Lesson 10: Introduction to Earth Observation- Data sources and access

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Overview of topics

Program of the day

- ❑ Data Acquisition
- ❑ EO basics
- ❑ Sensor classification and properties
- ❑ Images examples
- ❑ Exercises

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Learning Objectives

At the end of this subject, students should be able to:

- Explain the basics of Earth Observation (EO)
- Select appropriate sensors and image data for geospatial problem solving

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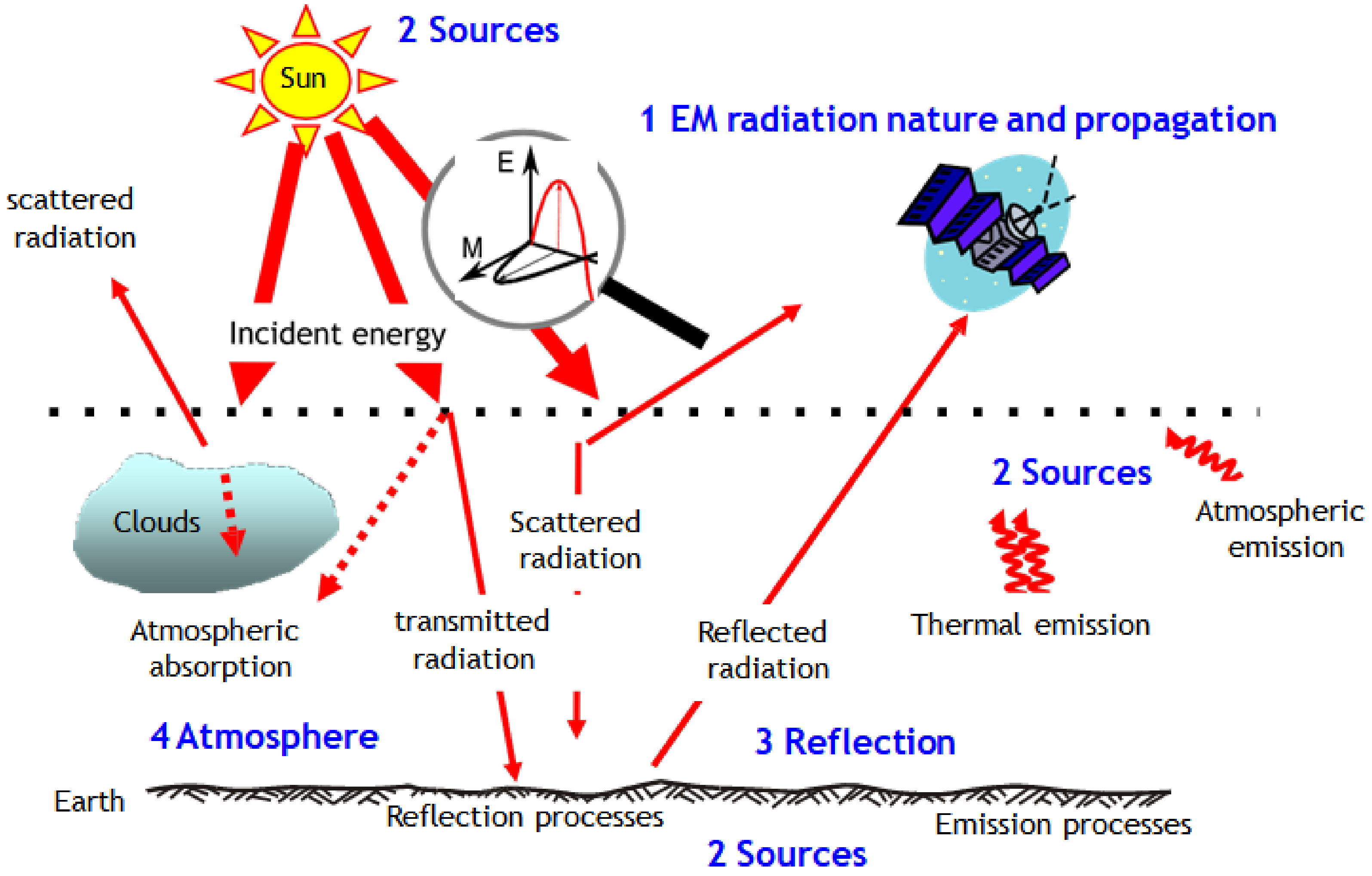
EO Data Acquisition



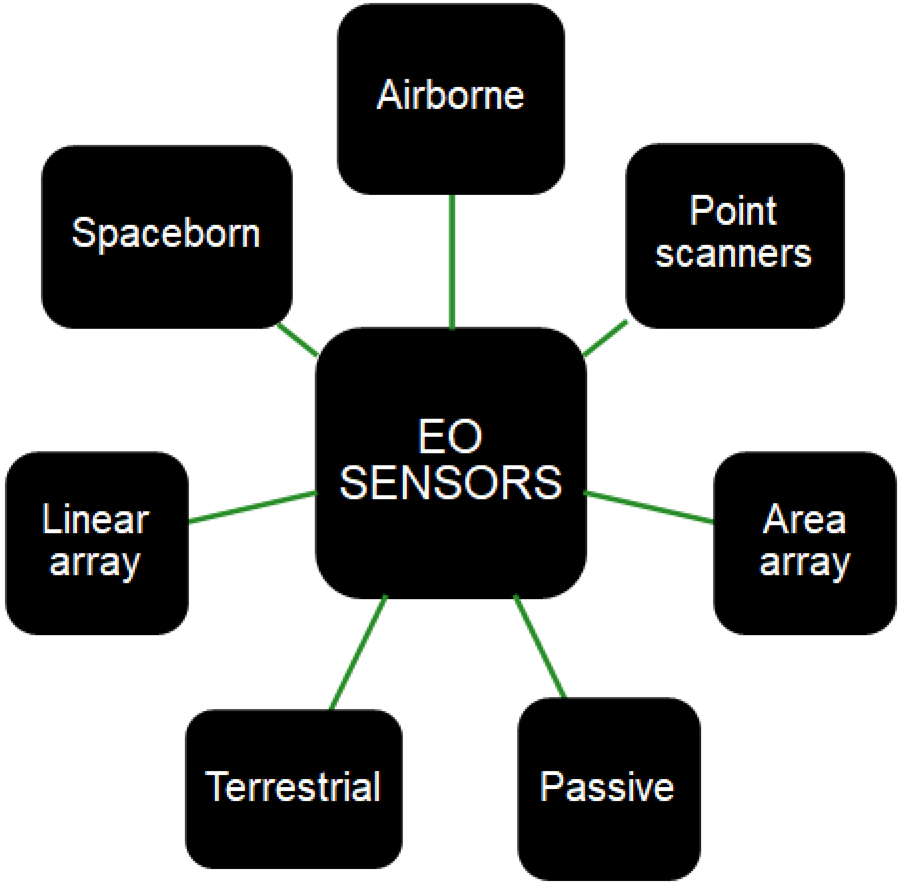
Data Acquisition

Data acquisition

- **is process of obtaining the reliable information about the properties of surfaces and objects.**
- is accomplished **without physical** contact with the objects
- Used as primary data for many applications
- Wide variety of data sources which acquire different product types
- **Type of imagery requirement depends on mapping/ other tasks**

Eo sensors classes

EO sensors are used for the collection of data which are typically used for remote sensing image analysis.



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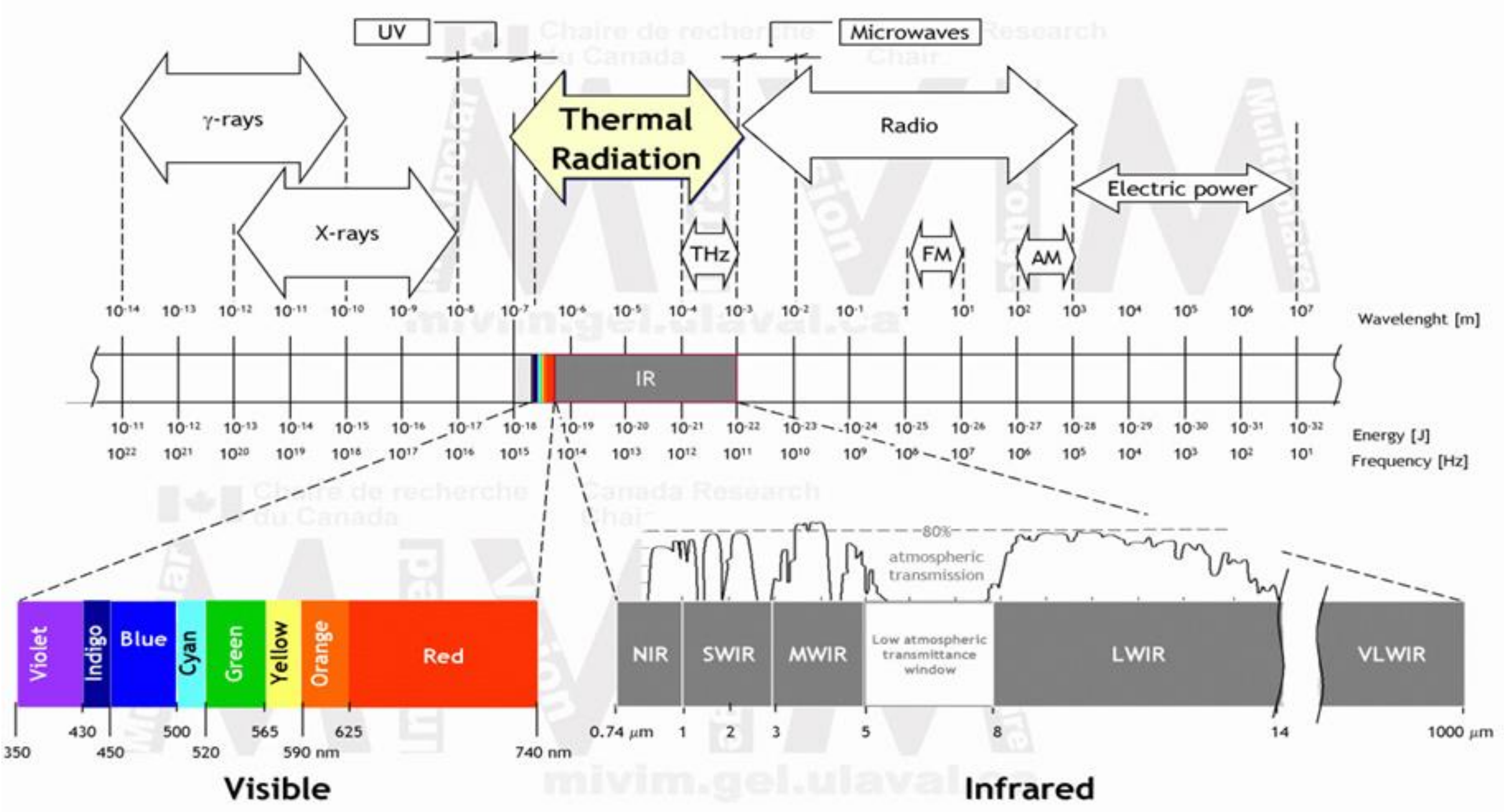
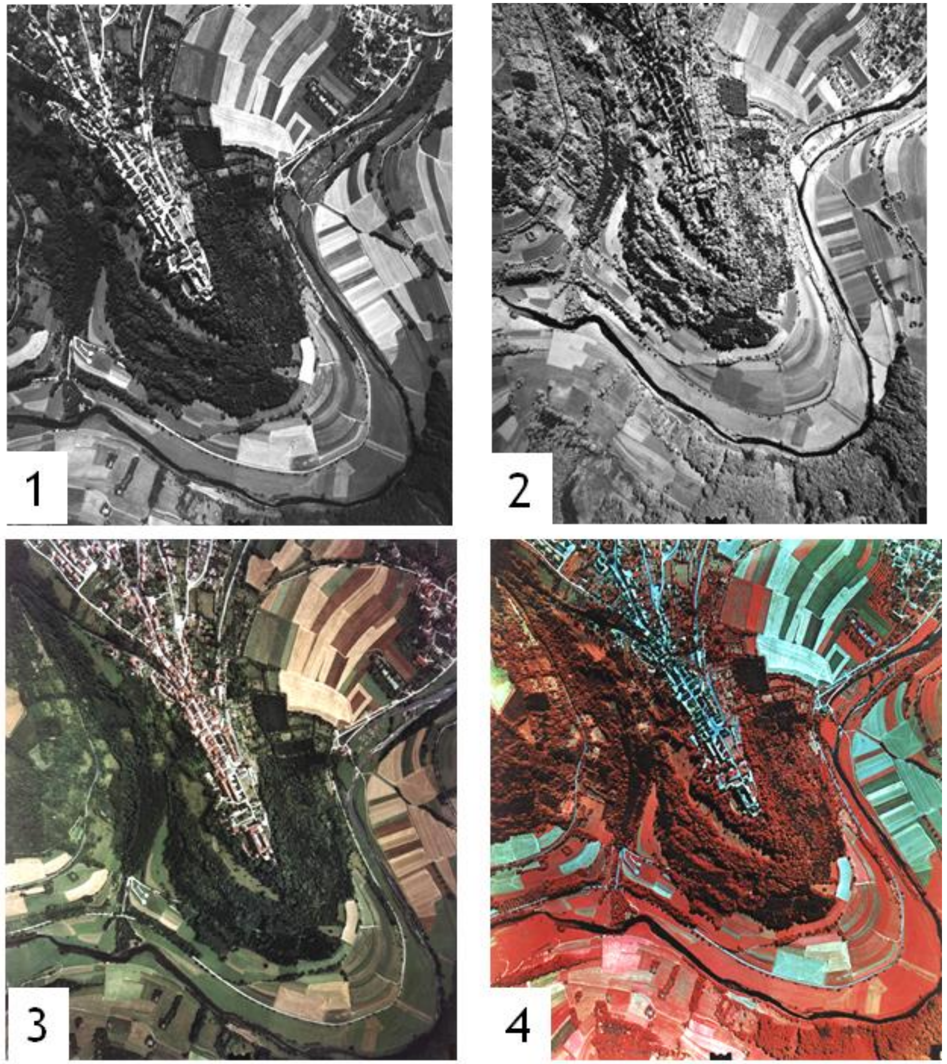
Electromagnetic spectrum (Fig.: C. Ibarra-Castanedo)

An image refers to any pictorial representation, regardless of what **wavelengths** or remote sensing device has been used to **detect and record the electromagnetic energy**



Images with different Appearance

Recording different wavelengths of electromagnetic spectrum



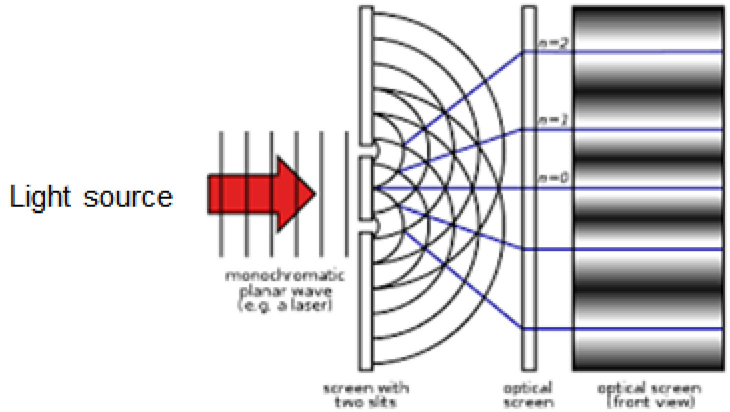
1. B&W Panchromatic :
2. B&W (Near) Infra Red
3. True color
4. False color

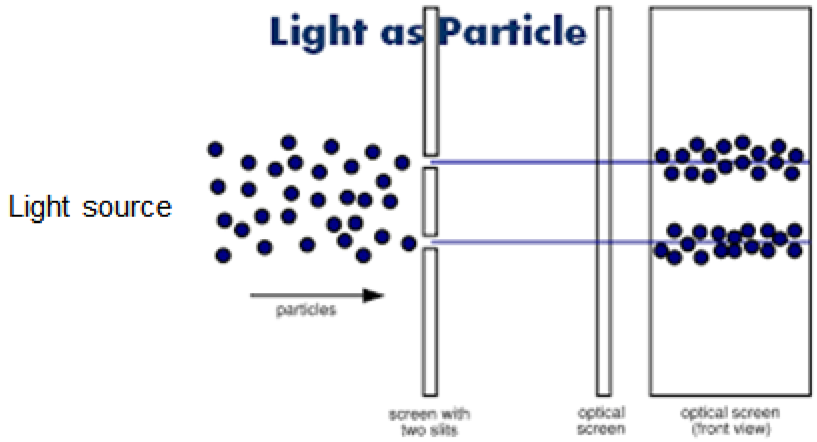
The Electromagnetic Radiation (EMR)

- Light is a “subset” of Electromagnetic (EM) radiation.

EMR keeps its secret… There is not a single theory that applies to all cases. Based on experimentation and the behavior of light during experiments, EMR can be modeled in 2 ways:

- EMR as a wave
- EMR as composed by photons (“particles” made of energy)

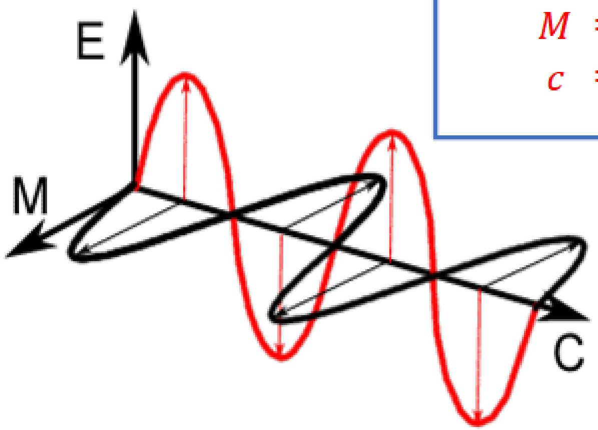




The Electromagnetic Radiation (EMR) : Wave model

- EMR travels as waves
- EMR Waves (not any wave) are characterized by 2 fields: Electric & Magnetic
- The 2 fields oscillate in an space orthogonal to each other and to the direction of travel.
- They support each other and can travel for ever at the speed of light. In space:

$$c = 299\,792\,458 \text{ ms}^{-1} = 3 \cdot 10^{8} \text{ ms}^{-1}$$

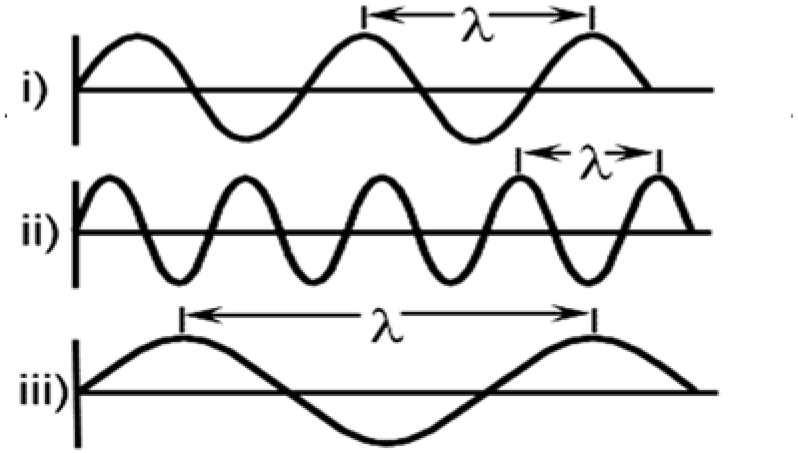


E = Electric vector
M = Magnetic vector
c = speed of light

The Electromagnetic Radiation (EMR) : Wavelength and cycle

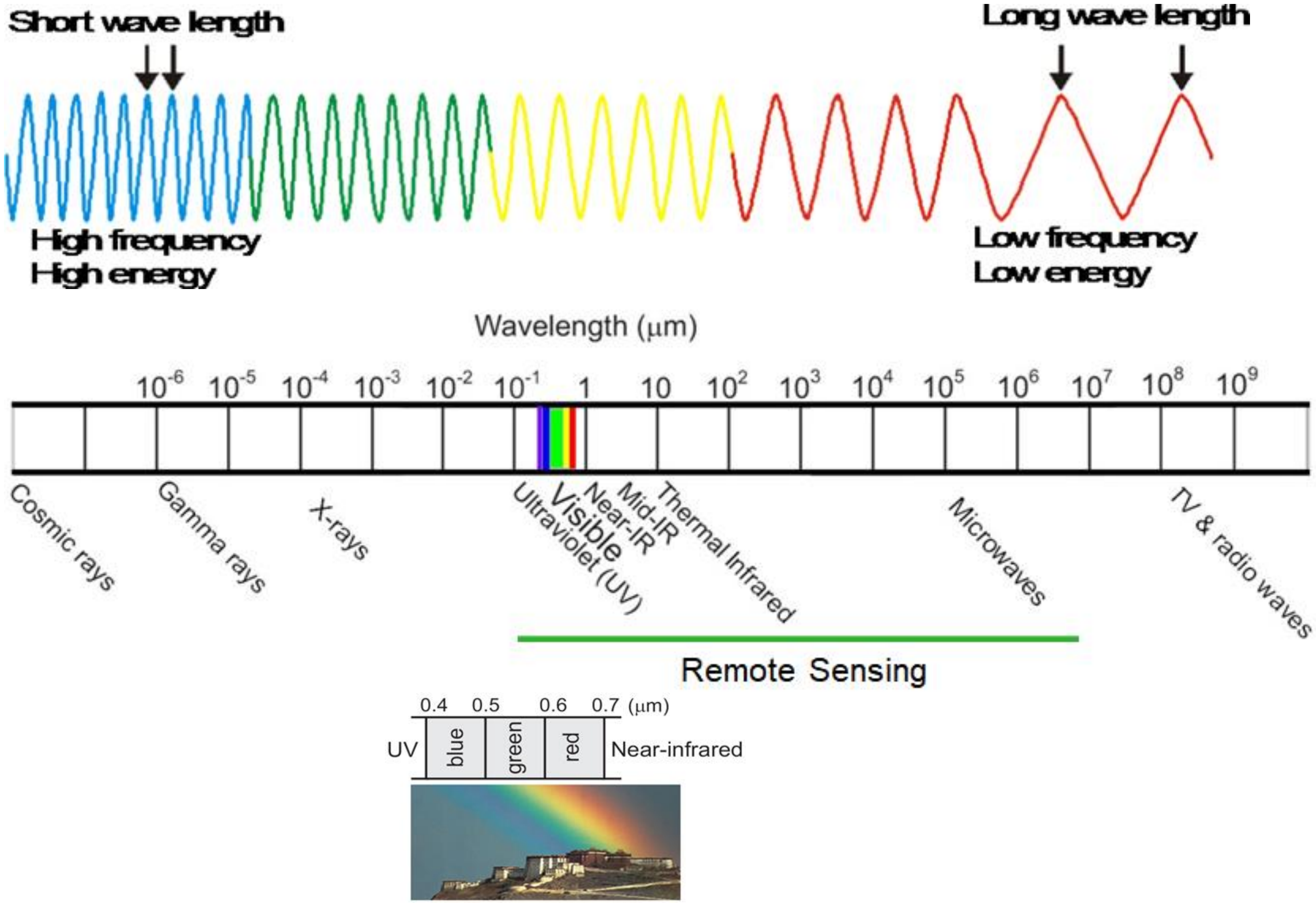
- Wavelength ‘λ’ [units of length: μm, nm, cm, m] is the distance between 2 crests (or two valleys)
- Frequency 'ν' [units of cycles per time: 1/sec] is the number of cycles passing a fixed point per second.
- Frequency is inversely proportional to wavelength (c is constant)

$$c[\underline{n}] = \lambda \cdot \nu$$

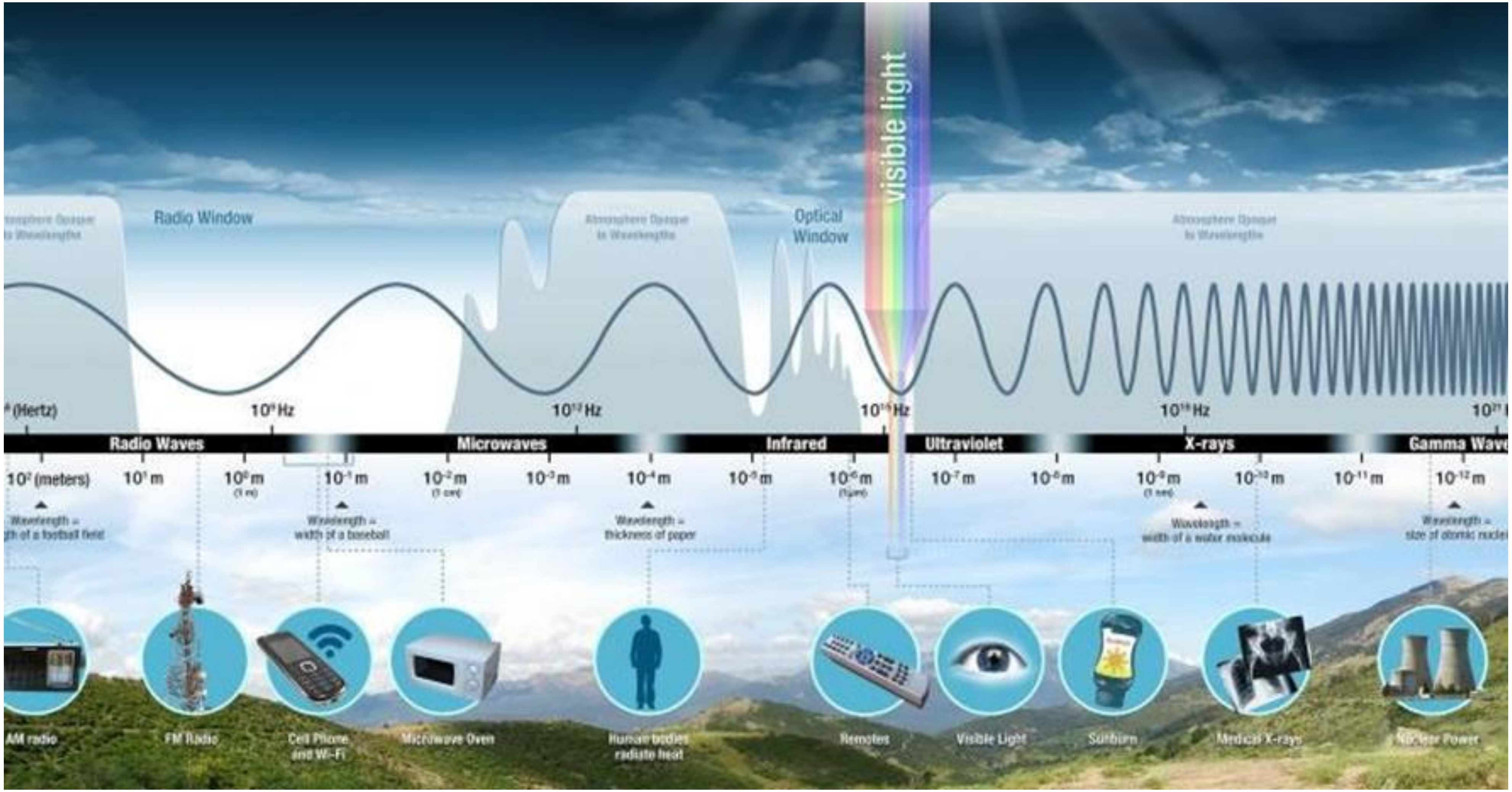


- Units in this equation 'λ' in metres [m]"
- ν in s^{-1} =[Hz] (hertz)

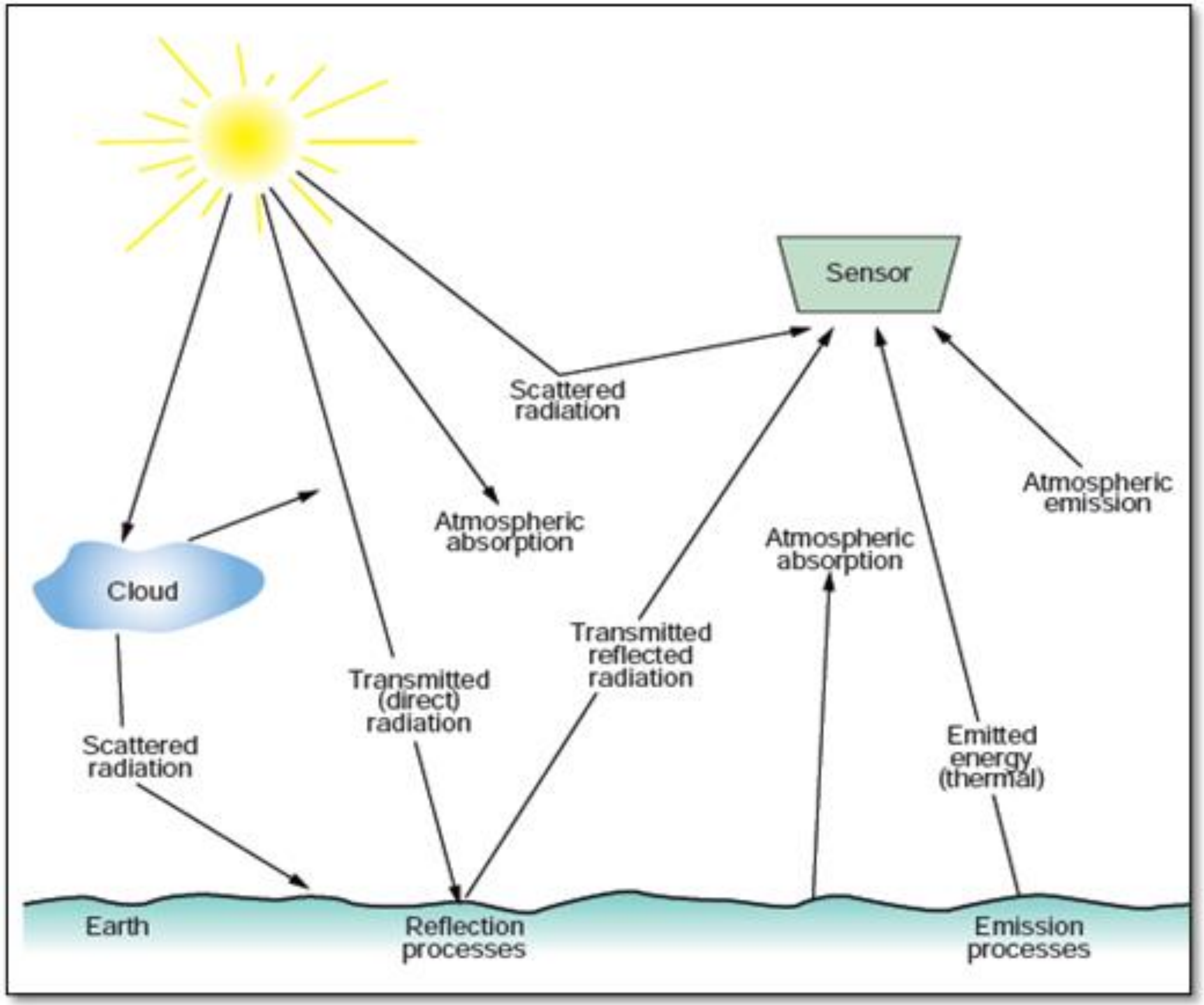
The EM spectrum - 1



The EM spectrum-2



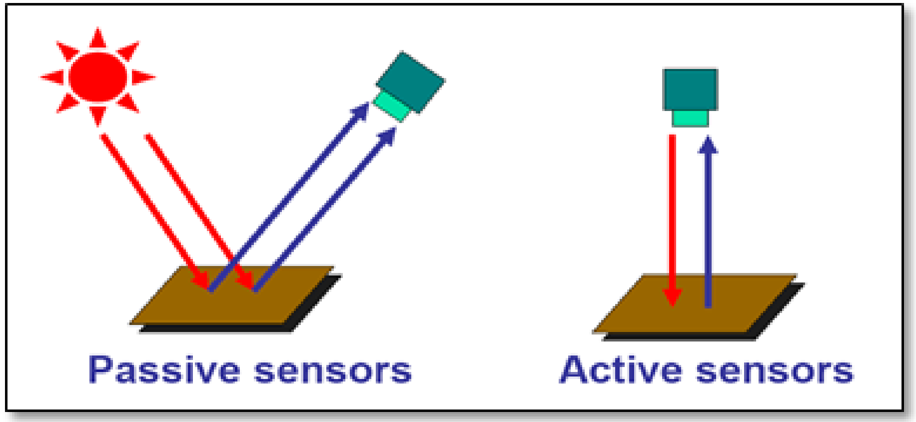
How EM radiation interacts with objects!



Sensors are instruments capable of measuring and recording EM radiation.

Two types:

- Active sensors
- Passive sensors



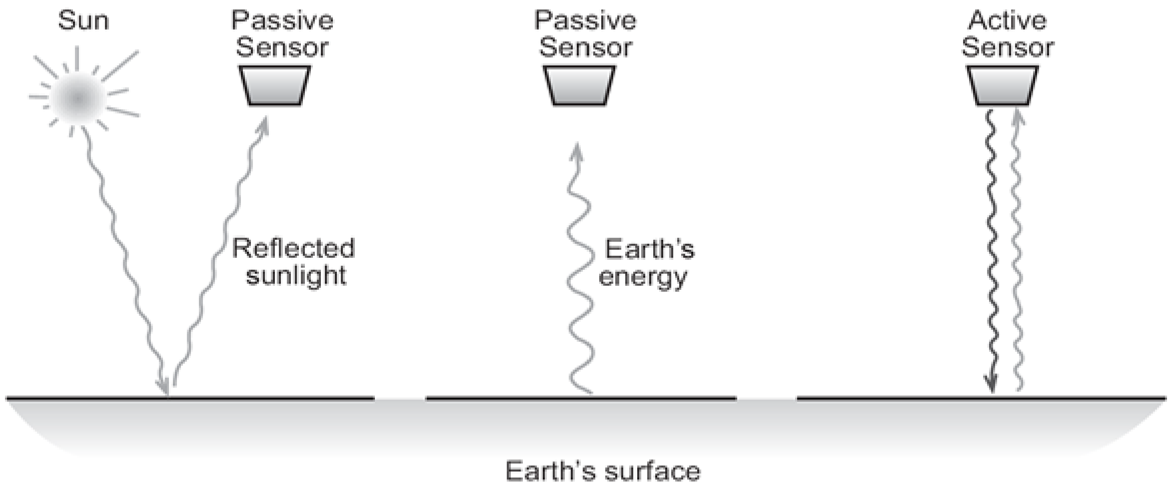
Active-Passive Sensors

- Passive systems record energy reflected or emitted by a target

  e.g. normal photography, most optical satellite sensors

- Active systems illuminate target with energy and measure reflection

  e.g. RADAR sensors, LIDAR

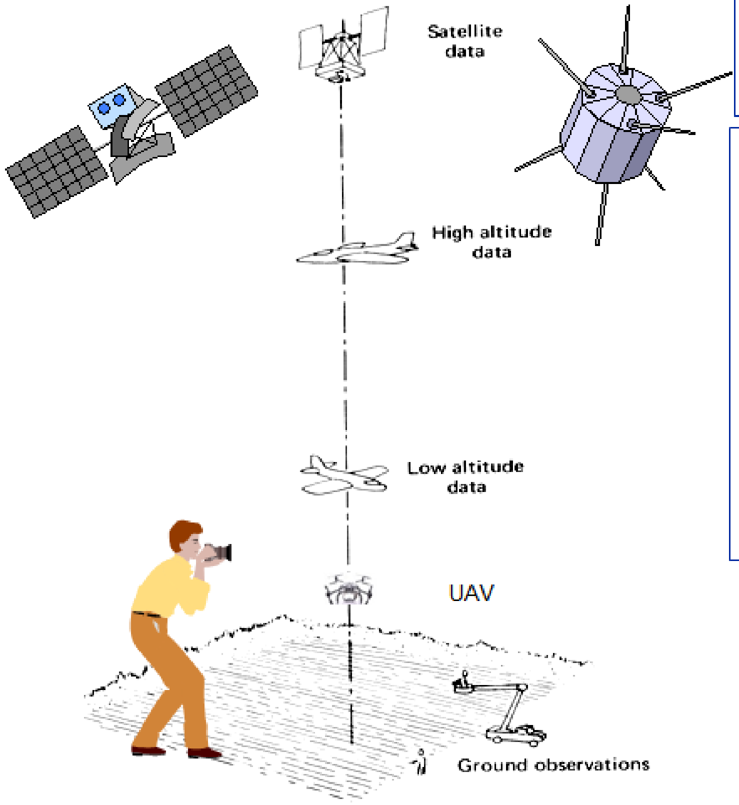


Sensor classification

Data Acquisition - **Platforms carry Sensors!!**

The same sensor can be settled in different platforms!

Sensors can be classified with respect to the platforms !!



Sensing from 1 meter to 36,000 km height

Sensors are mounted on Platforms:

- **Satellites/ Spaceborn** : polar-orbiting, equatorial, geostationary
- **Airborne/ Aircraft** (manned and unmanned - UAV)
- Ground-based

Multispectral Sensors

- A multispectral sensors records the reflected radiation simultaneously in different wavelength bands or spectral ranges
- Acquires multiple images

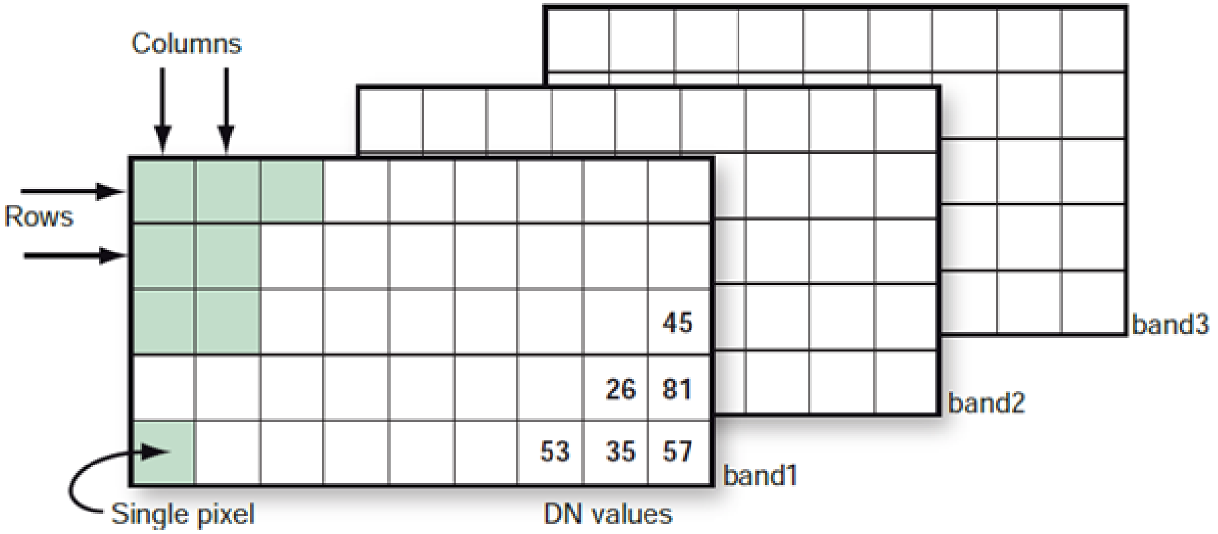
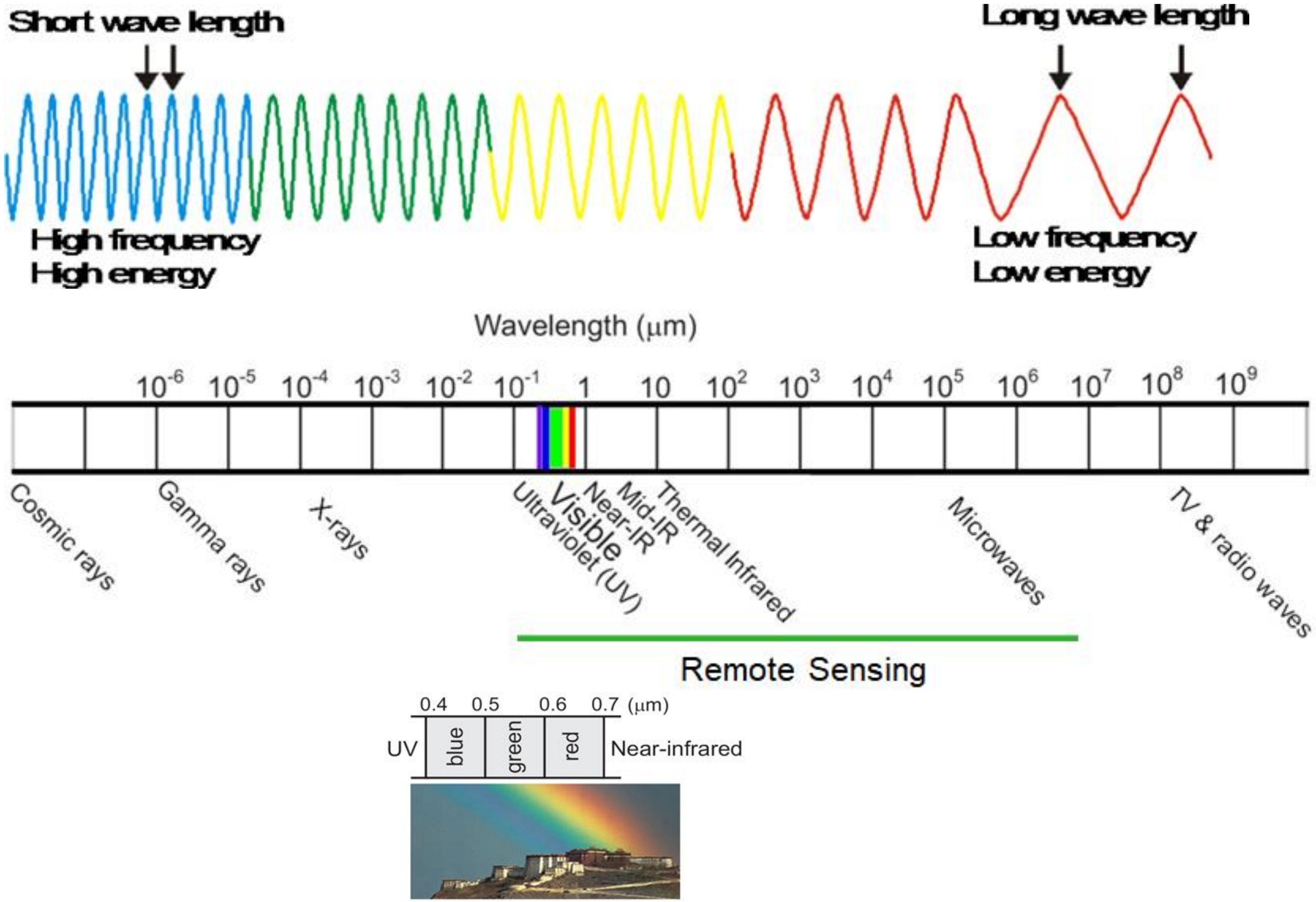


Figure 2.20
An image file comprises a digital image for each of the spectral bands of the sensor. The DN values for each band are stored in a row-column arrangement.

The EM spectrum



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Panchromatic Sensors

- Sensors records the intensity of radiation of a broad spectral bands-

  Acquires a **black-and-white** imagery exposed by all visible light

- Typical wavelength range, between 0.50-0.80 μm
- A panchromatic sensor produces images with much finer spatial resolution compared to the Multispectral sensor aboard on the same satellite

(Qian 2013)

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Resolutions

Spatial resolution (geometric)

Low resolution	$\geq$30m < 300m
Medium resolution	$\geq$5m < 30m
High resolution	$\geq$2m < 5m
Very high resolution < 2m	

Spectral resolution

Panchromatic (originally specified as visible range of spectrum, now often extended to NIR)

Multispectral $\geq$ 3 spectral bands (RGB, RGB NIR + MIR)

Hyperspectral $\geq$ 30 spectral bands (lower resolution)

Temporal resolution

Revisit Time

Radiometric resolution

8, 16, 32 bits

PAN-SHARPENING

Fusion between high spatial resolution and Multispectral resolution

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Example of Multispectral sensors – Landsat Series

Table 2.1 Characteristics of selected satellite sensors. (Adapted from Rogan and Chen 2004; updated for this publication)

Sensor (mission)	Organization[a]	Operation period	Swath width (km)	Spatial resolution (m)[b]	Temporal resolution	Radiometric resolution	Spectral resolution (µm)	Spectral bands
MSS (Landsat 1–5)	NASA, US	1972–1992	185	80 (MS), 240 (TIR)[c]	16–18 days	8-bit	0.5–1.1, 10.4–12.6[c]	4–5[c]
TM (Landsat 4, 5)	NASA, US	1982–2011	185	30 (MS), 120 (TIR)	16 days	8-bit	0.45–2.35, 10.4–12.5	7
ETM+ (Landsat 7)	NASA, US	1999	185	15 (PAN), 30 (MS), 60 (TIR)	16 days	8-bit	0.52–0.9 (PAN), 0.45–2.35, 10.4–12.5	7 + PAN
OLI (Landsat 8)	NASA, US	2013	185	15 (PAN), 30 (MS)	16 days	12-bit	0.5–0.68 (PAN), 0.433–0.453 (coastal/aerosol), 0.45–2.3, 1.36–1.39 (cirrus)	8 + PAN
TIRS (Landsat 8)	NASA, US	2013	185	100	16 days	12-bit	10.6–11.2, 11.5–12.5	2

a *NASA* National Aeronautics and Space Administration,
b Acronyms used in describing sensor channels/configurations: *PAN* panchromatic, *MS* multispectral, *VNIR* visible and near-infrared, *SWIR* short-wave infrared
TIR thermal infrared
c The MSS sensor on Landsat 3 had a fifth spectral band for thermal infrared. The MSS sensors on other Landsat missions had four-band configurations

- The Landsat series of satellites provides the longest continuous record of satellite-based observations.
- It is a valuable source **for monitoring global change**

(Khorram et al. 2016)

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Example of Applications of Multispectral sensors

Table 2.3 Capabilities and applications of Operational Land Imager (OLI) and thermal infrared sensor (TIRS) spectral bands. (Material adapted from Jensen 2005 and the US Geological Survey's Landsat Missions Web site, http://landsat.usgs.gov/)

Sensor	Band	Capabilities/applications
OLI	Band 1 (coastal/aerosol)	Analysis of coastal waters and atmospheric aerosol concentrations
OLI	Band 2 (blue)	Penetrating water bodies; analysis of land use, soil, and vegetation
OLI	Band 3 (green)	Discriminating healthy green vegetation
OLI	Band 4 (red)	Vegetation discrimination; delineation of soil and geologic boundaries
OLI	Band 5 (near-infrared)	Crop identification; emphasizes soil–crop and land–water contrasts
OLI	Band 6 (mid-infrared)	Drought studies; discrimination between clouds, snow, and ice
OLI	Band 7 (mid-infrared)	Discrimination of geologic rock formations
OLI	Band 8 (panchromatic)	Pan-sharpening to improve spatial resolution of multispectral data

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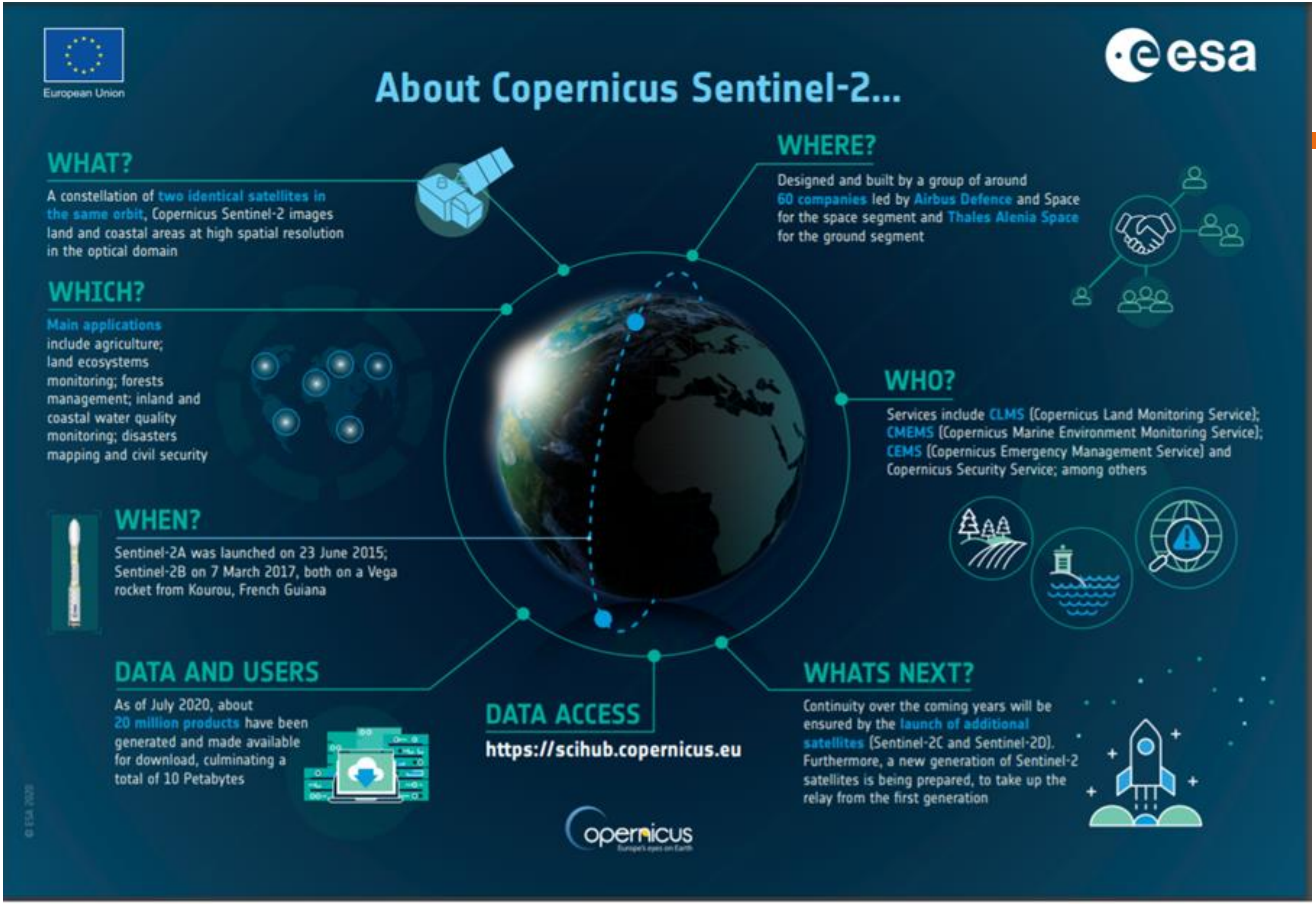


Example of Multispectral sensors –Sentinel 2

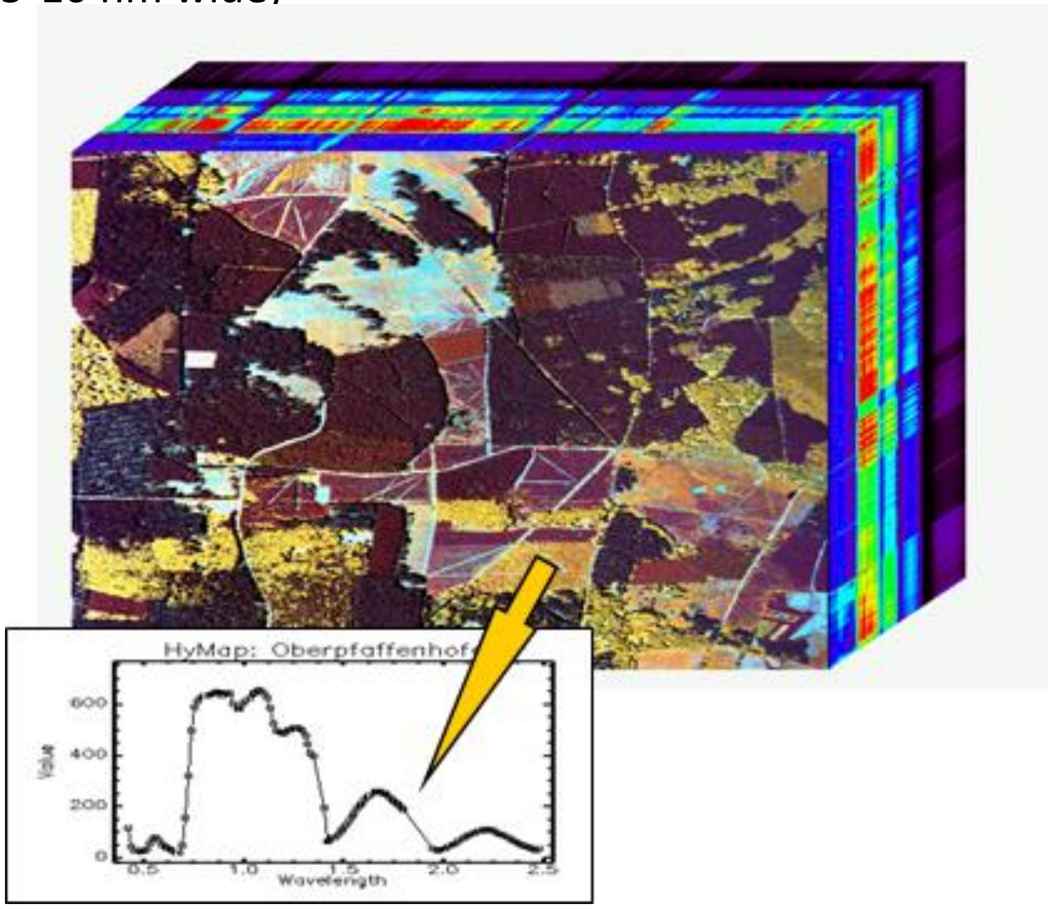
- It Is Wide-swath, High-resolution, Multi-spectral imaging mission
- 13 spectral bands: four bands at 10 metres, six bands at 20 metres and three bands at 60 metres spatial resolution.
- Global mission coverage, and High revisit time
- Interested thematic areas such as:

  Spatial planning, agro-environmental monitoring, water monitoring, forest and vegetation monitoring, land carbon, natural resource monitoring, global crop monitoring

Hyperspectral sensor

- Measures many (very narrow), continuous spectral bands (e.g. 5-10 nm wide)
- Acquires images in hundreds of spectral bands simultaneously
- Continuous reflection curves

- Wavelengths range from the near-ultraviolet to the SWIR
- Application: vegetation studies (chlorophyll content), geology (mineral composition), etc.



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Main remote sensing satellite systems.

Name	Funding, operator	Launch	Country	Constellation	Sensor	GSD range (m)	Swath width (km)	Revisit time (day)
Ikonos-2	Commercial	1999	USA	Single	PAN	0.8 × 0.8	11.3	3
					4 MS	3.2 × 3.2		
QuickBird-2	Commercial	2001	USA	Single	PAN	0.7 × 0.7	16.8–18	1–3.5
					4 MS	2.6 × 2.6		
RapidEye[a]	Commercial	2008	Germany	Five	5 MS	6.5 × 6.5	77	1–5.5
Pleiades 1	Commercial, government and private	2011	France	Dual	PAN	0.5 × 0.5	20	1
	partnership	2012			4 MS	2 × 2		
SPOT 6	Commercial	2012	France	Dual	PAN	1.5 × 1.5	60	1–5
SPOT 7		2014			4 MS	6 × 6		
Landsat-8	Government	2013	USA	Single	PAN	15 × 15	185	16
					11 MS	30 × 30		
SkySat	Commercial	2013	USA	2 (2014)	PAN	1.1 × 1.1	2 × 1	0.5 (2015)
					video			
		2014		3 (2015)	PAN	0.9 × 0.9	8	0.12 (2017)
		2015		24 full	4 MS	2 × 2		
WorldView-3	Commercial, government and private	2014	USA	Single	PAN	0.3 × 0.3	13.1	1–4.5
	partnership				8 MS	1.2 × 1.2		
					8 MS	3.7 × 3.7		
					(SWIR)			
					12 MS	30 × 30		
Planet Labs	Commercial	2014	USA	Flock of sats. (100+)	PAN	3 × 3	Unknown	Unknown
		2015			3 MS	5 × 5		
DMC-3	Commercial	2015	UK	Triple	PAN	1 × 1	23	1
					4 MS	4 × 4		
Sentinel-2	Government	2015	EU	Dual	13 MS	10 × 10	290	10
						20 × 20		
		2016				60 × 60		5 (dual)
Sentinel-3	Government	2015	EU	Dual (triple planned)	21 MS	300 × 300	1270	0.25
		2017			11 MS	500 × 500	1420	
					(IR)	1000 × 1000	750 (nadir)	
Terra	Government	1999	USA	Single	14 MS	15 × 15	60	16
			Japan		(IR)	30 × 30		
			Canada		36 HSI	90 × 90		
						250 × 250		
						500 × 500		
						1000 × 1000		

Main remote sensing satellite systems

						1000 × 1000		
Aqua	Government	2002	USA	Single, part of A-Train	36 HSI	250 × 250 500 × 500 1000 × 1000	2330	1–2
EnMAP	Government	2017	Germany	Single	232 HSI	30 × 30	30	4
ICESat	Government	2003	USA	Single	2 HSI	70 (footprint)	N/A	8
ICESat-2	Government	2018	USA	Single	1 HSI (9-beam)	10 (footprint)	N/A	N/A
Envisat	Government	2002	EU	Single, tandem with ERS-2	C-band SAR	28 × 28 150 × 150 950 × 980	5 100 400	35 (orbit repetition)
RADARSAT-2	Government and private partnership	2007	Canada	Single	C-band SAR	3 × 3 100 × 100	20 500	24 (orbit repetition)
TerraSAR-X	Government	2007	Germany	Single	X-band SAR	1 × 1 16 × 16	5 × 10 1500 × 100	11
TanDEM-X	Government and private partnership	2010	Germany	Single, tandem with TerraSAR-X	X-band SAR	1 × 1 3 × 3 16 × 16	5 × 10 1500 × 30 1500 × 100	11
Sentinel-1	Government	2014 2016	EU	Dual	C-band SAR	5 × 5 5 × 20 25 × 40	80 250 400	12 6 (dual)

HSI: Hyperspectral Imager, 1 HSI: LiDAR, one narrow band active HSI, 2 HSI: LiDAR, two narrow band active HSI, PAN: Panchromatic, MS: Multispectral, IR: Infrared, SWIR: Short Wavelength Infrared, SAR: Synthetic Aperture Radar.
a Acquired by Planet Labs (Planet Labs, 2015).

(Toth & Jóźków, 2016)

MULTI-TEMPORAL IMAGERY

Spectral characteristics of **features may change over time and these changes** can be detected by analysing **multi-temporal** images.

Example applications:

- map updating,
- monitoring and disaster evaluation,
- illegal building detection
- change detection for canopy height or individual trees
- deforestation
- urban planning

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Search and Download images

Main things to remember

- Project requirements
- Study area
- Sensor type – Sensor characteristics
- Cloud cover
- Reference system
- Corrections – Radiometric and Geometric

•https://scihub.copernicus.eu/dhus/#/home
•https://earthexplorer.usgs.gov/

Questions?