

PLATFORMS & SENSORS

Platform:

the vehicle carrying the remote sensing device

– e.g. ground, airborne, or spaceborne

Sensor:

the remote sensing device recording wavelengths of energy

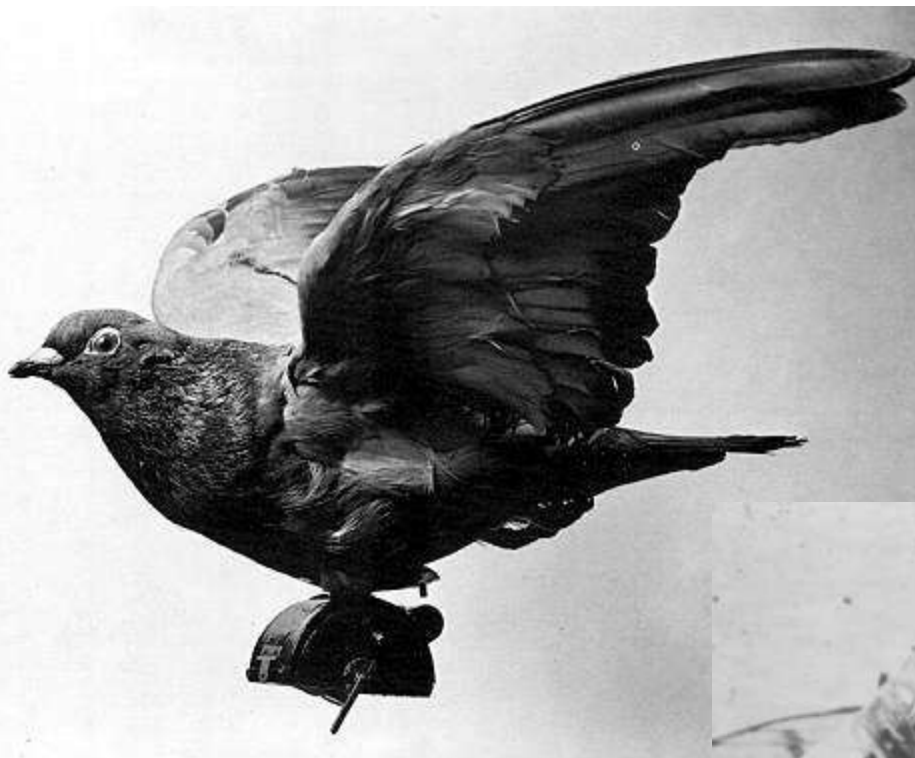
e.g. camera, or scanner

Image data might be referred to using platform or sensor e.g.

platform: Landsat (1, 5, 7 etc..)

Sensor: Multispectral Sensor (MSS) or Thematic Mapper (TM)

EARLY PLATFORMS & SENSORS



Birds, Kites,
Balloons, Planes,
with cameras

Succeeded today by
Unmanned Aerial Vehicles
(UAV) = Remotely Piloted
Airborne Systems (RPAS)



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



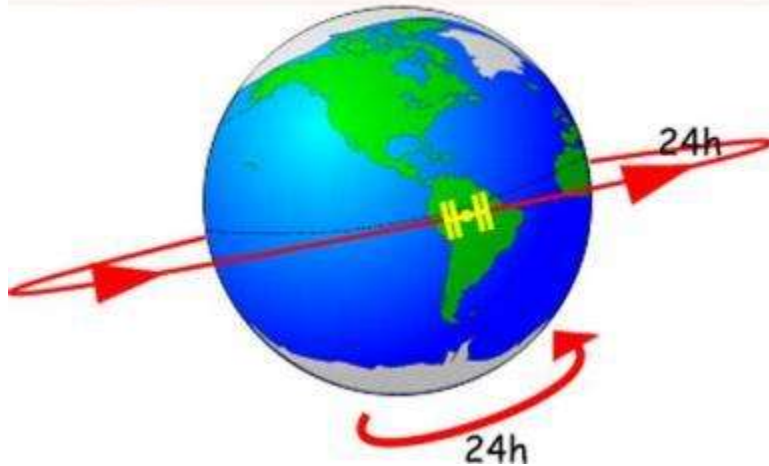
Film used –
Scanning
comes later



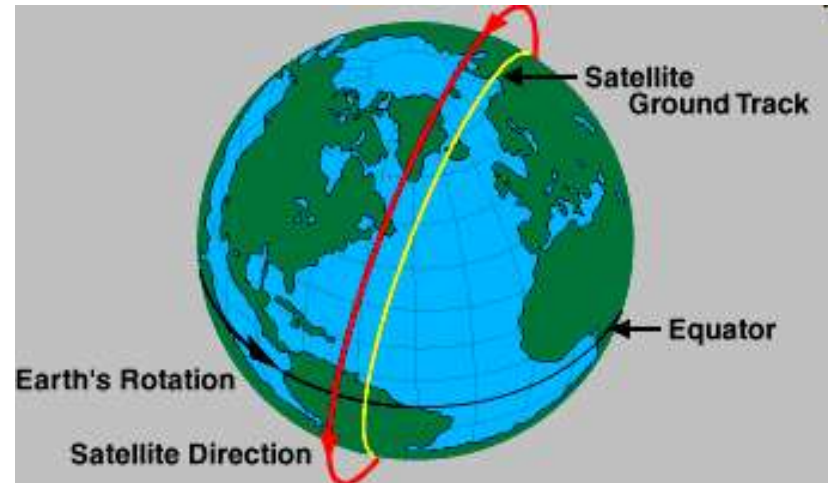
Platform = International Space Station
Sensor = Chris Hadfield's DSLR Nikon
ISS orbit is at 408 km altitude

1. Satellite orbits

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



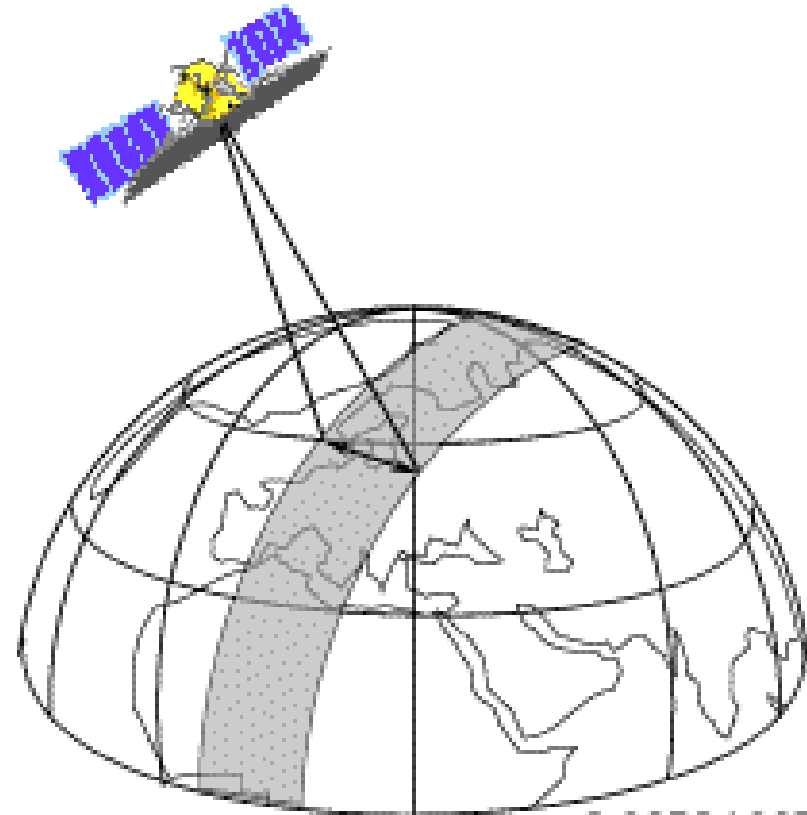
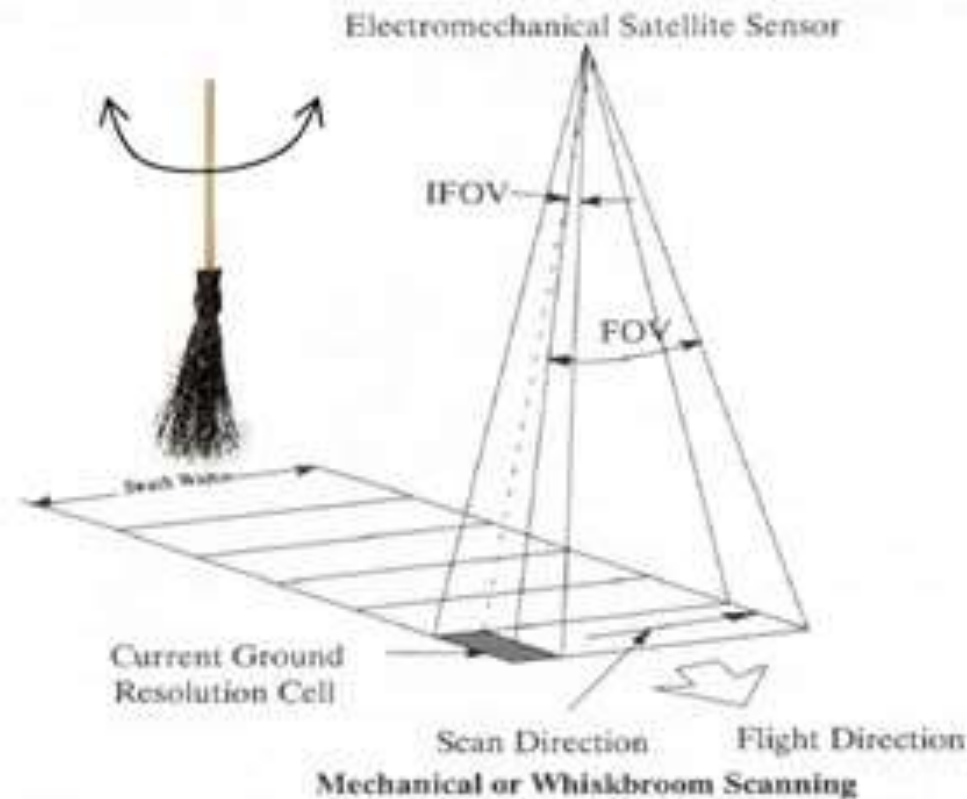
"Geostationary"
e.g. Weather satellites
TV, Internet, GPS-WAAS
~ 36,000 km altitude
capturing all day



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

2. Scanner types

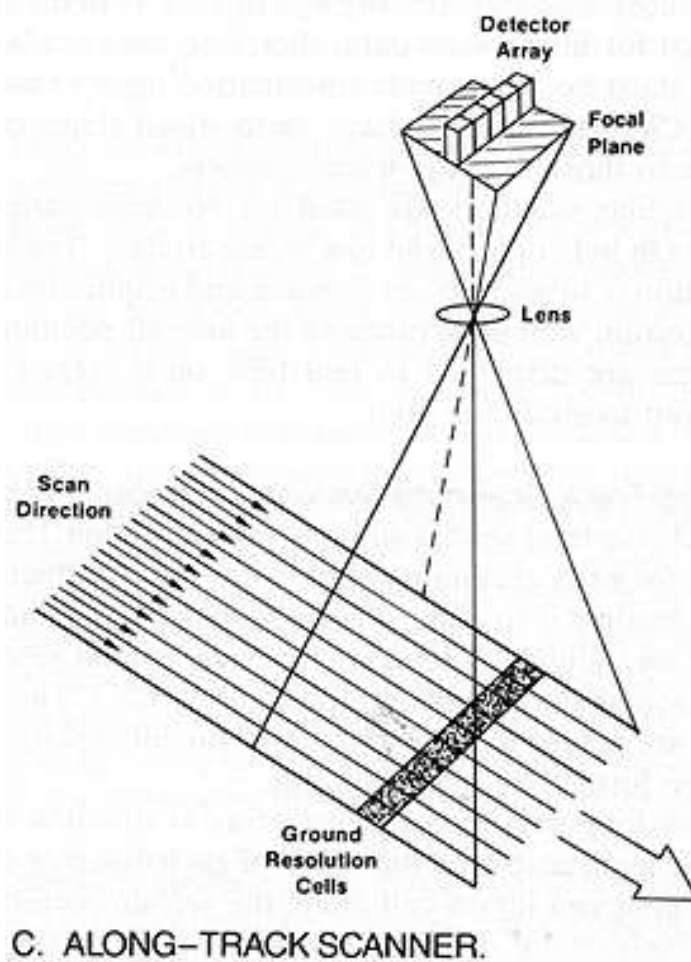
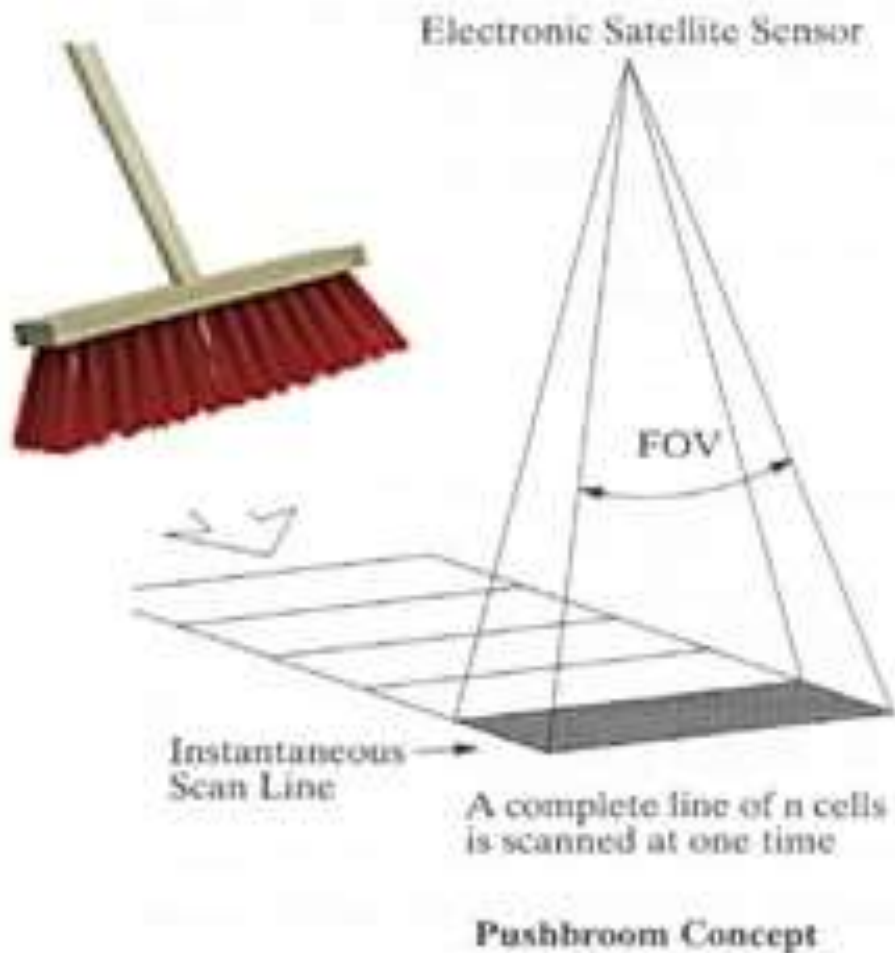
a. Whiskbroom (mirror/ cross-track): ... now a bit historic
a small number of sensitive diodes for each band sweep perpendicular
to the path or swath, centred directly under the platform, i.e. at nadir
e.g. LANDSAT 1-7 MSS / TM / ETM



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 8/9 OLI* - almost all now ..

* Landsat 8/9 are not redirectionned; swath = 185km = ~ 6000 pixels



3. Sensor groups

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

- Visible, Near IR, SWIR - Reflective (optical)
- Thermal - emissive (sometimes with optical)
- Microwave - emissive or RADAR

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

- Low 1-10km
- Medium 500m
- High 30m
- Very high 1m

Many satellites now carry multiple sensors with varying resolutions

4a. Low Resolution

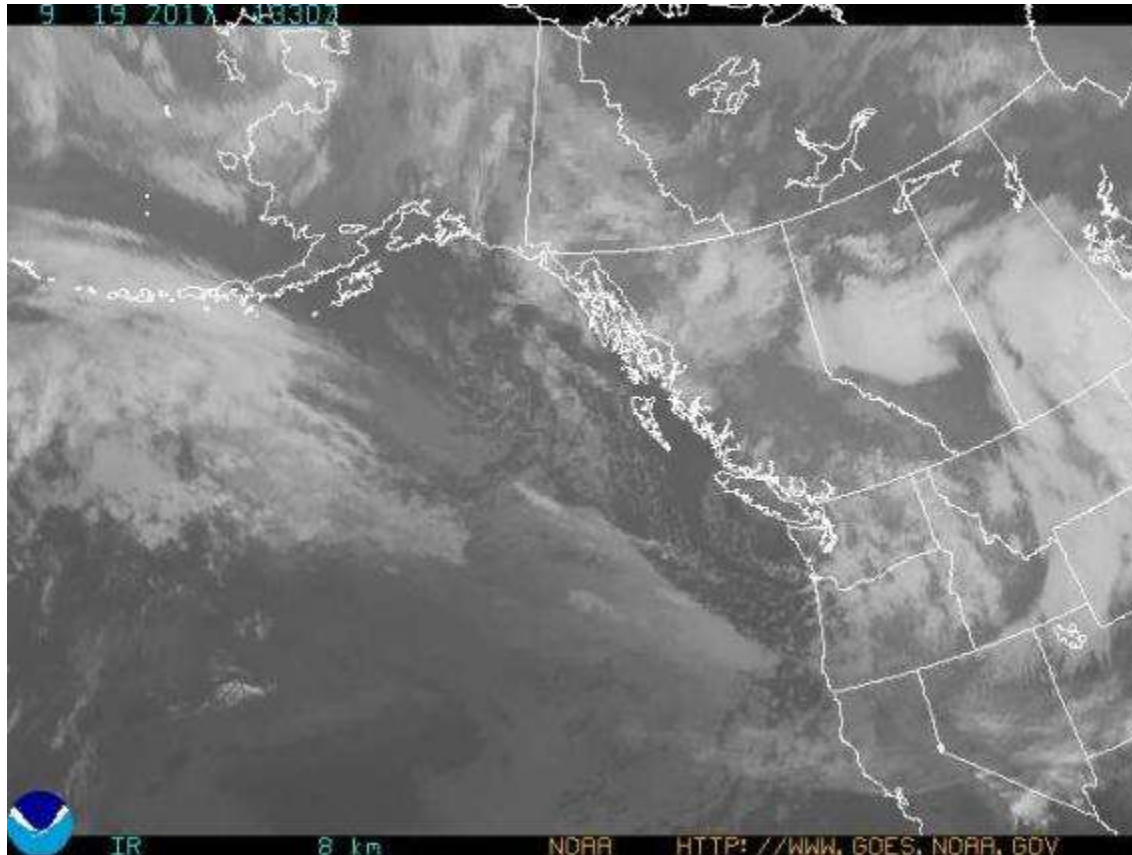
Weather: GOES (24 HOURS per day) - geostationary

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>

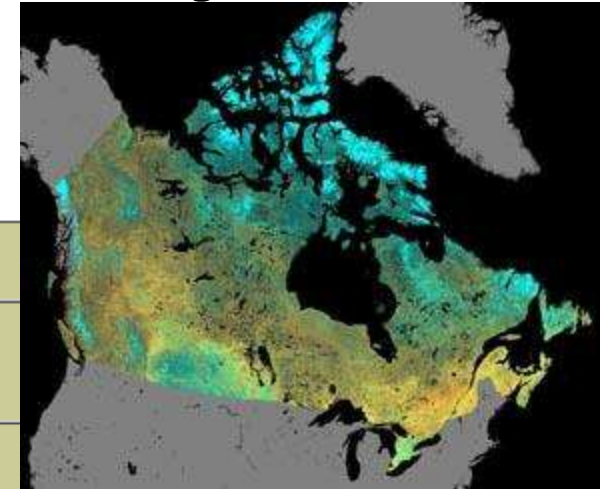


4b. Low Resolution

NOAA AVHRR (Advanced 'Very High' Resolution Radiometer)

1.1km Red / NIR / TIR very high temporal resolution' = repeats 1978-> present (19 satellites) - 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 |

5a. MEDIUM RESOLUTION (500m-1km)

MODIS (MODerate resolution Imaging Spectroradiometer)

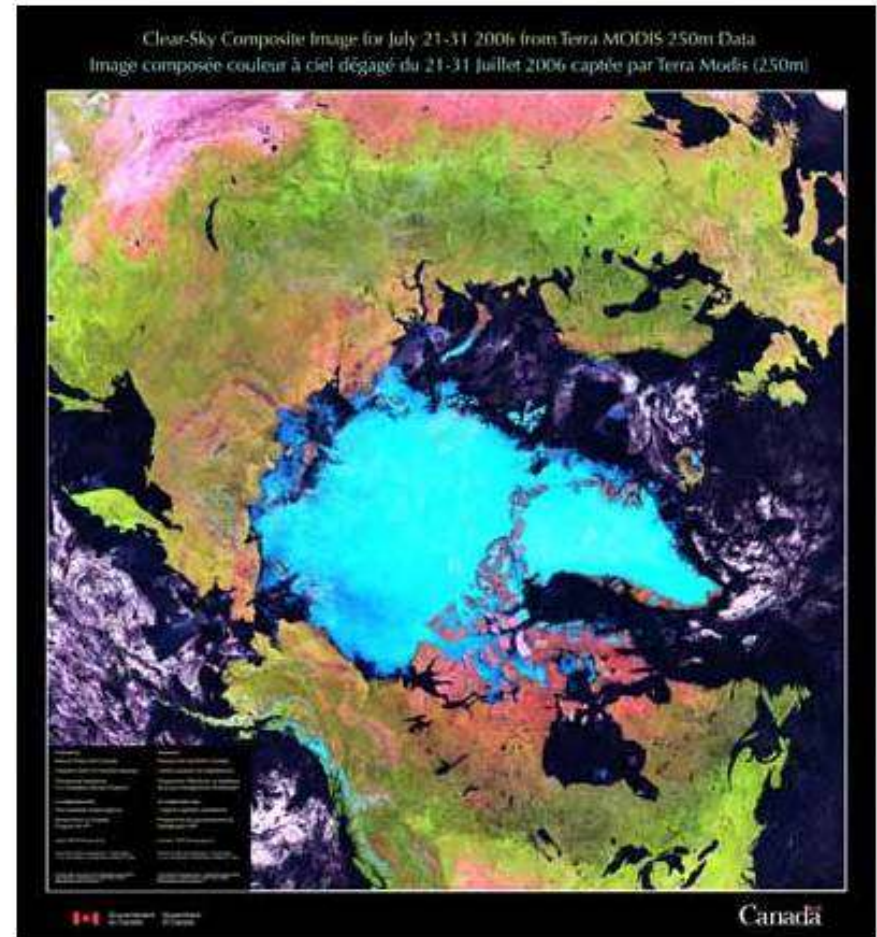
Descending 10.30am on Terra, Ascending 1.30pm on Aqua

<http://modis.gsfc.nasa.gov>

Red / NIR: 250metres (2 bands) Blue/Green/NIR/SWIR: 500m VNIR/SWIR/TIR:
1000 metres (29 bands) Swath width: 2330km

CCRS produced the first-ever, high-medium resolution, circumpolar satellite image by compositing cloud-free images from the MODIS sensor

<http://www.nrcan.gc.ca/earth-sciences/land-surface-vegetation/land-cover/north-american-landcover/9144>



5b. Medium-High RESOLUTION

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

1972 Landsat 1 until 1978 (ERTS 1) Manual interpretation e.g. fault lines

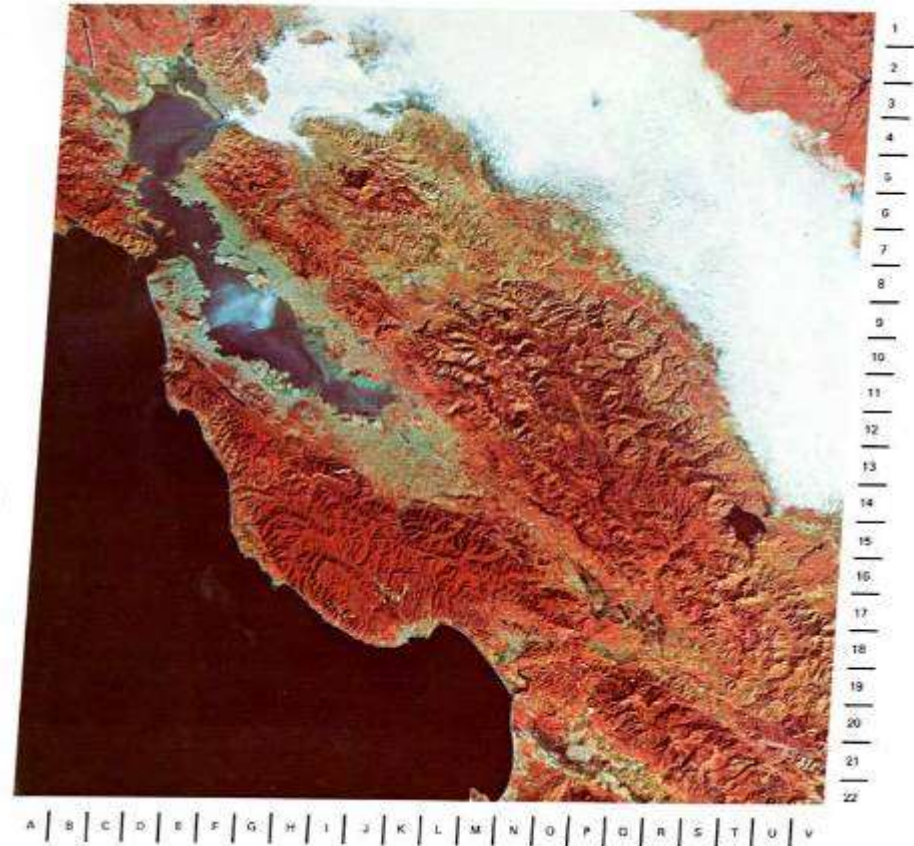
1975 Landsat 2 until 1982

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 |

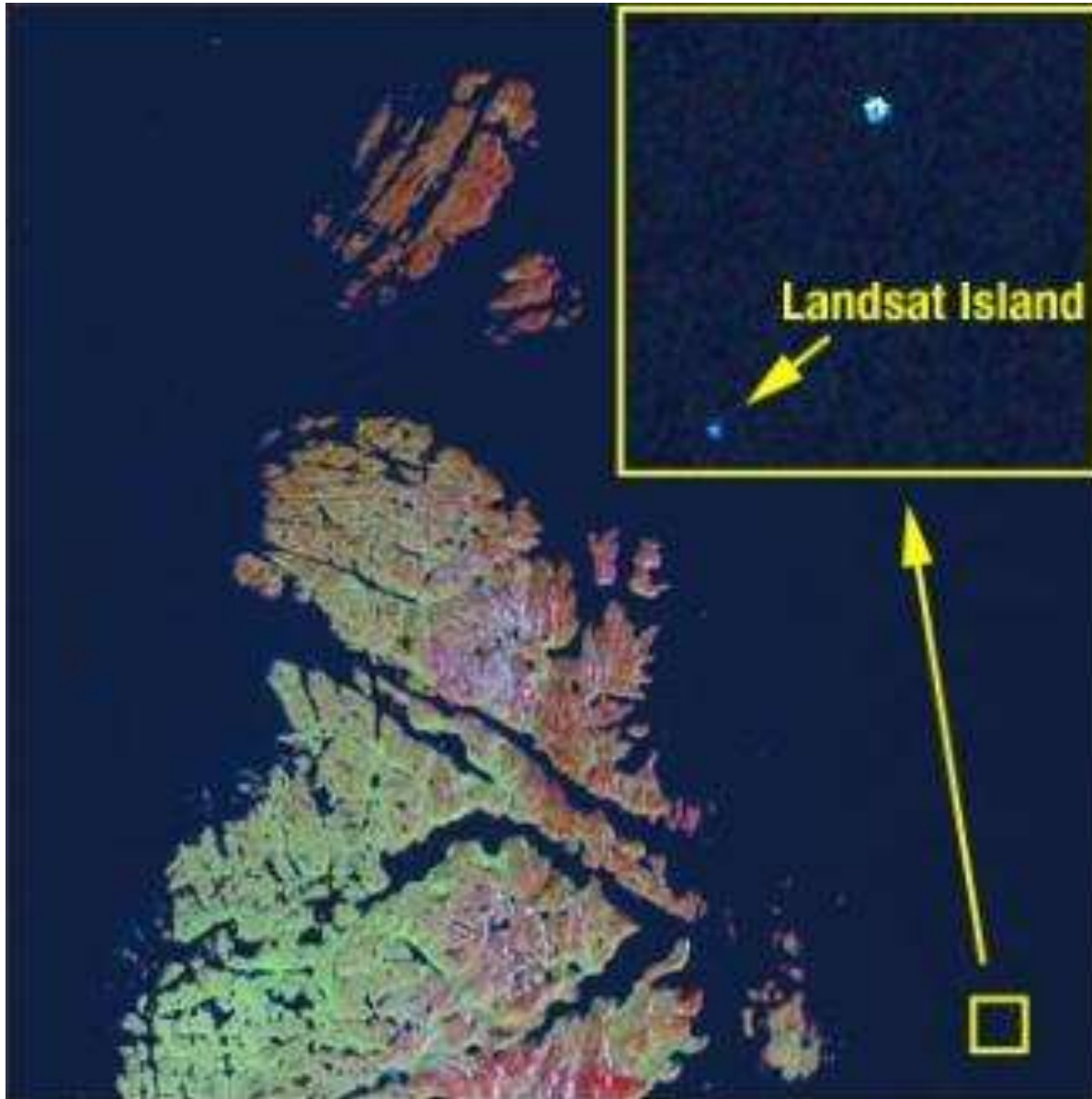
(No SWIR bands)

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 off 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.

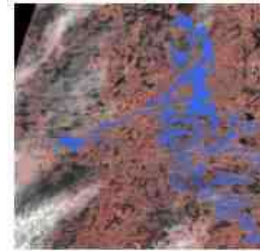
The bear was on the highest point on the island and it was hard for him to see because it was white.

1970s Multispectral image processing: The Landsat Era -this changed everything..

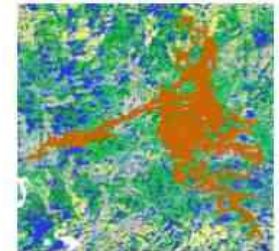
1972 Launch of Landsat (ERTS) 1 satellite and the 80m MultiSpectral Sensor (MSS)

Virginia Tower Norwood: "The Mother of Landsat" designed the MSS

<https://www.technologyreview.com/2021/06/29/1025732>



MSS Image 16/22 (09 Jul 1978)



EOSD Image 15/22 (15 June 2001)

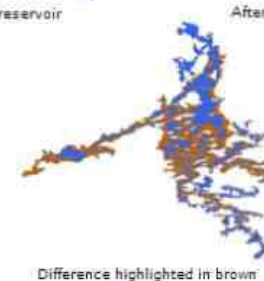


Before flooding of reservoir



After flooding of reservoir

Map updating
1:250,000

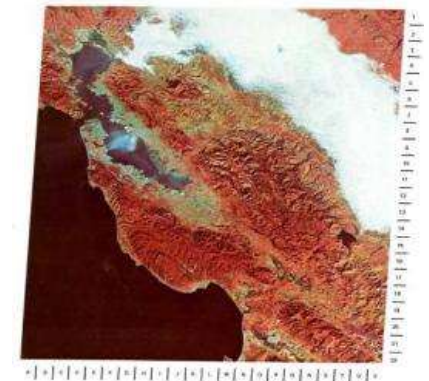


Difference highlighted in brown

6. High resolution

**Landsat 4/5 Thematic Mapper (TM) 1982/84: ‘the next generation’
– Landsat 5 TM failed November 2011**

| 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 | SWIR | 30 |
| 6 | 10.40 - 12.50 | Thermal IR | 120 |
| 7 | 2.08 - 2.35 | SWIR | 30 |



- Improved resolution (80 -> **30 m**)
- Addition of **SWIR** (and thermal band)
- Included MSS 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 |
| | SWIR | 1,58 - 1,75 μm | 20m x 20m |
| M - monospectral | PAN | 0,61 - 0,68 μm | 10m x 10m |

France launches SPOT 1986 (*Satellite Pour l'Observation de la Terre*)

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 SWIR bands) |
| Scanner type | Mirror (Whisk broom) | Pushbroom |
| Pixel size | 30m | 10 / 20m |

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 (2005)

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

Enhanced Thematic Mapper Plus (ETM+) (Landsat 7): New band 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 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 the Google Earth mosaic
using Landsat 7 ETM+ ~2000 (pre- calibration failure)



Landsat 1

Landsat 8 successfully launched February 2013

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

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)^[20]

| | Bands | Wavelength (micrometers) | Resolution (meters) |
|---|---------------------------------------|--------------------------|---------------------|
| → | Band 1 - Ultra Blue (coastal/aerosol) | 0.435 - 0.451 | 30 |
| | Band 2 - Blue | 0.452 - 0.512 | 30 |
| | Band 3 - Green | 0.533 - 0.590 | 30 |
| | Band 4 - Red | 0.636 - 0.673 | 30 |
| | Band 5 - NIR | 0.851 - 0.879 | 30 |
| | Band 6 - SWIR 1 | 1.566 - 1.651 | 30 |
| | Band 7 - SWIR 2 | 2.107 - 2.294 | 30 |
| → | Band 8 - Panchromatic | 0.503 - 0.676 | 15 |
| → | Band 9 - Cirrus | 1.363 - 1.384 | 30 |
| | Band 10 - Thermal 1 | 10.60 - 11.19 | 100* (30) |
| | Band 11 - Thermal 2 | 11.50 - 12.51 | 100* (30) |

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter

Landsat 9 launched September 2021: OLI-2 / TIRS-2

Launch rocket de-orbit burn, seen from Yorkshire
(Slightly further north than Prince George)



Bands near identical to Landsat 8; 8 days apart from Landsat 8

Landsat 9 will replace Landsat 7 (launched in 1999), taking its place in orbit.

OLI: 12 bit (4096) OLI-2: 14-bit (16,384) – both stored in 16-bit channels (65,536 DNs)

14 v 12 bit data = more discrimination in shadows, details in snow accumulation areas ?

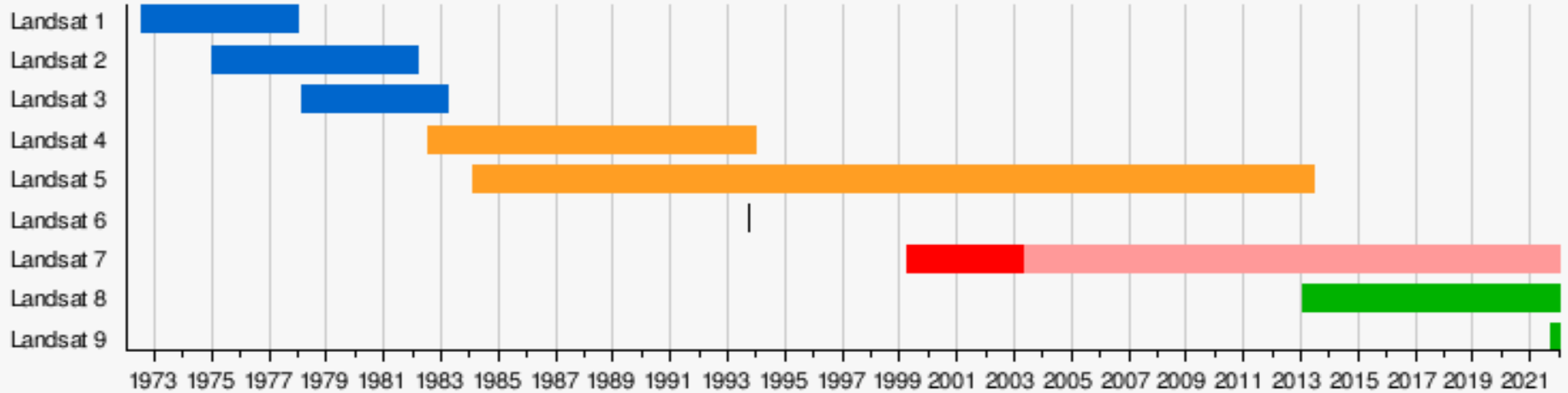
Landsat continuation and the end of Landsat 5

the longest-operating Earth observation satellite 1984-2011 / 2013

The basis for Google Earth TimeLapse <https://earthengine.google.com/timelapse/>

- Landsat 5 TM transmission ceased November 2011 fully decommissioned May 2012

The secondary instrument, the Multispectral Scanner (MSS) had been turned off in 1995. Mission operations engineers realized that the communication links used by MSS were still good, and the mission could continue if the MSS still worked. Seventeen years after turning the instrument off, engineers powered it back on, and amazingly, it worked. This allowed Landsat 5 to acquire one more year of data until Landsat 8 was ready to take its place in early 2013. i.e. Jan 2012-13



* Landsat 5 TM transmission ceases November 2011

**European
Space Agency
(ESA)**

**Copernicus
Program
Sentinel 2A/B
2015 / 17**

free download

Multi-Spectral
Instrument
(MSI)
10 / 20m

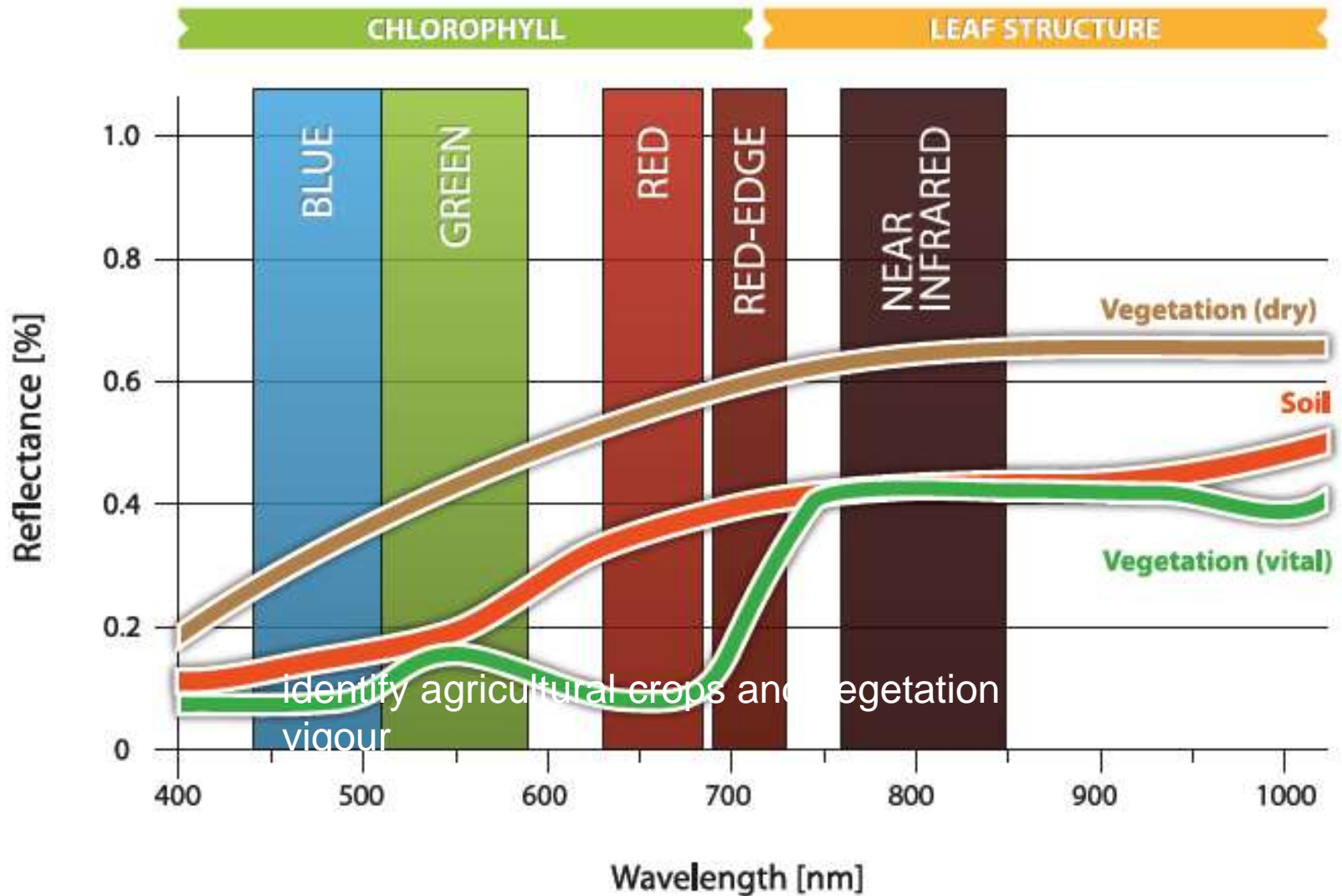
Reykjavik

A satellite image of Iceland, showing the capital city of Reykjavik and the surrounding rugged, mountainous terrain. The city is visible as a dark, dense area of buildings and infrastructure, situated in a valley. The surrounding landscape is characterized by steep, rocky slopes and patches of green vegetation. The ocean is visible to the west and south of the city.

ESA Copernicus Program - Sentinel 2A/B, 2015/2017 - free download; multi-spectral instrument (MSI) - 12 bit

| 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 |

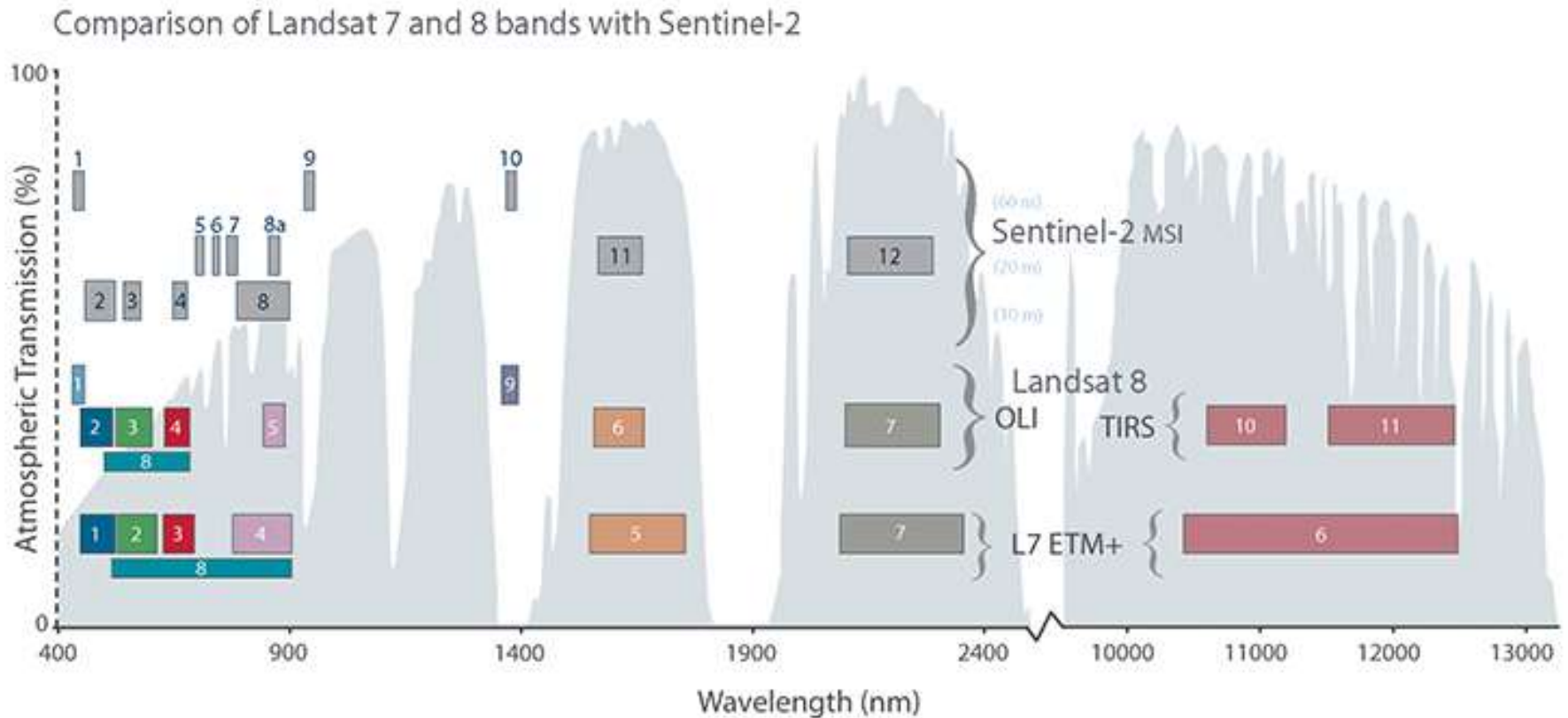
Introducing the Red Edge



Typical spectral reflectance curves of selected surfaces

Useful for studies in agriculture and vegetation health

Sentinel 2 vs Landsat 8(9) OLI vs Landsat 7 ETM+ bands:



S2 has finest **'spectral'** resolution = narrowest bands

L9 has highest **'radiometric'** resolution (14 bit)

All have finer **'spectral'** resolution than L7 ETM+

Earth Observing satellite lists

So far we've seen AVHRR, MODIS, Landsat, SPOT, Sentinel – are there more?
- Yes many more .. e.g. from Brazil, China, India, especially very high resolution

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

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

<https://www.eoportal.org/satellite-missions>

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