

PLATFORMS & SENSORS

Platform:

the vehicle carrying the remote sensing device - e.g. ground, airborne, spaceborne

Sensor:

the remote sensing device recording wavelengths of energy e.g. camera, scanner

Image data might be referred to using platform or sensor

Another copy of my (old) lecture notes:

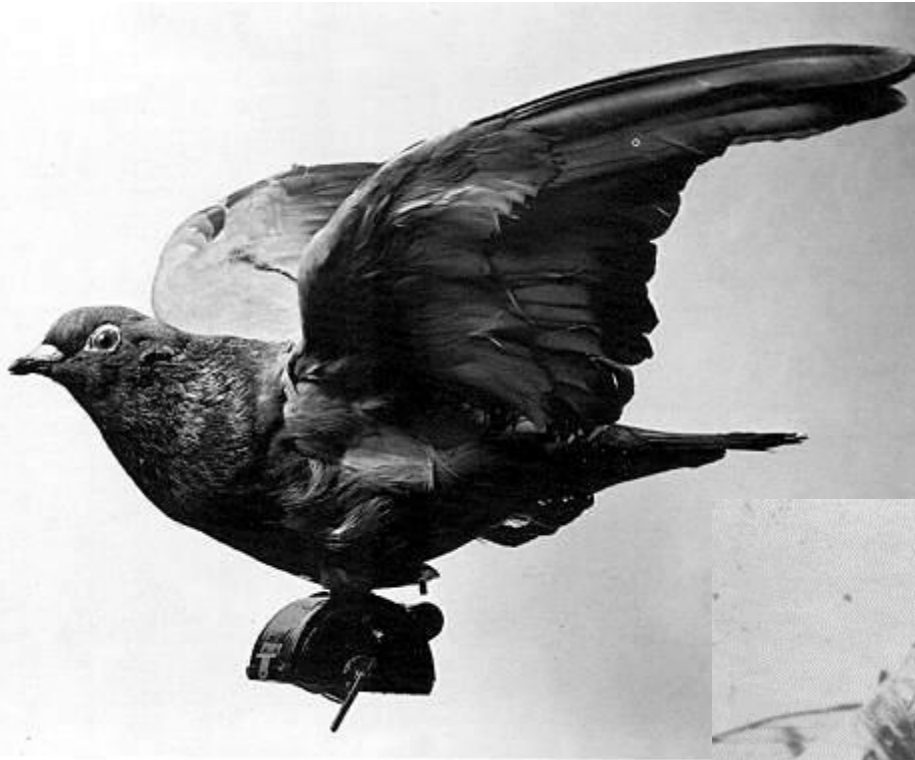
<http://web.pdx.edu/~nauna/resources/15-sensors.pdf>



Platform = International Space Station

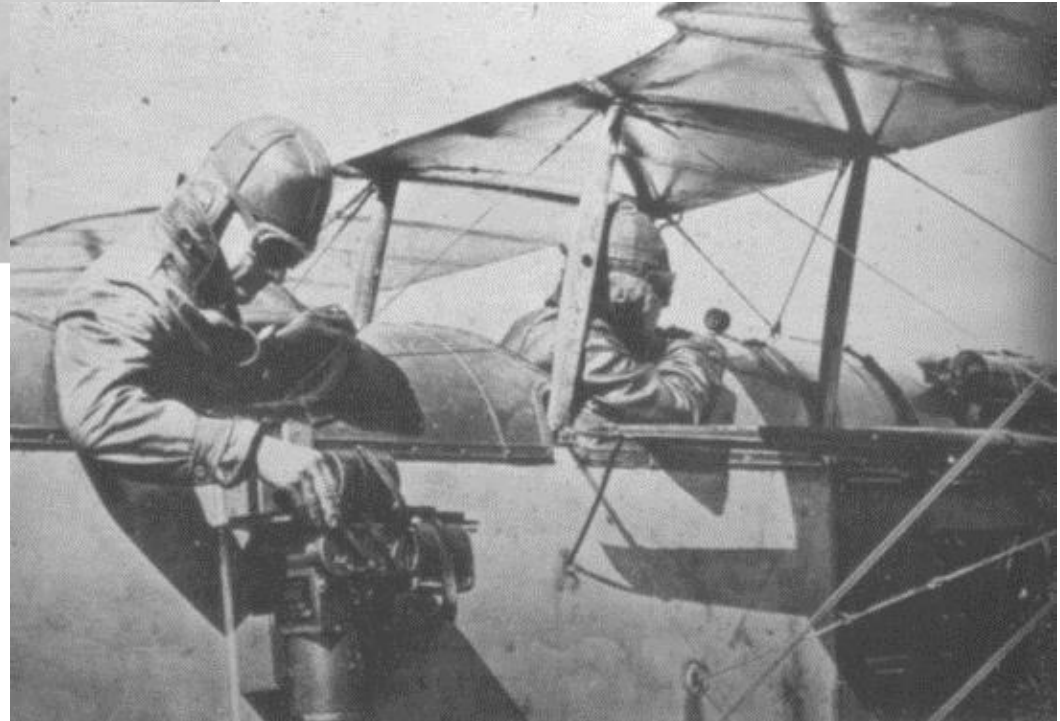
Sensor = Chris Hadfield's Nikon

EARLY PLATFORMS & SENSORS



Birds, Kites,
Balloons, Planes,
with cameras

Superceded today by
Unmanned Aerial
Vehicles (UAV)

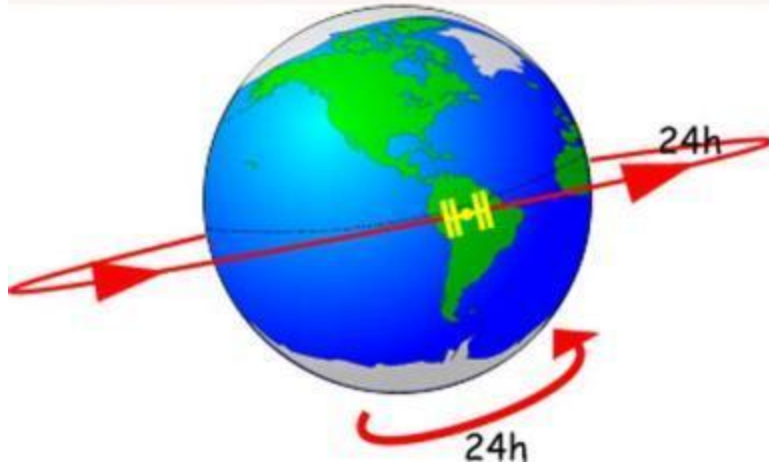


Corona 1959-1972 (CIA) Cold War Reconnaissance / Spy

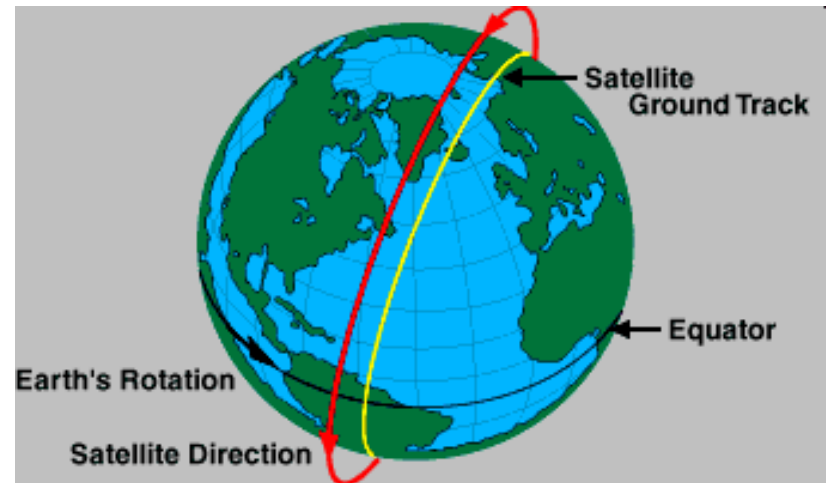


1. Satellite orbits

<http://resources.yesican-science.ca/orbits1/goes.html>



"Geostationary"
e.g. Weather satellites
TV, Internet, GPS-WAAS
~ 36,000 km altitude

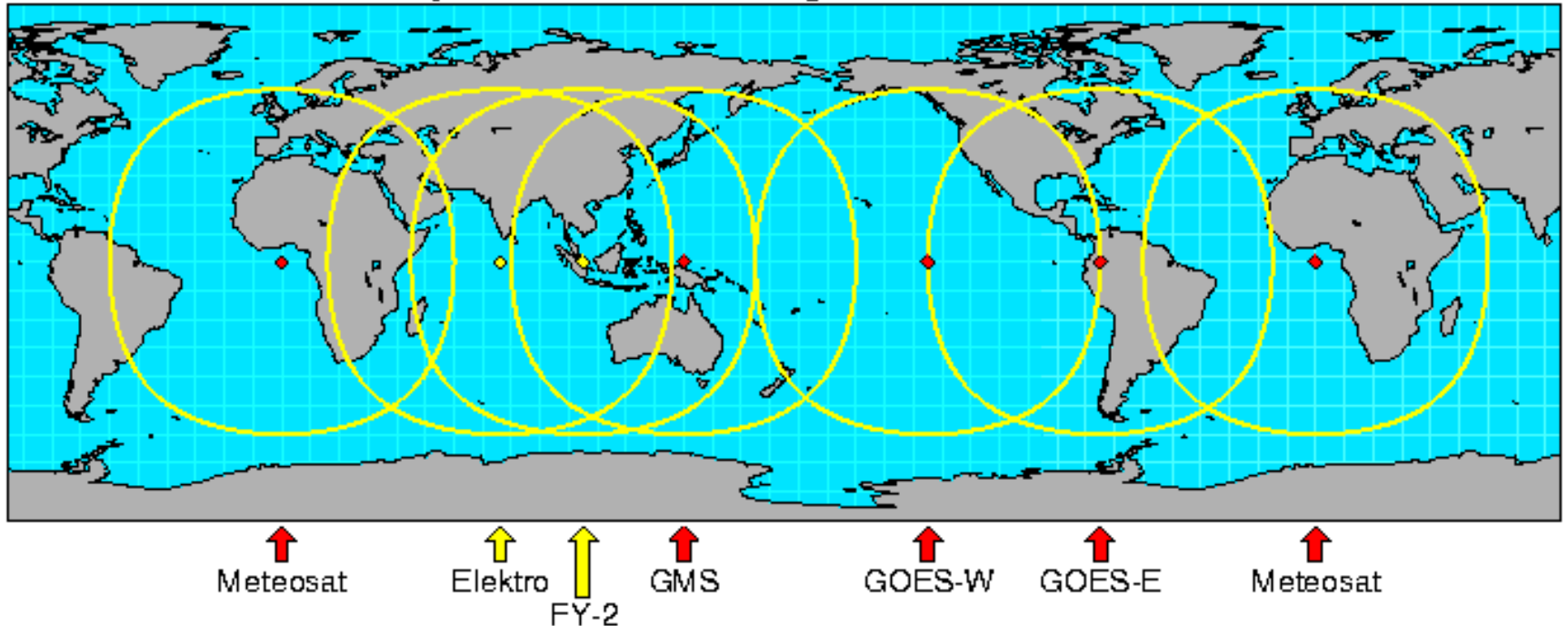


"Sun-synchronous"
EO Surface monitoring
mapping / updating
~ 400-900 km altitude

Satellite orbits

Geostationary / geosynchronous : 36,000 km above the equator, stays vertically above the same spot, rotates with earth - weather images, communications, e.g. GOES (Geostat. Operational Env. Satellite)

Global Geostationary Satellite Coverage

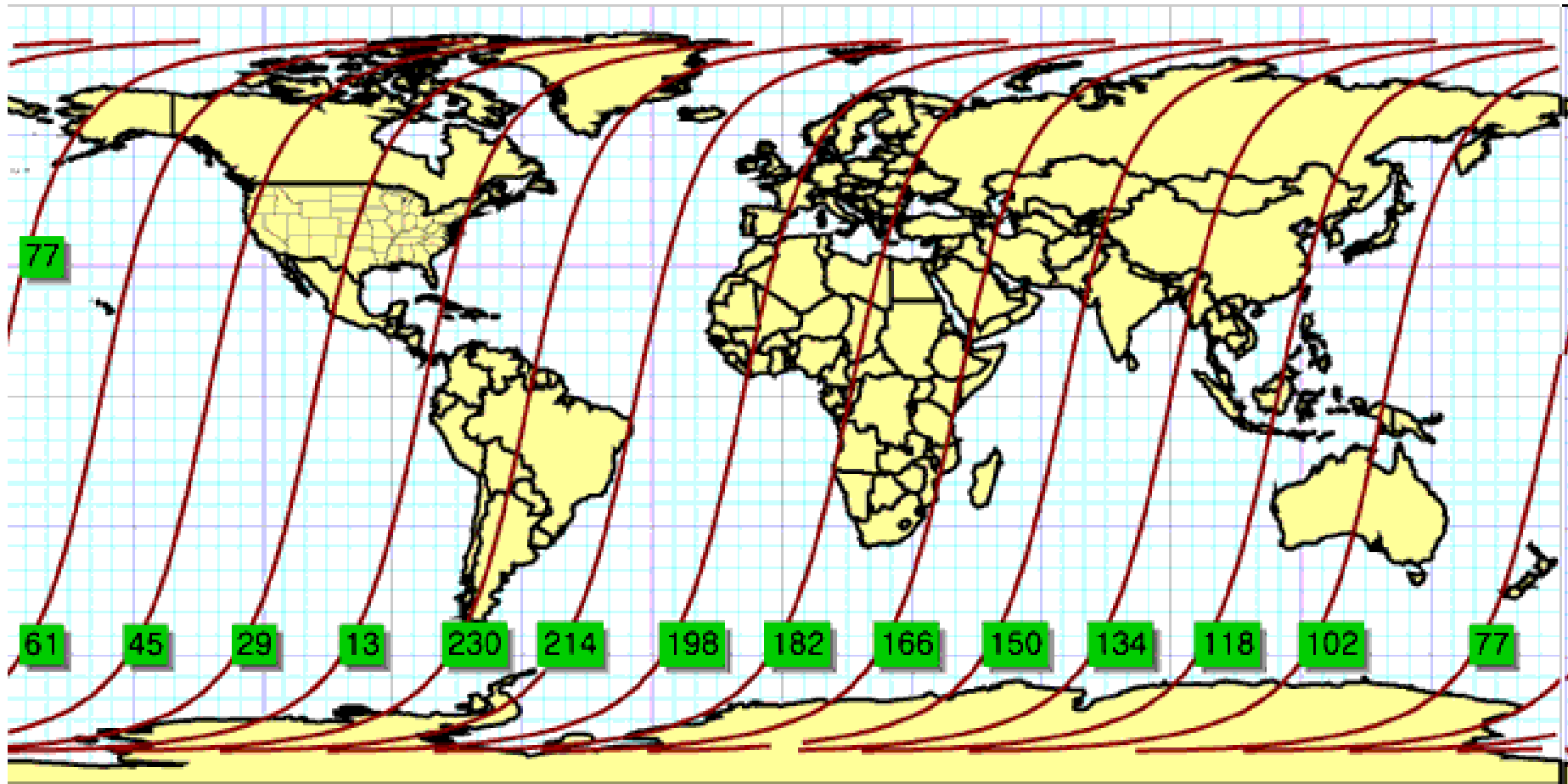


Geostationary satellites capture a (~rectangular) scene,

Sun-synchronous satellites: 400-900km altitude, rotate at ~81-82 degree angle to equator: imagery ~ the same local time each day (~10.30am)

Time of day = compromise between minimum shadow and clouds (9.30-11.00am)

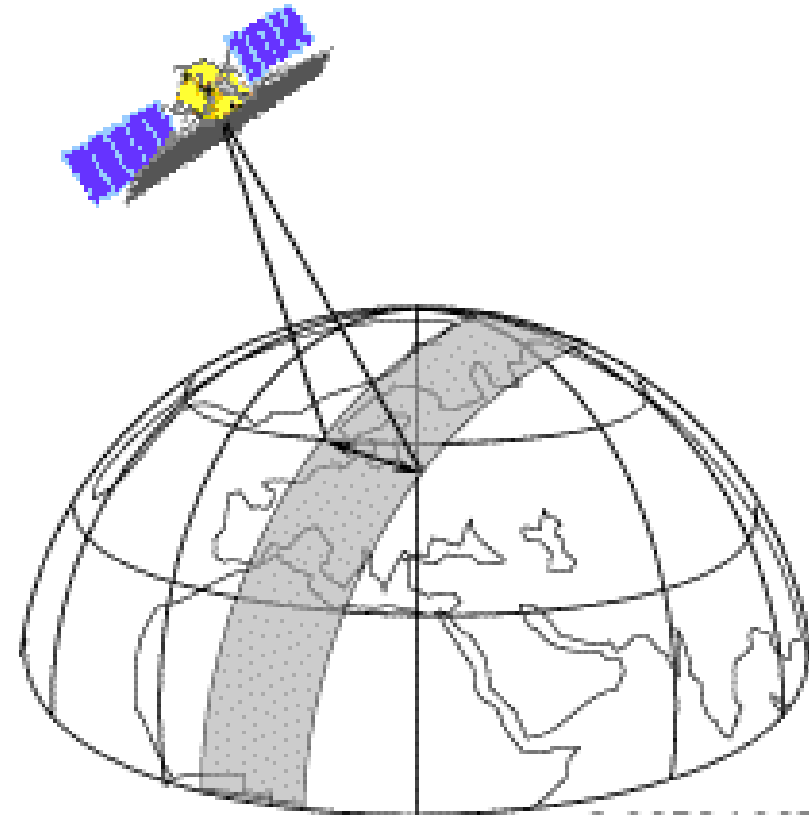
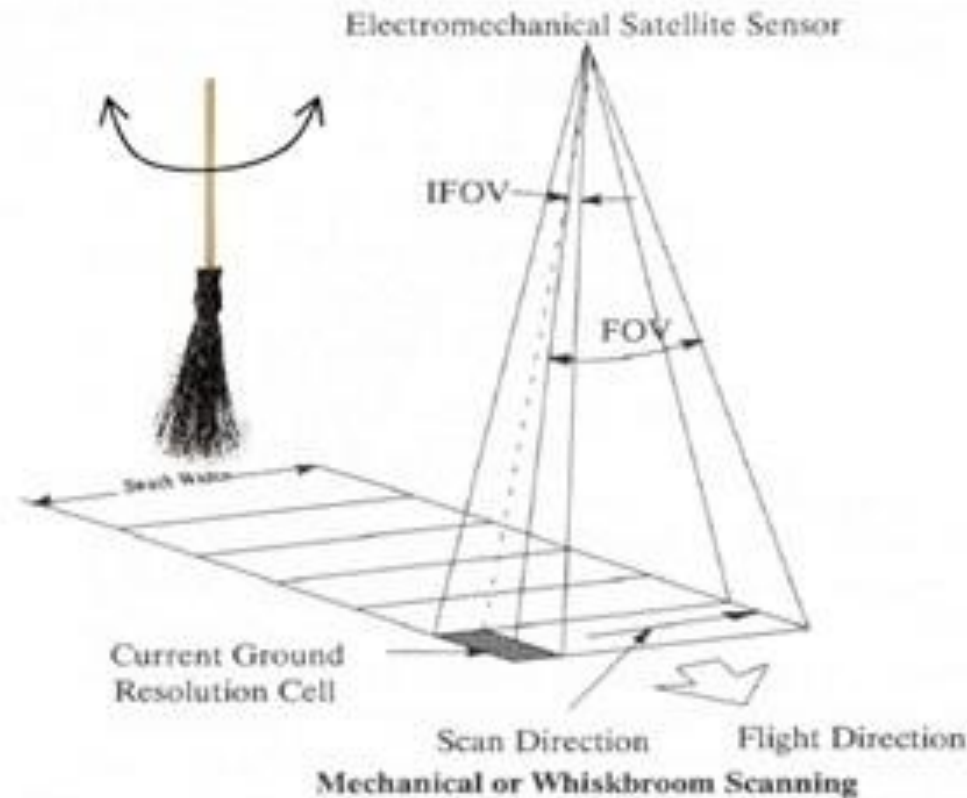
ISS orbit is at 408 km altitude



Landsat path: [earthnow](http://earthnow.nasa.gov)

2. Scanner types

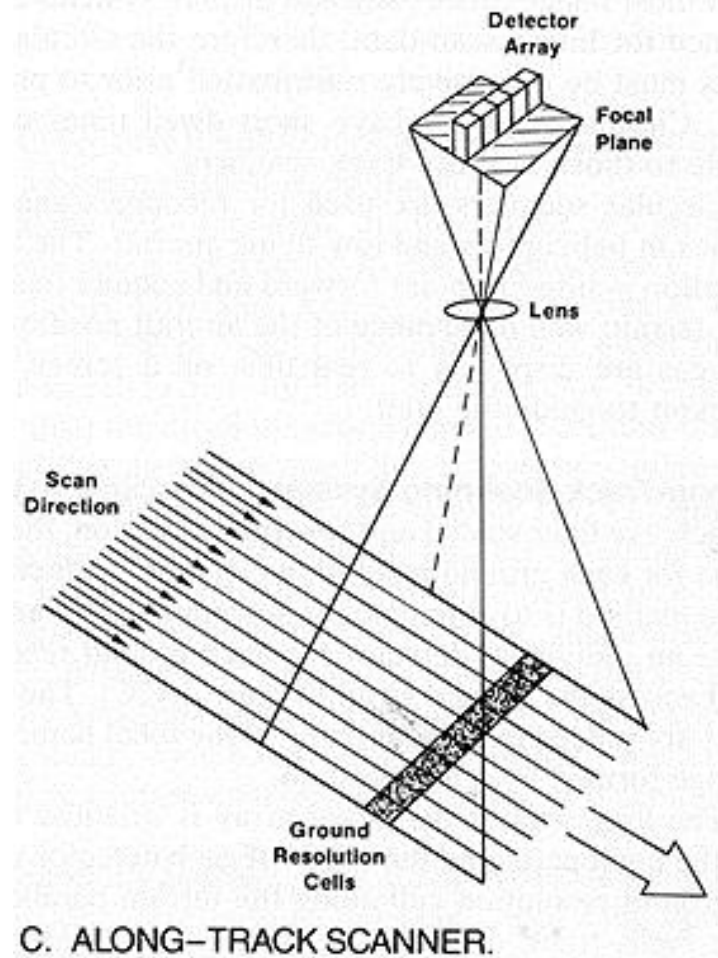
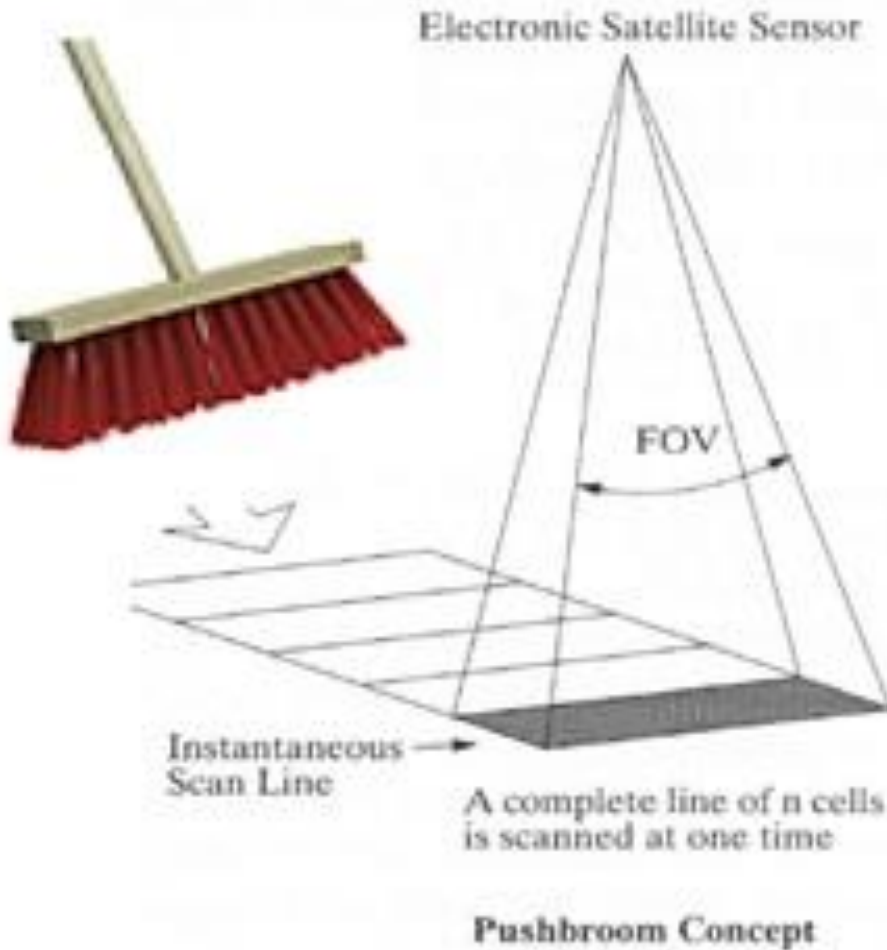
a. **Whiskbroom** (mirror/ cross-track): a small number of sensitive diodes for each band sweep perpendicular to the path or swath, centred directly under the platform, i.e. at 'nadir' e.g. LANDSAT MSS /TM/ETM



b. Pushbroom (along-track):

an array of diodes (one for each column of pixels) can be 'pointed' in a selected direction, **nadir** or **off-nadir**, on request, usually 0-30 degrees (max.), e.g. SPOT HRV, Landsat 8 OLI* - almost all now ..

* Landsat 8 is not redirectionned; swath = 185km = ~ 6000 pixels



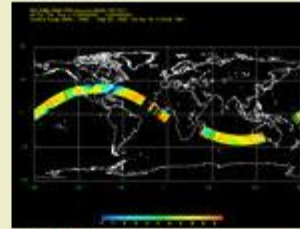
Selected satellite remote sensing systems



ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)



AVHRR (Advanced Very High Resolution Radiometer)



CERES (Clouds and the Earth's Radiant Energy System)



DMSP/OLS (Defense Meteorological Satellite Program/Operational Linescan System)



ETM+ (Enhanced Thematic Mapper Plus)



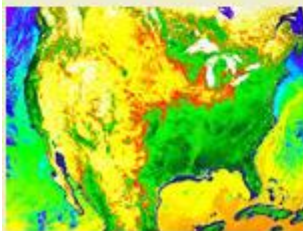
IKONOS



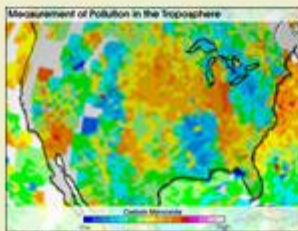
IRS (Indian Remote Sensing Satellite)



MISR (Multi-Angle Imaging Spectroradiometer)



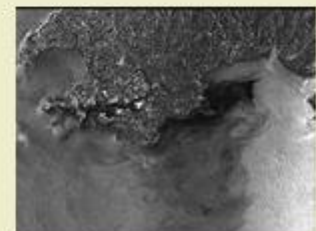
MODIS (Moderate-Resolution Imaging Spectroradiometer)



MOPITT (Measurements of Pollution in the Troposphere)



QuickBird



SAR (Synthetic Aperture Radar)

3. Sensor groups

Multi-spectral sensors record bands in multiple **wavelengths**:
... but tend to focus on one of these groups

- Visible, Near IR, Mid IR - Reflective
- Thermal - emissive
- Microwave - emissive or RADAR

And at different **spatial resolutions** (pixel size e.g...):

- Low 1km
- Medium 250m
- High 30m
- Very high 1m

Most satellites now carry multiple sensors with varying resolutions

4. Low Resolution

Weather: GOES (24 HOURS per day)

GOES 8: 75W longitude, GOES 9: 135W longitude

Visible: 1km, Thermal: 4km, 10-bit data (DN = 0- 1023)

GOES 17: 16 bands, VNIR (5)/ TIR (11)

<http://www.goes.noaa.gov>



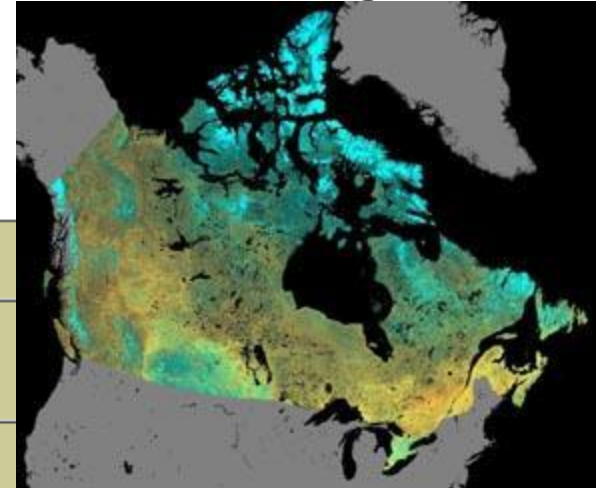
4. Low Resolution

NOAA AVHRR (Advanced 'Very High' Resolution Radiometer)

1.1km Red / NIR / TIR

1978-present (19 satellites to 2010) - global vegetation monitoring:
data are freely downloadable. 18, 19 operational

2500 x 2500 pixels, 10 bit data



| AVHRR/3 Channel Characteristics | | | |
|---------------------------------|---------------------|-----------------|--|
| Channel Number | Resolution at Nadir | Wavelength (um) | Typical Use |
| 1 | 1.09 km | 0.58 - 0.68 | Daytime cloud and surface mapping |
| 2 | 1.09 km | 0.725 - 1.00 | Land-water boundaries |
| 3A | 1.09 km | 1.58 - 1.64 | Snow and ice detection |
| 3B | 1.09 km | 3.55 - 3.93 | Night cloud mapping, sea surface temperature |
| 4 | 1.09 km | 10.30 - 11.30 | Night cloud mapping, sea surface temperature |
| 5 | 1.09 km | 11.50 - 12.50 | Sea surface temperature |

5. Medium RESOLUTION

LANDSAT (U.S.) initially known as ERTS (Earth Resource Technology Satellite); **Multi-Spectral Scanner (MSS: 80m)**

1972 Landsat 1 until 1978

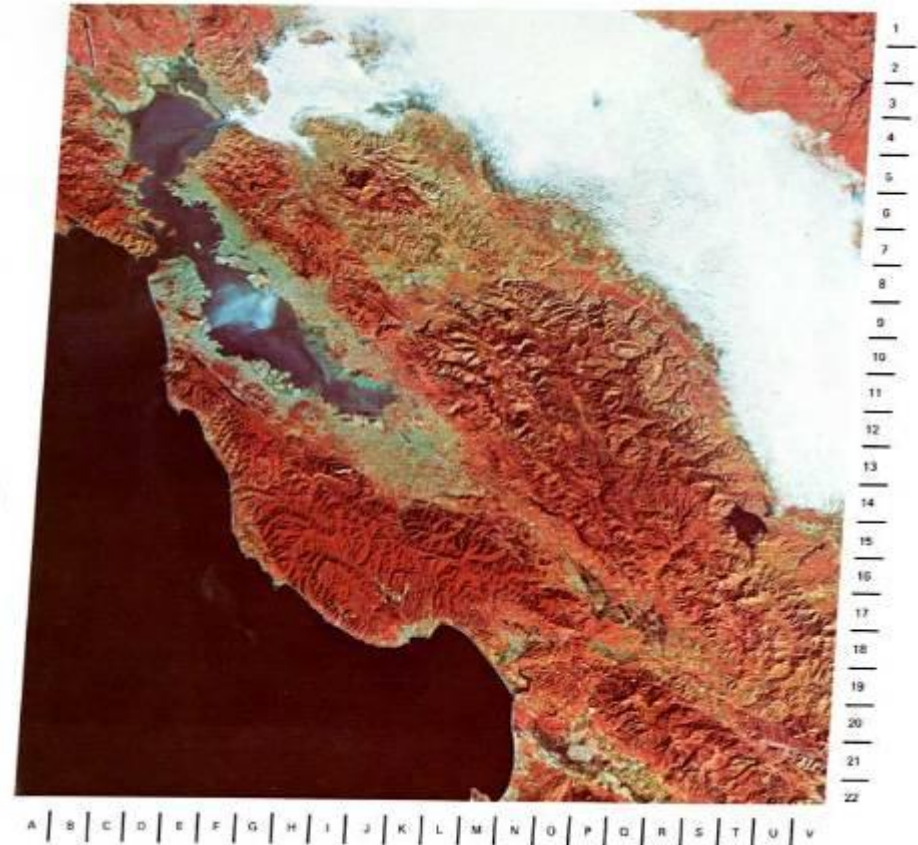
1975 Landsat 2 until 1982

1978 Landsat 3 until 1983

| Band | Spectral band | Resolution |
|------|-------------------------|-------------|
| 4 | 0,5 - 0,6 μm | 79 m x 82 m |
| 5 | 0,6 - 0,7 μm | 79 m x 82 m |
| 6 | 0,7 - 0,8 μm | 79 m x 82 m |
| 7 | 0,8 - 1,1 μm | 79 m x 82 m |

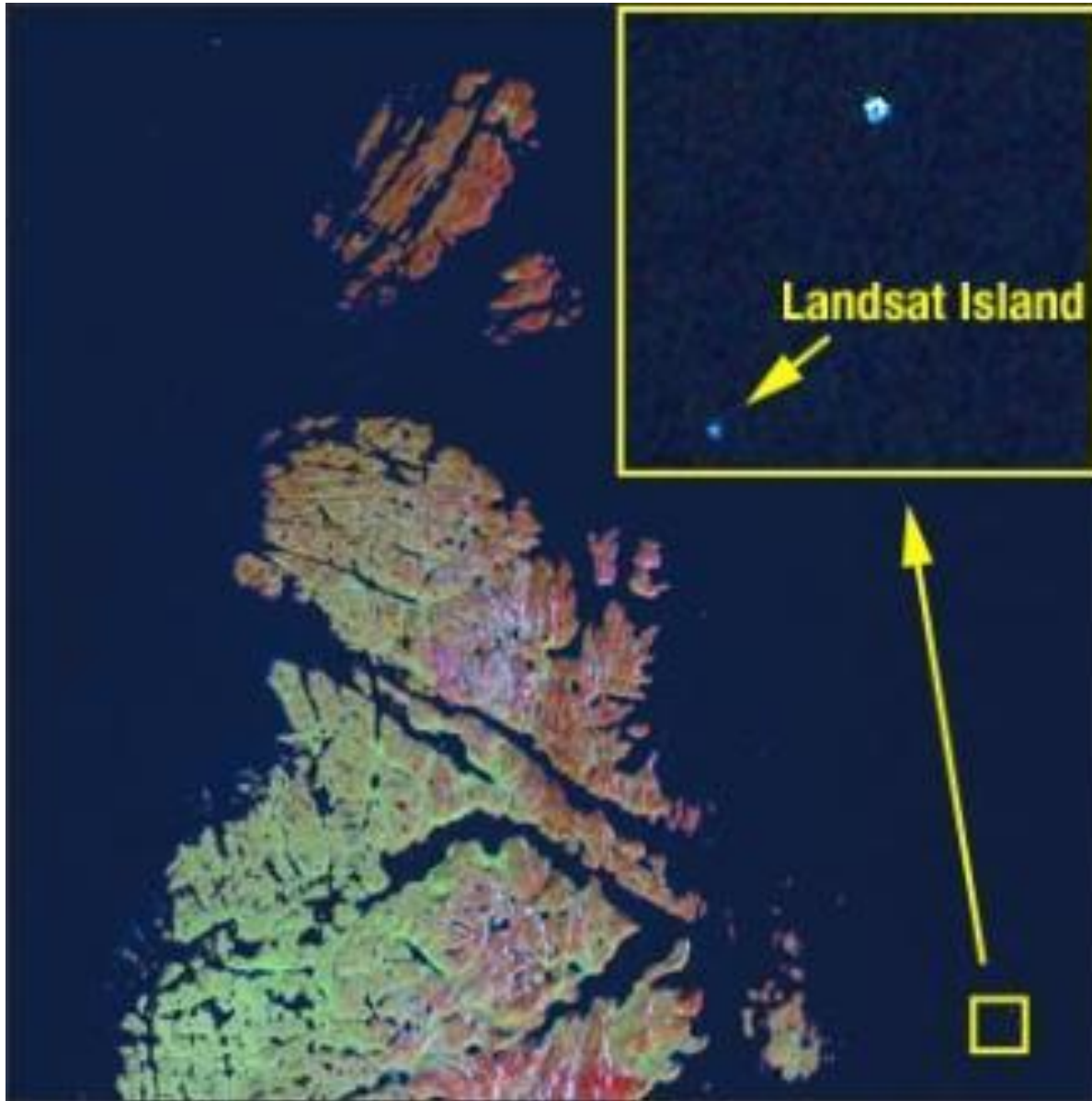
(No mid-IR bands)

Bands 1,2,3 were on the 'Return Beam Vidicon' (RBV)



Landsat image data

Discovered in 1976, Labrador
25m x 45m (Landsat 1)



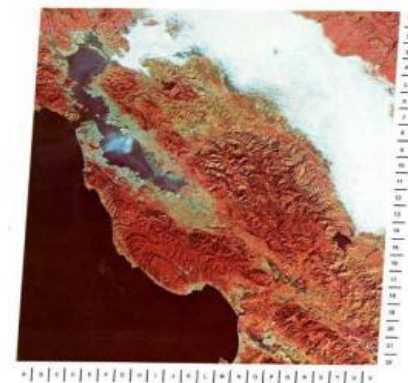
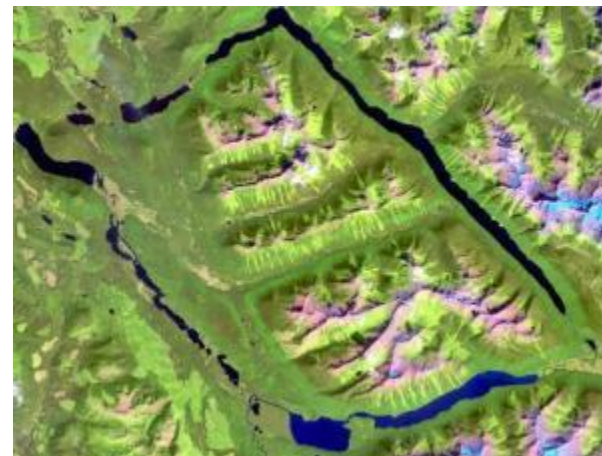
[**Landsat Island** is a small, uninhabited island located 20 kilometres (12 mi) the northeast coast of Labrador

Verified by Dr. Frank Hall (Canadian Hydrographic Service). He was strapped into a harness and lowered from a helicopter down to the island. As he was lowered out of the helicopter, a polar bear took a swat at him.

The bear was on the highest point on the island and it was hard for him to see because it was white.

6. High resolution Landsat 4/5 Thematic Mapper (TM) 1982/84: 'the next generation'

| Band No. | Wavelength Interval (μm) | 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 |



- Improved resolution (80 -> 30 m)
- Addition of **mid-IR** (and thermal)
- Included MSS (till 1999) for continuity

High resolution SPOT (France)

High Resolution Visible (HRV) bands 1986 ->

SPOT 1-3: 1986, 1990, 1993

| Mode | Band | Spectral band | Resolution |
|------------------|------|---------------------------|------------|
| XS-multispectral | XS1 | 0,50 - 0,59 μm | 20m x 20m |
| | XS2 | 0,61 - 0,68 μm | 20m x 20m |
| | XS3 | 0,79 - 0,89 μm | 20m x 20m |
| P-panchromatique | PAN | 0,51 - 0,73 μm | 10m x 10m |

SPOT 4- 5: 1998, 2002

| Mode | Band | Spectral band | Resolution |
|------------------|------|---------------------------|------------|
| Multispectral | B1 | 0,50 - 0,59 μm | 20m x 20m |
| | B2 | 0,61 - 0,68 μm | 20m x 20m |
| | B3 | 0,79 - 0,89 μm | 20m x 20m |
| | MIR | 1,58 - 1,75 μm | 20m x 20m |
| M - monospectral | PAN | 0,61 - 0,68 μm | 10m x 10m |

Summary table: Landsat TM versus SPOT HRV (1980s)

| | LANDSAT TM | SPOT HRV |
|---------------------|---------------------------|-------------------------------------|
| Launch | 1982 / 1984 | 1986 |
| Altitude | 705 km | 832 km |
| Attitude (polar) | 8.2 degrees | 8.7 degrees |
| Equatorial time | 9.45 am | 10.30 am |
| Swath width | 185km | 60km |
| Repeat coverage | 16 days | 26 days |
| Sensor | Thematic Mapper (TM) | High Resolution Visible (HRV) |
| Number of detectors | 100 | 6000/3000 |
| Advantages | #bands, swath size | higher resolution, # 'looks' |
| Bands | 7 | 3 + 1 (no MIR bands) |
| Scanner type | Mirror (Whisk broom) | Pushbroom |

SPOT (ESA / France)

<http://www.spot.com>

1 - 3: 1986 - 1993 (-> 2003)
programmable, pushbroom - 60km wide
20m RedGreen/near-IR 10m PAN

4 'next generation' included
Mid-IR 1998 20m (PAN 10m)



SPOT 5 (2002): Similar to 4, but also high-res PAN option (2.5 / 5m)

SPOT receiving station built at U. Lethbridge (2005)

SPOT 4/5 imagery for Canada (2005-2010) downloadable at geobase.ca

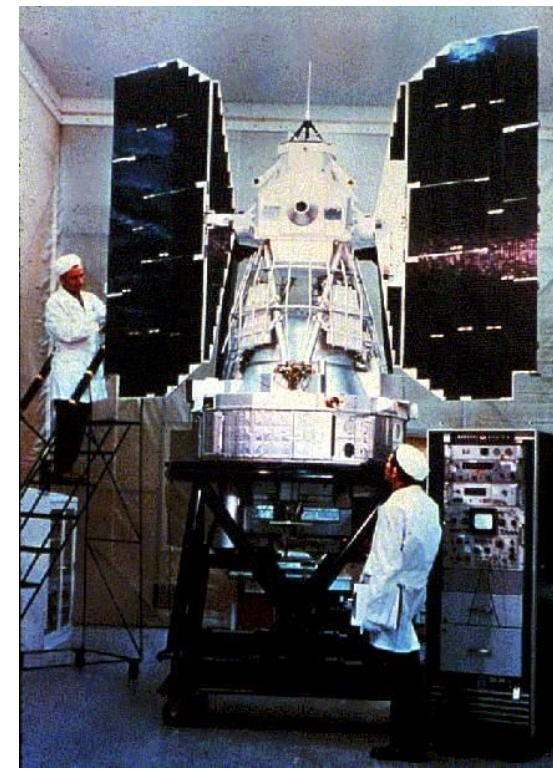
Otherwise - Not Free !

[SPOT 6 and 7: 2012 / 2014 very high res. 1.5m]

Landsat image data

Not the only land image data but ..

- The most accessible/downloadable
- free after 2008
- Longest continuous record: 1972 (1984)
- Suitable resolution (30m) for northern environments
- Suitable scale for landscape analysis
- These factors enabled it for Google Earth mosaic



Landsat 1

Landsat 4-7 summary

1982 Landsat 4 Thematic Mapper (TM) until 1987

1984 Landsat 5 TM ... operational till Nov 2011

1993 Landsat 6 Enhanced TM: (ETM+) failed after launch

1999 Landsat 7 ETM+ ... sensor malfunctioned April 2003

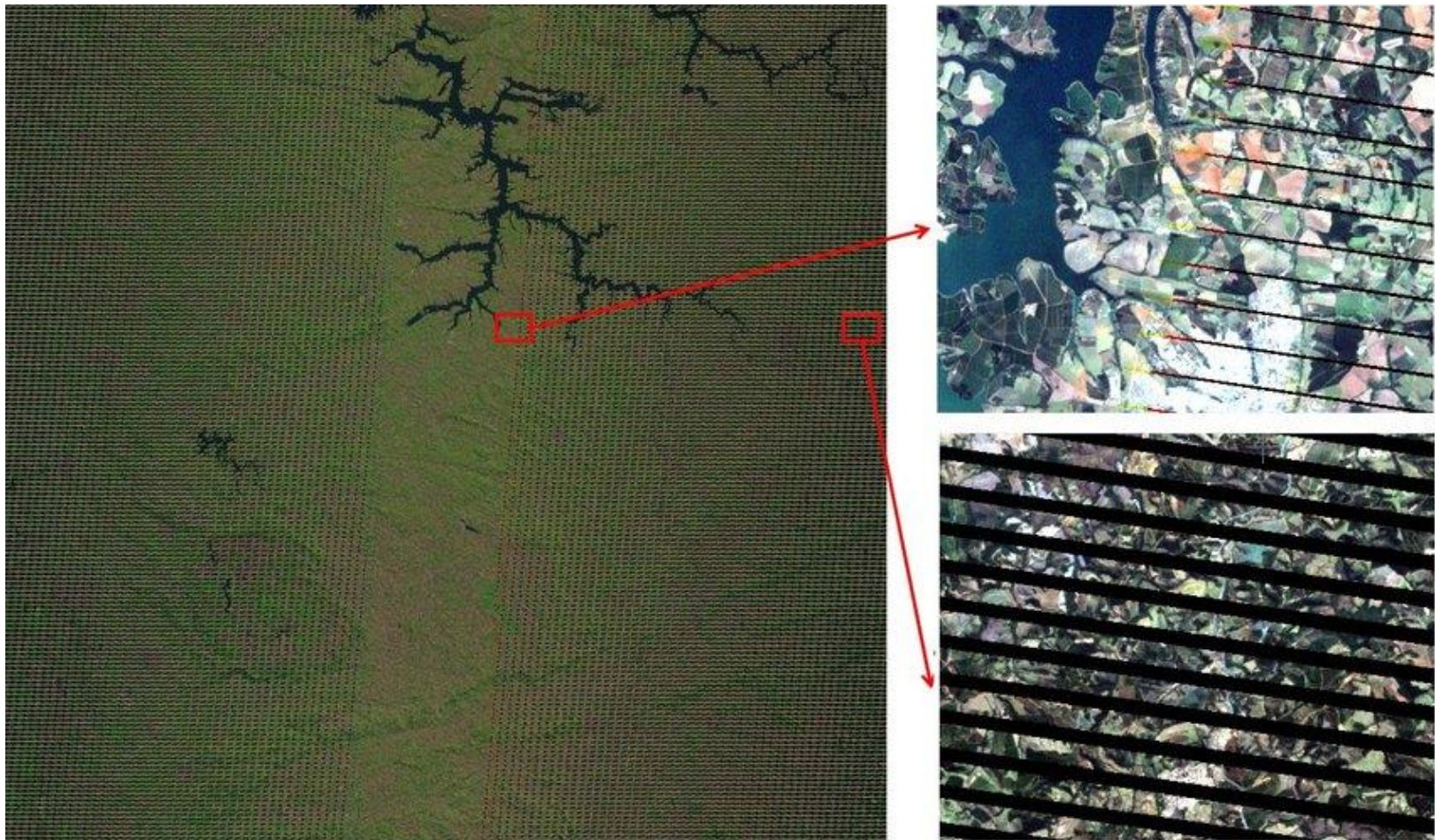
Landsat imagery (ETM+ ~2000) Google Earth mosaic in 2005

[Overlap for Landsat scenes is 14% at equator, 45% at 50 degrees]

Enhanced Thematic Mapper Plus (ETM+) (Landsat 7): New bands versus Landsat 5 TM: PAN 0.52-0.9 (Green->IR) band 15m

Sensor malfunctioned, April 2003
'Scan Line Calibrator' failed

Missing data lines thin towards the
centre leaving a usable 20km strip;
data are still transmitting



Landsat 8 successfully launched February 2013

Operational Land Imager (OLI): 16-bit data (versus 8-bit for previous sensors)

| | Spectral Band | Wavelength | Resolution |
|-------------|------------------------------------|-----------------------------|-------------------|
| TM | Band 1 - Coastal / Aerosol | 0.433 - 0.453 μm | 30 m |
| 1 | Band 2 - Blue | 0.450 - 0.515 μm | 30 m |
| 2 | Band 3 - Green | 0.525 - 0.600 μm | 30 m |
| 3 | Band 4 - Red | 0.630 - 0.680 μm | 30 m |
| 4 | Band 5 - Near Infrared | 0.845 - 0.885 μm | 30 m |
| 5 | Band 6 - Short Wavelength Infrared | 1.560 - 1.660 μm | 30 m |
| 7 | Band 7 - Short Wavelength Infrared | 2.100 - 2.300 μm | 30 m |
| ETM+ | Band 8 - Panchromatic | 0.500 - 0.680 μm | 15 m |
| 8 | Band 9 - Cirrus | 1.360 - 1.390 μm | 30 m |

OLI Spectral Bands ^[13]

Landsat 8 successfully launched February 2013

Thermal InfraRed Sensor TIRS

- OLI + TIRS = 2 sensors on one platform

| Spectral Band | Wavelength | Resolution |
|------------------------------------|-----------------------------|------------|
| Band 10 - Long Wavelength Infrared | 10.30 - 11.30 μm | 100 m |
| Band 11 - Long Wavelength Infrared | 11.50 - 12.50 μm | 100 m |

TIRS Spectral Bands ^[13]

http://landsat.usgs.gov/L8_band_combos.php

European
Space Agency
(ESA)

Copernicus
Program
Sentinel 2a,b
2015/17

free download

Multi-Spectral
Instrument
(MSI)
10 / 20m

Reykjavik

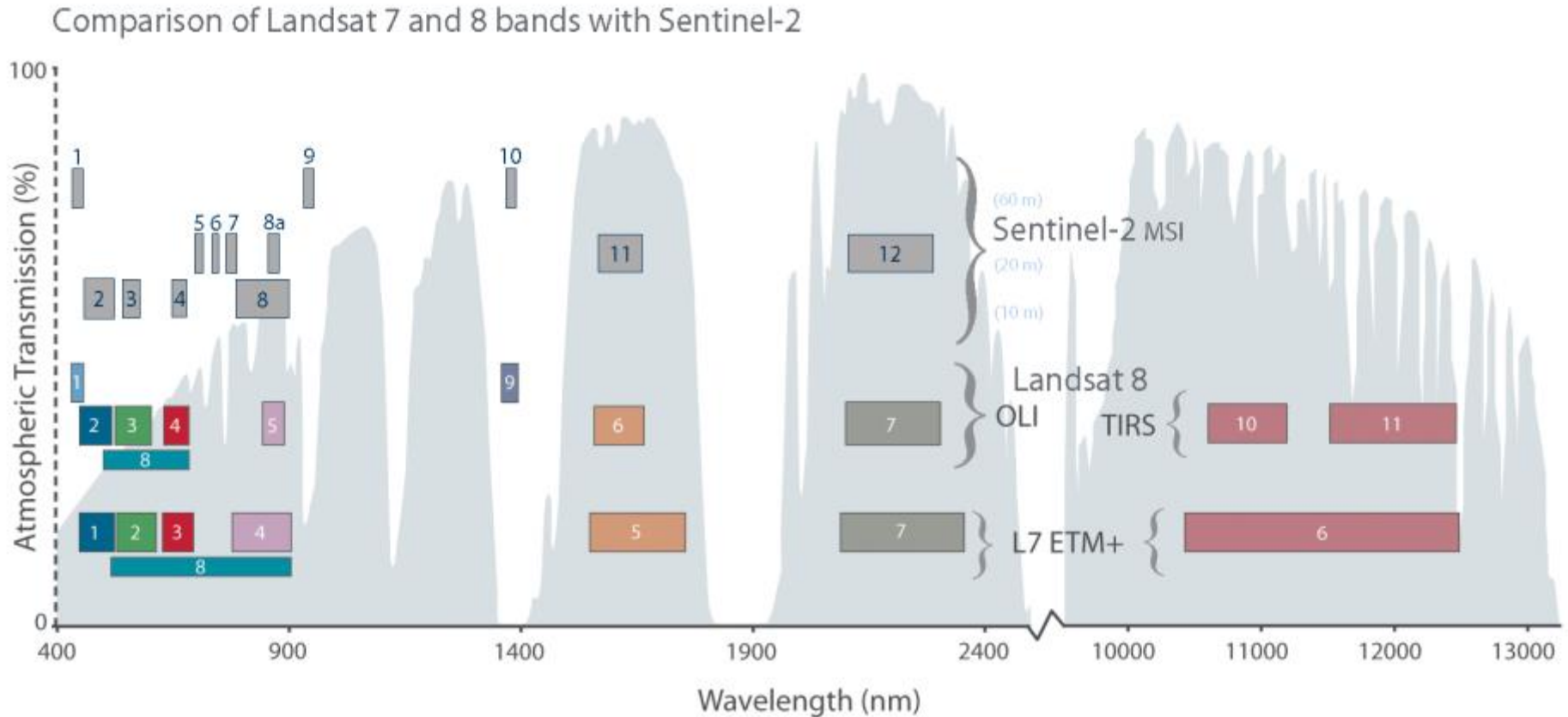
A satellite image of Reykjavik, Iceland, showing the city and surrounding terrain. The city is visible as a dark area in the lower left, surrounded by a large body of water. The surrounding land is rugged and mountainous, with various shades of green, brown, and red indicating different vegetation and terrain types. The word "Reykjavik" is written in yellow text over the water area.

ESA Copernicus Program - Sentinel 2, 2015/2017 - free download; multi-spectral instrument (MSI)

| Sentinel-2 Bands | Central Wavelength (μm) | Resolution (m) |
|-------------------------------------|--|---------------------------|
| Band 1 – Coastal aerosol | 0.443 | 60 |
| Band 2 – Blue | 0.490 | 10 |
| Band 3 – Green | 0.560 | 10 |
| Band 4 – Red | 0.665 | 10 |
| Band 5 – Vegetation Red Edge | 0.705 | 20 |
| Band 6 – Vegetation Red Edge | 0.740 | 20 |
| Band 7 – Vegetation Red Edge | 0.783 | 20 |
| Band 8 – NIR | 0.842 | 10 |
| Band 8A – Narrow NIR | 0.865 | 20 |
| Band 9 – Water vapour | 0.945 | 60 |
| Band 10 – SWIR – Cirrus | 1.375 | 60 |
| Band 11 – SWIR | 1.610 | 20 |
| Band 12 – SWIR | 2.190 | 20 |

<https://en.wikipedia.org/wiki/Sentinel-2#Instruments>

Sentinel 2 vs Landsat 8 OLI vs Landsat 7 ETM+ bands:



S2 has finest '**spectral**' (radiometric) resolution = narrowest bands

L8 has finer '**spectral**' resolution than L7 ETM+

Sensor Summary so far:

NASA

- Landsat MSS 1-3 1972-82 Free (since 2008)
- Landsat TM 4-8 1982-> Free
- SPOT (France) 1-4 1986- > NOT Free
Satellite Pour l'Observation de la Terre
- Sentinel-2 (ESA) 2013-> Free
- Many others – Free except for very high resolution (see later lectures)

<http://www.youtube.com/watch?v=cfSaztUiw5s>

Earth Observing satellite systems

https://en.wikipedia.org/wiki/List_of_Earth_observation_satellites

<https://directory.eoportal.org/web/eoportal/satellite-missions>

<https://www.itc.nl/Pub/sensordb/AllSensors.aspx>

<https://gisgeography.com/satellite-list/>

7. Very high resolution 0.3-5m (Corporate) 2000- >
e.g. Ikonos, Quickbird, Worldview, Geoeye and others



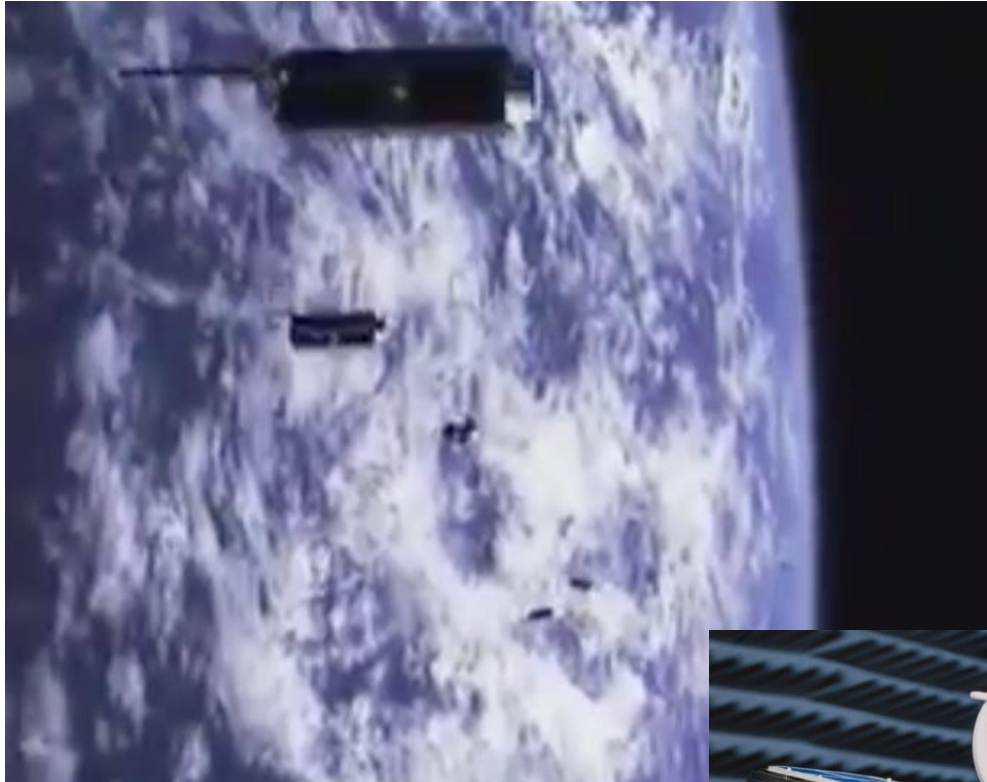
Inauguration of Barack Obama as US President - Jan 20 2009 (Geoeye)

mini- 'dove' nanosatellites

Very high resolution – 1 metre

Planet Labs: www.planet.com

2017: Planet Labs orbits 88 'doves'



Not a Rocket scientist ->

Platform and sensor ->



Low-tech from balloon, launched by students

UK space program: Teddies in Space



Total cost: (weather) balloon, camera (from eBay) and hand warmers < \$130
Platform = balloon, sensor = eBay camera