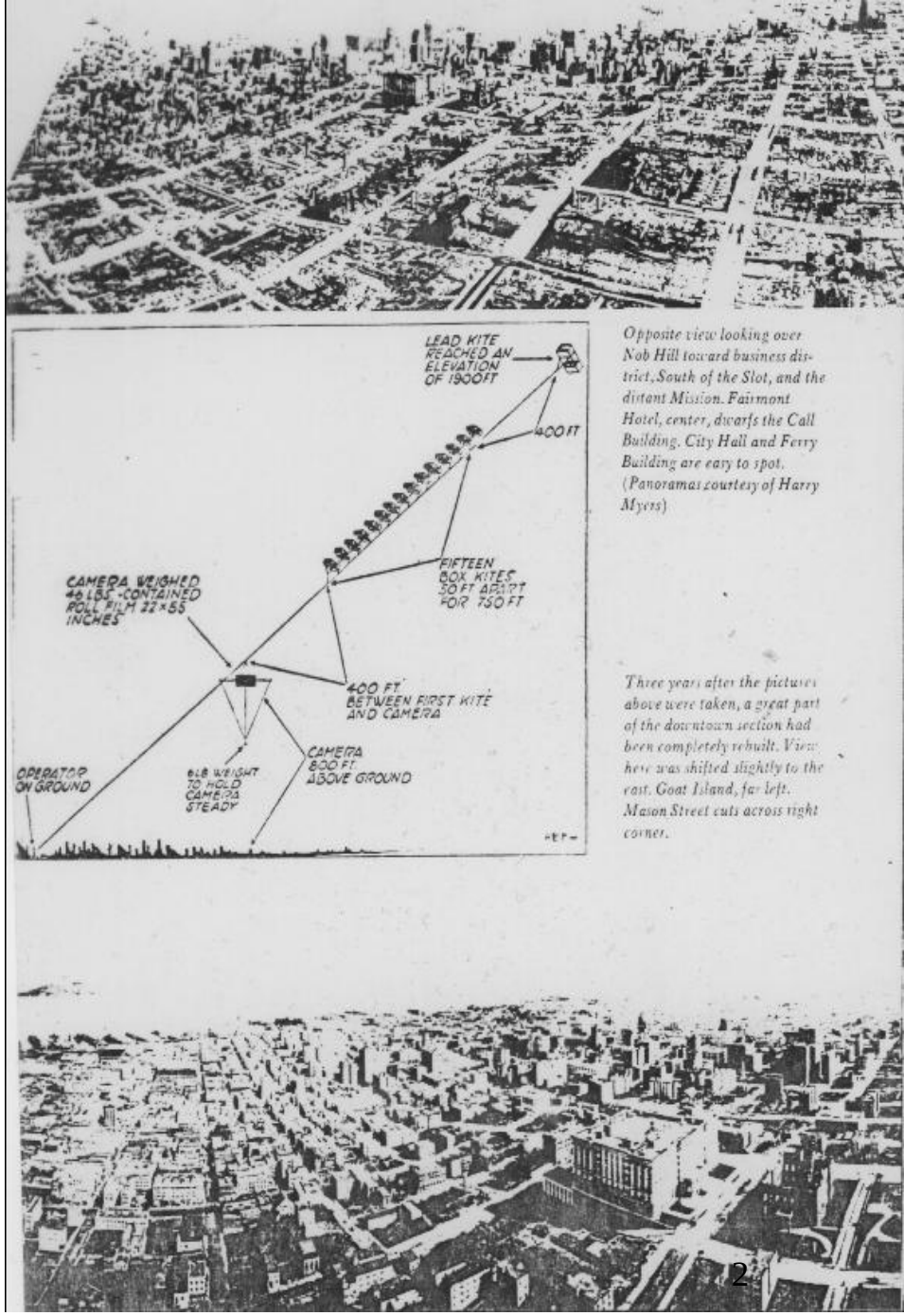
# Digital Image Acquisition

- Digitization of analog aerial photography, can be very useful for historical studies and/or for high spatial resolution needs
- Direct acquisition using some form of digital imaging sensor

# Early attempts

- **Kite system acquired aerial photos of the great San Francisco earthquake and fire**
- **Pigeon cameras**
- **The development of aircraft**

- **World Wars I and II**



# Aerial Cameras

A large format oblique camera

Keystone's Wild RC-10 mapping camera

# Aerial photos

- **Black & White - single panchromatic layer**
- **Color: 3 layers B-G-R**
- **Color IR: 3 layers G-R-NIR**

# Remote Sensing Systems - Instrumentation

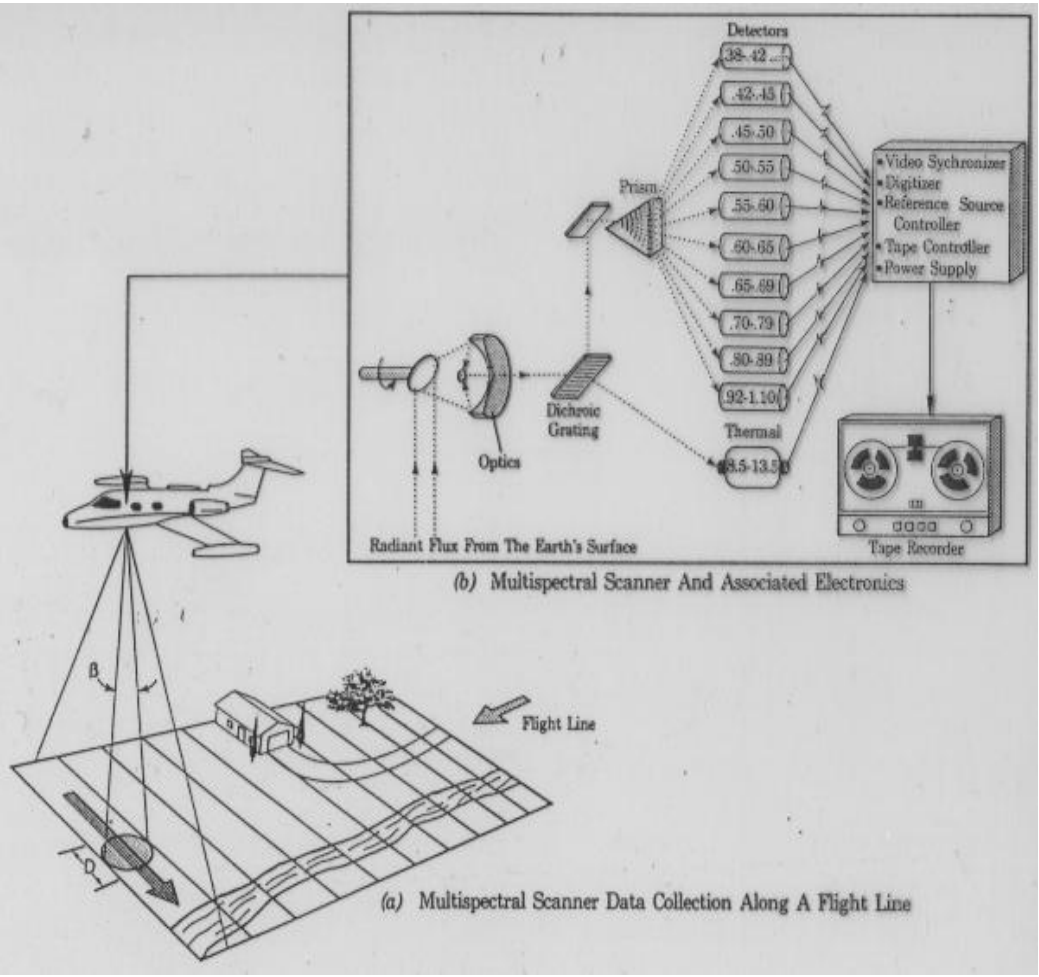
- Radiometer - electro-optical instrument measuring radiant flux (energy)
- Spectroradiometer - instrument that measures radiant flux as a function of wavelength - often as a continuous spectra
- Multispectral scanner - imaging spectro-radiometer measuring radiant flux in specific spectral wavebands

# Major Elements of electro-optical scanners

- Optical system: lenses, mirrors, apertures, modulators & dispersion devices
- Detectors: provide an electrical signal proportional to the irradiance on its active surface, generally some type of semiconductors
- Signal Processor: performing specified functions on the electrical signal to provide the desired output data

# Electro-optical scanners

- **Elements sensitive to electro magnetic energy (EME) of certain wavelengths focus energy onto a sensor plane. A prism is used to divide the energy into specific wavelengths. The CCD's are stimulated and produce an electrical signal equal to the energy focused upon it. These data are recorded.**
- **Data are converted from an analog electrical signal to a digital number**

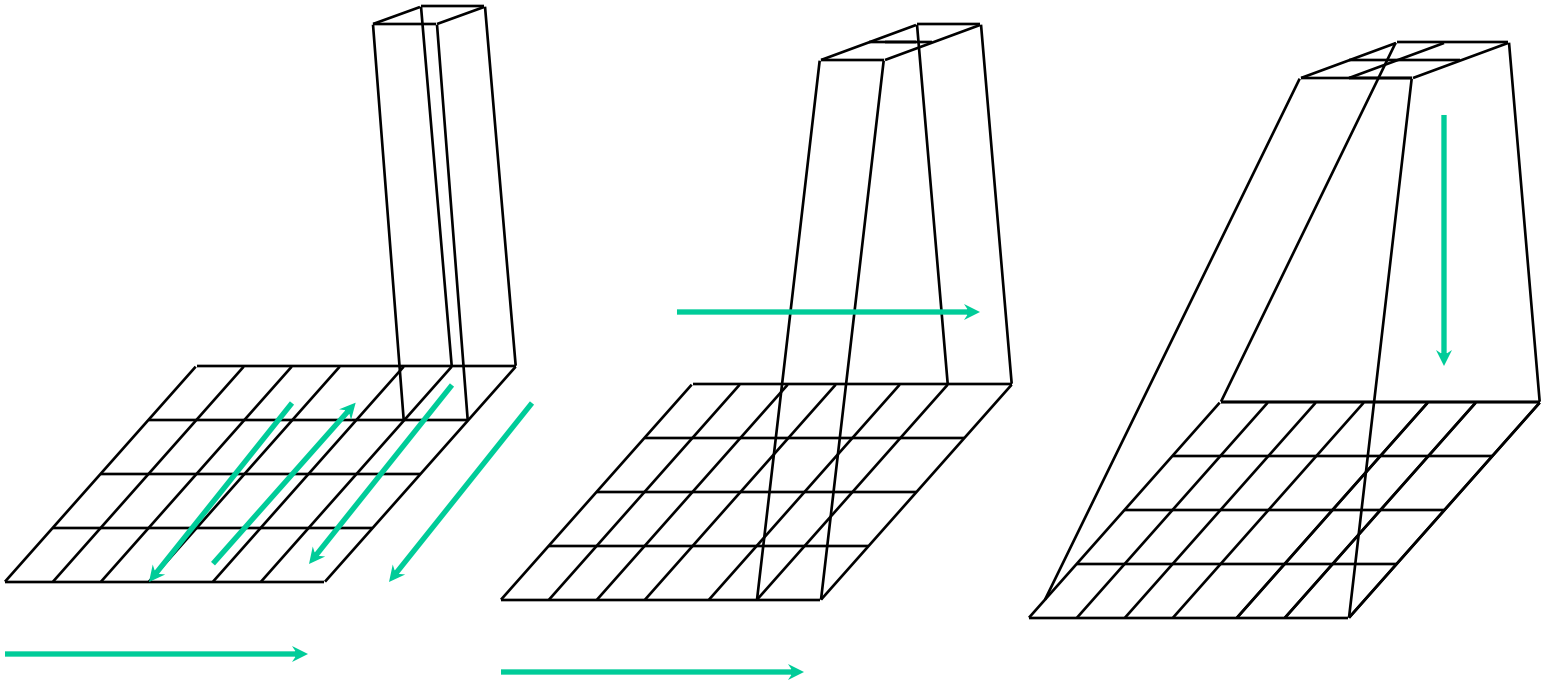


# 3 different scanner designs

Single detector
CCD-Scan Mirror
TM

Pushbroom scanner
SPOT

Two dimensional
Staring Array
Space Imaging



Original

Current

Future

# Important imaging parameters

- The Instantaneous Field of View (IFOV) subtends an area on the terrain called a Ground Resolution Cell (GRC)
- The Angular Field of View determines the width of the Ground Swath
- The Dwell Time, the time required for the detector IFOV to sweep across the GRC

# Airborne Remote Sensing

**Aircraft Scanners** Digital imagery acquired from several multispectral scanners on board NASA ER-2, NASA C-130B, and NASA Learjet aircrafts (1982 - 1995).

For more info: http://edcdaac.usgs.gov/airborne/air_scan.html

**Digital Cameras** increasingly aerial imagery is being acquired through digital camera framing systems that can collect multispectral (VIS-NIR) imagery and be quickly corrected through GPS-based navigational systems to produce digital orthophotographic imagery in near-real time

# Remote Sensing Satellites in Space: How do they get there?

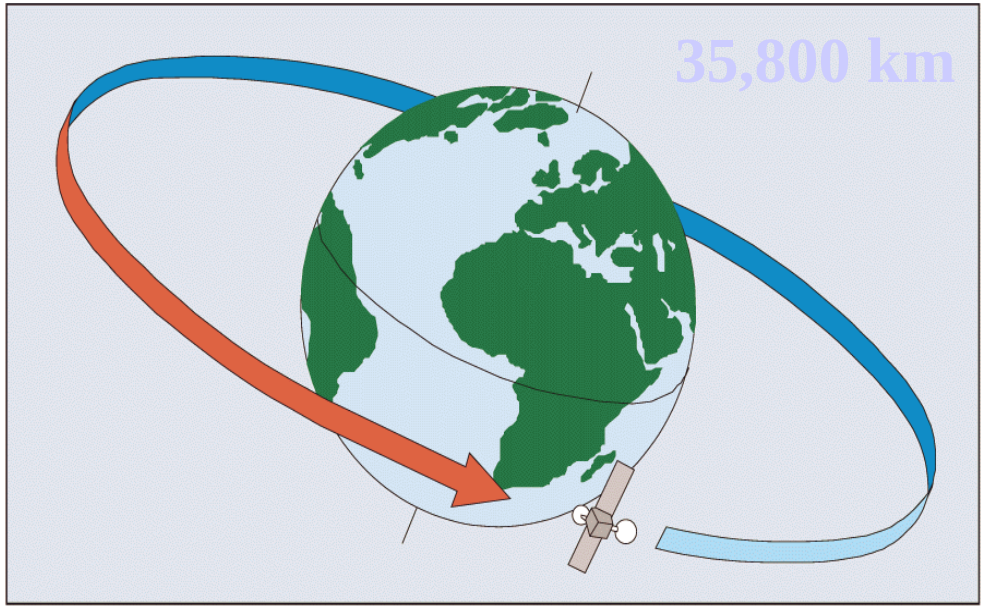
http://visibleearth.nasa.gov/cgi-bin/viewrecord?492

# MODIS Terra Launches

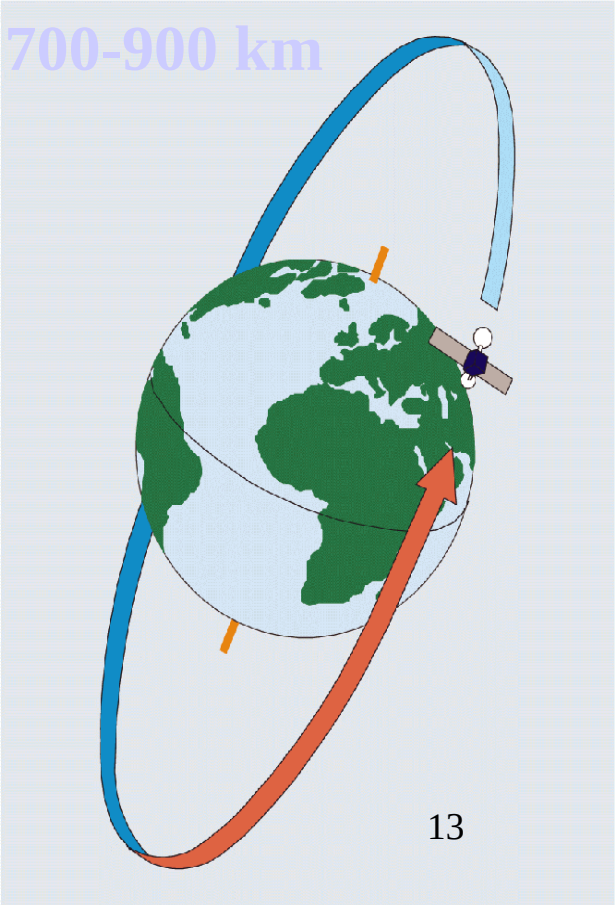
http://visibleearth.nasa.gov/cgi-bin/viewrecord?135

# Types of satellite orbits

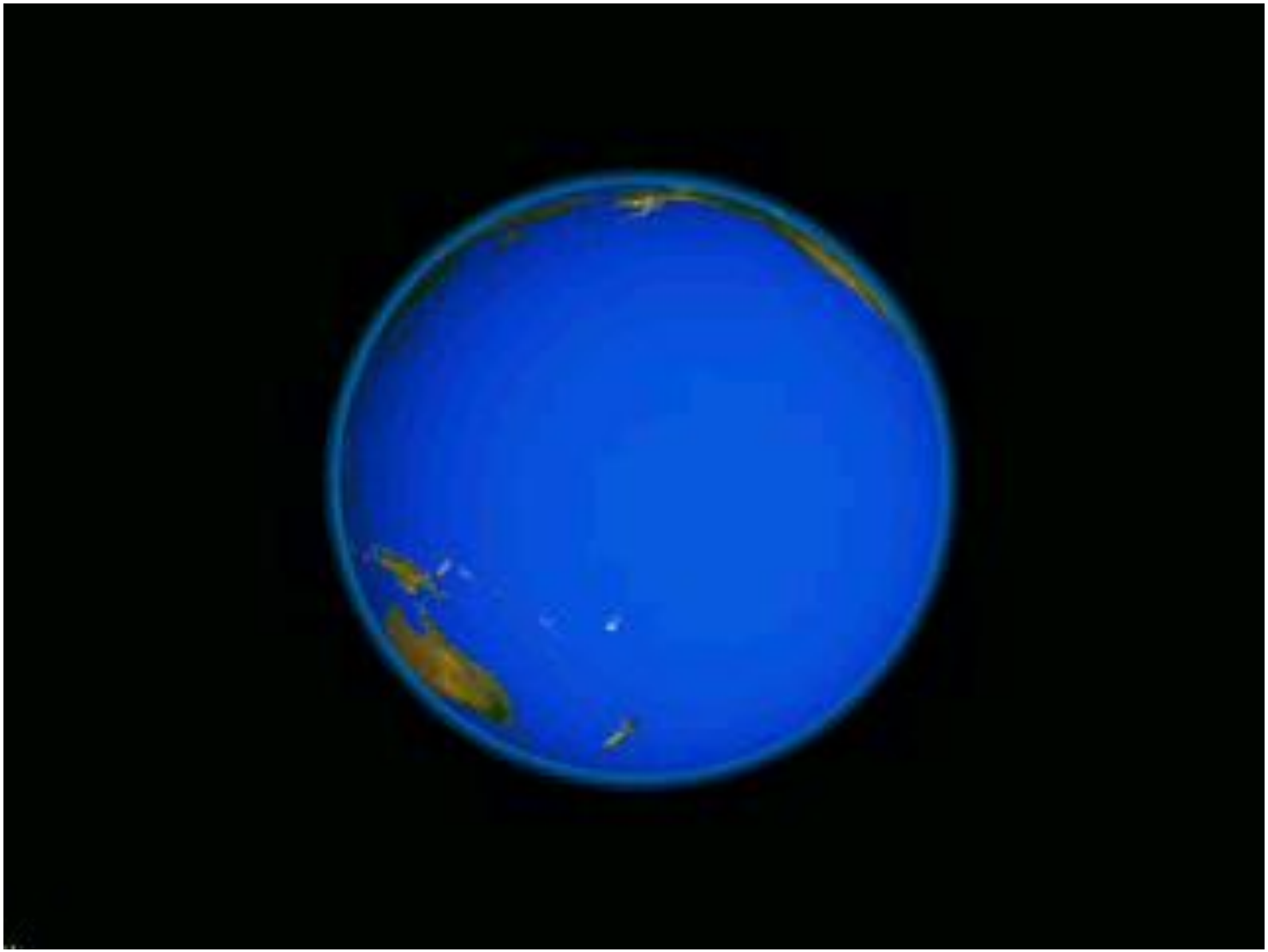
- **Geostationary**




**Polar**



# Polar Orbitting Satellite

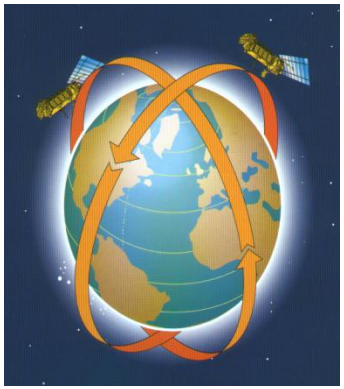


http://visibleearth.nasa.gov/cgi-bin/viewrecord?134

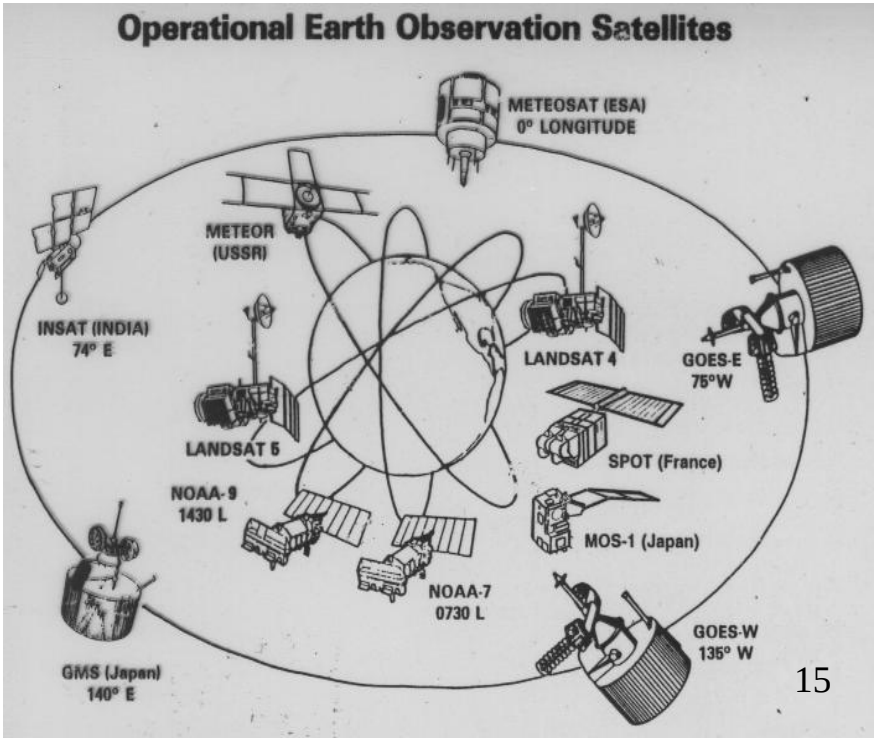
# Geostationary vs. polar orbiting sensors

**Geostationary sensors orbit with the earth continually viewing the same hemispheric area**

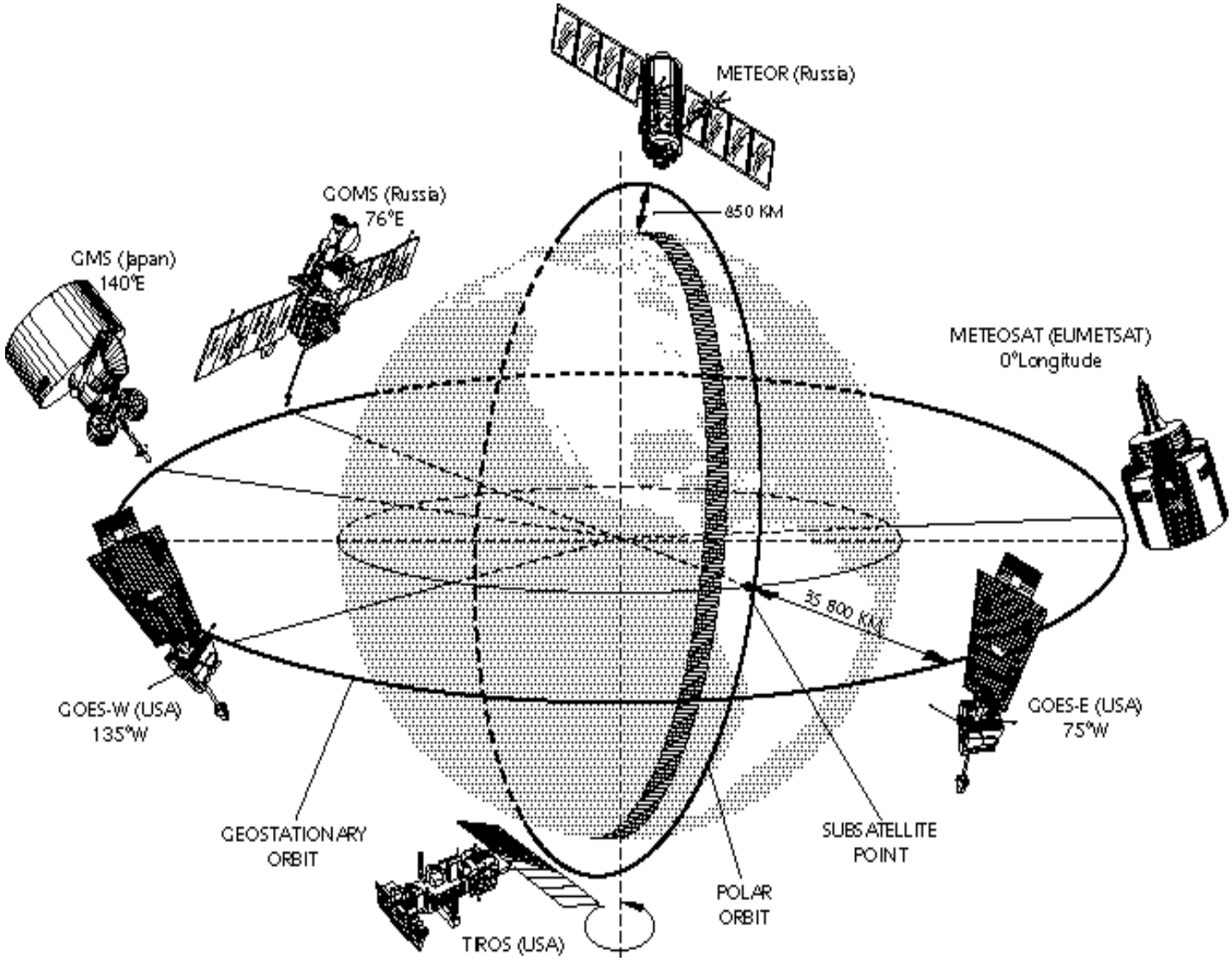
**Polar orbiters, continually view new areas of the earth as the planet rotates underneath the sensor. Keeps the same general solar time as it cross the equator on each orbit - called sun synchronous**



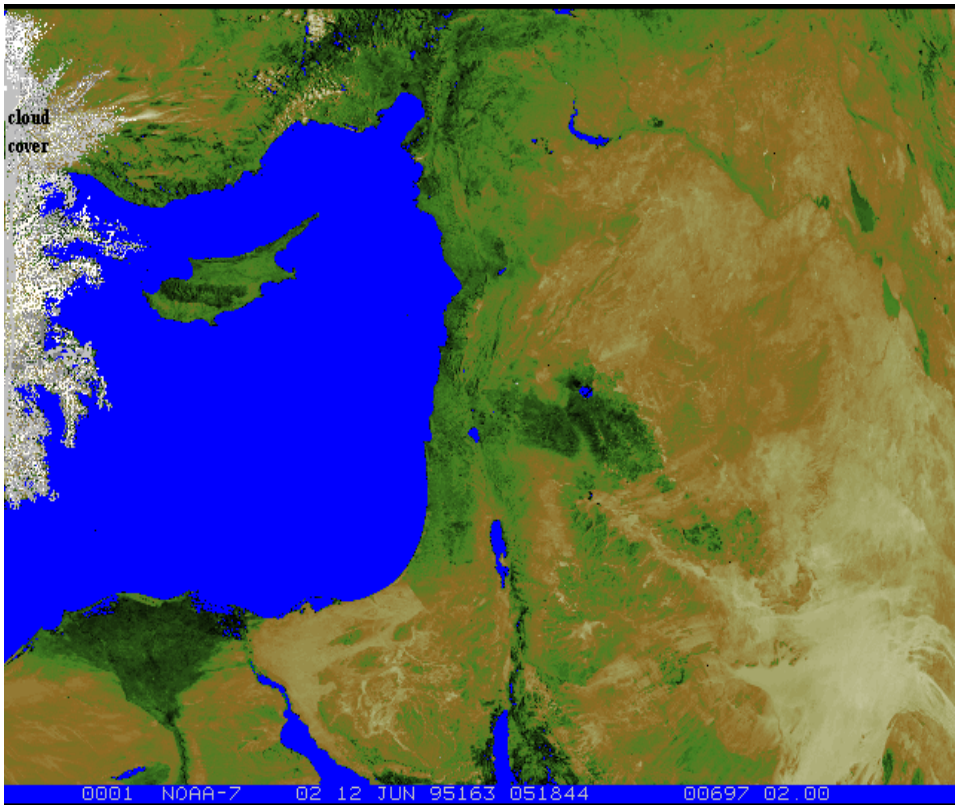
Polar orbit



# Many different systems - which to choose?

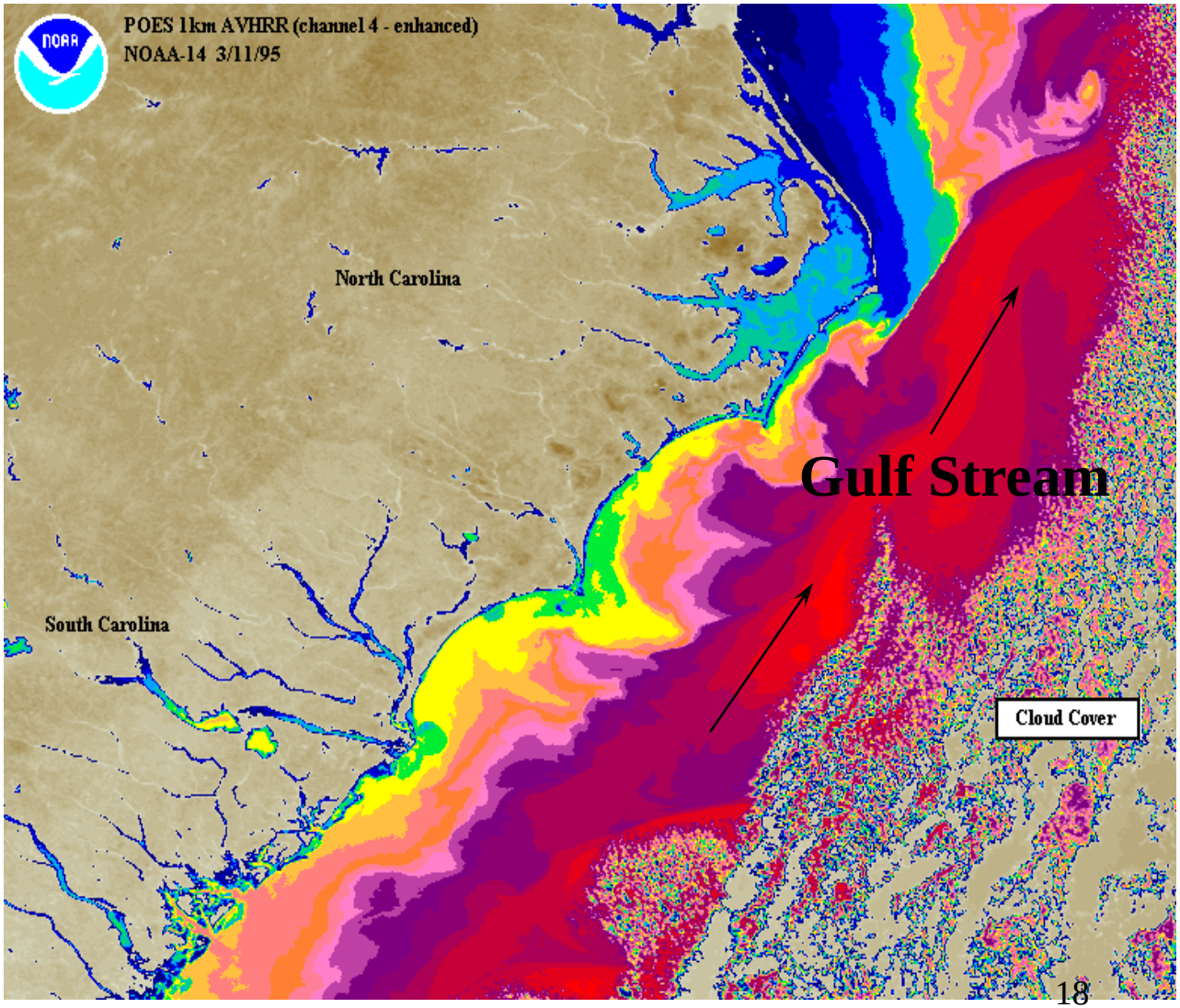


- AVHRR-Advanced Very High Resolution Radiometer
- Polar orbit, coarse spatial resolution: 1 and 4 km cells, broad 2400 km ground swath width
- 2 operational now-1 day and 1 night pass for each



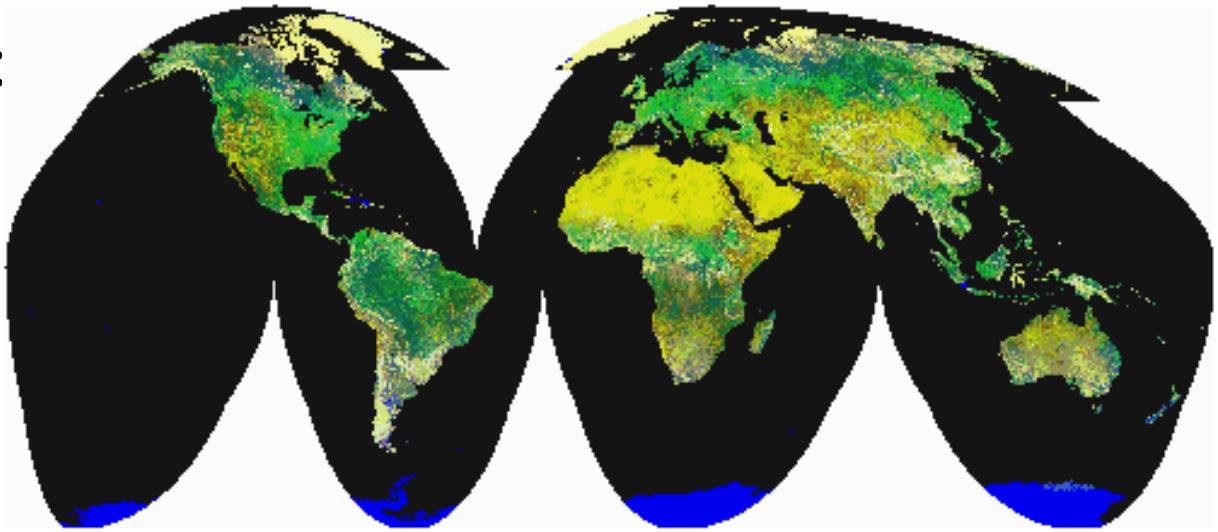

# AVHRR

- Thermal AVHRR provides water temperature data
- 3 bands in TIR

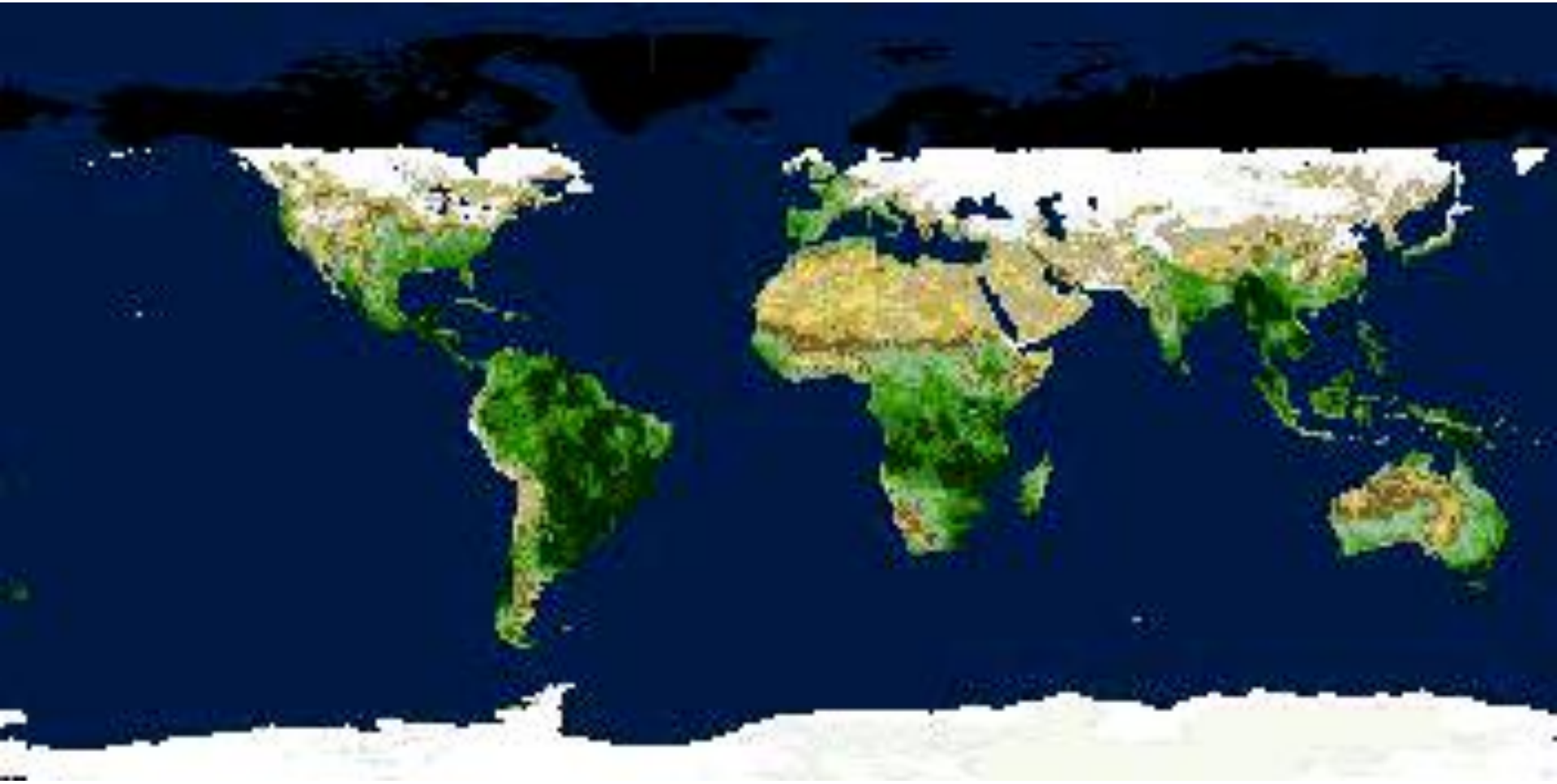


# Global AVHRR composite

- 1 band in the Red: .58-.6 um
- 1 band in the NIR: .72-1.1 um
- Vegetation Index to map vegetation amount and productivity



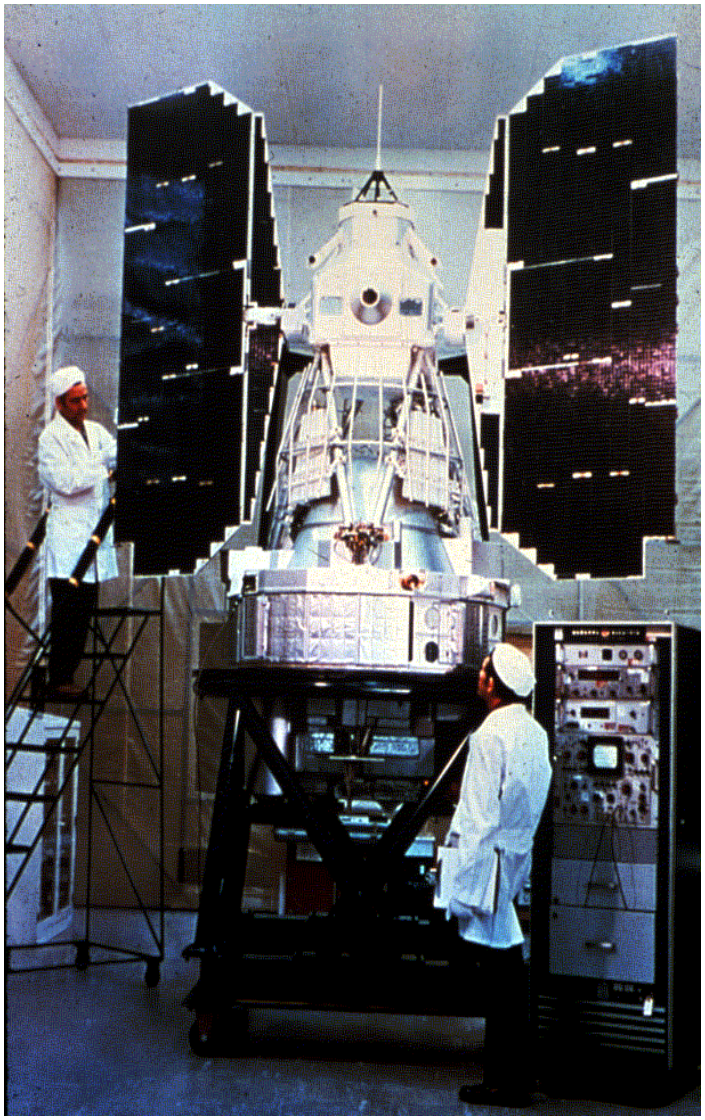
# Can you see the Green Wave?



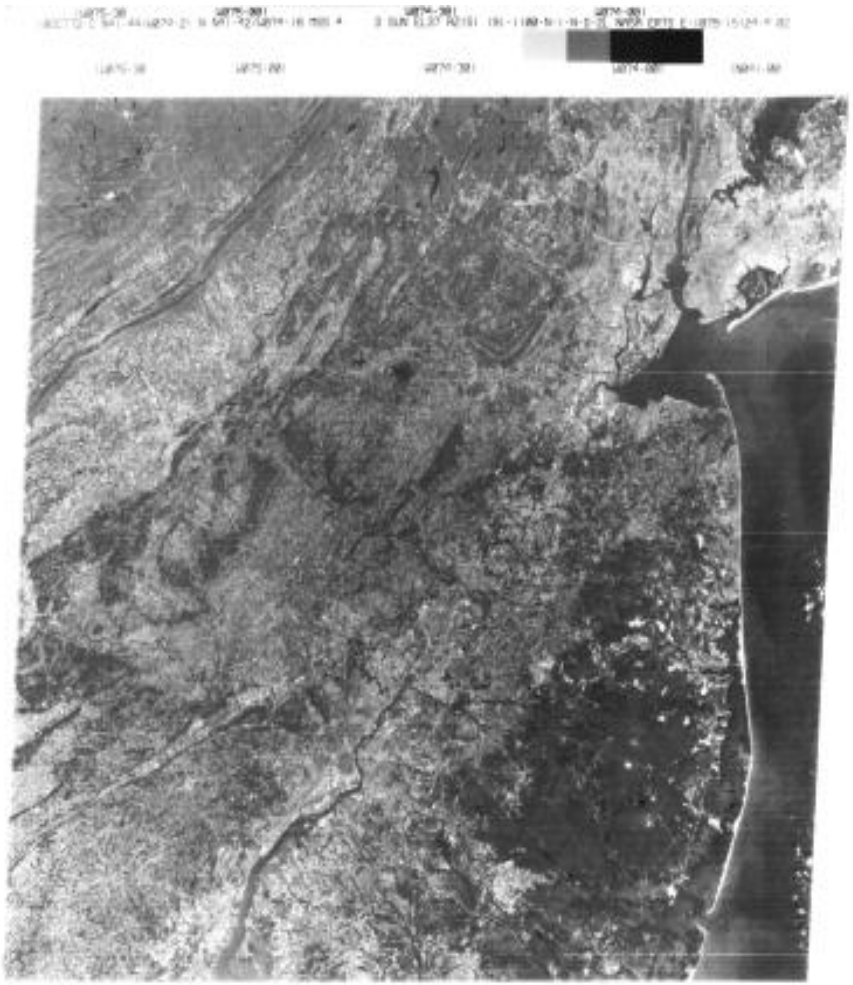
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/GLBDST_Images.html

# ERTS-1

- **Earth Resources Technology Satellite-1**
- **Renamed Landsat Multispectral scanner (MSS)**
- **First images in late 1972**
- **Was the first civil remote sensing satellite**



# Landsat MSS bands 4 and 5

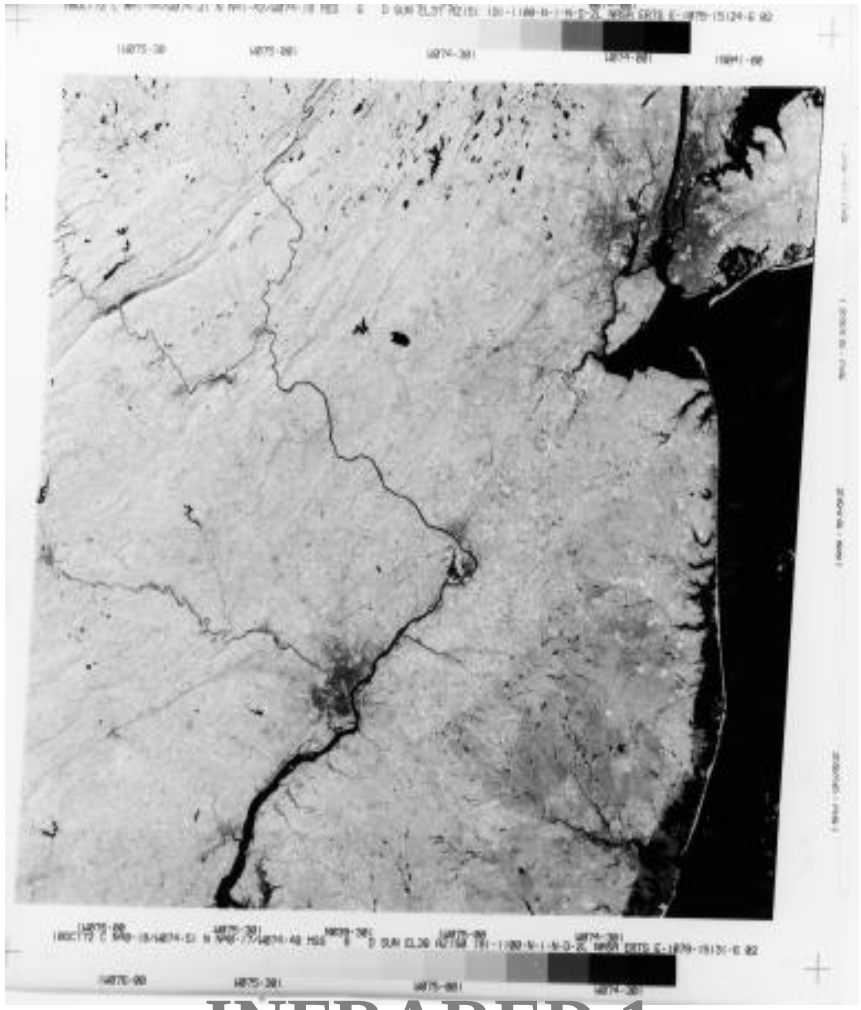


**GREEN**

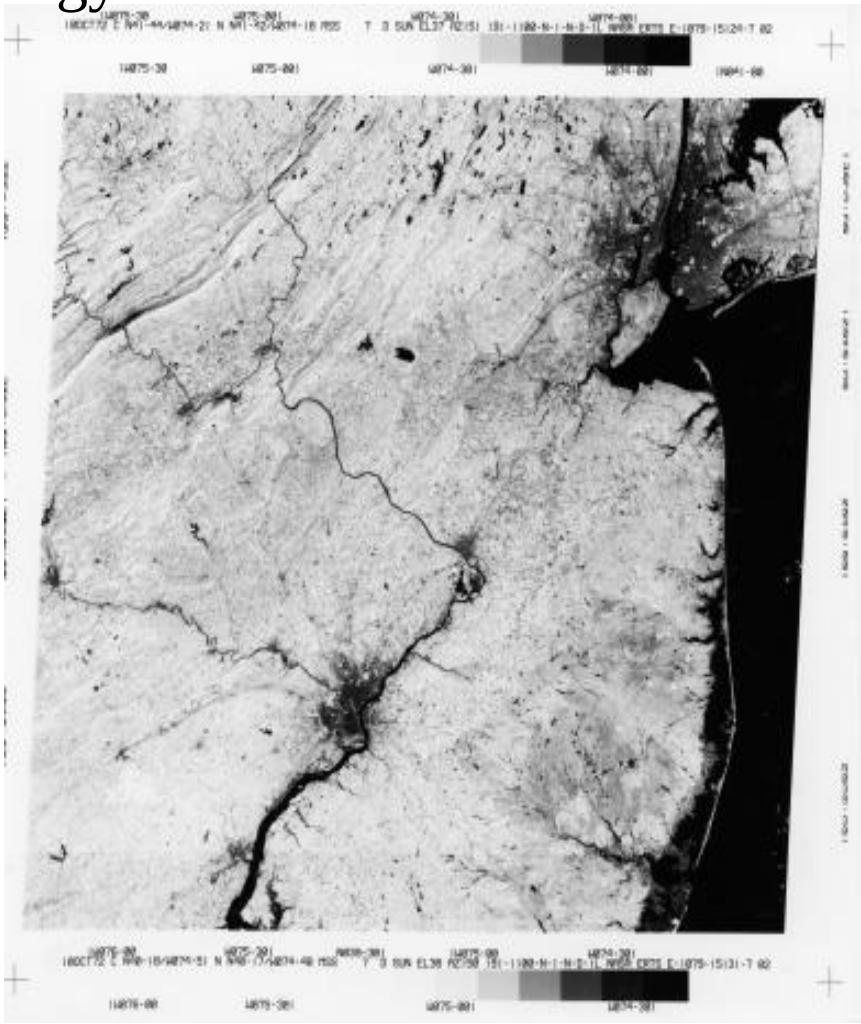
**RED**

# Landsat MSS bands 6 and 7

Note: water absorbs IR energy-no return=black



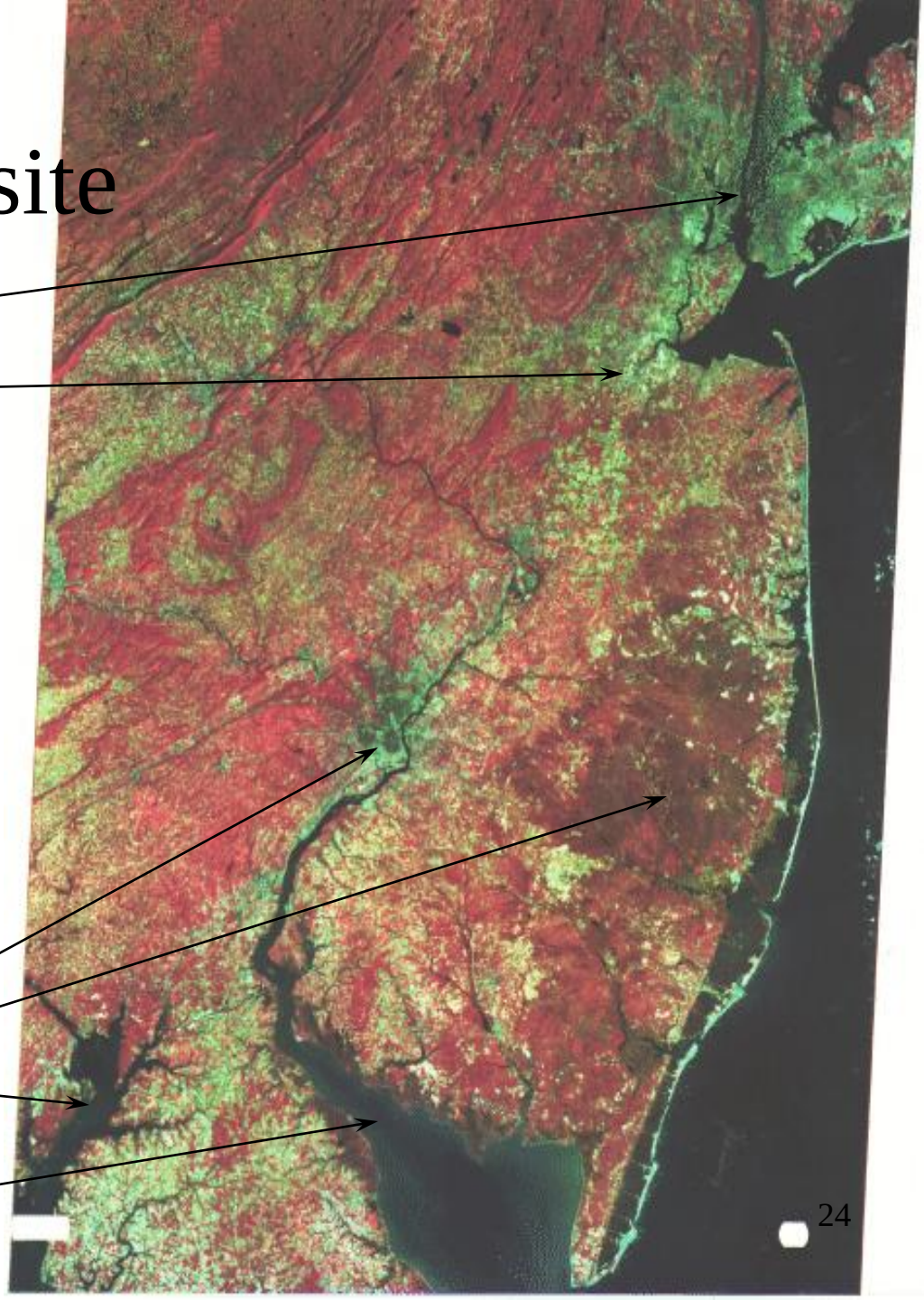
INFRARED 1



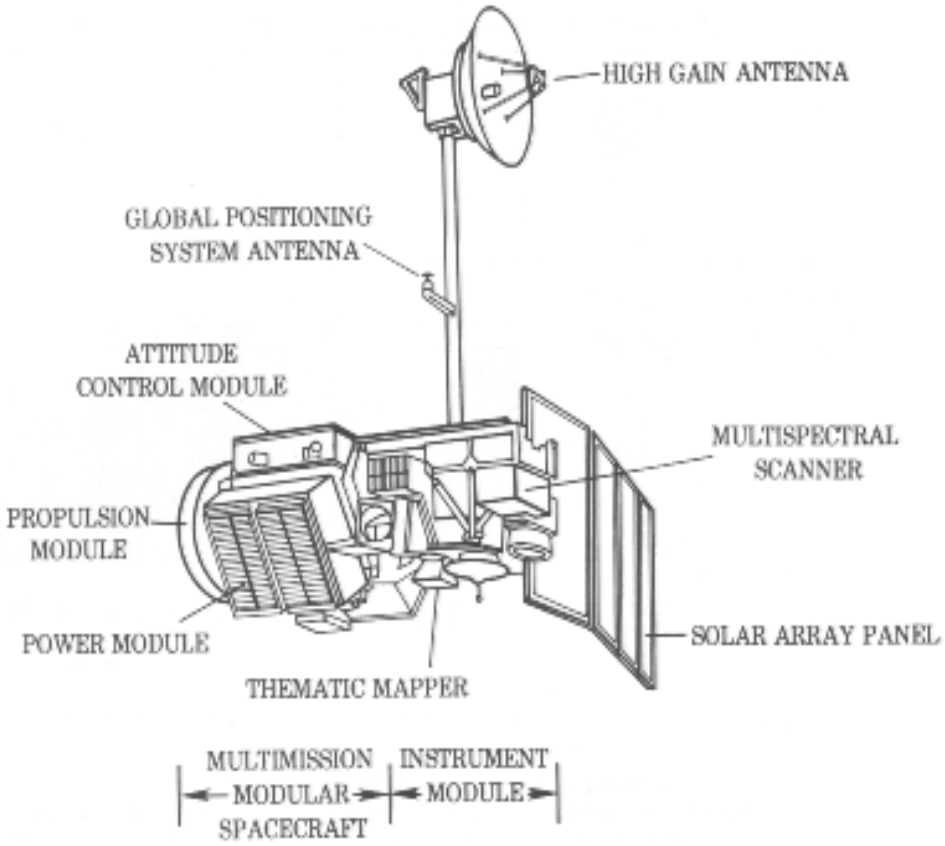
INFRARED 2

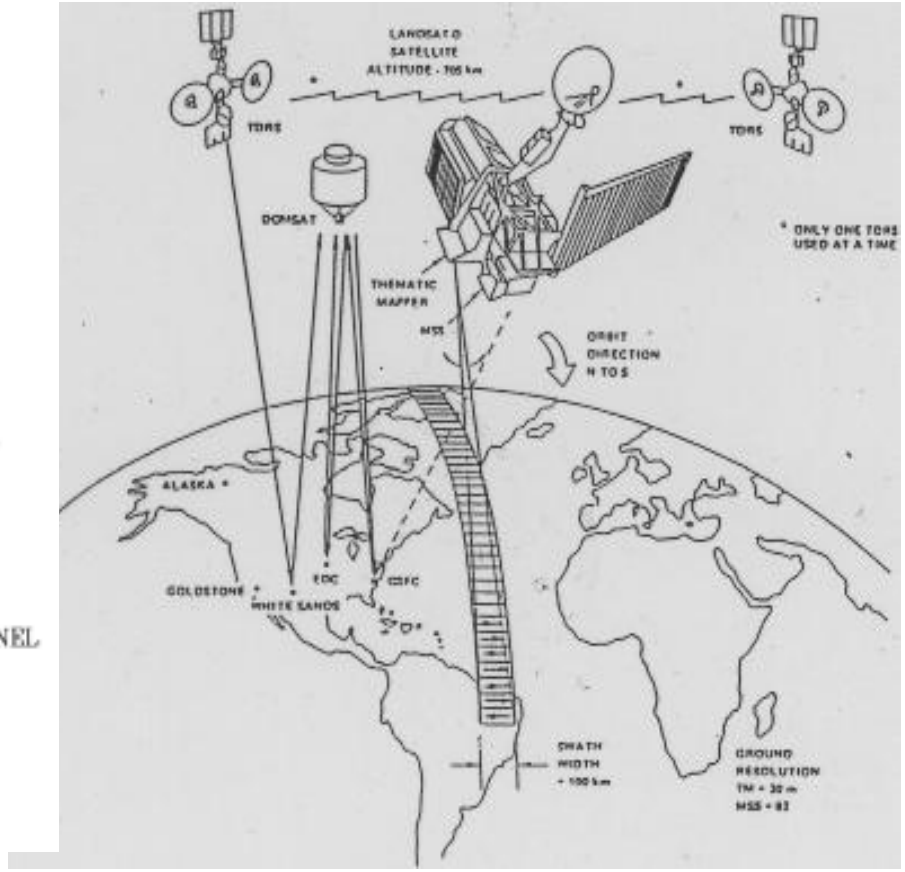
# MSS color composite

- combining bands creates a false color composite
- red=vegetation
- light blue=urban
- black=water
- pink=agriculture



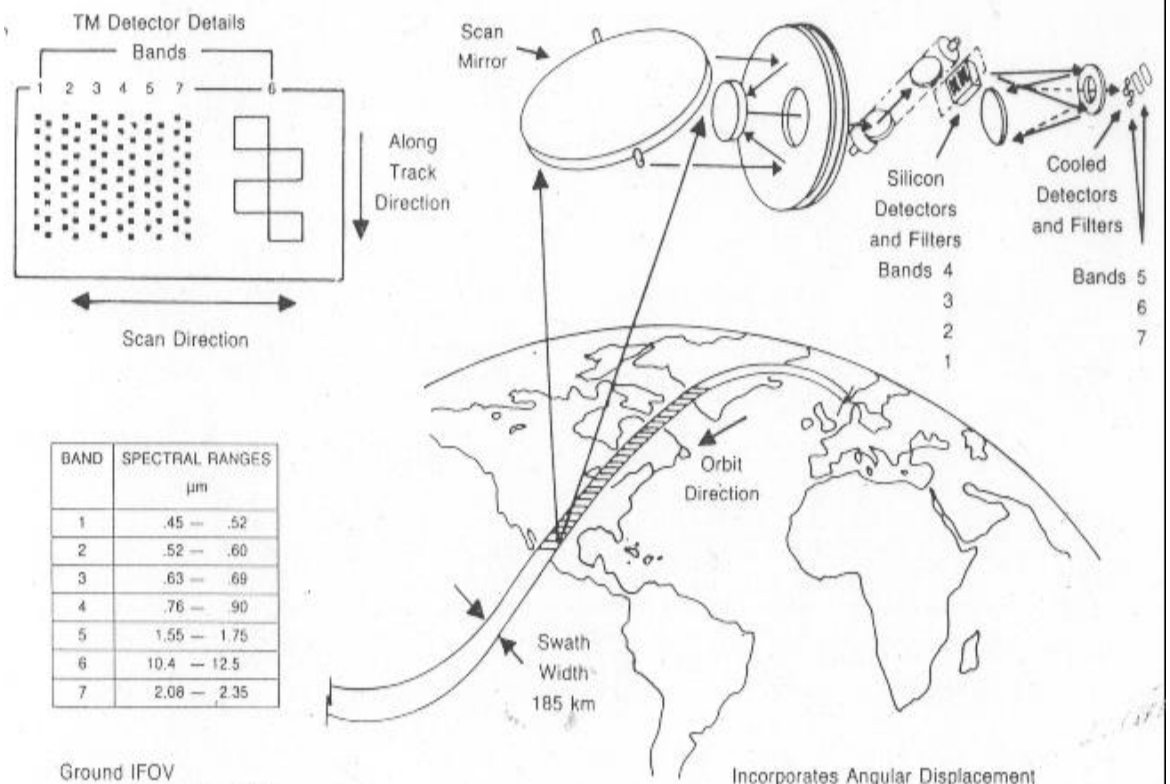
# Landsat 4-5 Thematic Mapper (TM)



# Cross-track scanning system

## Thematic Mapper (TM) Sensor




| BAND | SPECTRAL RANGES µm |
|---|---|
| 1 | .45 — .52 |
| 2 | .52 — .60 |
| 3 | .63 — .69 |
| 4 | .76 — .90 |
| 5 | 1.55 — 1.75 |
| 6 | 10.4 — 12.5 |
| 7 | 2.08 — 2.35 |

Ground IFOV
Bands 1-5 & 7 30 Meters
Band 6 120 Meters

Data Rate — 84.9 Mbps
Quantization Levels — 256

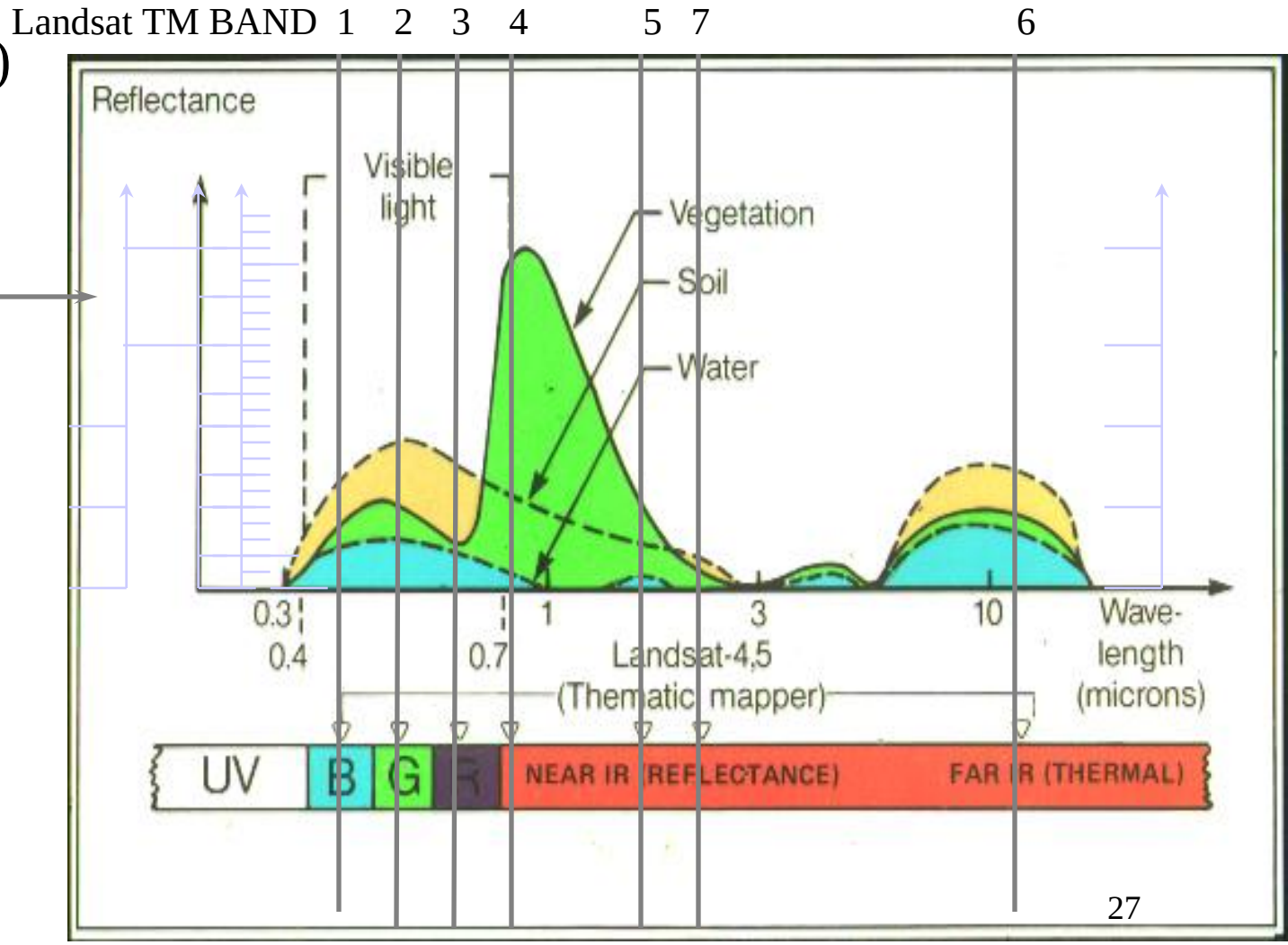
Incorporates Angular Displacement Sensor (ADS)
Measures Angle of Motion from 2 to 12.5 Hz
Source of Jitter Compensation Data

215

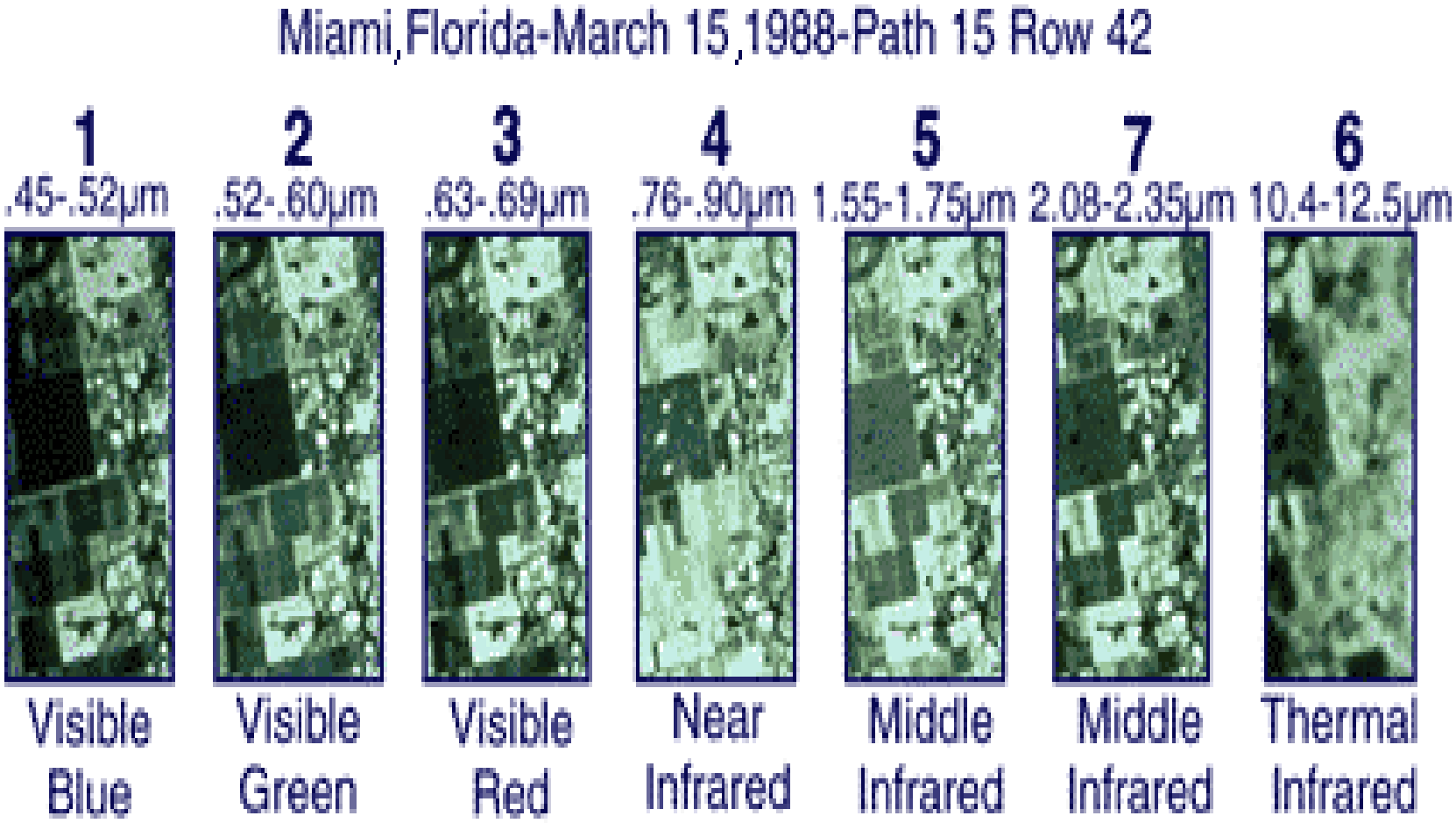
# Landsat TM-7 bands-8 bit data

Spectral
(where we look)

Radiometric
(how finely can we measure the return)
0-63, 0-255, 0-1023



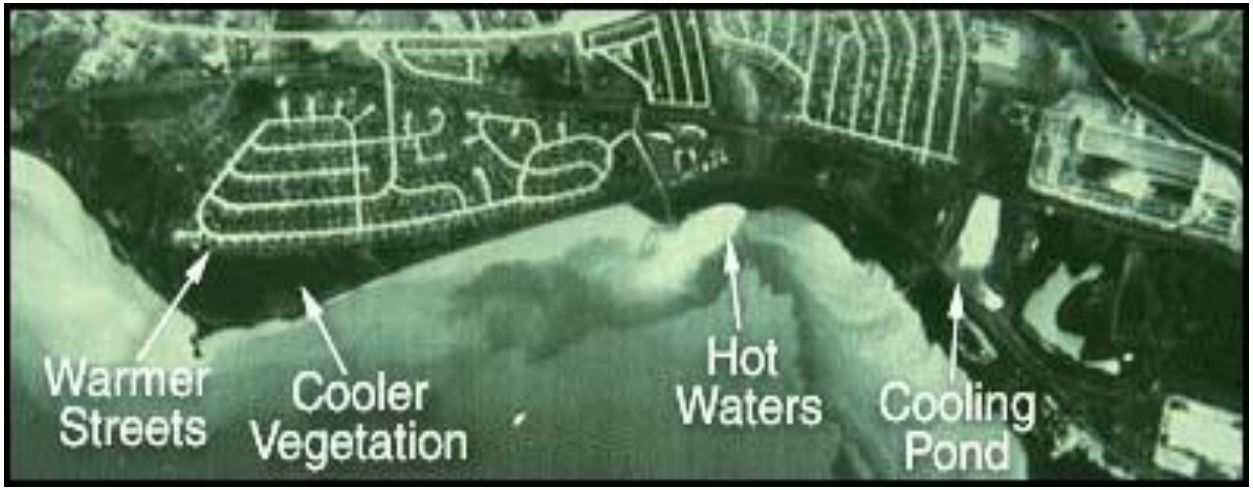
# Spectral wavebands of Landsat TM



# Landsat TM: each waveband provides different information about earth surface features

| 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 |

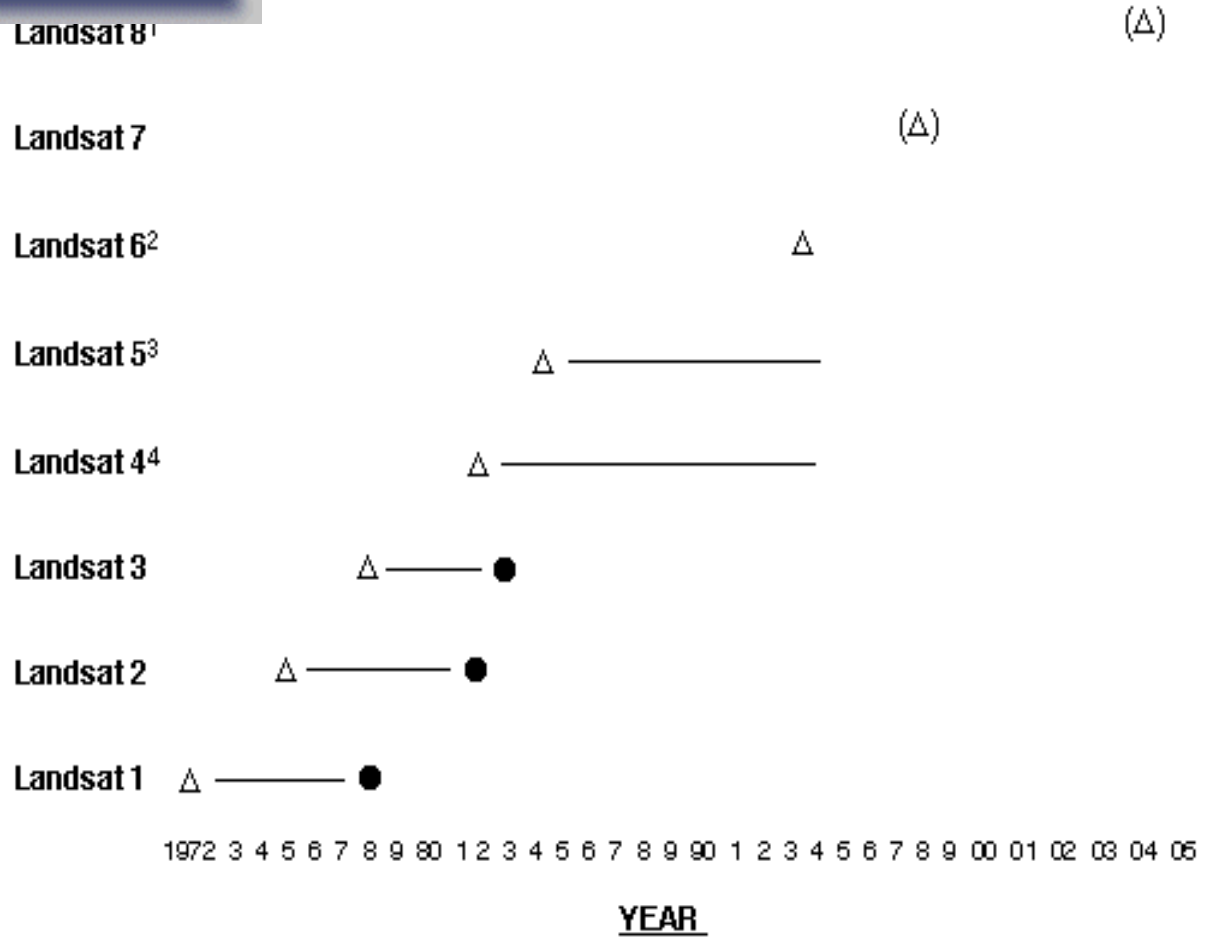
# Thermal imagery-temperature




**Water analysis-nuclear power cooling ponds)**

Landsat Program

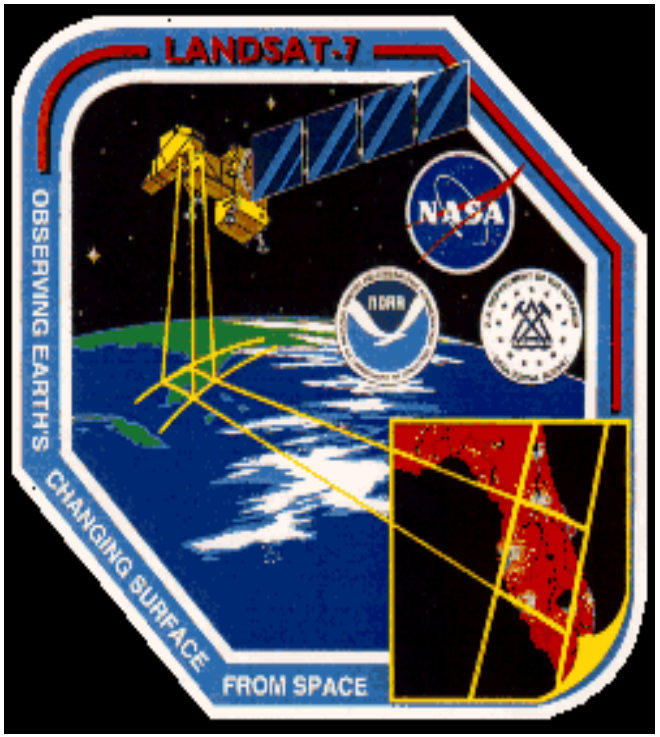
## LANDSAT COVERAGE HISTORY




[1] ETM+ follow-on instrument on EOS AM-2
[2] Launched Oct. 5, 1993. Failed to obtain orbit.
[3] Data transmission by direct downlink only
[4] No longer transmitting TM data

△ Launch ( ) Anticipated
● End of Service

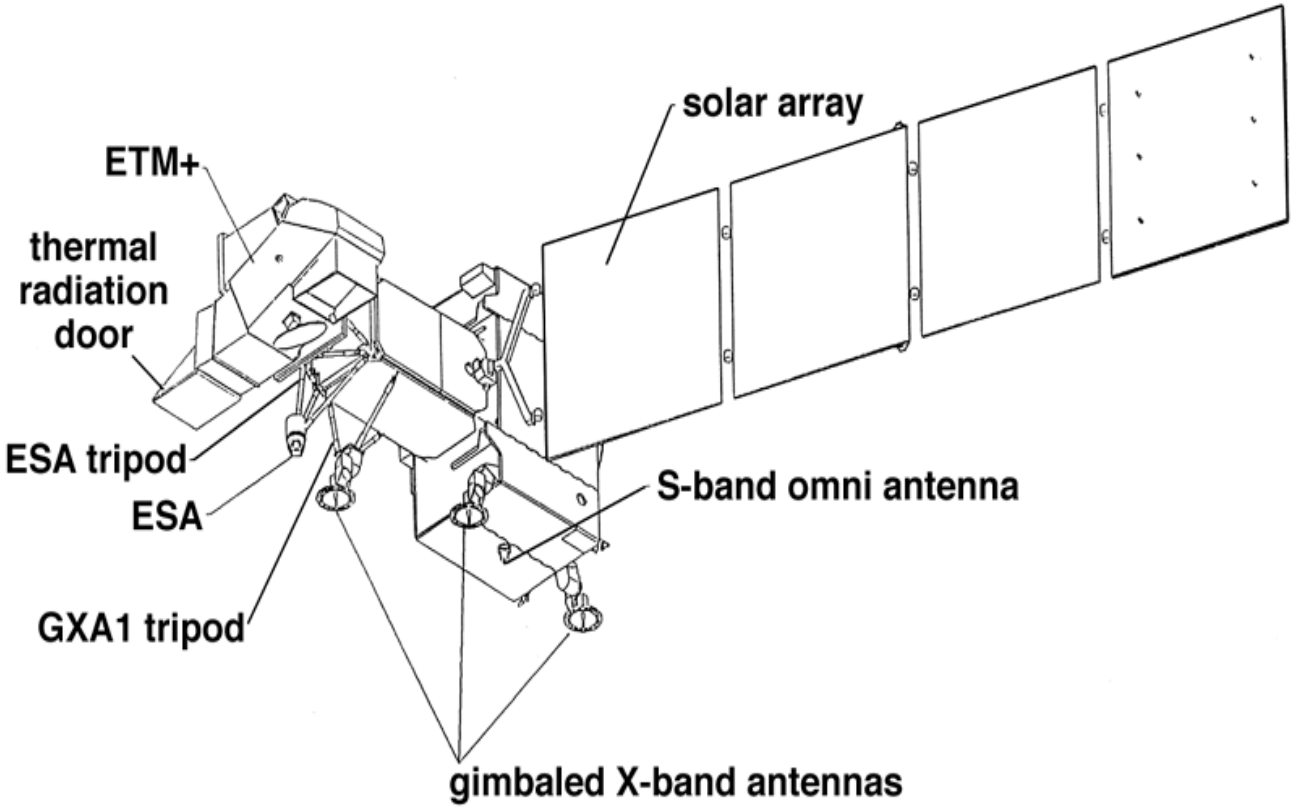
# *Landsat 7*

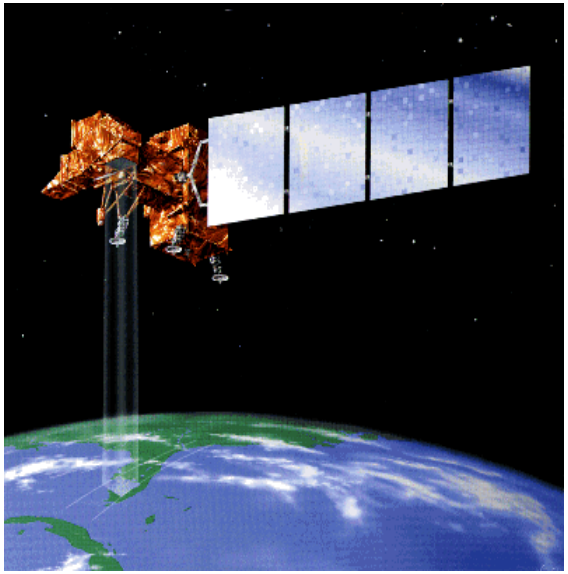



- 15 m ETM+ (enhanced TM) sensor
- April 1999 launch
- Oct.'92 Land remote sensing policy act
- a panchromatic band with 15m spatial resolution-fully coregistered w/30m
- on-board, full aperture, 5% absolute radiometric calibration
- a thermal IR channel with 60m spatial resolution

•for more info go to: http://landsat.gsfc.nasa.gov/


Landsat Program


solar array
ETM+
thermal radiation door
ESA tripod
ESA
GXA1 tripod
S-band omni antenna
gimbaled X-band antennas



# Landsat Program

- **ETM+ sensitivity:**

| Band Number | Spectral Range(μm) | Ground Resolution(m) |
|---|---|---|
| 1 | .45 to .515 | 30 |
| 2 | .525 to .605 | 30 |
| 3 | .63 to .690 | 30 |
| 4 | .75 to .90 | 30 |
| 5 | 1.55 to 1.75 | 30 |
| 6 | 10.40 to 12.5 | 60 |
| 7 | 2.09 to 2.35 | 30 |
| Pan | .52 to .90 | 15 |

- **Swath width:** 185 km
- **Repeat coverage interval:** 16 days (233 orbits)
- **Altitude:** 705 km
- **Quantization:** best 8 of 9 bits
- **On-board data storage:** ~ 375 Gb (solid state)
- **Inclination:** Sun-synchronous, 98.2°
- **Equatorial crossing:** Descending node, 10:00am +/- 15 min.
- **Launch vehicle:** Delta II
- **Launch date:** December 1998

SPOT IMAGE

- **French commercial remote sensing system**
- **First launch in 1986**
- **10 and 20 m spatial resolution**
- **60 km swath width**
- **Stereo viewing ability**
- **Will have 2.5 m in 1999**

Panchromatic (PAN) sensor: 10 m GRC

Pan 0.51-.73 um

High Resolution Visible (HRV) sensor: 20m GRC

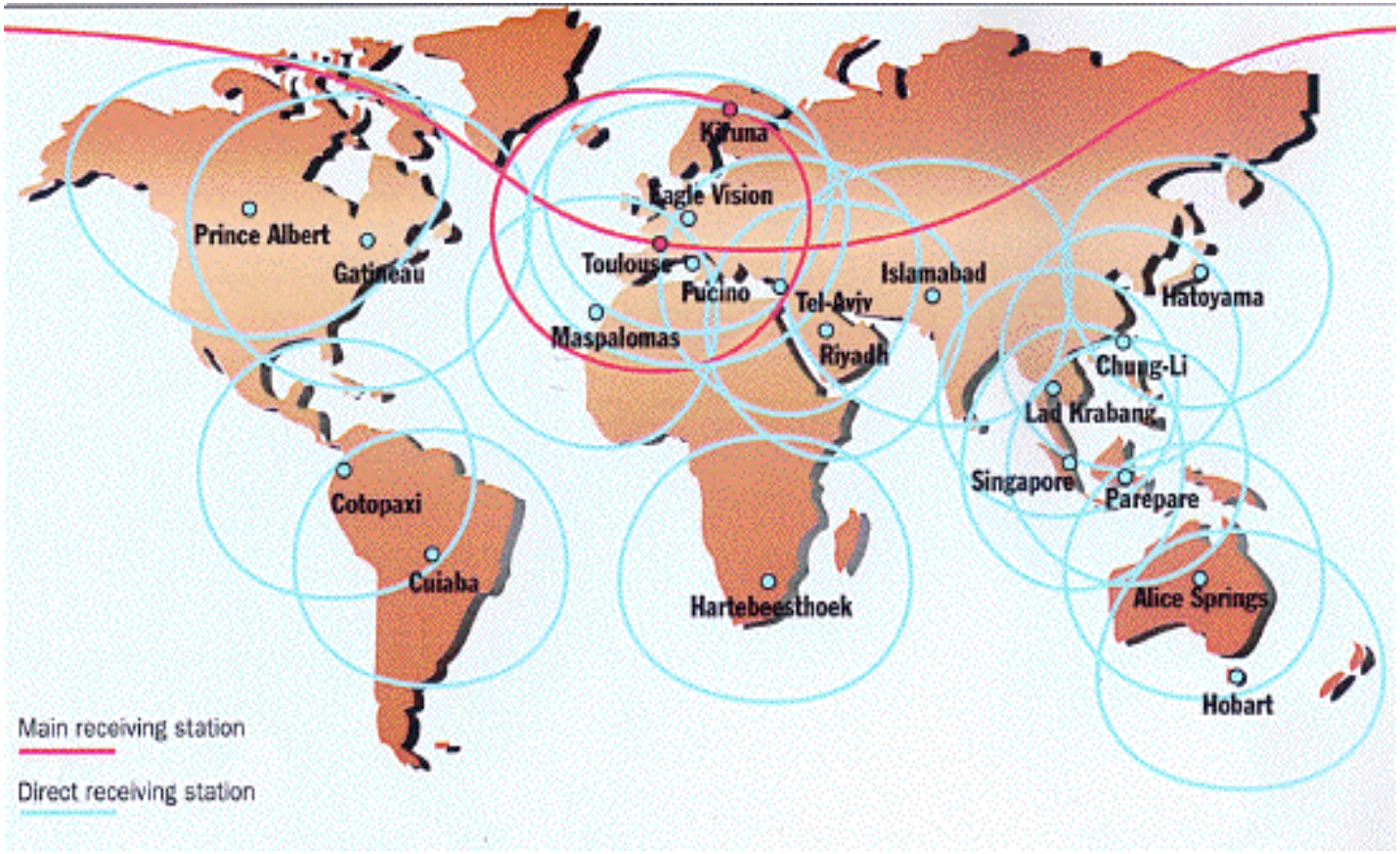
G (.5-.59), R (.61-.68), NIR (.79-.89)

Ground Swath Width of 60 km

For more info go to: http://www.spotimage.fr/home/home.htm

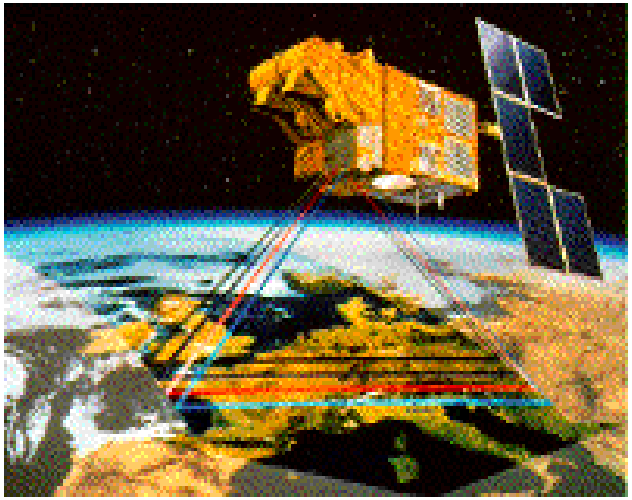
# SPOT before launch

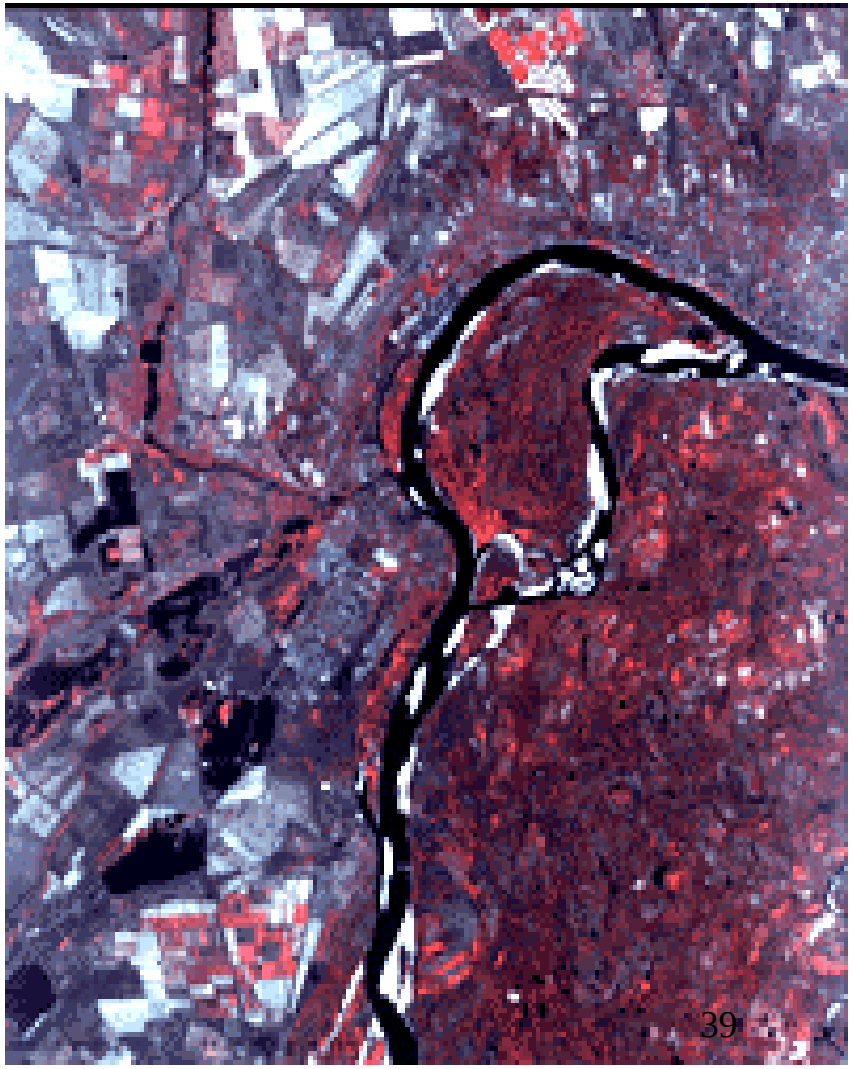
# SPOT ground stations



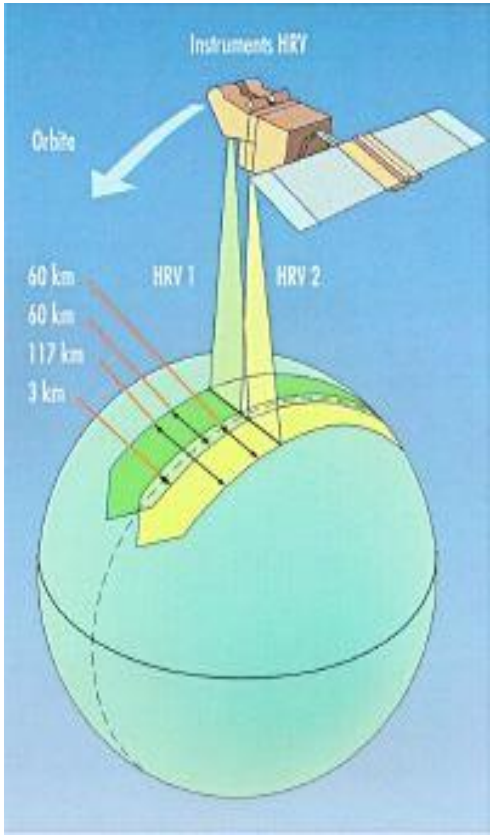

# SPOT 4

1st images taken March 31, 1998



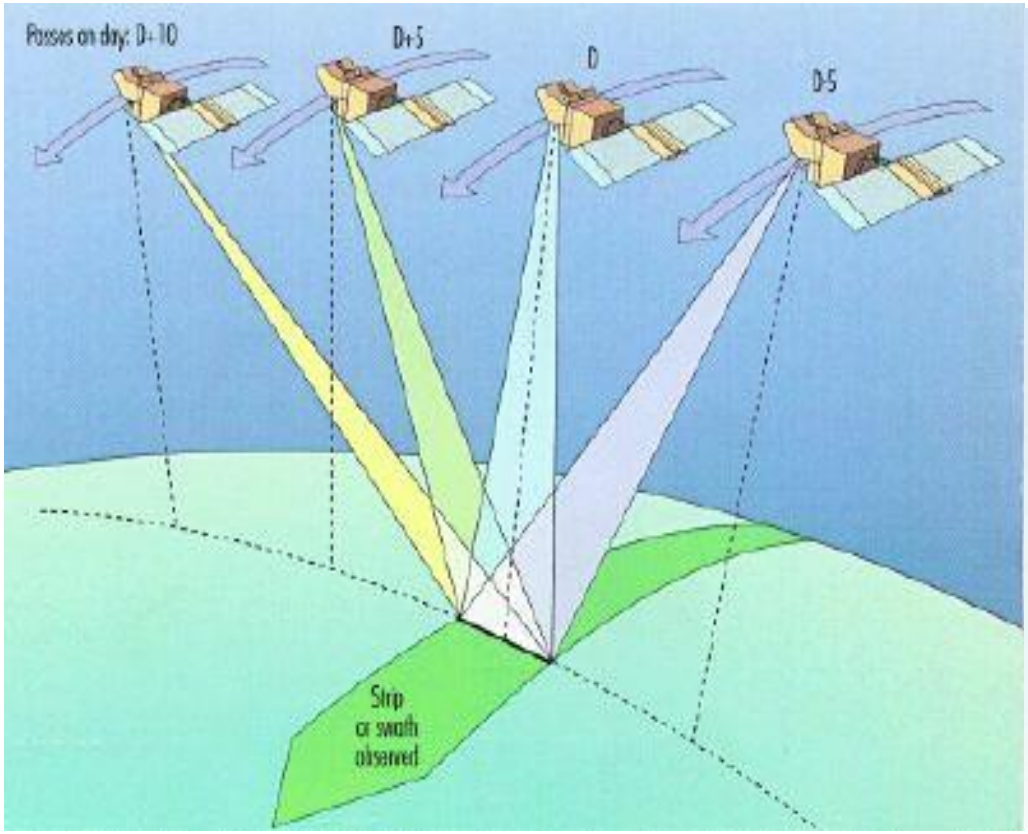


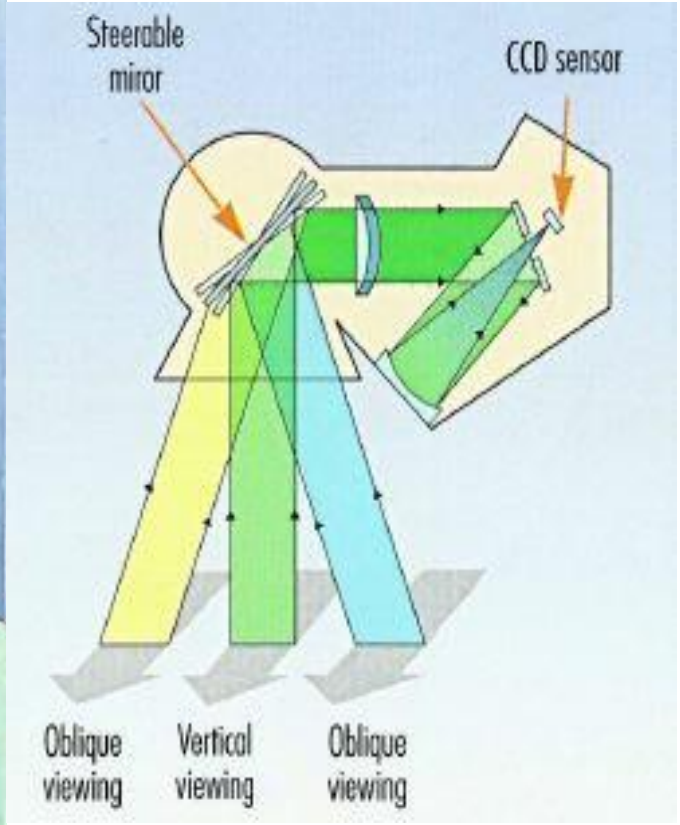
# Polar Sun synchronous orbit



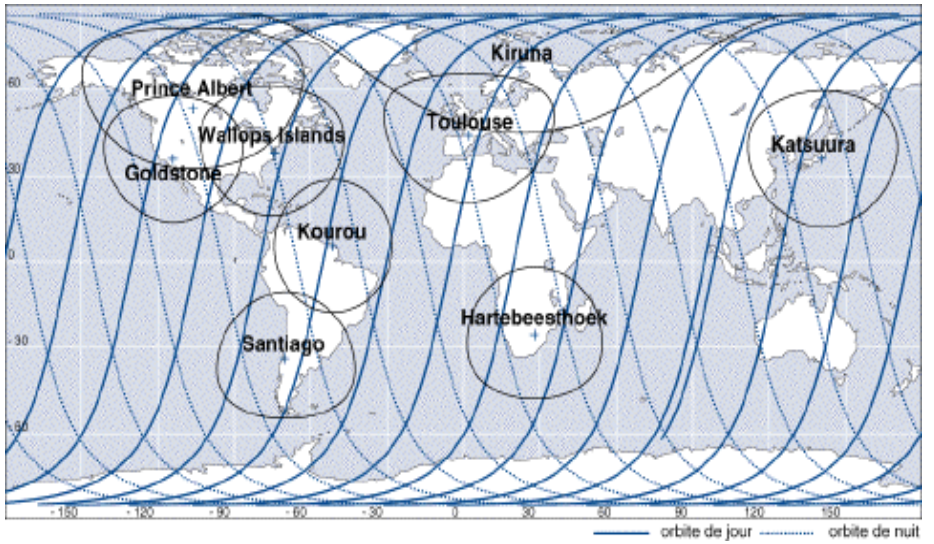

2 side-by-side HRV sensors

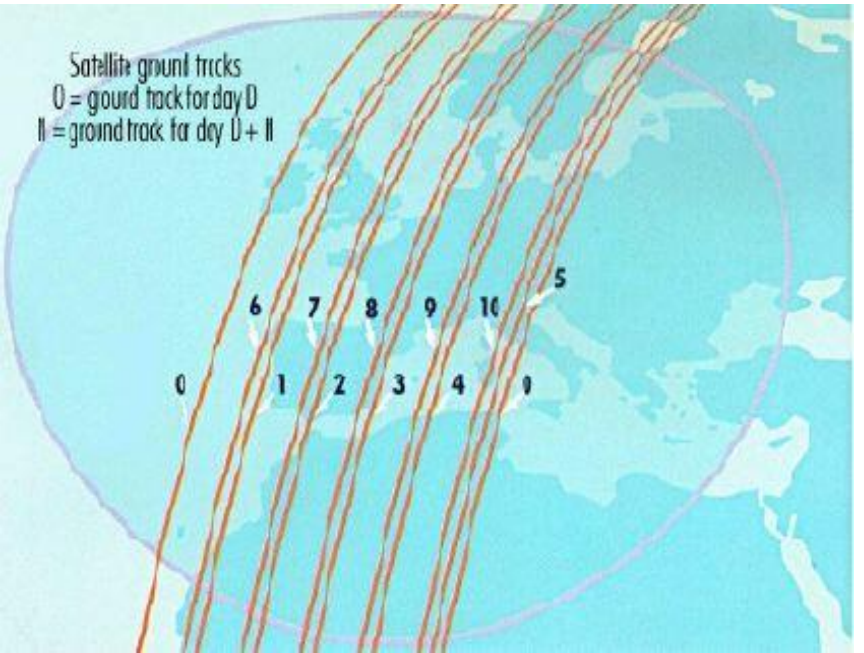
# SPOT has steerable mirror

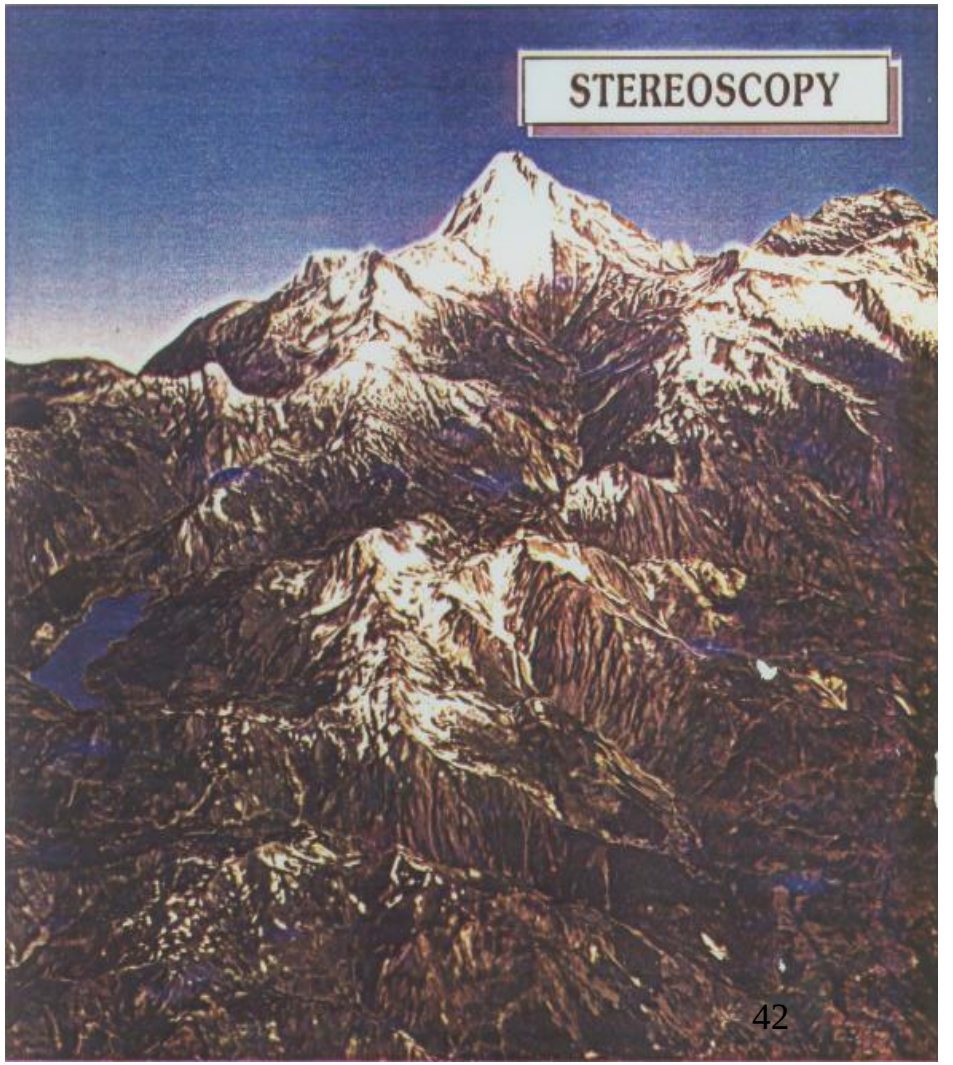


# Stereo imaging



# Indian Remote Sensing (IRS) satellite

- IRS-1C  launched in December 1995
- IRS1D launched in September 1997
- Panchromatic:  0.5-0.75 um
- 5.8 m GRC, 30 km ground swath
- 22 day repeat cycle with off-nadir pointability

# Space Imaging IKONOS

- Panchromatic (045-0.9 um): 1 m
- Multispectral: 4 m
  Blue (445-516nm), Green(506-595nm)
  Red (632-698nm) NIR (757-853nm)
- 11 km swath width
- Pointable to 45$^{o}$ for daily viewing
- For more info go to:
  http://www.spaceimage.com/index.htm

# IKONOS SAMPLE IMAGERY

Multi-spectral

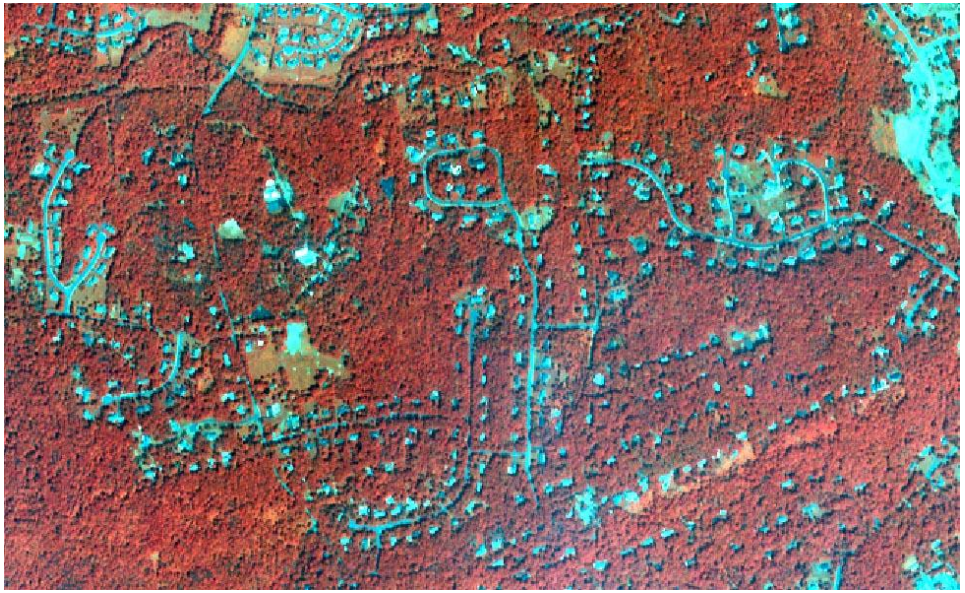
4m GRC

Pan-chromatic

1m GRC

# Space Imaging IKONOS Imagery
# Sample: Bound Brook NJ

1 m panchromatic



4 m multi-spectral

ORBIMAGE *See the Possibilities*

OrbView-3

- Panchromatic: 1 m
- Multispectral (color): 4 m
- Pointable: anywhere on globe within 3 days
- Additional hyperspectral sensor
- For more info go to:

http://www.orbimage.com/index.html


ORBVIEW-4 LAUNCH
OrbView-4 will be among the world's first commercial satellites to provide high-resolution imagery from space and the world's first commercial satellite to provide hyperspectral imagery.
Location
Vandenberg Air Force Base, CA
Date
The launch is currently scheduled for early September, 2001.
Webcast
The Launch of OrbView-4 will be shown LIVE via webcast.
Check back soon for details.
ORBIMAGE
GLOBAL IMAGING INFORMATION

# Quickbird

- DigitalGlobe™ successfully launched its **QuickBird** satellite on the Boeing Delta II launch vehicle on October 18, 2001.
- Panchromatic: 0.61-1m
- Multispectral (color): 2.5-4 m
- Can increase the resolution system by adjusting the orbit in which the satellite is flown. As a result, panchromatic resolution increases from 1 meter to 61 centimeters and multi-spectral increases from 4- to 2.5-meter resolution.
- The satellite will operate in a 450-km 98-degree sun-synchronous orbit, with each orbit taking 93.4 minutes

http://www.digitalglobe.com/index.shtml

# *Different sensors and resolutions*

| sensor | spatial | spectral | radiometric | temporal |
|---|---|---|---|---|
| AVHRR | 1.1 and 4 KM<br>2400 Km | 4 or 5 bands<br>.58-.68, .725-1.1, 3.55-3.93<br>10.3-11.3, 11.5-12.5 (micrometers) | 10 bit<br>(0-1023) | 12 hours<br>(1 day, 1 night) |
| Landsat MSS | 80 meters<br>185 Km | 4 bands<br>.5-.6, .6-.7, .7-.8, .8-1.1 | 6 bit<br>(0-63) | 16 days |
| Landsat TM | 30 meters<br>185 Km | 7 bands<br>.45-.52, .52-.6, .63-.69,<br>.76-.9, 1.55-1.75,<br>10.4-12.5, 2.08-2.3 um | 8 bit<br>(0-255) | 14 days |
| SPOT P | 10 meters<br>60 Km | 1 band<br>.51-.73 um | 8 bit<br>(0-255) | 26 days<br>(2 out of 5) |
| SPOT X | 20 meters<br>60 Km | 3 bands<br>.5-.59, .61-.68, .79-.89 um | 8 bit<br>(0-255) | 26 days<br>(2 out of 5) |
| IKONOS | 1 and 4 meters<br>11 km | 1 and 4 bands<br>.45-.9, .44-.51, .52-.60,<br>.63-.70, .76-.85 | 10 bit<br>(0-1023) | 1-2 days |