GEOSPATIAL TECHNOLOGY
*** A virtual workshop ***
Kentucky State University
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Fundamentals and Applications of Remote Sensing

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AMERICA VIEW™

KENTUCKY STATE UNIVERSITY®
COLLEGE OF AGRICULTURE, COMMUNITIES, AND THE ENVIRONMENT

KENTUCKY VIEW

Outline

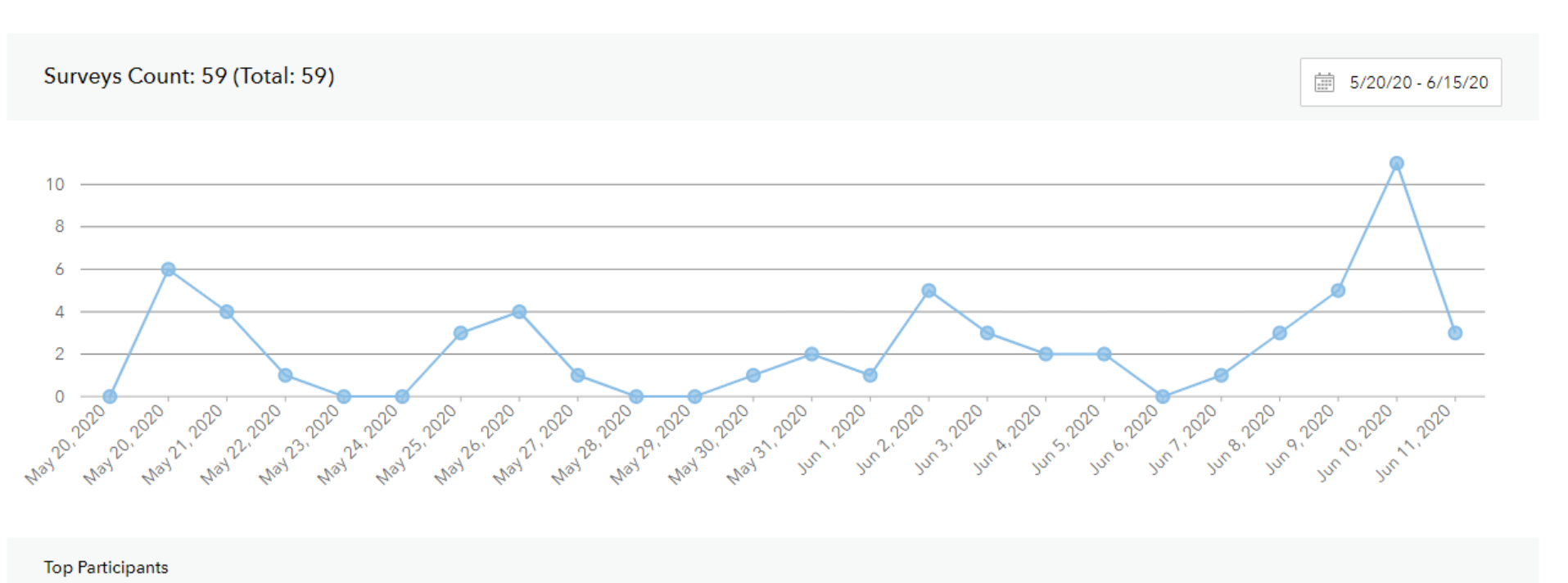
- General information
- Defining GIS
- Defining remote sensing
- Photography and photointerpretation
- The electromagnetic spectrum
- Types of resolutions
- Platforms and sensors
- Some demonstrations: Google Earth Pro, ArcGIS Online

General information…

- Program materials

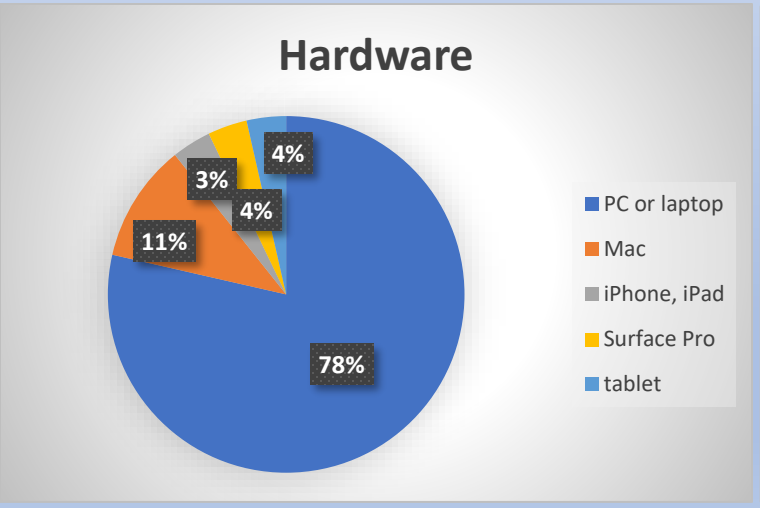
https://kysu.edu/wp-content/uploads/2020/05/Geospatial_Technology_Virtual_Workshop_061020.pdf

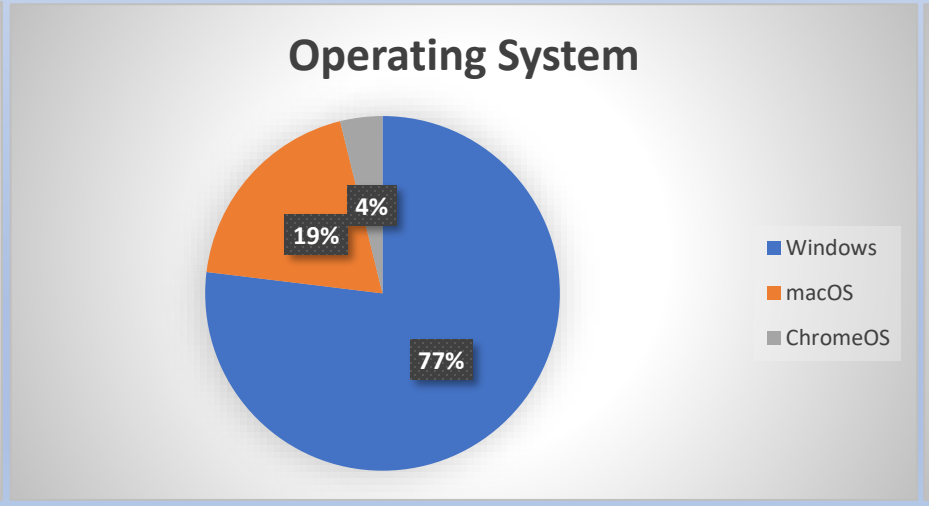
- Registration time trend

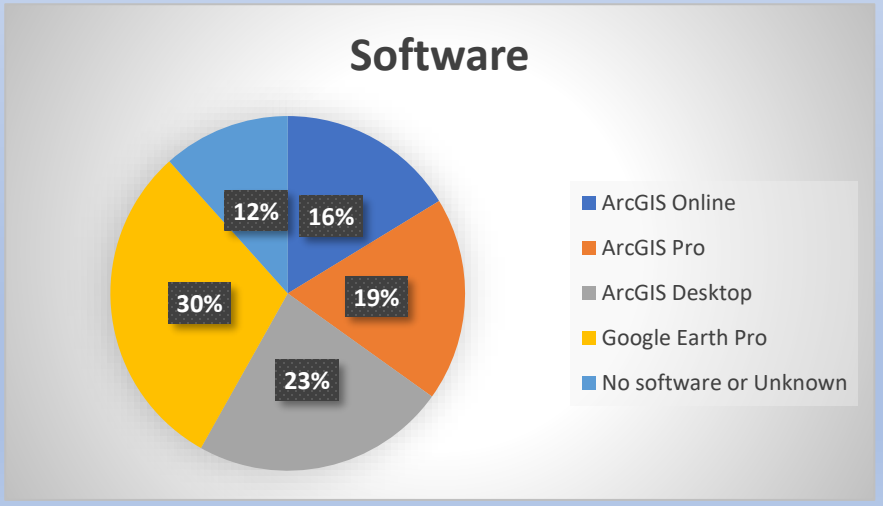


General information… (cont.)

- Geographies represented https://arcg.is/1zn80H
- Technological profile (sample)



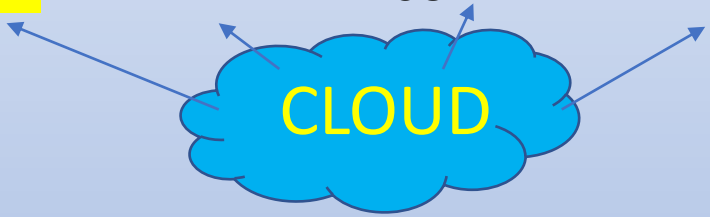




What is GIS?

A framework to organize, communicate, and understand the science of our world.

PEOPLE + HARDWARE + SOFTWARE + DATA



A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions.

DATA >>> INFORMATION >>> KNOWLEDGE >>> WISDOM >>> ….?

(https://www.esri.com/en-us/what-is-gis/overview)

Examples of GIS

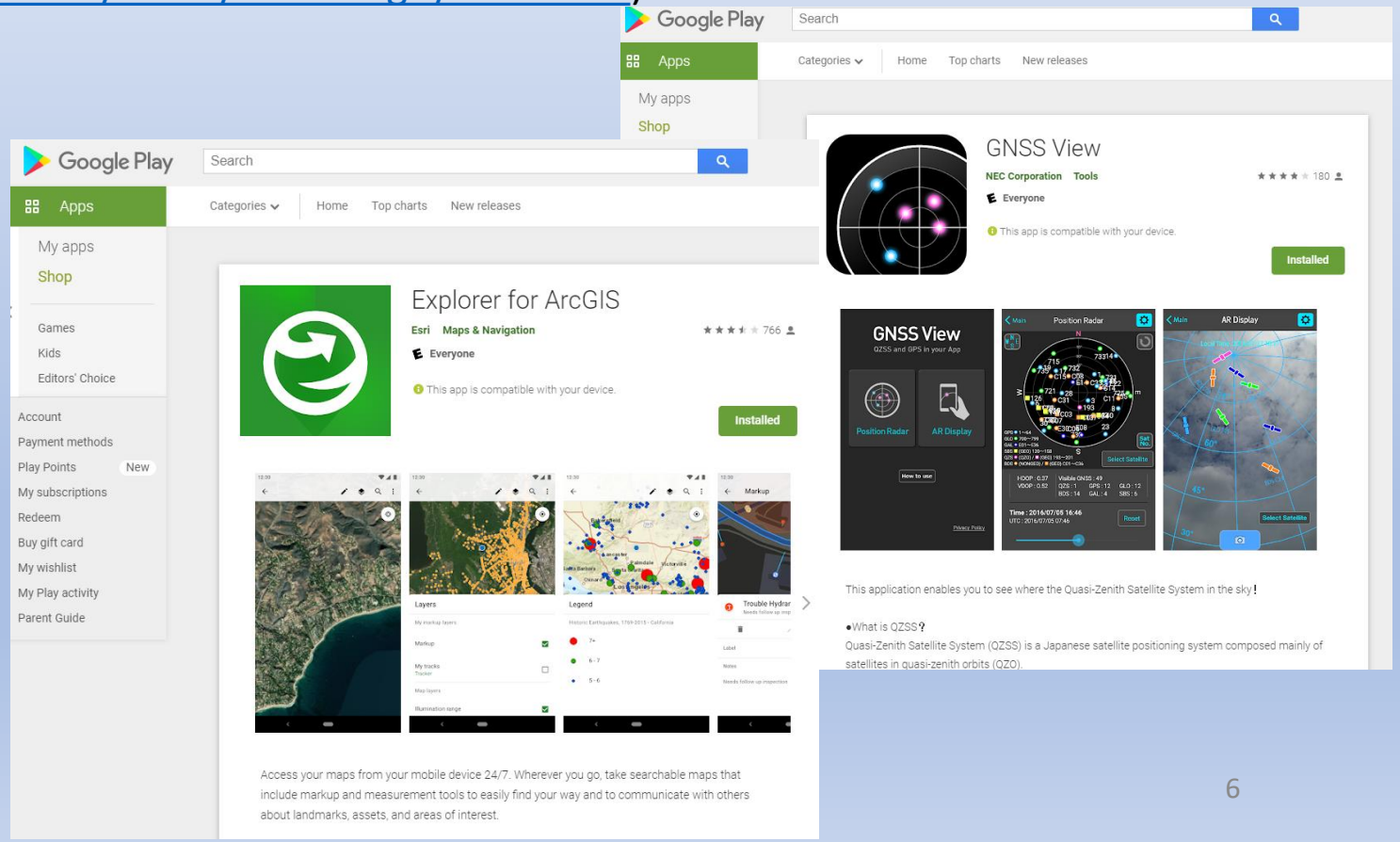
GIS maps do more than display and analyze data—they also tell powerful stories (https://www.esri.com/en-us/what-is-gis/showcase)

1- Web Maps

2- Mobile Apps

3- Desktop mapping apps

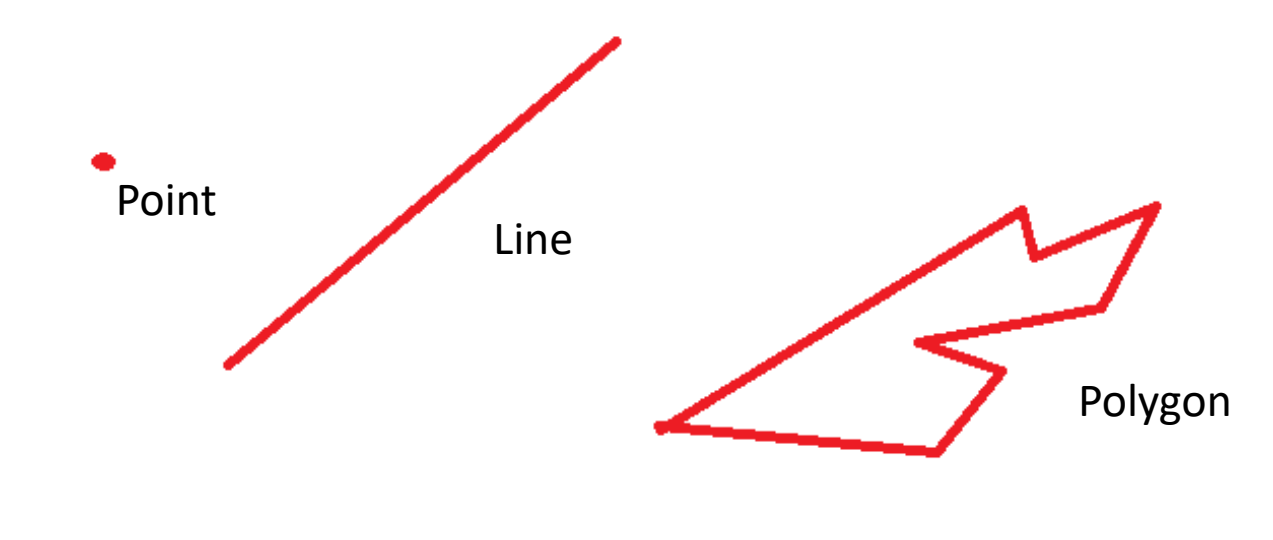
4- Other



Remote sensing software is part of a GIS!!

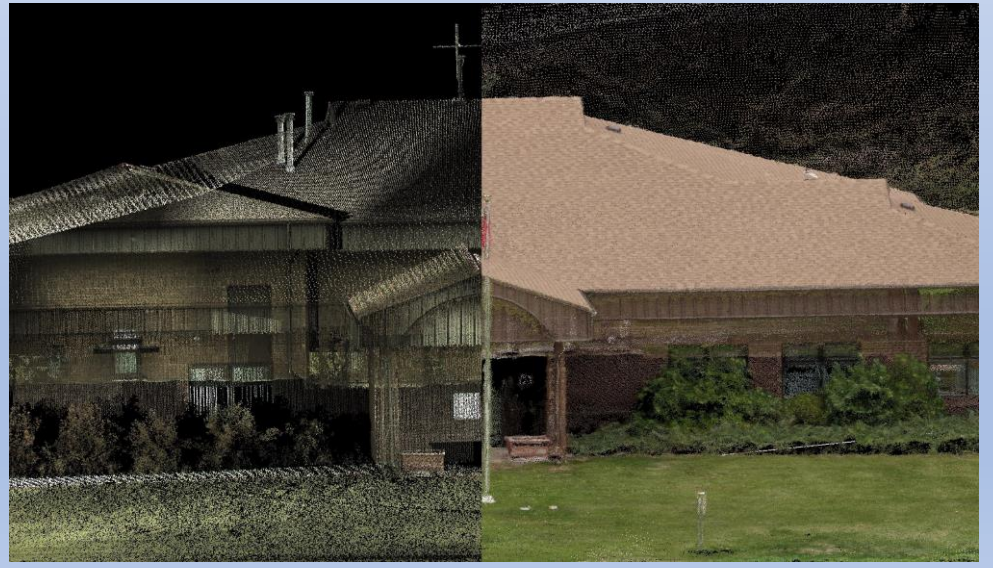
Data models…

- Vector data



- Point cloud (LiDAR and photogrammetric == drone imagery)

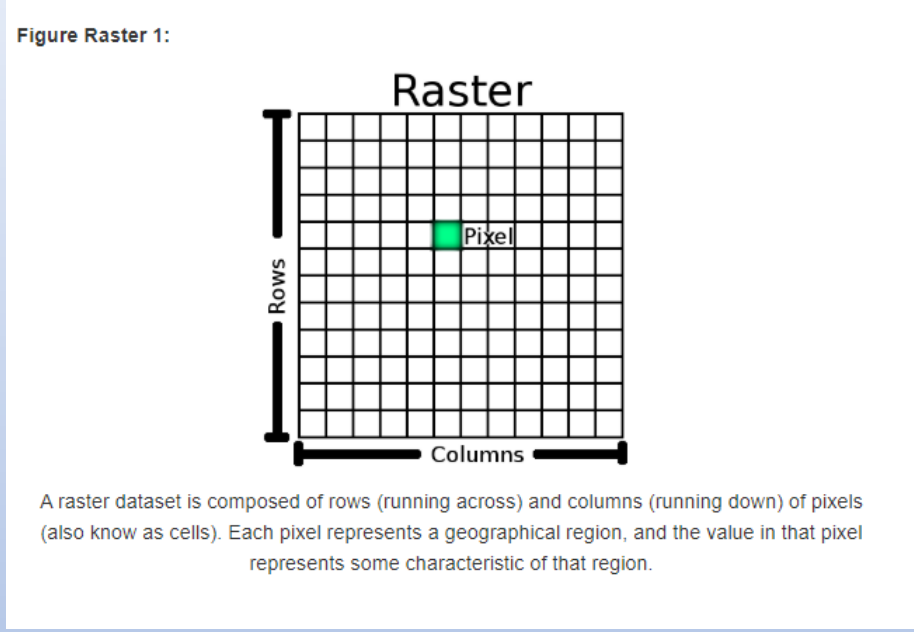
http://paradise.caltech.edu/~yli/software/pceditor.html



https://www.pix4d.com/blog/behind-the-scenes-of-pix4dmapper

… AND raster (grid) data

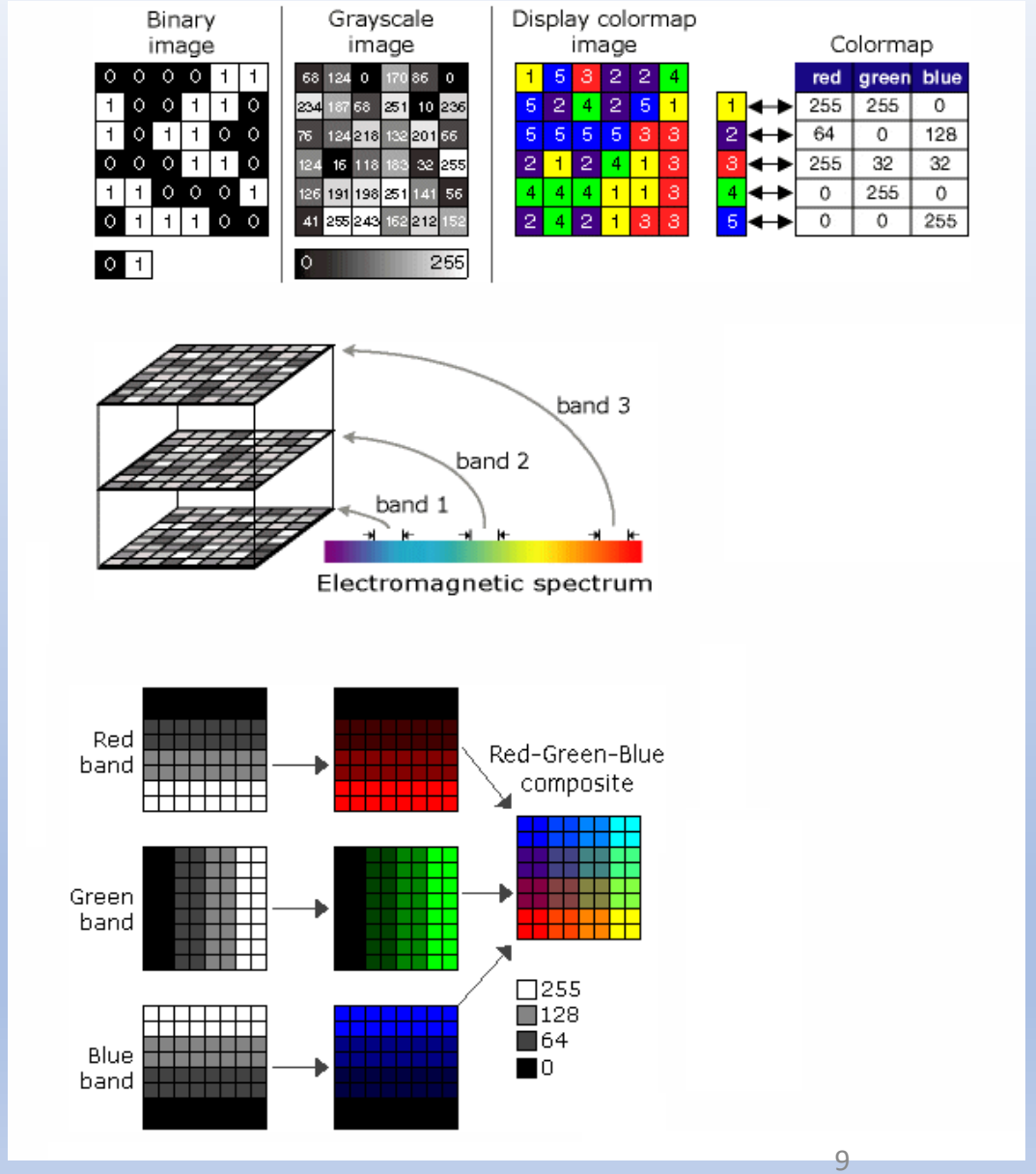
- Pixels: picture elements (also voxels, etc.)
- Rows and columns
- BANDS
- Data type (bit depth): powers of 2
  (e.g. “8-bit”= 256 shades of gray)



https://docs.qgis.org/2.8/en/docs/gentle_gis_introduction/raster_data.html

Many bands…

- Monochromatic (1-band)
  - DEM (1 band)
  - NDVI (1 band)
- 3-band= “true color”, “RGB”, “natural color”
  - TIFF, JPG, .img, etc.
- Multispectral
  - Landsat (7 to 11)
  - UAV, sUAS (4 to 10)
  - Multispectral (>3, <50)
- Hyperspectral (e.g. 224)
  - Hyperion, AVIRIS



https://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/raster-bands.htm

REMOTE SENSING TUTORIALS

Tutorials are arranged in order, from simple, introductory information appropriate for elementary school science teachers to advanced, technical information more appropriate for middle, high school, and undergraduate teachers. They are listed by grade level to aid teachers in selecting the most appropriate tutorial, at their level of understanding.

Geology.com's Introduction to Landsat Images (K-8)

geology.com
News and Information About Geology

The satellite images and maps at this site can be used in simple tutorials to introduce Landsat imagery without any of the technical details underlying the discipline of remote sensing. Images are categorized by the type of feature shown in each image such as agriculture, alluvial fans and deltas, cities, clouds, deserts, forests and mountains, glaciers, volcanoes, and water features. Some of the images are presented in colors that do not always correspond to natural colors as seen by the human eye, since Landsat images capture reflected energy in a much wider range of the electromagnetic spectrum. So, for instance, images of fallow fields in agricultural areas are shown in pink and/or red rather than brown or grey, with no explanation of why they are pink or red. The reason is that Landsat and many other satellite images capture infrared energy as well as 'visible' energy, requiring the computer to show them in a color that we humans can see. Don't let this confuse you, but use this as a way to describe the power and utility of satellite imagery – satellites 'see' much more than we do, and therefore provide very useful information that would otherwise be unavailable or extremely difficult to reconcile if they were limited to 'seeing' only what we humans can see from space. The more advanced tutorials explain this principle very effectively.

SEOS Remote Sensing Tutorial (7-12)

EDUCATION LINKS

- Education
  - Earth Image Puzzles
  - Earth Observation Day
  - Educational Resource Portal
  - Esri Story Maps
  - Google Earth Engine Tutorials
  - Lesson Plans (AV)
  - Lesson Plans (Other)
  - Remote Sensing Imagery Game
  - Remote Sensing Tutorials
  - AmericaView University
  - SATELLITES

(https://americaview.org/program-areas/education/remote-sensing-tutorials/)

… in the beginning (kinda)…

- iGETT

http://www.igettremotesensing.org/

What is Remote Sensing?

- Acquisition of information about a distant object or phenomenon using electromagnetic radiation* and the interpretation of derived information products.

  * *includes sound, and other forms of energy*

Or,

- Matter-energy interactions
- recorded by sensors
- processed with computers to enhance and derive information
- interpreted by human brain and visual system.

<<< and now, A.I. (e.g. computer vision, machine learning)>>>

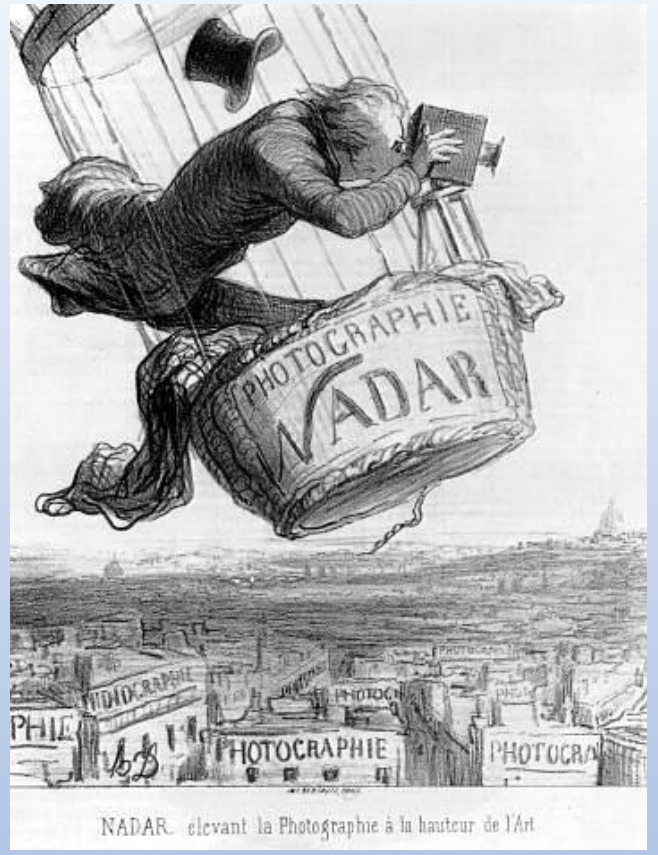
***Some slide materials borrowed/edited from*: "Intro to Remote Sensing" (https://rscc.umn.edu/lessons/lessons-intro/whatisrs)**

Short History of Remote Sensing

1826	Niepee takes first photo
1873	Vogel changes photo emulsions to allow infrared photography
1903	First flight
1914-18	World War I photo reconnaissance
1939-45	World War II photo reconnaissance
1940s	Radar invented
1942	Kodak patents false infrared film
1950s	Thermal infrared developed by military; advances during Korean Conflict
1956-60	CIA U-2 Program
1957-58	First Russian and American Satellites
1960s	Emphasis on photointerpretation; U-2 imagery shown to world; first digital processing and public unveiling of thermal infrared and radar.

In 1827, Joseph Nicéphore Niepee reportedly took the first photograph.

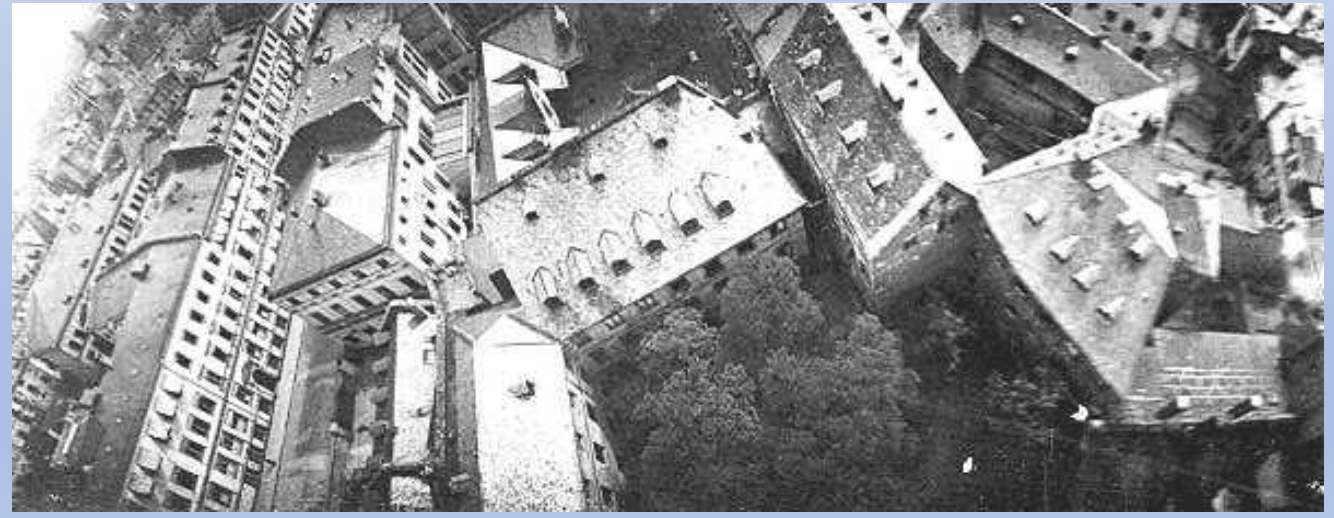
Taken in 1839, this photograph, taken from the roof of a tall building, might be considered the first oblique aerial photograph.

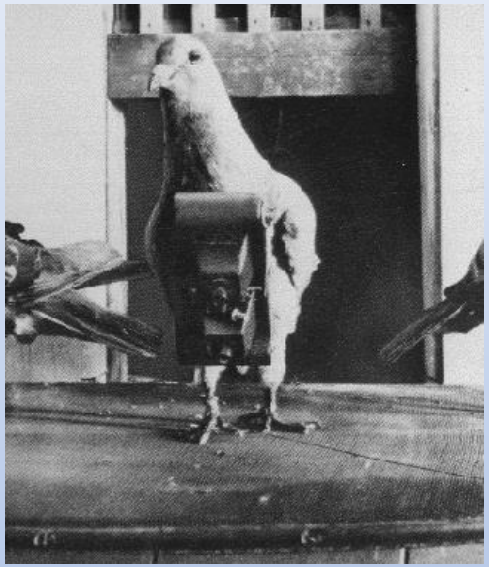


However, credit for the first aerial photograph goes to French author and artist Gaspard-Félix Tournachon who used the nom de plume *Nadar*. He captured the first aerial photo from a balloon tethered over the Bievre Valley in 1858.

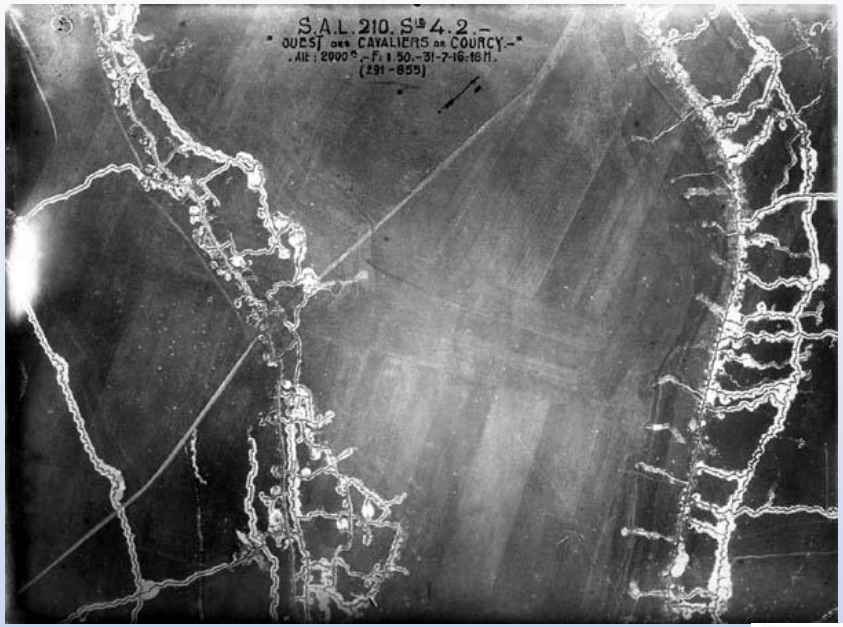
The oldest extant aerial photograph is a view of Boston by James Wallace Black in 1860.

In 1903, Julius Neubronner, photography enthusiast, designed and patented a breast-mounted aerial camera for carrier pigeons





In 1879, George Eastman discovered the formula for making a successful gelatin emulsion covered dry-plate. These developments led to the invention of rolled paper film. The resulting prints were sharp, clear and free from paper grain distortion



His work was shortly followed in 1903 by the Wright Brothers' first successful flight of a heavier-than-air aircraft. Another type of aerial platform was available.

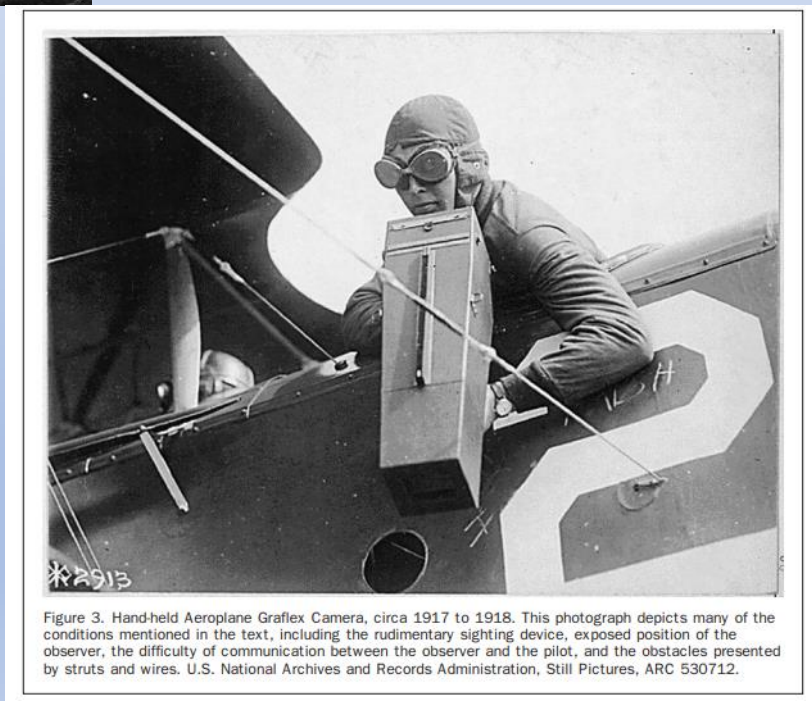
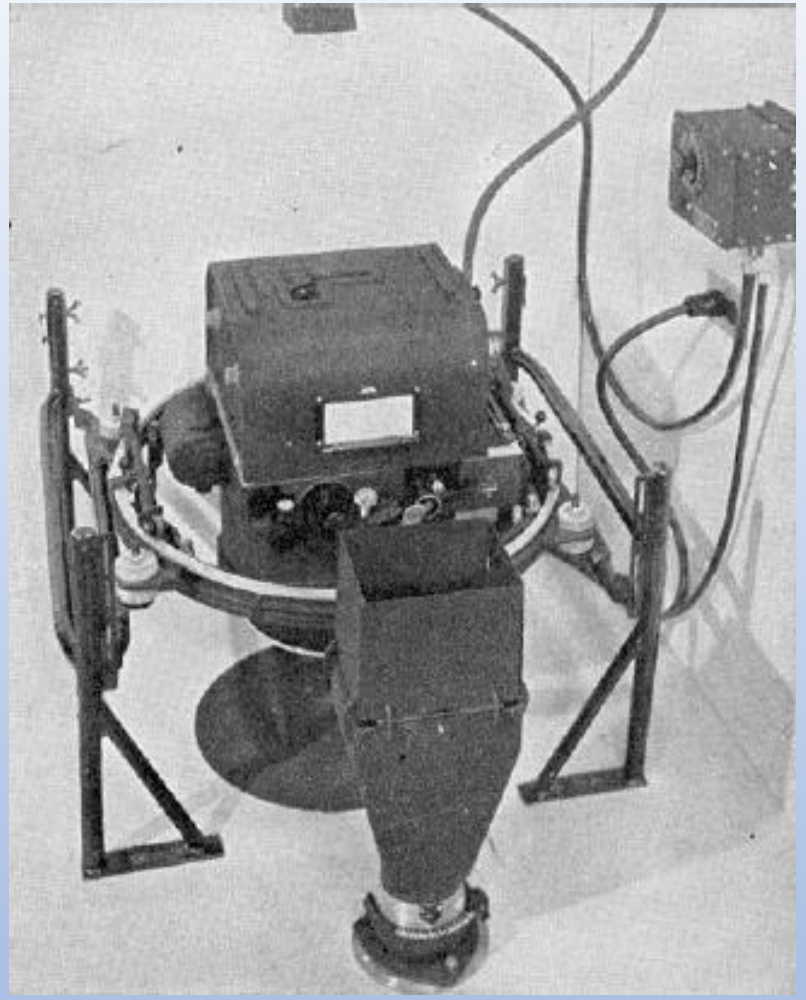
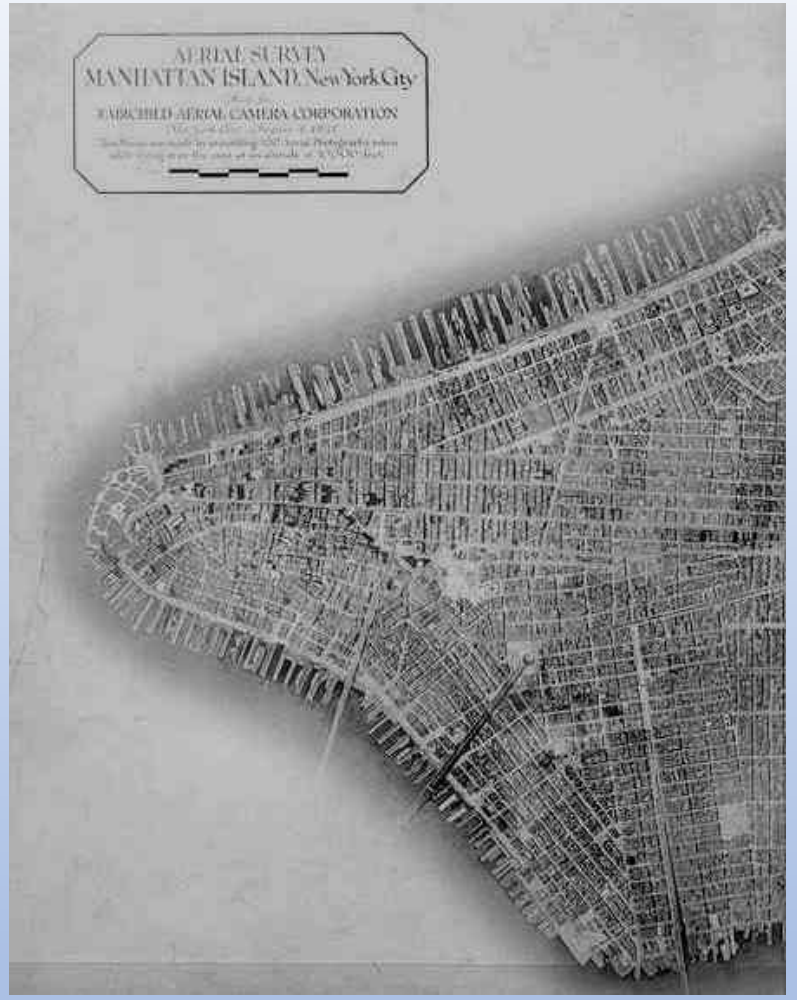


Figure 3. Hand-held Aeroplane Graflex Camera, circa 1917 to 1918. This photograph depicts many of the conditions mentioned in the text, including the rudimentary sighting device, exposed position of the observer, the difficulty of communication between the observer and the pilot, and the obstacles presented by struts and wires. U.S. National Archives and Records Administration, Still Pictures, ARC 530712.

(J.B. Campbell. Photogrammetric Engineering & Remote Sensing Vol. 74, No. 1, January 2008, pp. 77–93.)

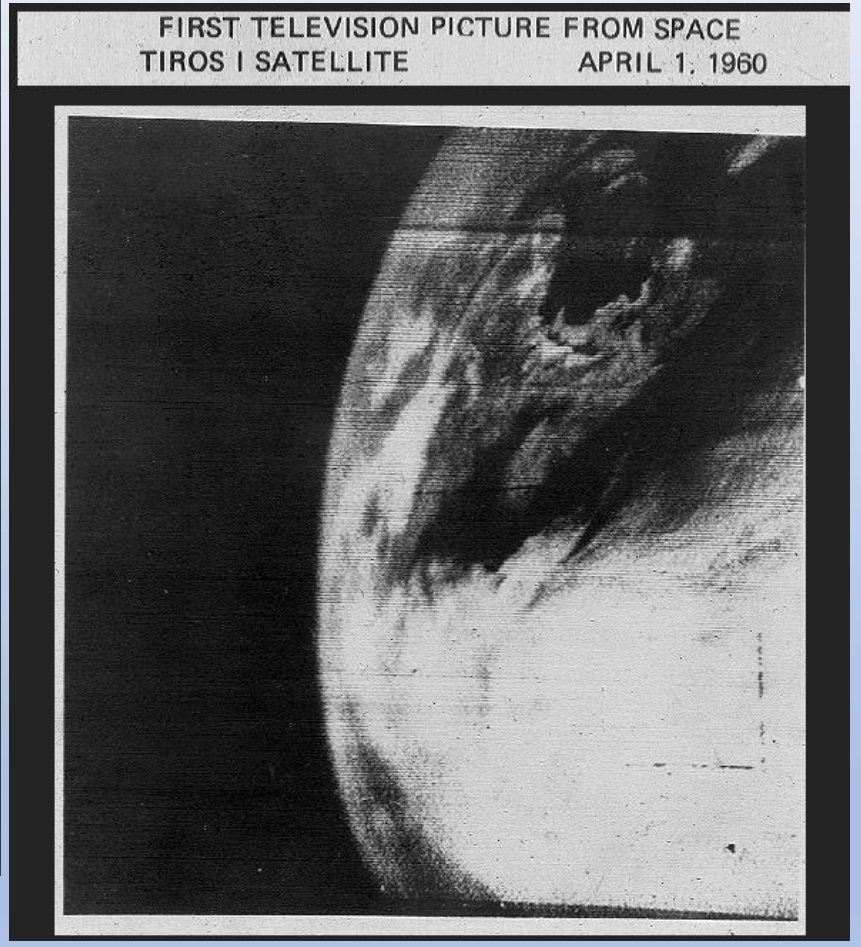




Toward the end of the World War I, Sherman M. Fairchild developed the first true aerial camera system.

Fairchild C-119J Flying Boxcar recovers CORONA Capsule
1960 USAF 040314-O-9999R-001.jpg

This is the first crude picture obtained from Explorer VI Earth satellite launched August 7, 1959



Short History of Remote Sensing

1970s	Specialization in R.S. available; R.S. first integrated with GIS
1973-79	Skylab
1972, 1975, 1978	Landsat 1, 2, 3
1981	Space Shuttle
1982-84	Landsat 4, 5
1986	SPOT Imaging
1990s	Degrees in R.S. available; digital photogrammetry; LIDAR; Hyperspectral imagery; USGS takes over Landsat program
1990	SPOT 2
1993	Landsat 6 dives into Indian Ocean; SPOT 3
1998	SPOT 4
1999	Landsat 7 TM+; IKONOS
2000s	Imagery readily available, often free (MODIS)
2001+	Quickbird, Google Earth, Worldview, GeoEye, Landsat 8 …….

From DATA to INFORMATION

- Traditionally, images ("photography", now *digital* imagery) had to be interpreted by humans
  - First, in real time ("reconnaissance")
  - Later, from film photography

https://commons.wikimedia.org/wiki/File:Aerial_observer_in_balloon_gondola,_1918.jpg

FIG. 5. Photo Interpretation Center, aboard ship.

(D.A. Brugioni. Photogrammetric Engineering & Remote Sensing Vol. 50, No. 9, Septembrer 1984, pp. 1313-1318)

- Now, software and hardware ("artificial intelligence") can "interpret" the data in digital images and generate "human readable" information…

… so, first step to image exploitation is **PHOTOINTERPRETATION**

Image Elements Used in Photo Interpretation

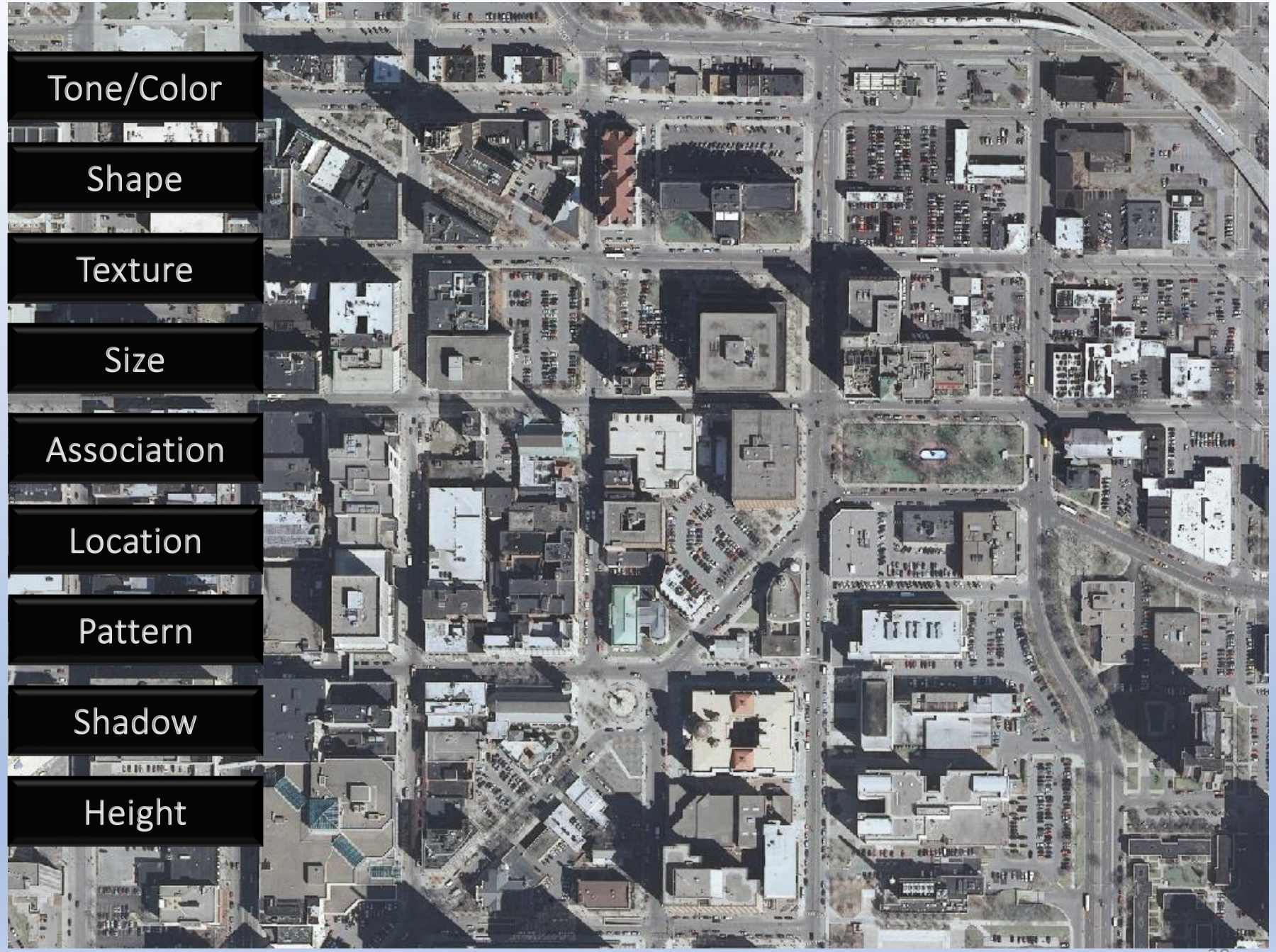
- **Tone** or **Color** – relates to the spectral reflectance characteristics of objects
- **Size** – measure of surface dimensions of objects, including height, length-width, slope
- **Shape** – describes the form or configuration of an object
- **Texture** – frequency of tonal or color change which determines apparent roughness vs. smoothness of an image region; depends on angle of illumination and surface characteristics

Image Elements, cont.

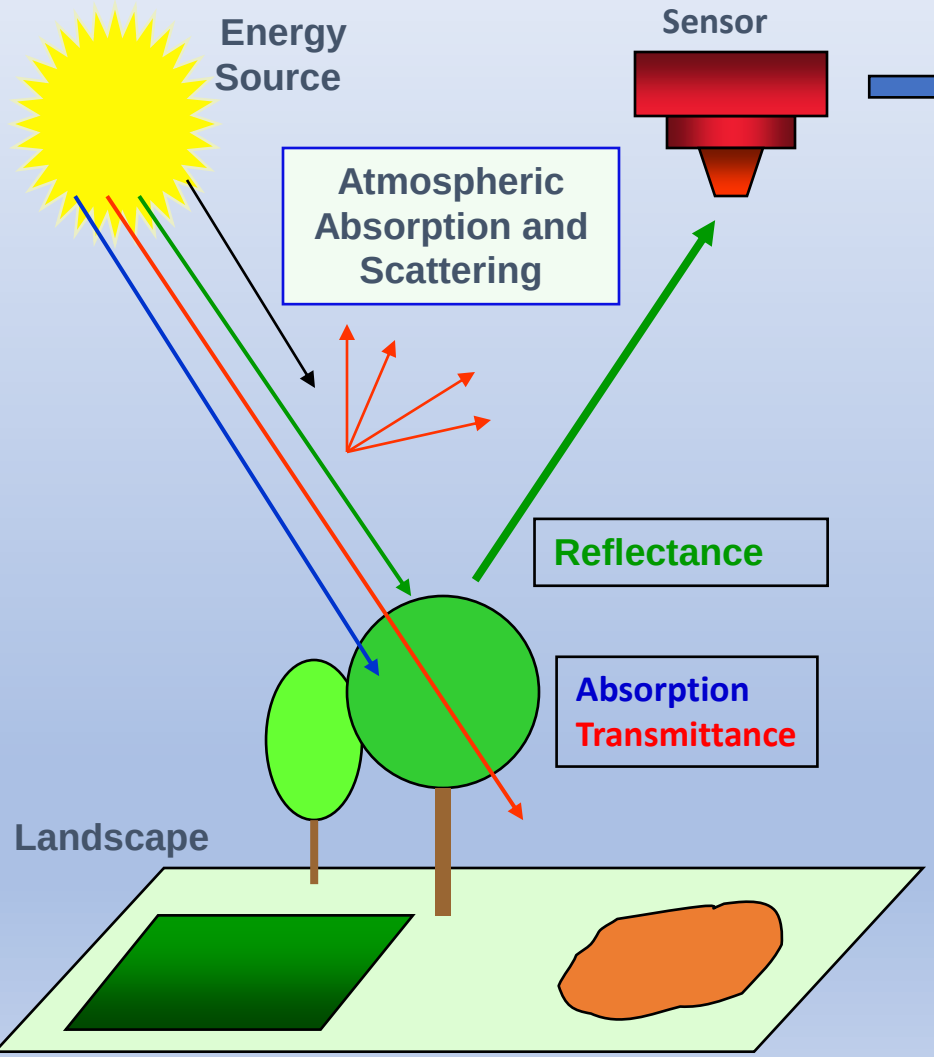
- **Pattern** – spatial arrangement of individual objects into distinctive, recurring forms
- **Shadows** – may reveal details about size and shape not apparent from overhead view
- **Site** – location of object in relation to its geographic or topographic setting
- **Association** – occurrence of certain features in relation to others

Predominant Land-use?

Predominant Land-use?


Tone/Color
Shape
Texture
Size
Association
Location
Pattern
Shadow
Height

Energy Flow Concept

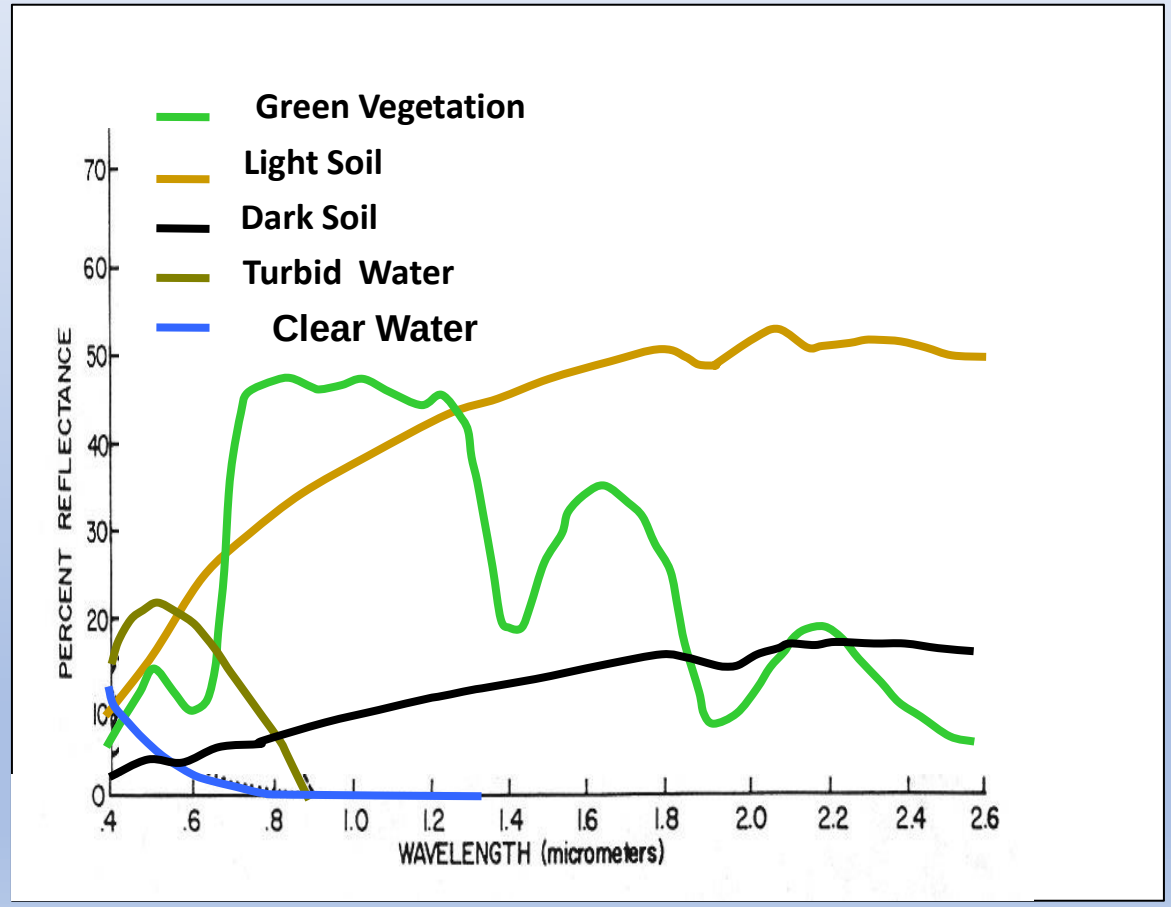


Image

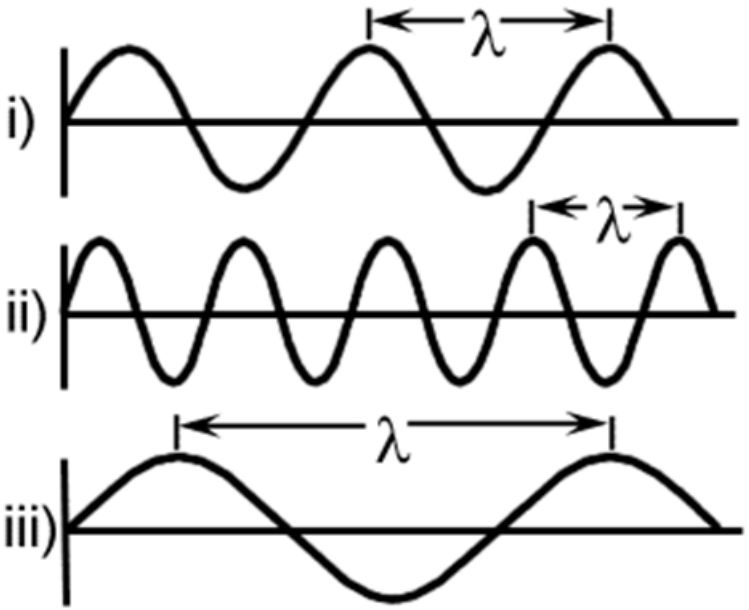
Interpretation and Analysis

Information, maps and statistics, for Applications

Spectral responses of different materials



Wavelength and Frequency



Wavelength and frequency are related by the following formula:

$c = \lambda v$

where:

λ = wavelength (m)

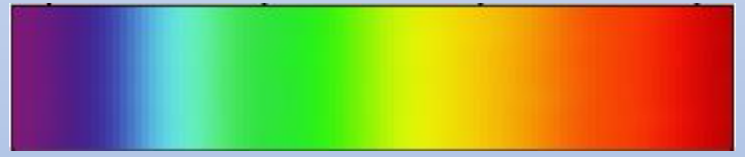
V = frequency (cycles/second, Hz)

c = speed of light (3×10^8 m/s)

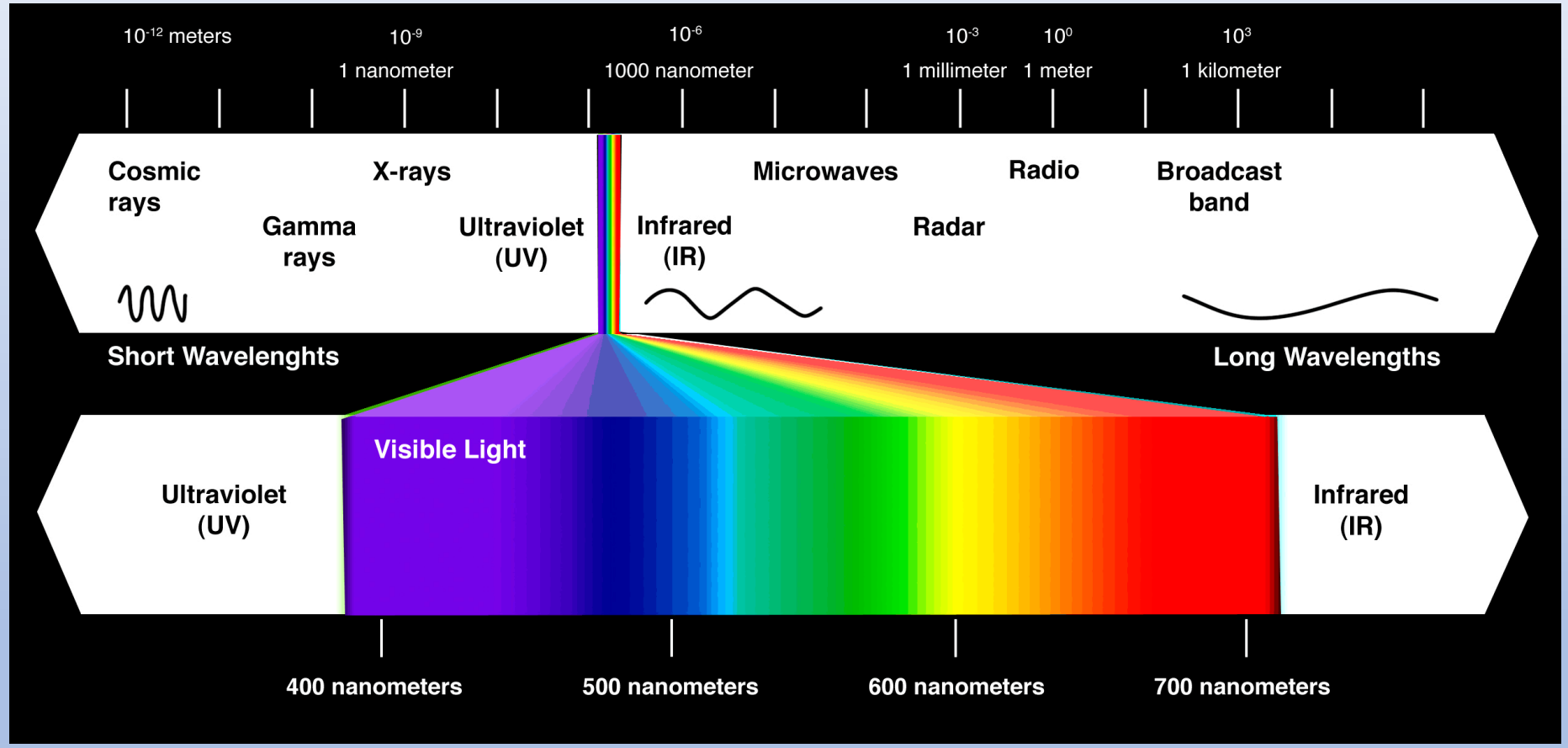
Units of wavelength:

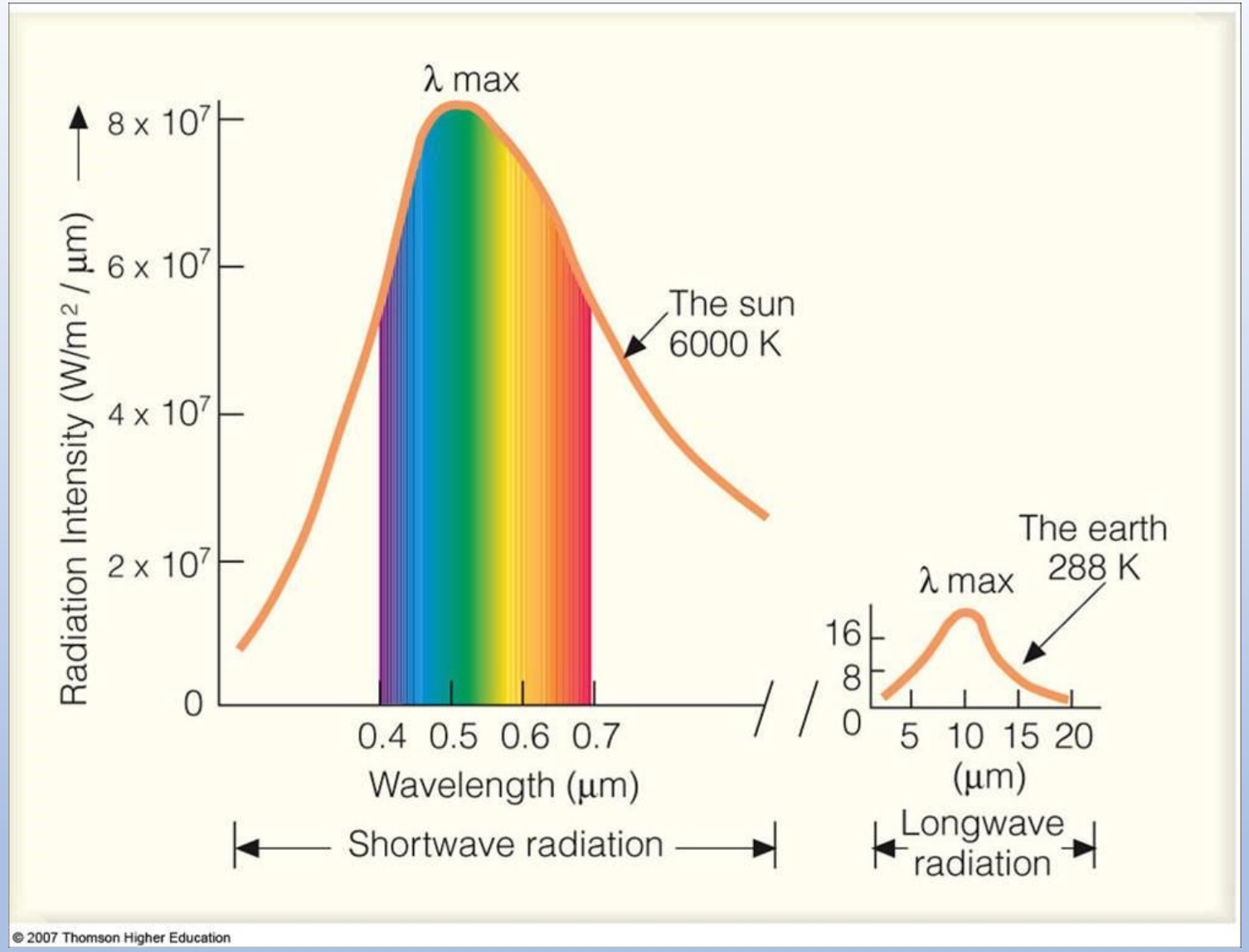
Nanometers: 1 nm = 10^{-9} m

Micrometers: 1 μm = 10^{-6} m

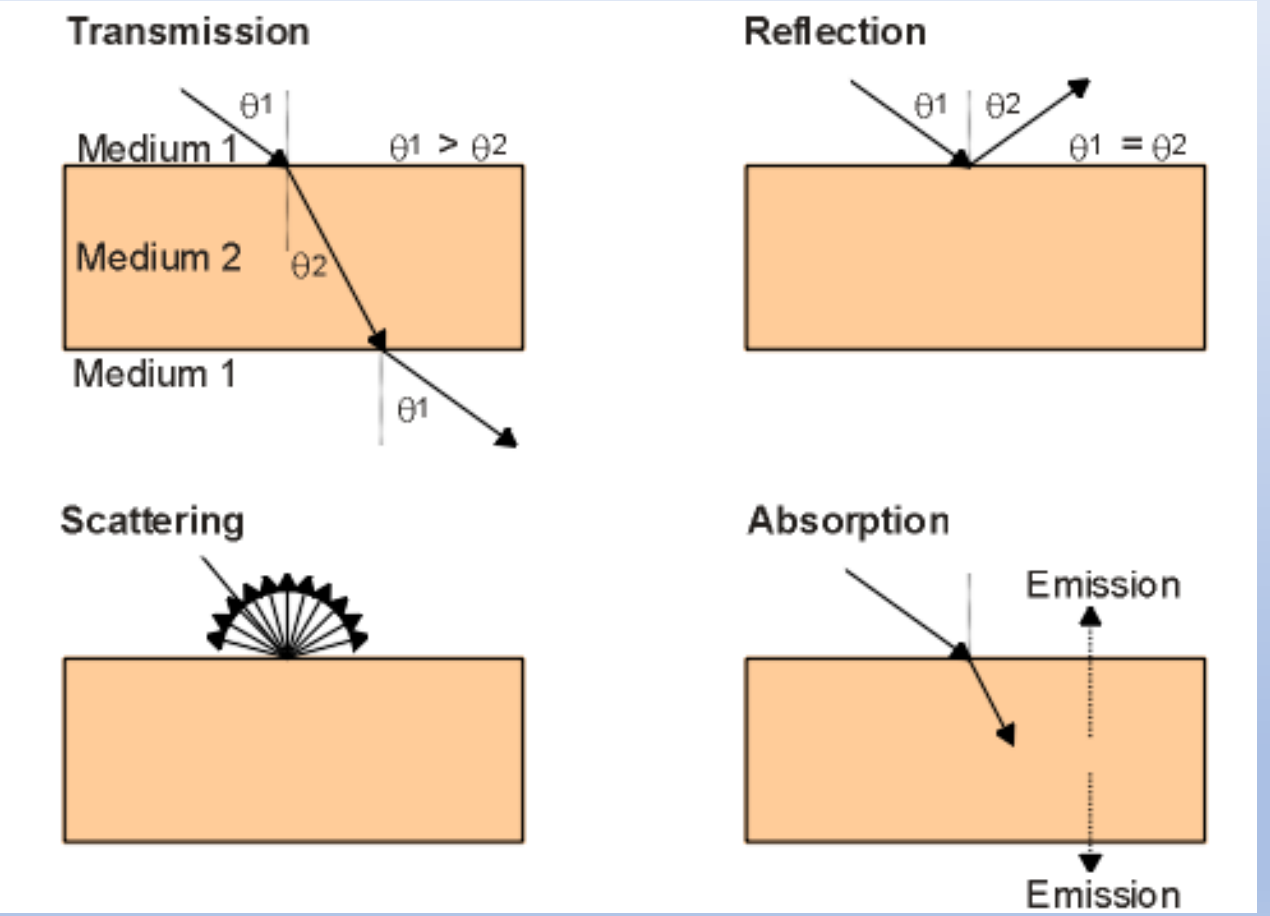


Electromagnetic Spectrum

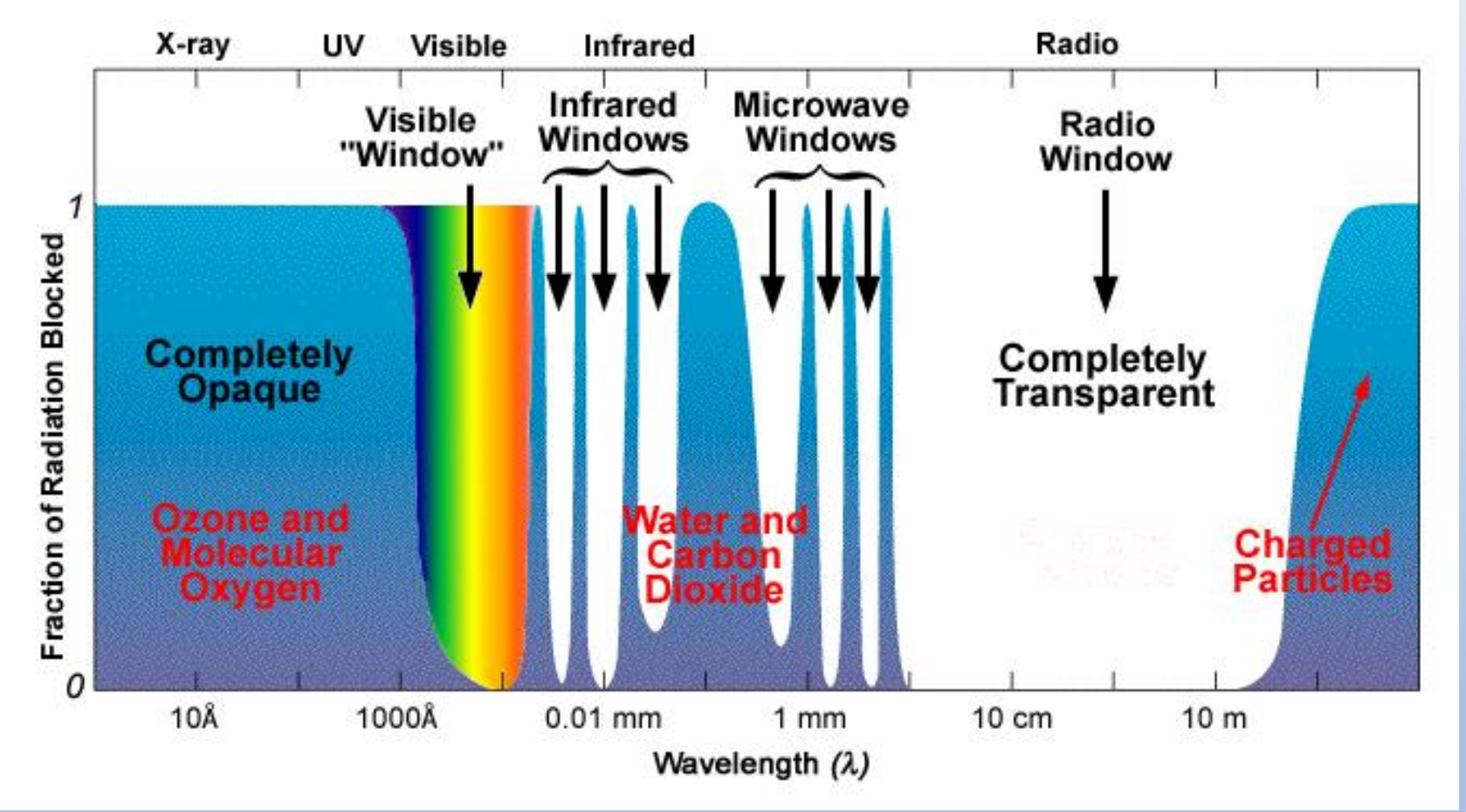



λ max
8 x 10⁷
6 x 10⁷
4 x 10⁷
2 x 10⁷
0
Radiation Intensity (W/m² / μm)
The sun
6000 K
The earth
288 K
λ max
16
8
0
0.4 0.5 0.6 0.7
Wavelength (μm)
5 10 15 20
(μm)
Shortwave radiation
Longwave radiation
© 2007 Thomson Higher Education

EM interactions with matter



Atmospheric Absorption

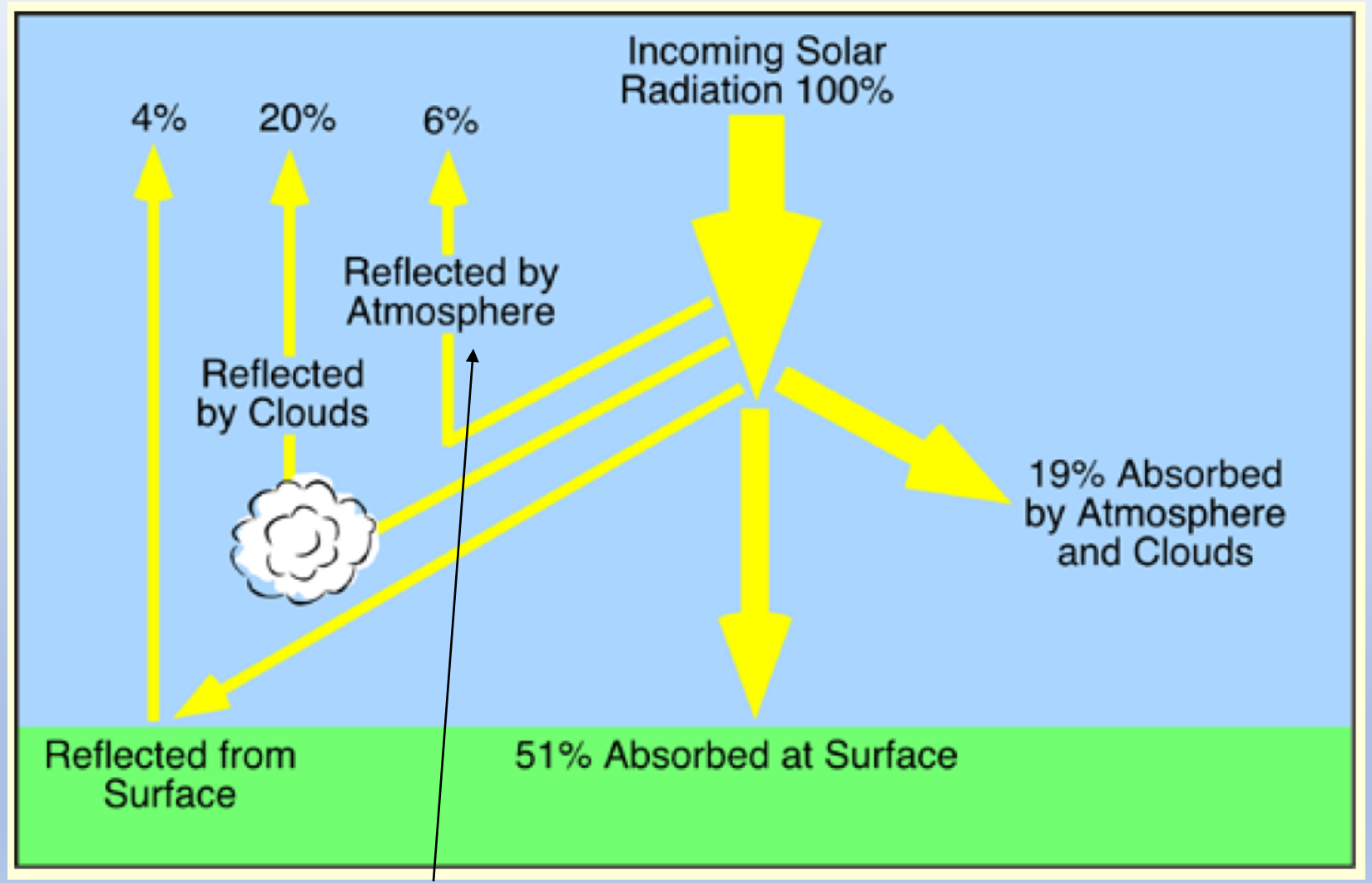


Atmospheric Effects

- **Scattering** by suspended particles or large gas molecules redirects electromagnetic energy
- Type of scattering depends on atmospheric composition

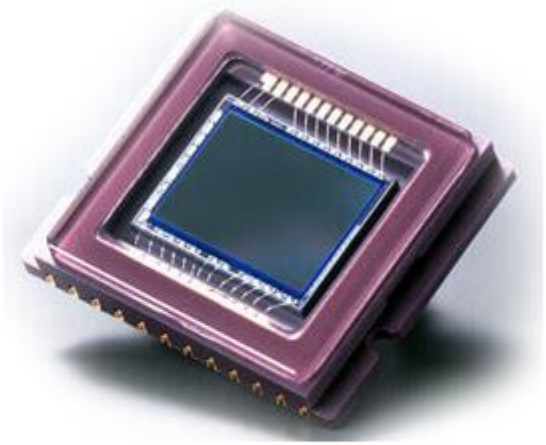
Atmospheric Visibility… a good indictor of atmospheric effects in remote sensing

EMR Energy Budget



AKA: Backscatter
or path radiance

CCD (Charged Coupled Device)



To break it down simply, **CCD** stands for **Charged Coupled Device**. The CCD is the digital equivalent of film.

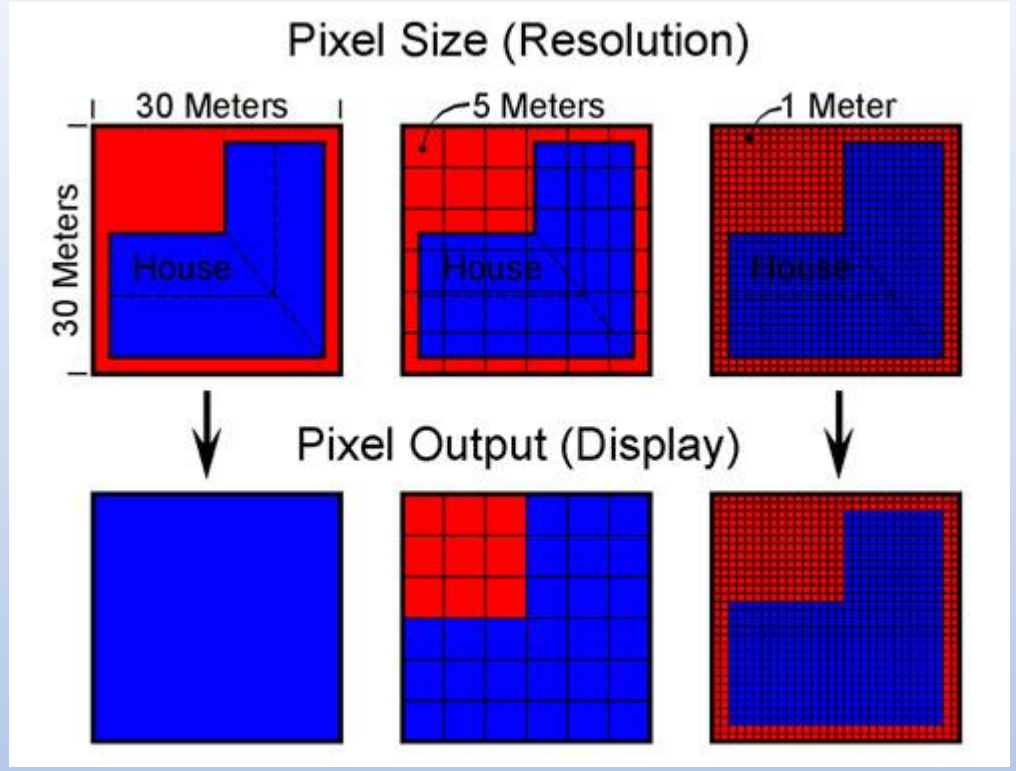
The **CCD** is a type of sensor that is used to capture an image by taking the light and translating it into digital data. There are thousands of tiny little pixels that make up the surface of the sensor so that every little facet of light will be caught, converted, and refined into electrical energy, and organized into a digital image. It is through the pixels that the light is translated into electrons, which in turn, become the digital data you need in order to print, edit, or store a picture.

An IMAGE that has:

1- Spectral resolution
2- Spatial resolution
3- Radiometric resolution

http://photographycourse.net/what-is-the-ccd/

- ***SPATIAL RESOLUTION***: (x, y) distance on the ground, covered by each pixel
- ***SPECTRAL RESOLUTION***: number of spectral bands (monochromatic, multispectral, hyperspectral)
- ***RADIOMETRIC RESOLUTION***: at its highest, from 0 to 65,536 shades of gray (16-bit image) or **BRIGHTNESS**

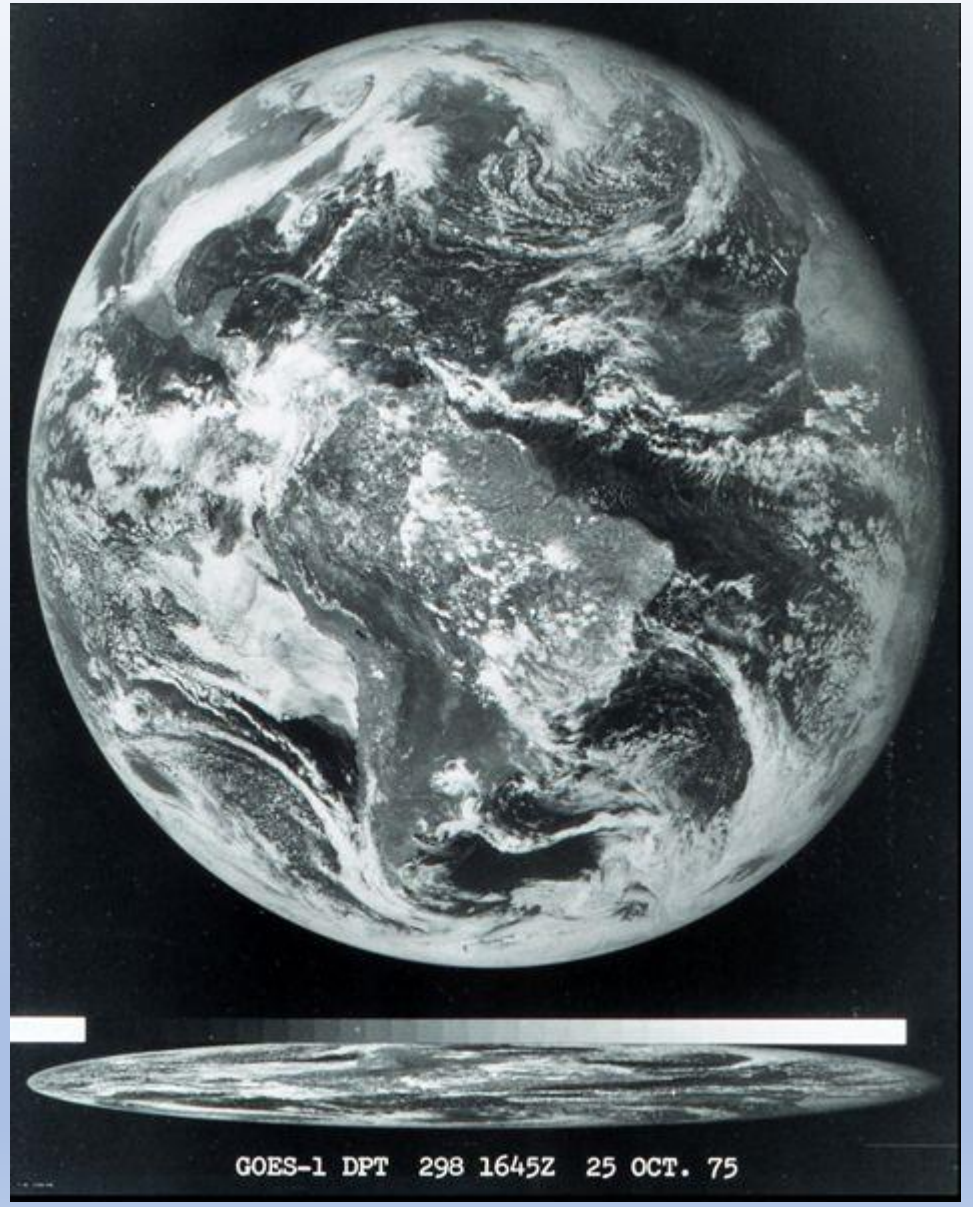


https://www.satimagingcorp.com/services/resources/characterization-of-satellite-remote-sensing-systems/

Temporal Resolution (revisit time)

- Landsat 8: 16 days
- Sentinel 2: 10 days
- GOES: 0 days (geostationary!)

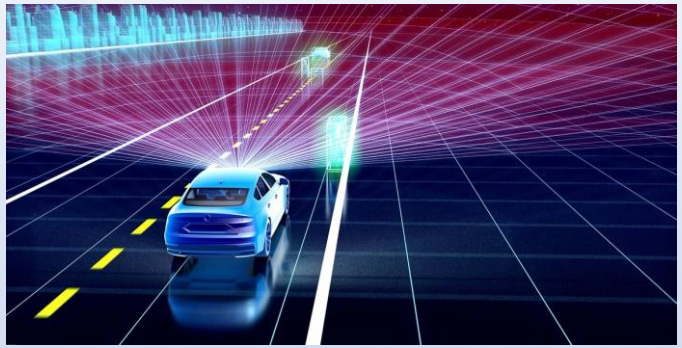
https://www.star.nesdis.noaa.gov/goes/



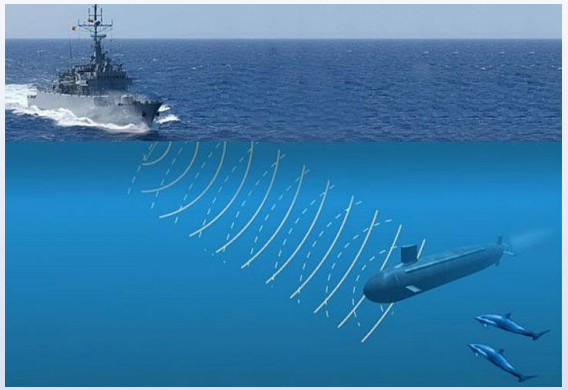
https://commons.wikimedia.org/wiki/File:First_image_from_GOES_Spac0041.jpg
NOAA Photo Library / Public domain

Examples of platforms/sensors

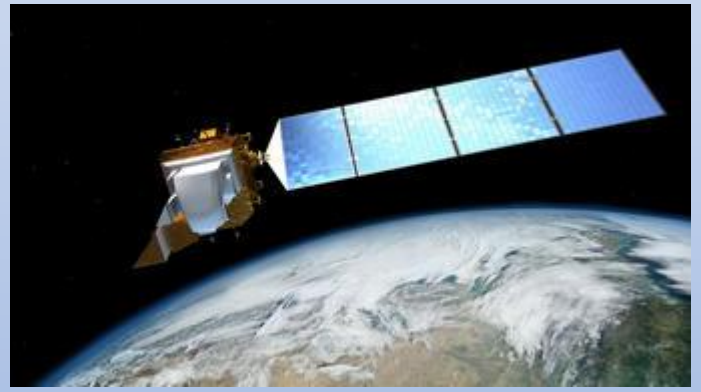
Platform	Sensor
Head	Eyes, nose, ears
Selfie-stick	Phone camera
Airplane	Digital camera
Drone (UAV)	Video camera
Satellite	Multispectral scanner
Tower	Doppler Weather Radar
Car	LiDAR
Submarine	Sonar



(https://www.autofutures.tv/2019/02/11/the-who-what-when-where-why-and-how-of-lidar/)



(https://www.militaryaerospace.com/computers/article/16726249/navy-iznterested-in-new-computing-and-sensor-technologies-for-shipboard-and-submarine-sonar)



(https://www.usgs.gov/media/images/landsat-8-illustration-above-earth)

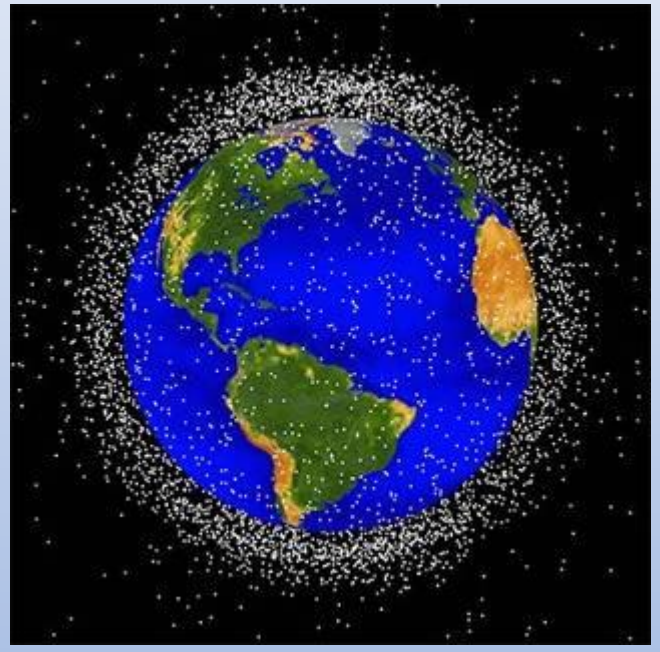
(http://airbornescientific.com/)

(https://www.maxwell.af.mil/News/Display/Article/1449484/nexrad-next-generation-radar-impacts-far-and-wide/)

(https://www.dji.com/camera-drones)

It is getting to be a bit too crowded up there…

https://qz.com/296941/interactive-graphic-every-active-satellite-orbiting-earth/



https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-orbital-debris-k4.html

SpaceX plans to put more than 40,000 satellites in space

SPACE 17 October 2019

By Mark Harris

60 Starlink satellites stacked for launch at SpaceX facility in Cape Canaveral, Florida
SpaceX

SpaceX has filed documents with telecommunications authorities that show it has plans to launch

https://www.newscientist.com/article/2220346-spacex-plans-to-put-more-than-40000-satellites-in-space/

Demo 1: Google Earth Pro

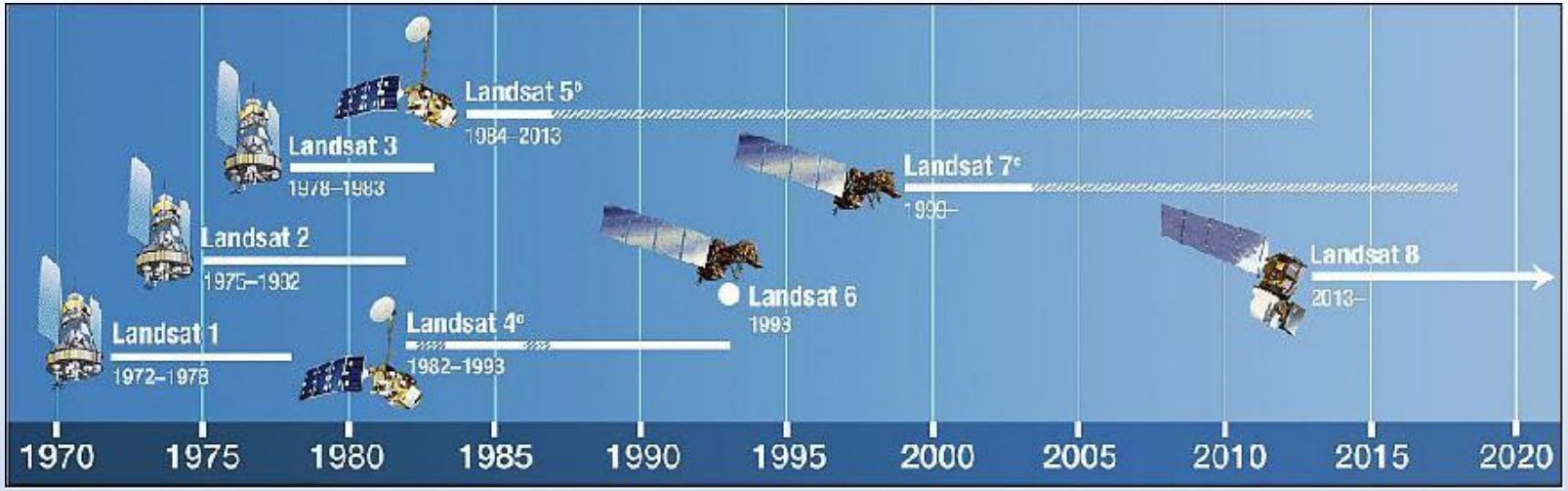
- Geocoding
- Imagery sources
- Temporal change detection (Way Back Machine)
- Frederick Douglass High School – Lexington KY
- Adding an image service (http://kyraster.ky.gov/arcgis/rest/services)

Passive vs. Active Remote Sensing

- *PASSIVE*:
  - Illumination is from the SUN
  - Reflectance measured (REFLECTED ENERGY)
  - Physics of irradiance rule us
  - Visible and non-visible portions of electromagnetic radiation spectrum
  - Also measures emitted energy (microwave, thermal infrared)
  - Most imaging systems are based on this type of remote sensing

- *ACTIVE*:
  - Energy provided by us (emitter)
  - Measures energy bounced-off or transmitted through the target object/system/phenomenon…
  - Radar (radio waves)
  - LiDAR (IR light, now blue-green… topography+bathymetry)
  - Sonar (sound)
  - MRI
  - X-ray, Gamma-ray radiography

The Landsat example



(https://directory.eoportal.org/web/eoportal/satellite-missions/l/landsat-9)

- Mission/Program: Landsat
- Platform: Landsat 1, 2, 3, 4, 5, (6), 7, 8, … 9 -- *satellites*
- On-board sensors through the ages:
  - RBV (Return Beam Vidicon – 3 TV cameras)
  - MSS (Multispectral Scanner System): 4 or 5 bands
  - Thematic Mapper (TM): Multispectral scanning radiometer: 7 bands
  - Enhanced Thematic Mapper (ETM+): same; 8 bands
  - Operational Land Imager (OLI) + Thermal Infrared Sensor (TIRS): 11 bands

Bands and Band Math

Example: Landsat 8
https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands/

Band Number	µm	Resolution
1	0.433–0.453	30 m
2	0.450–0.515	30 m
3	0.525–0.600	30 m
4	0.630–0.680	30 m
5	0.845–0.885	30 m
6	1.560–1.660	30 m
7	2.100–2.300	30 m
8	0.500–0.680	15 m
9	1.360–1.390	30 m
10	10.6-11.2	100 m
11	11.5-12.5	100 m

Of its 11 bands, only those in the very shortest wavelengths (bands 1–4 and 8) sense visible light – all the others are in parts of the spectrum that we can't see. The true-color view from Landsat is less than half of what it sees. To understand the value of all the bands, let's look at them each in turn… The Bands...

Band	Wavelength	Useful for mapping
Band 1 – coastal aerosol	0.43-0.45	coastal and aerosol studies
Band 2 – blue	0.45-0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53-0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - red	0.64-0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	085.-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57-1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11-2.29	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	.50-.68	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.36 -1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.5-12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

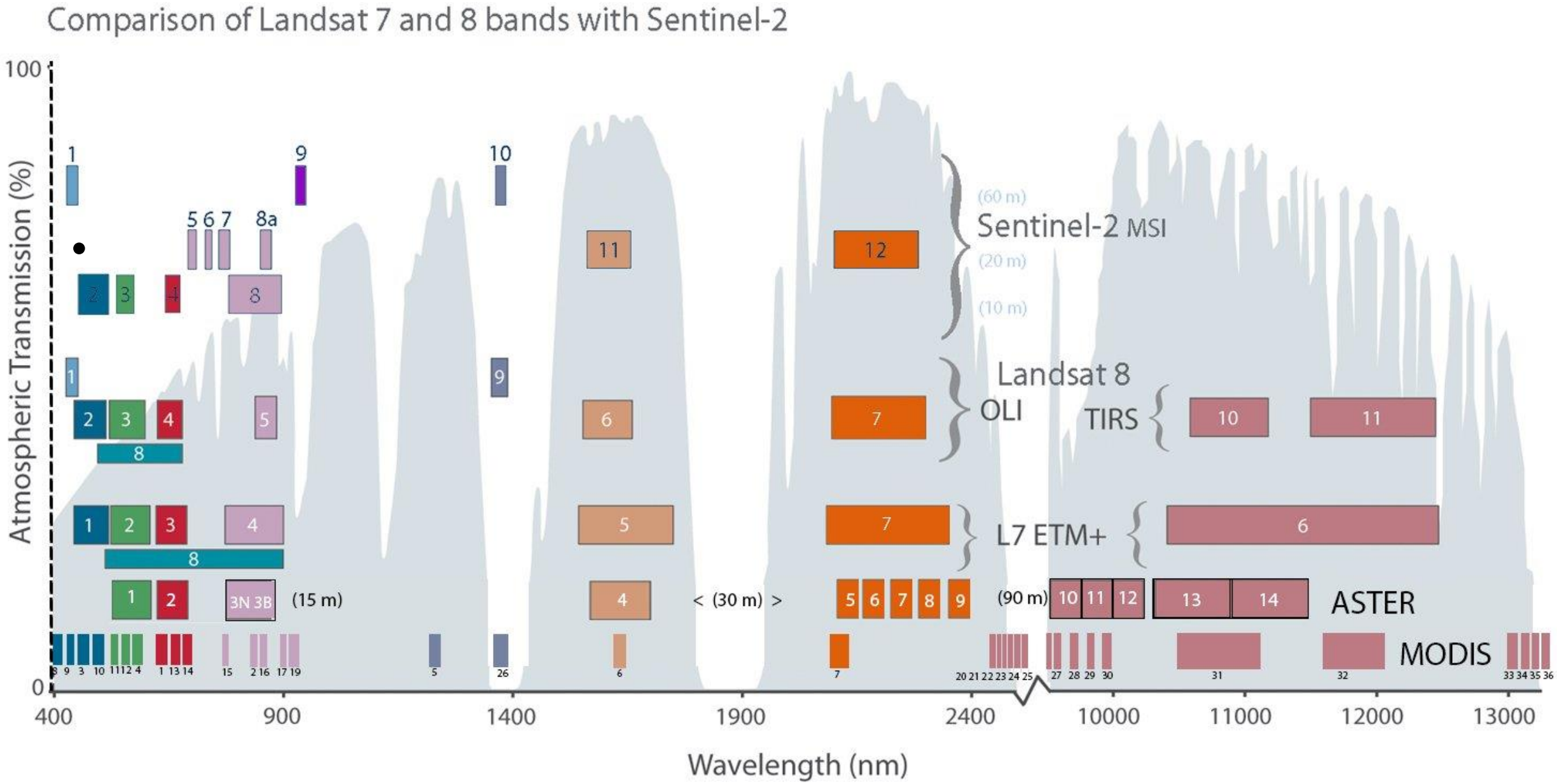
https://www.usgs.gov/media/images/landsat-8-oli-and-tirs-and-their-uses

Sentinel 2

Multispectral Imager (MSI) covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands).

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 - Vegetation Red Edge	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://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/sentinel-2a/



https://pbs.twimg.com/media/Cr2V5GJUAAAU6DX?format=jpg&name=large

Demo 2: ArcGIS Online

- Discovering Landsat 8 and Sentinel 2 data
- Adding an image layer
- Enhancing the image – creating band composite images (false color)
- Adding image services: https://kyraster.ky.gov/arcgis/rest/services/ImageServices/Ky_NAIP_2018_2FT/ImageServer

Questions?