band-interleaved by line (BIL)
(3) Band-interleaved by pixel (BIP)

If the processing is a pixel-by-pixel, the BIP format is convenient because the pixel gray levels in each band are stored contiguously within a data record

If the processing is only on a single band from the multispectral image, the BSQ format is most attractive because it minimize the amount of data that must be read to access a single band

The BIL format represents a good compromise of efficiency and convenience for general application and is probably used more widely than either of the other formats.