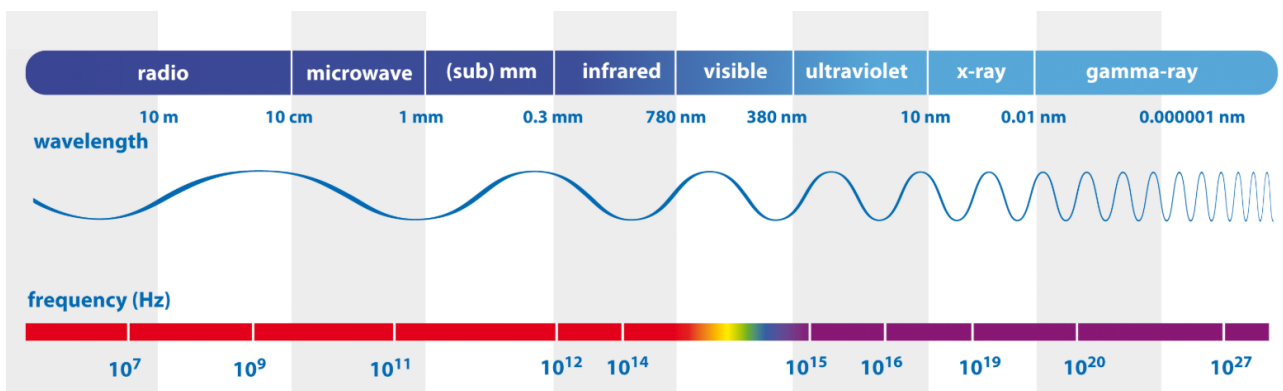


# GEOG 357

## LECTURE 4

1



Presentation Title

2

2

# 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

3



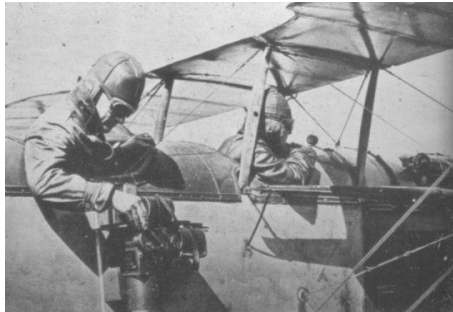
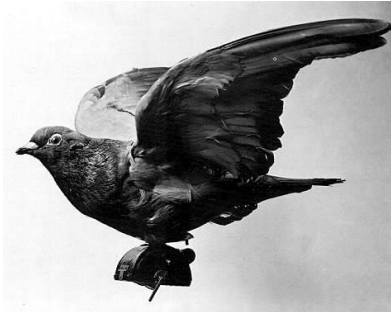
Platform => International Space Station

Sensor => Chris Hadfield's Nikon

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# EARLY PLATFORMS & SENSORS

**Birds, Kites, Balloons, Planes all with cameras**



**Superseded  
today by  
Unmanned Aerial  
Vehicles (UAV)**

Presentation Title

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

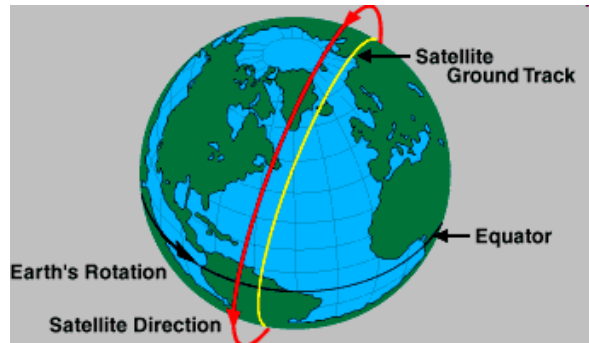
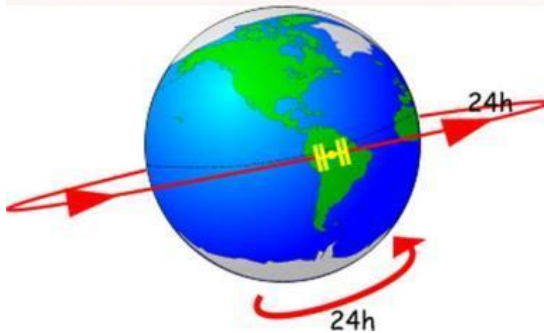


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## Satellite orbits

- "Geostationary" e.g. Weather satellites, TV, Internet, GPS-WAAS ~ 36,000 km altitude
- "Sun-synchronous" Earth and Ocean Surface monitoring mapping / updating, ~ 400-900 km altitude

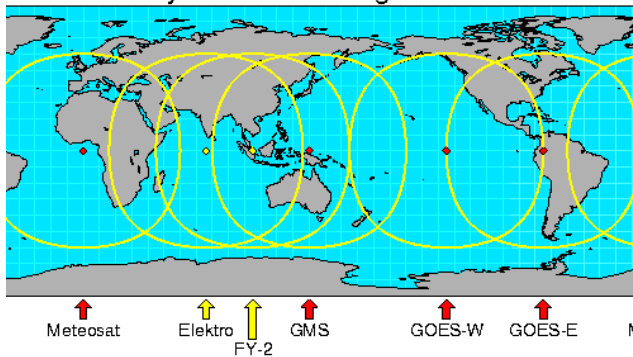
<http://resources.yesican-science.ca/orbits1/goes.html>



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## Satellite orbits

Geostationary Satellite Coverage



- **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)
- i.e. to the observer on Earth it appears to be stationary in the sky

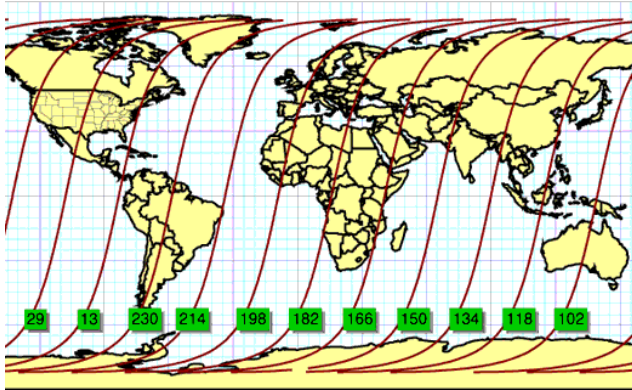
9/4/20XX

Presentation Title

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**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
- Polar orbit

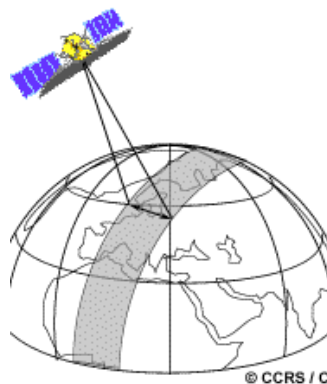
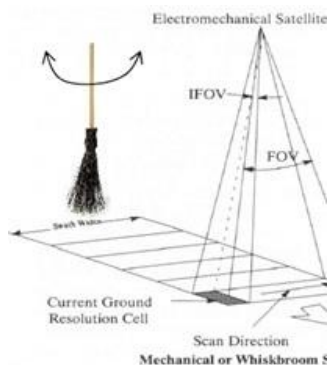
9/4/20XX

Presentation Title

9

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## Scanner types (Sensor Types)

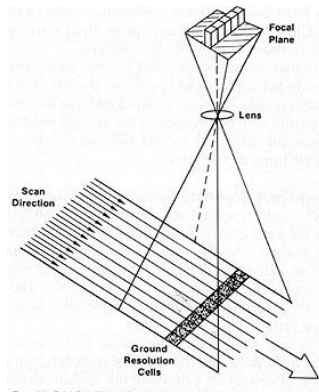


**a. Whiskbroom** (mirror/ cross-track): a small number of sensitive diodes for each band sweep perpendicular to the path or swath, centred directly under the platform, i.e. at 'nadir' e.g. LANDSAT MSS /TM/ETM

© CCRS / C

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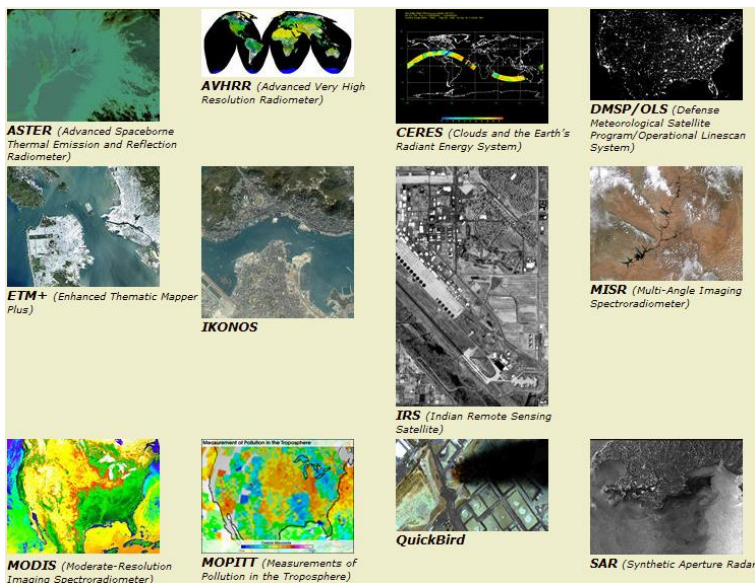


### b. Pushbroom (along-track)

- 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

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### Selected satellite remote sensing systems

#### Wim Bakker's website

<http://members.home.nl/wim.h.bakker>

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### 3. Sensor groups

- Grouping by Wavelength
  - 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
- Grouping by Spatial Resolution
  - 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

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### Low Resolution

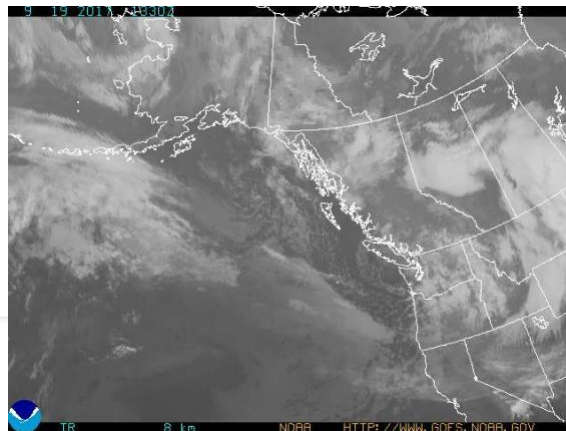
**Weather: GOES** (24 HOURS per day)

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>



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## Low Resolution

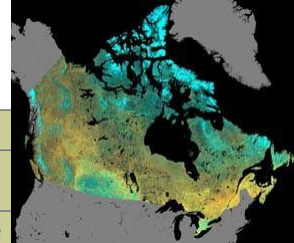
### NOAA AVHRR (Advanced 'Very High' Resolution Radiometer)

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



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## 5. Medium RESOLUTION

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

1972 Landsat 1 until 1978

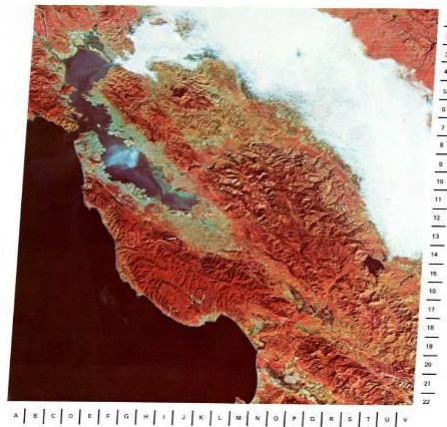
1975 Landsat 2 until 1982

1978 Landsat 3 until 1983

Band	Spectral band	Resolution
4	0,5 - 0,6 $\mu\text{m}$	79 m x 82 m
5	0,6 - 0,7 $\mu\text{m}$	79 m x 82 m
6	0,7 - 0,8 $\mu\text{m}$	79 m x 82 m
7	0,8 - 1,1 $\mu\text{m}$	79 m x 82 m

(No mid-IR bands)

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

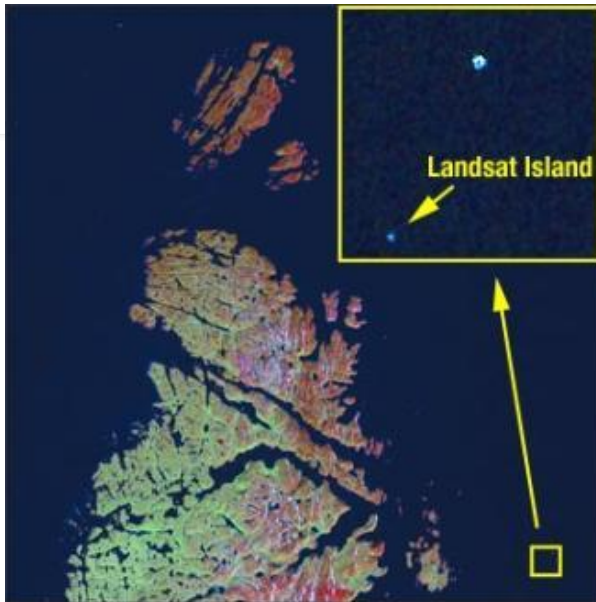


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## Landsat image data

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

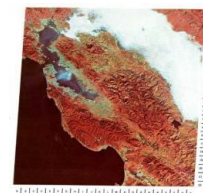
Verified by Dr. Frank Hall (Canadian Hydrographic Service). He was strapped into a harness and lowered from a helicopter down to the island. As he was lowered out of the helicopter, a polar bear took a swat at him.

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

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

Band No.	Wavelength Interval ( $\mu\text{m}$ )	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



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

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## 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 $\mu\text{m}$	20m x 20m
	XS2	0,61 - 0,68 $\mu\text{m}$	20m x 20m
	XS3	0,79 - 0,89 $\mu\text{m}$	20m x 20m
P-panchromatique	PAN	0,51 - 0,73 $\mu\text{m}$	10m x 10m

SPOT 4- 5: 1998, 2002

Mode	Band	Spectral band	Resolution
Multispectral	B1	0,50 - 0,59 $\mu\text{m}$	20m x 20m
	B2	0,61 - 0,68 $\mu\text{m}$	20m x 20m
	B3	0,79 - 0,89 $\mu\text{m}$	20m x 20m
	MIR	1,58 - 1,75 $\mu\text{m}$	20m x 20m
M - monospectral	PAN	0,61 - 0,68 $\mu\text{m}$	10m x 10m

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### 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	<b>185km</b>	60km
Repeat coverage	16 days	26 days
Sensor	Thematic Mapper (TM)	High Resolution Visible (HRV)
Number of detectors	100	6000/3000
Advantages	<b>#bands, swath size</b>	<b>higher resolution, # 'looks'</b>
Bands	7	3 + 1 (no MIR bands)
Scanner type	Mirror (Whisk broom)	Pushbroom

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## 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](http://geobase.ca)

Otherwise - Not Free !

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

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## Landsat image data

*Not the only land image data but ..*

➤ The most accessible/downloadable  
- free after 2008

➤ Longest continuous record: 1972 (1984)



Landsat 1

➤ Suitable resolution (30m) for northern environments

➤ Suitable scale for landscape analysis

➤ These factors enabled it for Google Earth mosaic

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## 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

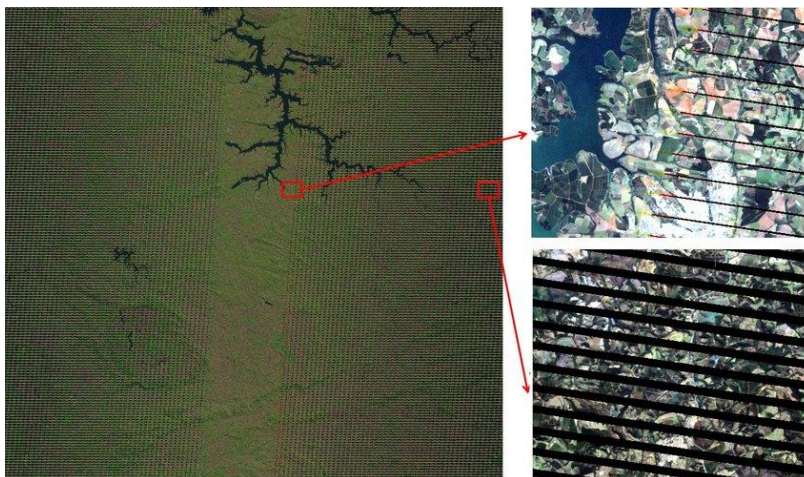
*[Overlap for Landsat scenes is 14% at equator, 45% at 50 degrees ]*

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### **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



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## 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 $\mu\text{m}$	30 m
1	Band 2 - Blue	0.450 - 0.515 $\mu\text{m}$	30 m
2	Band 3 - Green	0.525 - 0.600 $\mu\text{m}$	30 m
3	Band 4 - Red	0.630 - 0.680 $\mu\text{m}$	30 m
4	Band 5 - Near Infrared	0.845 - 0.885 $\mu\text{m}$	30 m
5	Band 6 - Short Wavelength Infrared	1.560 - 1.660 $\mu\text{m}$	30 m
7	Band 7 - Short Wavelength Infrared	2.100 - 2.300 $\mu\text{m}$	30 m
ETM+	Band 8 - Panchromatic	0.500 - 0.680 $\mu\text{m}$	15 m
8	Band 9 - Cirrus	1.360 - 1.390 $\mu\text{m}$	30 m

OLI Spectral Bands <sup>[13]</sup>

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## Landsat 8 successfully launched February 2013

### Thermal InfraRed Sensor TIRS

- OLI + TIRS = 2 sensors on one platform

	Spectral Band	Wavelength	Resolution
6	Band 10 - Long Wavelength Infrared	10.30 - 11.30 $\mu\text{m}$	100 m
	Band 11 - Long Wavelength Infrared	11.50 - 12.50 $\mu\text{m}$	100 m

TIRS Spectral Bands <sup>[13]</sup>

[http://landsat.usgs.gov/L8\\_band\\_combos.php](http://landsat.usgs.gov/L8_band_combos.php)

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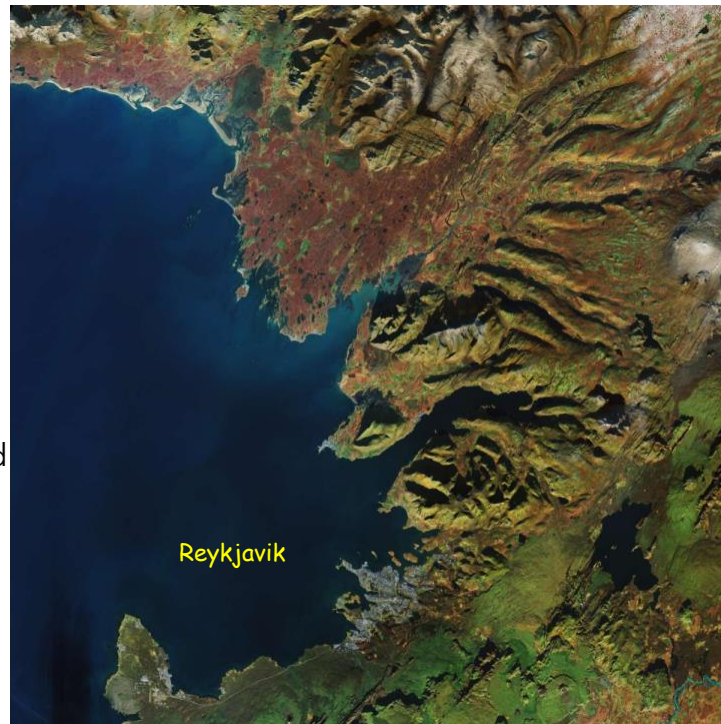
**European  
Space Agency  
(ESA)**

**Copernicus  
Program**

Sentinel 2a,b  
2015/17

free download

Multi-Spectral  
Instrument (MSI)  
10 / 20m



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

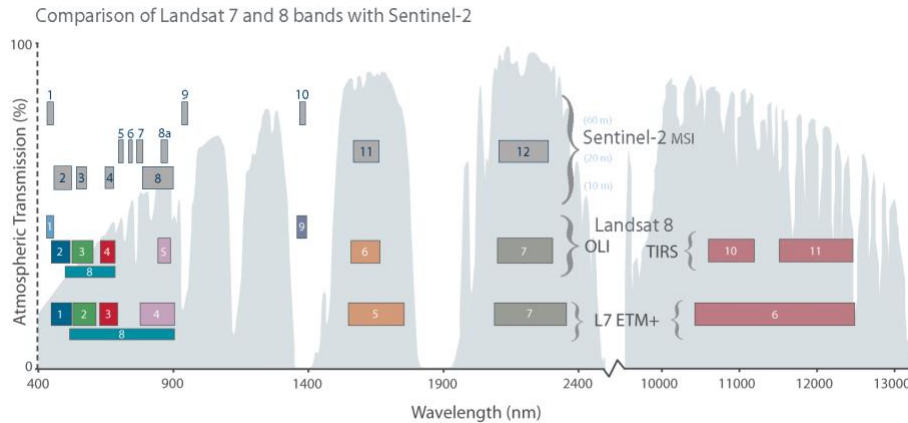
<b>Sentinel-2 Bands</b>	<b>Central Wavelength (µm)</b>	<b>Resolutio n (m)</b>
<b>Band 1 - Coastal aerosol</b>	<b>0.443</b>	<b>60</b>
<b>Band 2 - Blue</b>	<b>0.490</b>	<b>10</b>
<b>Band 3 - Green</b>	<b>0.560</b>	<b>10</b>
<b>Band 4 - Red</b>	<b>0.665</b>	<b>10</b>
<b>Band 5 - Vegetation Red Edge</b>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

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

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## 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+

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## Optical 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 -including very high resolution (see later lectures)

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## Earth Observing satellite systems

[https://en.wikipedia.org/wiki/List\\_of\\_Earth\\_observation\\_satellites](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/>

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### **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)**

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