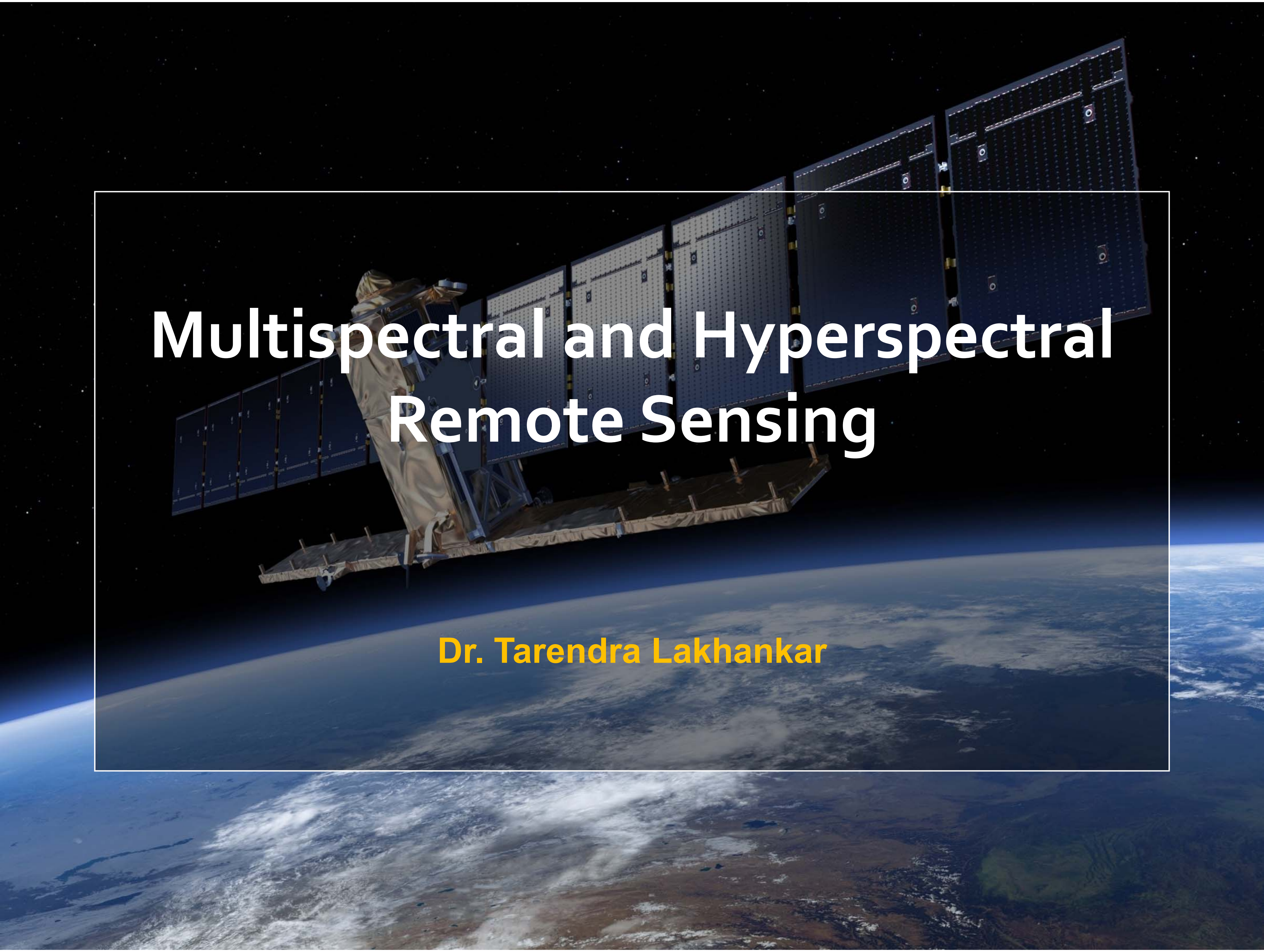


Multispectral and Hyperspectral Remote Sensing

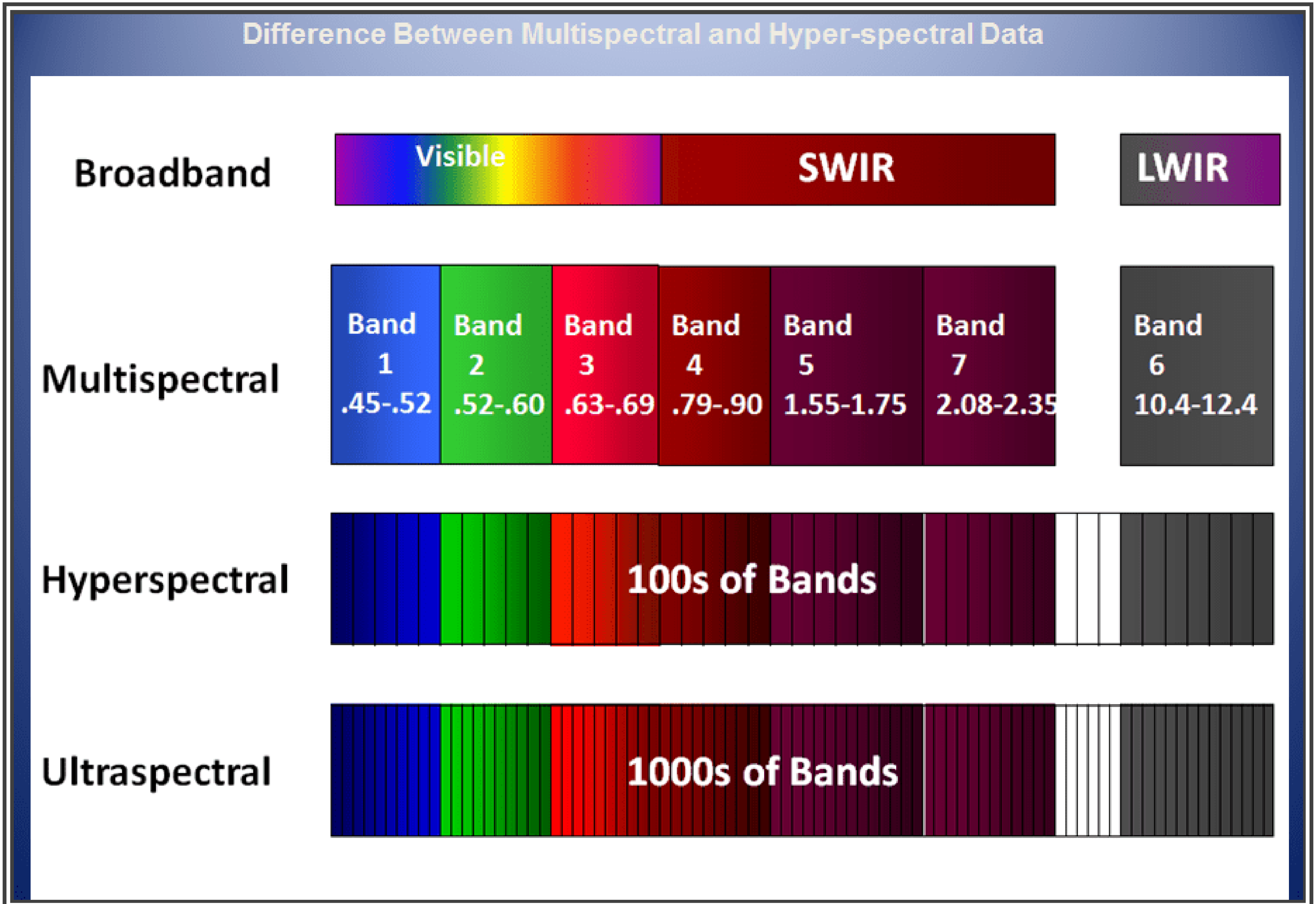
Dr. Tarendra Lakhankar

Multispectral and hyperspectral Comparison

The main difference between multispectral and hyperspectral is the number of bands and how narrow the bands are.

Hyperspectral and multispectral images have many real world applications. For example, hyperspectral imagery has been used to map invasive species and help in mineral exploration.

There are hundreds more applications in the fields of agriculture, ecology, oil and gas, oceanography and atmospheric studies where multispectral and hyperspectral remote sensing are being used to better understand the world we live in.



A *band* represents a segment of the electromagnetic spectrum.

Bands and Wavelengths

- Spectral remote sensing data are collected by powerful camera-like instruments known as imaging spectrometers. Imaging spectrometers collect reflected light energy in “bands.”
- You can think of it as a bin of one “type” of light. For example, the wavelength values between 800 nanometers (nm) and 850 nm might be one band captured by an imaging spectrometer.
- The imaging spectrometer collects reflected light energy within a pixel area on the ground. Since an imaging spectrometer collects many different types of light - for each pixel the amount of light energy for each type of light or band will be recorded. So, for example, a camera records the amount of red, green and blue light for each pixel.
- Often when you work with a multispectral dataset, the band information is reported as the center wavelength value. This value represents the center point value of the wavelengths represented in that band. Thus in a band spanning 800-850 nm, the center would be 825 nm.

Types of Sensing

- Mono-Spectral Imagery →

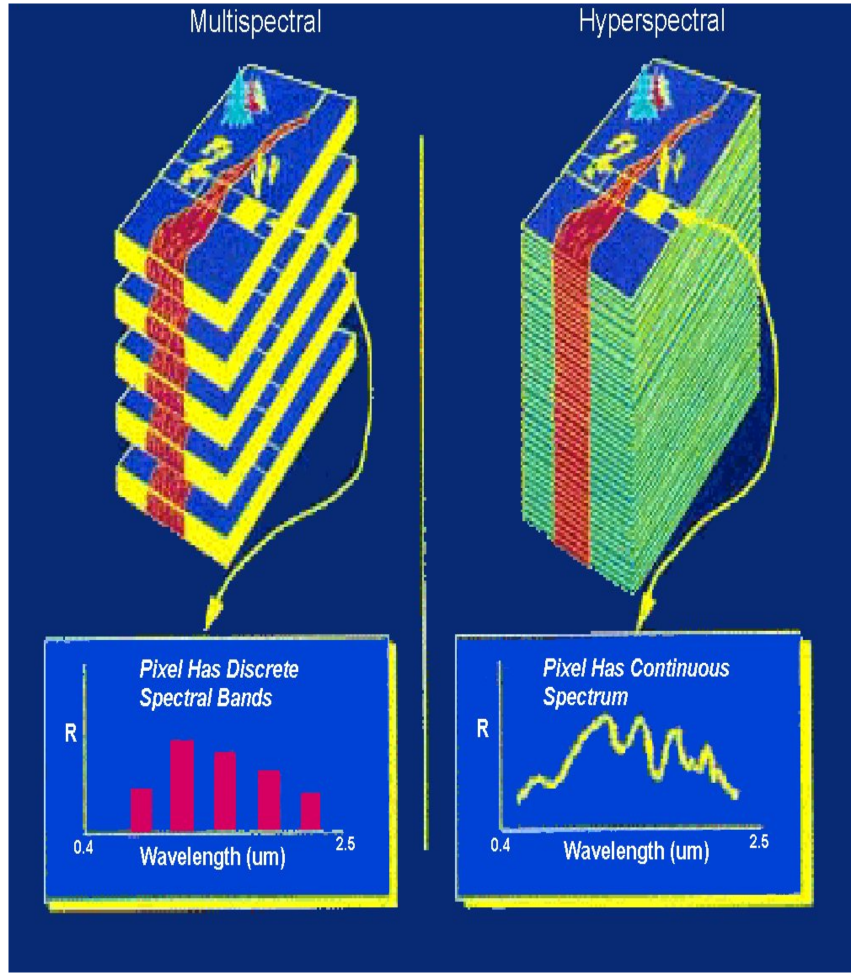
1 band (SPOT ≡ panchromatic)

- Multi-Spectral Imagery →

10s of bands (MODIS ≡ 36 bands, SeaWiFS ≡ 8 bands, IKONOS ≡ 5 bands)

- Hyperspectral Imagery →

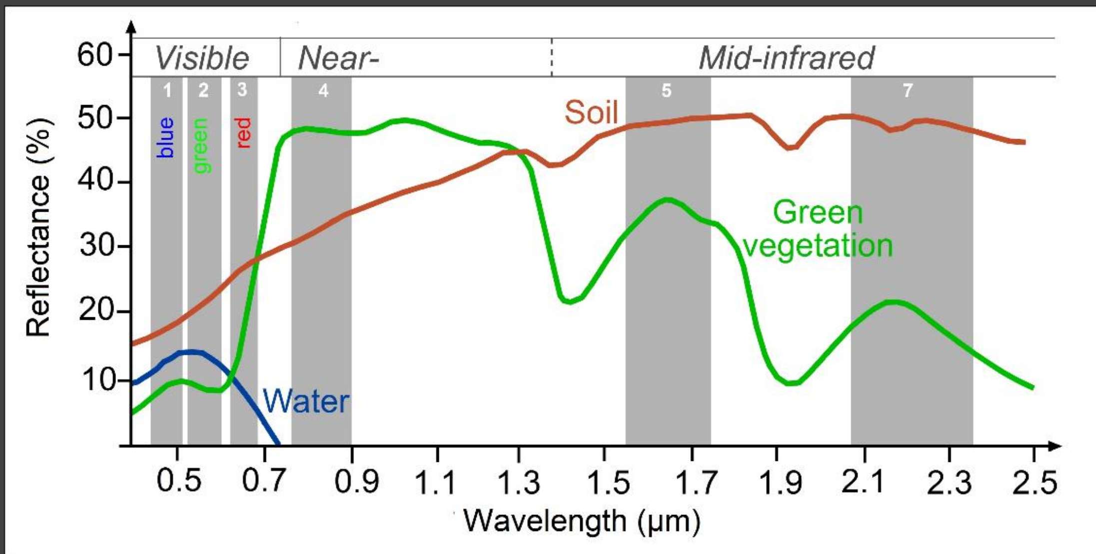
100s-1000s of bands (AVIRIS ≡ 224 bands, AIRS ≡ 2378 bands)

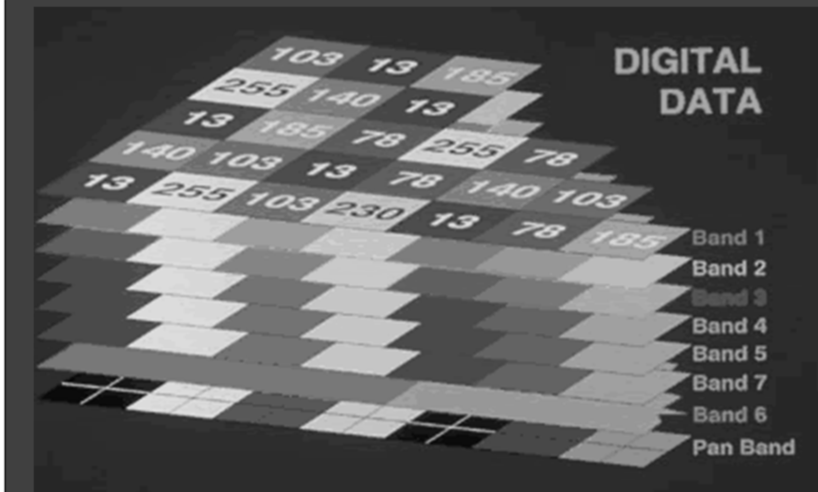


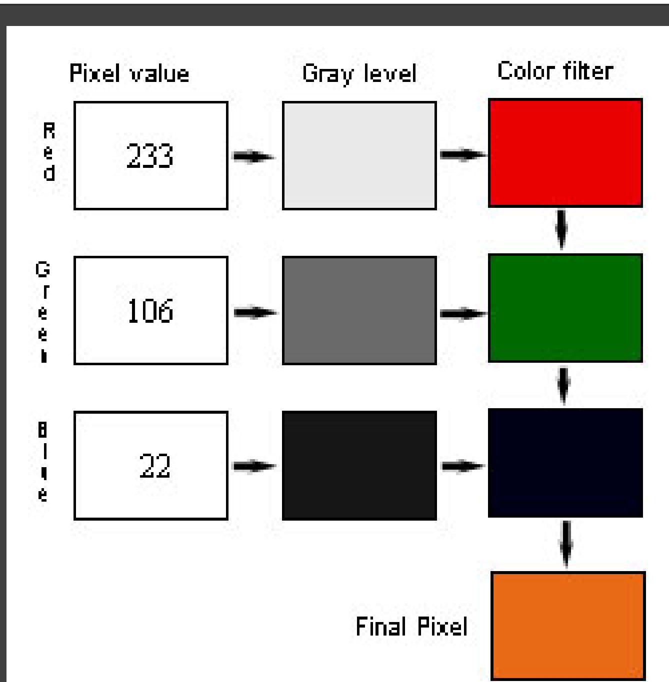
Multispectral / Hyperspectral Imagery Comparison

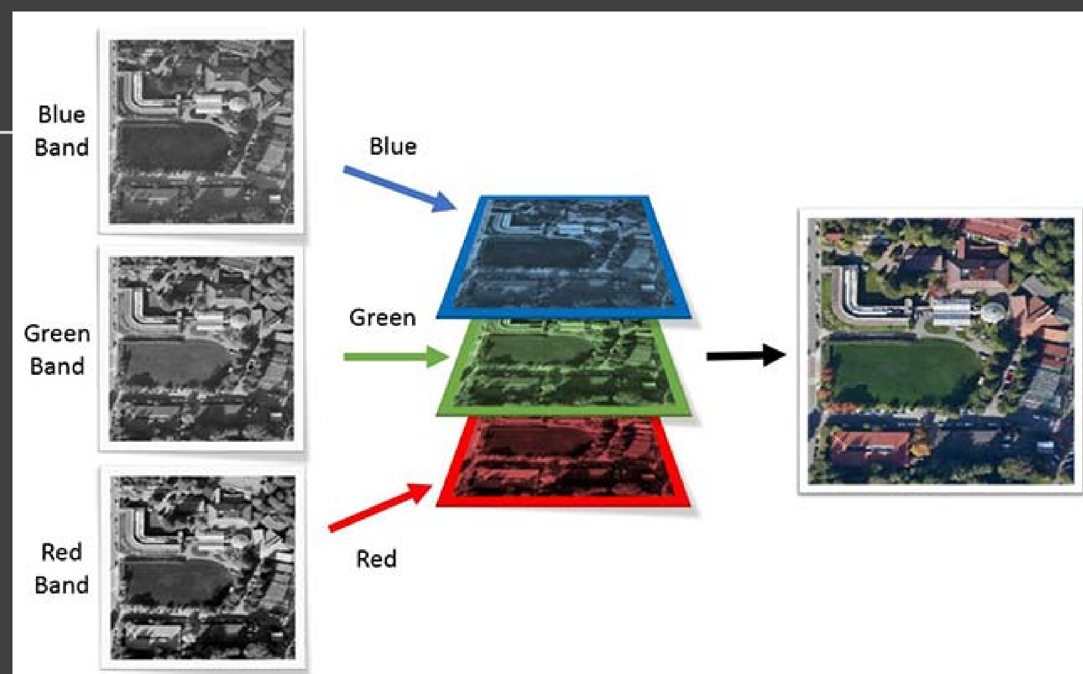
Multispectral Remote Sensing

How satellite collects the data?

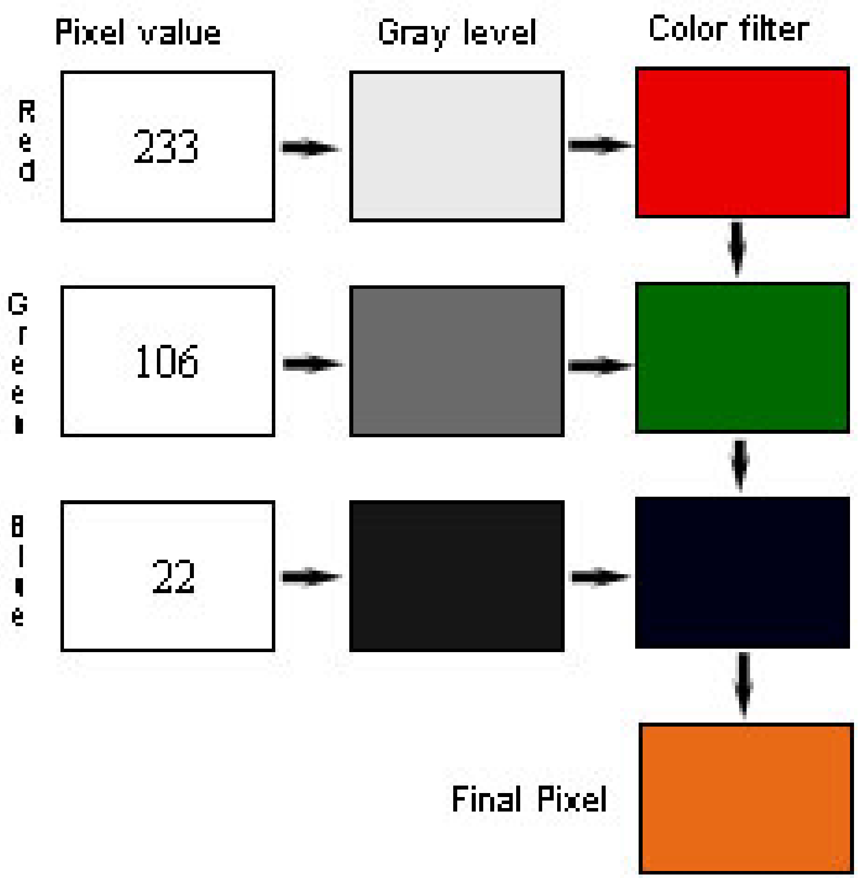


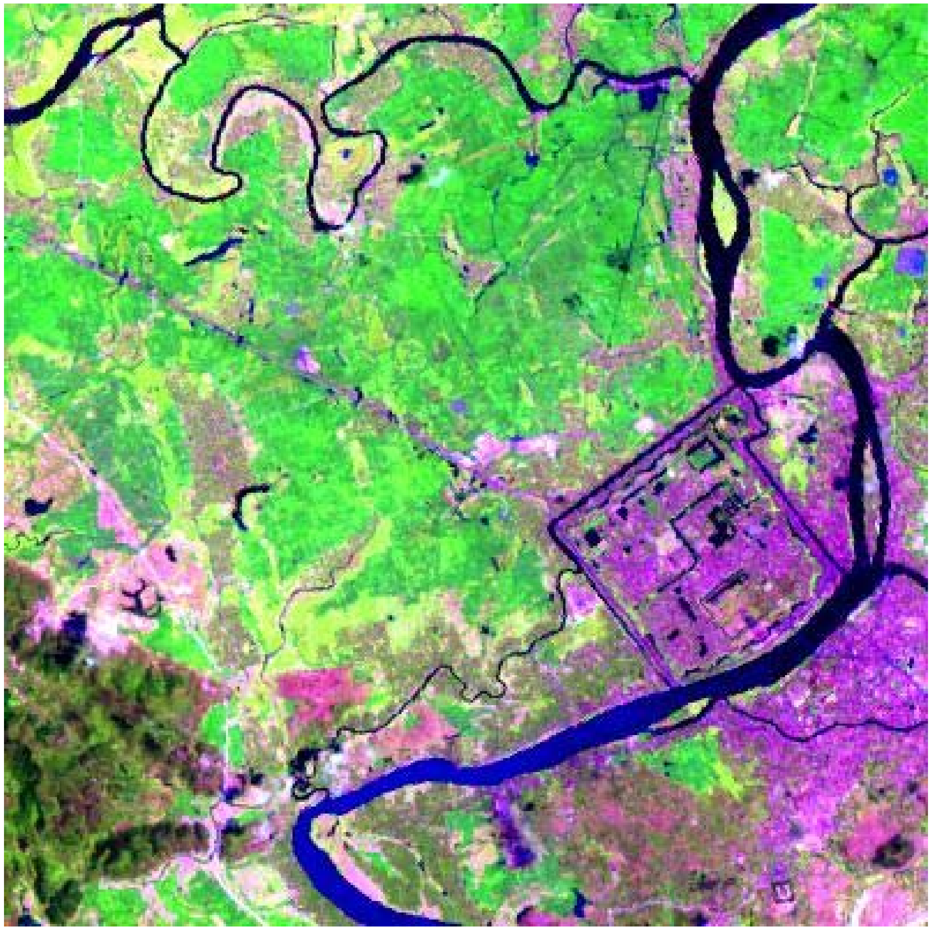




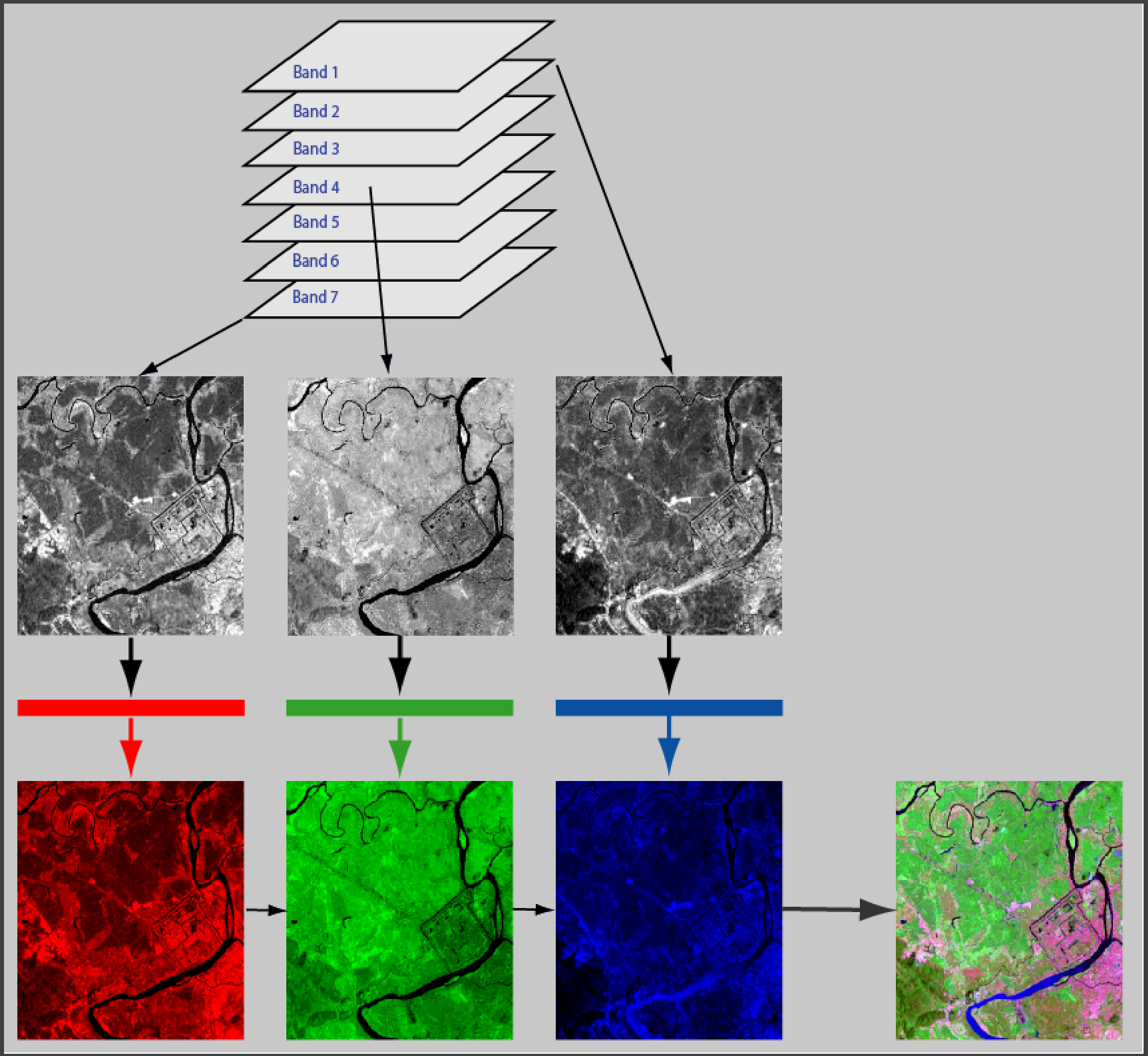


Pixel color and brightness is determined by the pixel value





RGB Band Composite



True Color composite RGB = 3,2,1

- Visible bands are selected and assigned to their corresponding color guns to obtain an image that approximates true color.
- Tends to appear flat and have low contrast due to scattering of the EM radiation in the blue visible region.

Near Infra Red Composite RGB = 4,3,2

- Blue visible band is not used and the bands are shifted;
- Visible green sensor band to the blue color gun
- Visible red sensor band to the green color gun
- NIR band to the red color gun.

Results in the familiar NIR composite with <u>vegetation portrayed in red</u>.

Landsat ETM+ bands 3,2,1 – Penetrates shallow water and shows submerged shelf, water turbidity

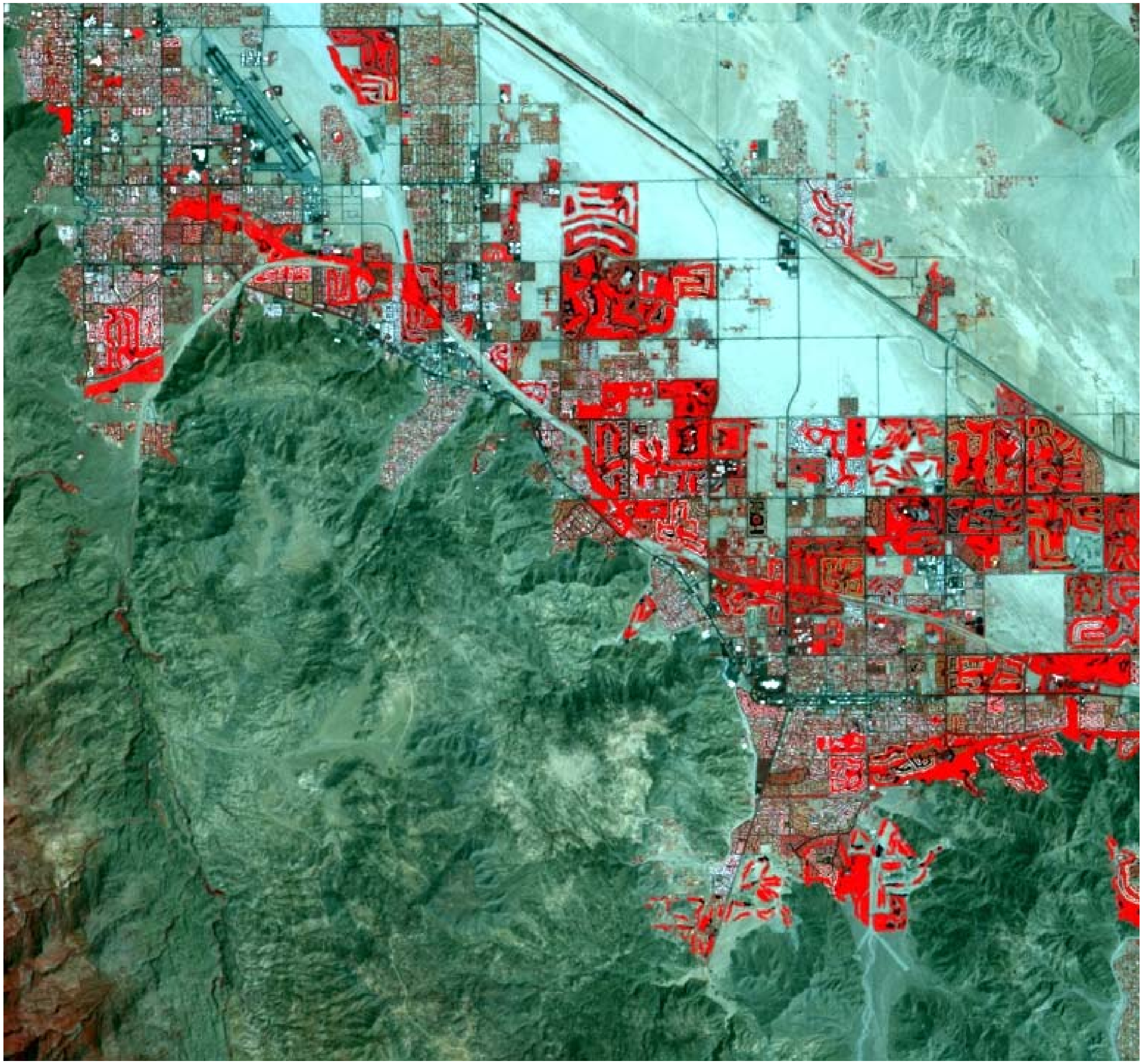
Landsat ETM+ bands 4,3,2 – Peak chlorophyll, land/water boundary, urban areas

Palm Springs, CA

Bands 3,2,1 (red, green, blue)

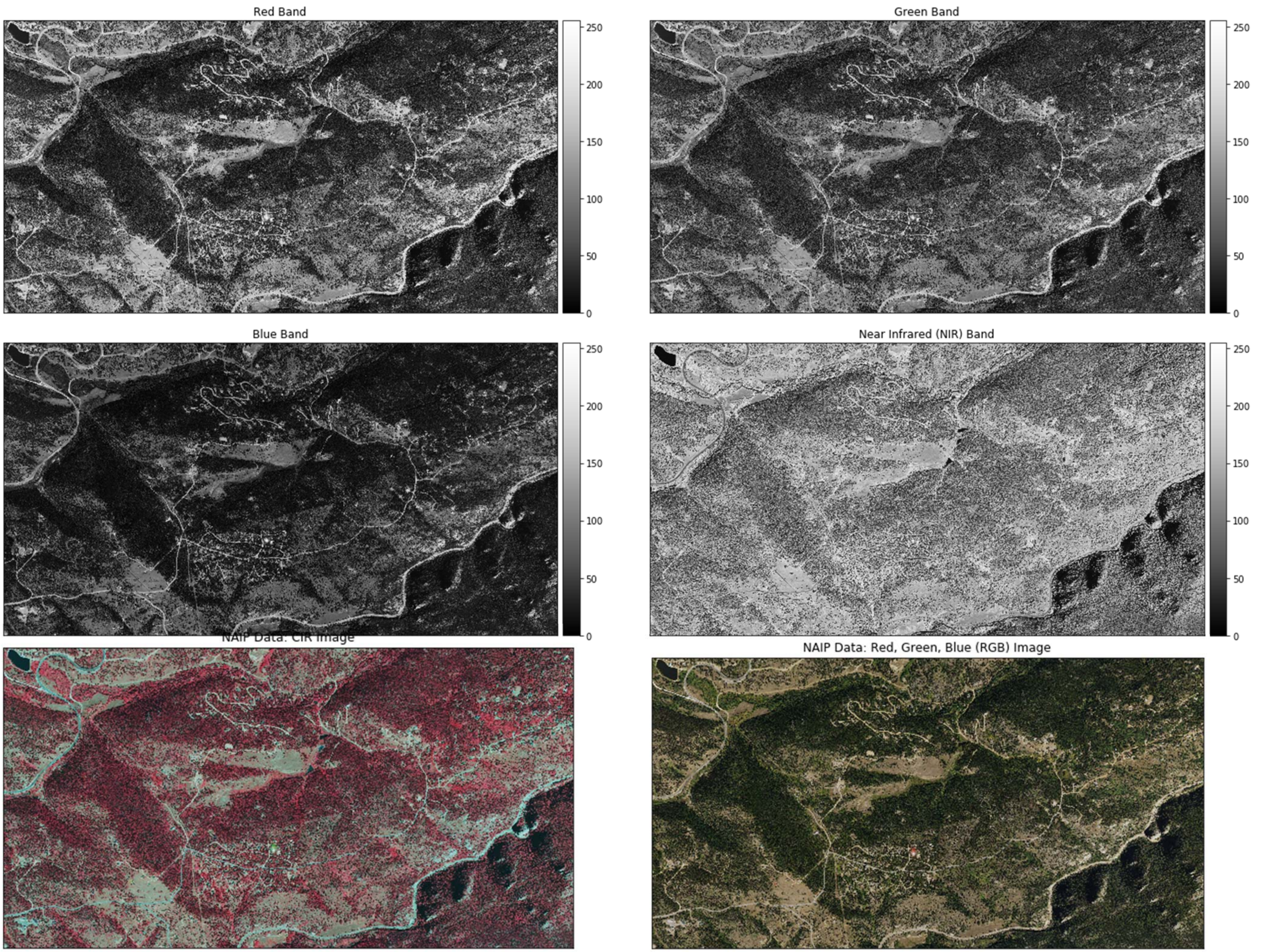
Palm Springs, CA

Bands 4, 3, 2 (NIR, red, green)



Depending upon the band combination and colors assigned, land cover appears in various colors

	True Color Red: Band 3 Green: Band 2 Blue: Band 1	False Color Red: Band 4 Green: Band 3 Blue: Band 2	SWIR (GeoCover) Red: Band 7 Green: Band 4 Blue: Band 2
Trees and bushes	Olive Green	Red	Shades of green
Crops	Medium to light green	Pink to red	Shades of green
Wetland Vegetation	Dark green to black	Dark red	Shades of green
Water	Shades of blue and green	Shades of blue	Black to dark blue
Urban areas	White to light blue	Blue to gray	Lavender
Bare soil	White to light gray	Blue to gray	Magenta, Lavender, or pale pink



https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/

NAIP Multispectral Imagery

- NAIP imagery is available in the United States and typically has **three bands - red, green and blue**. However, sometimes, there is a 4th near-infrared band available.
- NAIP imagery typically is 1m spatial resolution, meaning that each pixel represents 1 meter on the Earth's surface.
- NAIP data is often collected using a camera mounted on an airplane and is collected for a given geographic area every few years.

Landsat 8 Imagery

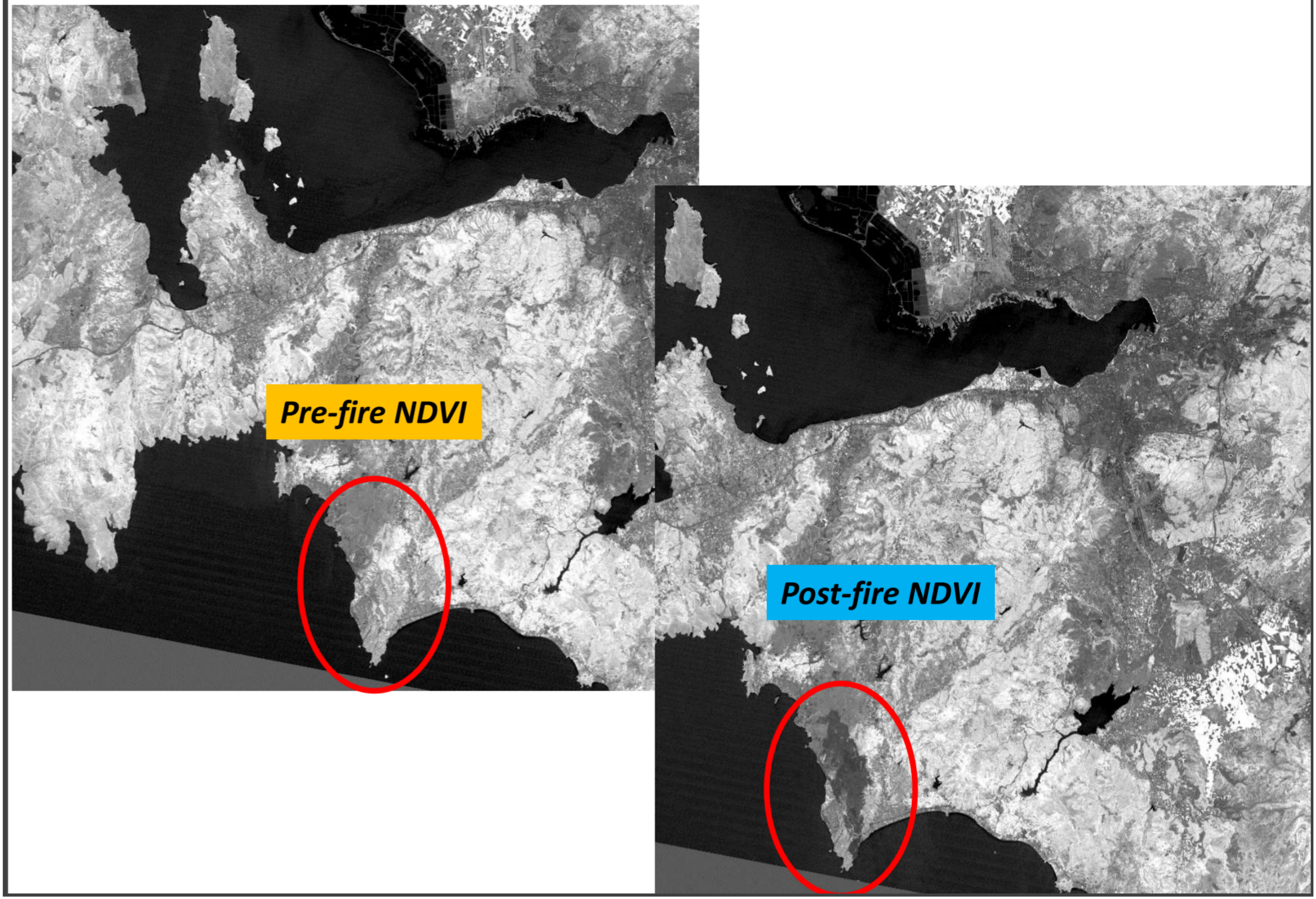
- Compared to NAIP, Landsat data are collected using an instrument mounted on a satellite which orbits the globe, continuously collecting images.
- The Landsat instrument collects data at 30 meter spatial resolution but also has 11 bands distributed across the electromagnetic spectrum compared to the 3 or 4 that NAIP imagery has.
- Landsat also has one panchromatic band that collects information across the visible portion of the spectrum at 15 m spatial resolution.

Landsat Thematic Mapper Imagery

Band	Wavelength	Useful for mapping
Band 1 – Blue	0.435 - 0.451	Coastal and aerosol studies
Band 2 – Blue	0.452 - 0.512	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 3 - Green	0.533 - 0.590	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - Red	0.636 - 0.673	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.851 - 0.879	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.566 - 1.651	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.107 - 2.294	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.503 - 0.676	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.363 - 1.384	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	11.50 - 12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

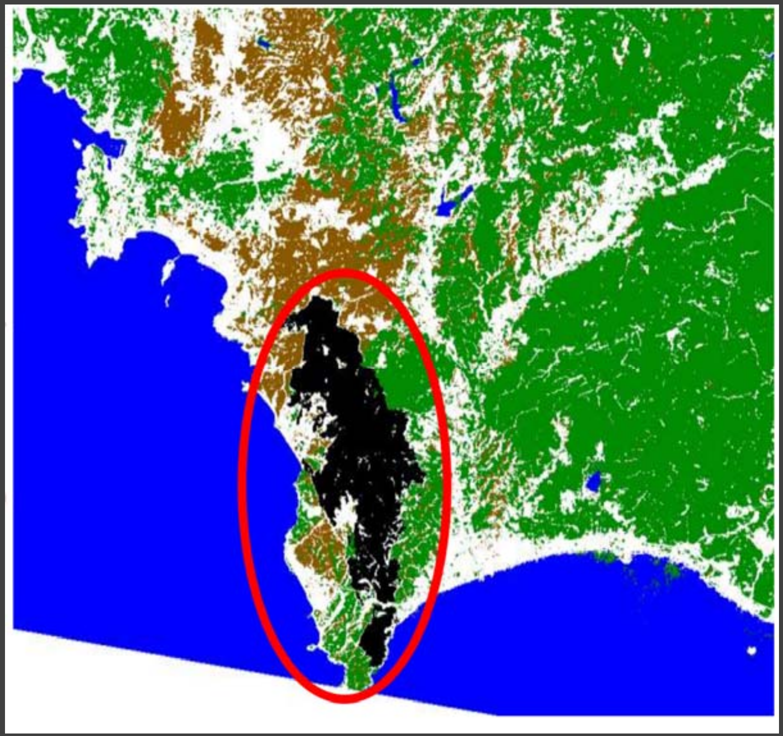
MODIS Imagery

- The Moderate Resolution Imaging Spectrometer (MODIS) instrument is satellite-based instrument that continuously collects data over the Earth’s surface.
- MODIS consists of two seperate satellites with distinct missions (Aqua and Terra) focus their data collection on their area of specialty, water and land respectively.
- For land-based earth analytics projects, such as calculating NDVI (Normalized Difference Vegetation Index) or NBR (Normalized Burn Index), you should generally be getting your data from the Terra satellite, as it is the one that focuses on land-based data collection.
- MODIS collects spectral information at several spatial resolutions including 250m, 500m and 1000m.
- MODIS has 36 bands however in class you will learn about only the first 7 bands.


Pre-fire NDVI
Post-fire NDVI

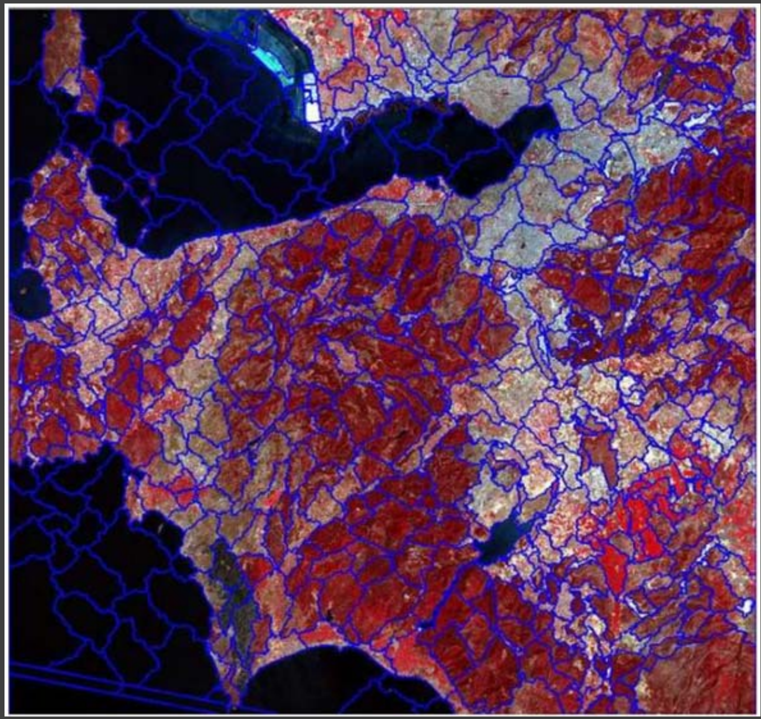
Pixel based image analysis

- Pixel based image classification is an analysis intented to make clusters and classes in a multi dimensional spectral space, using image pixels of multispectral satellite imagery.

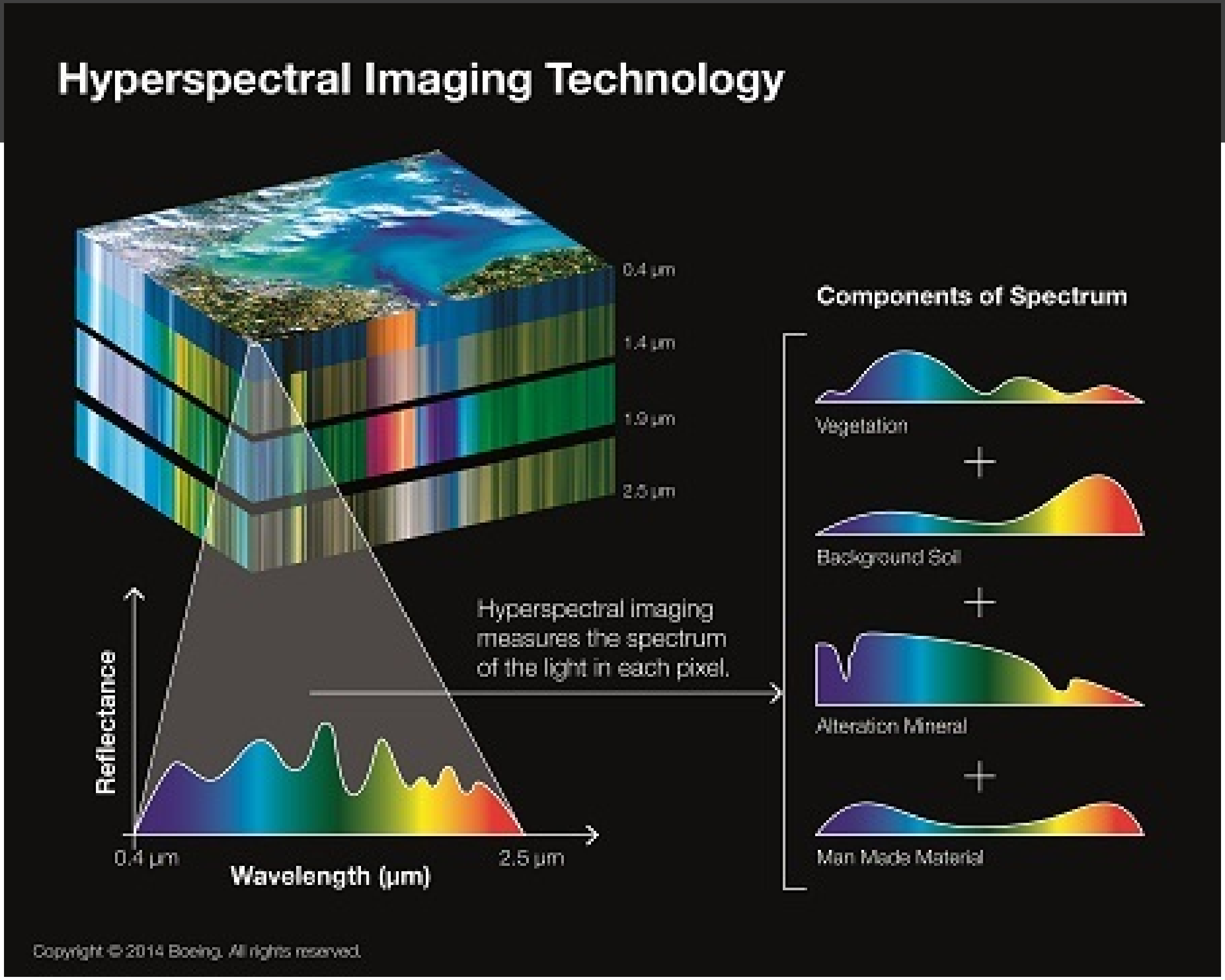


Segmentation

- The most convenient parameters (such as scale, color, shape, smoothness and compactness) can be chosen to obtain the objects in case study area.



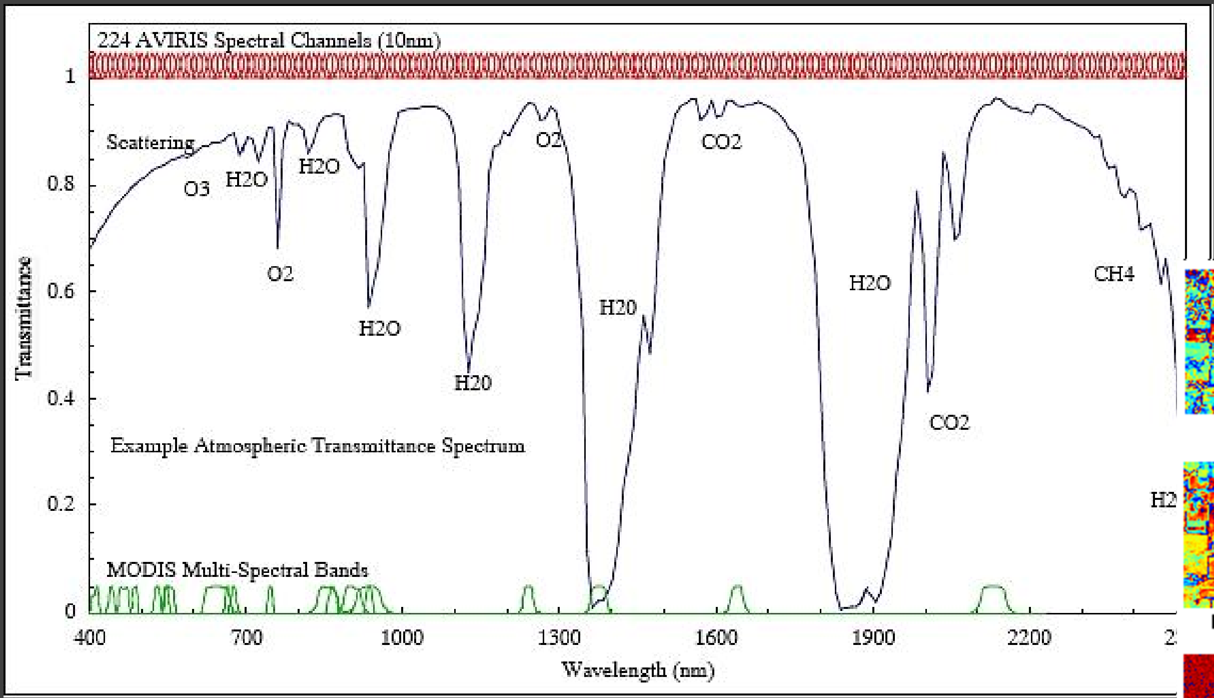
Hyperspectral Remote Sensing

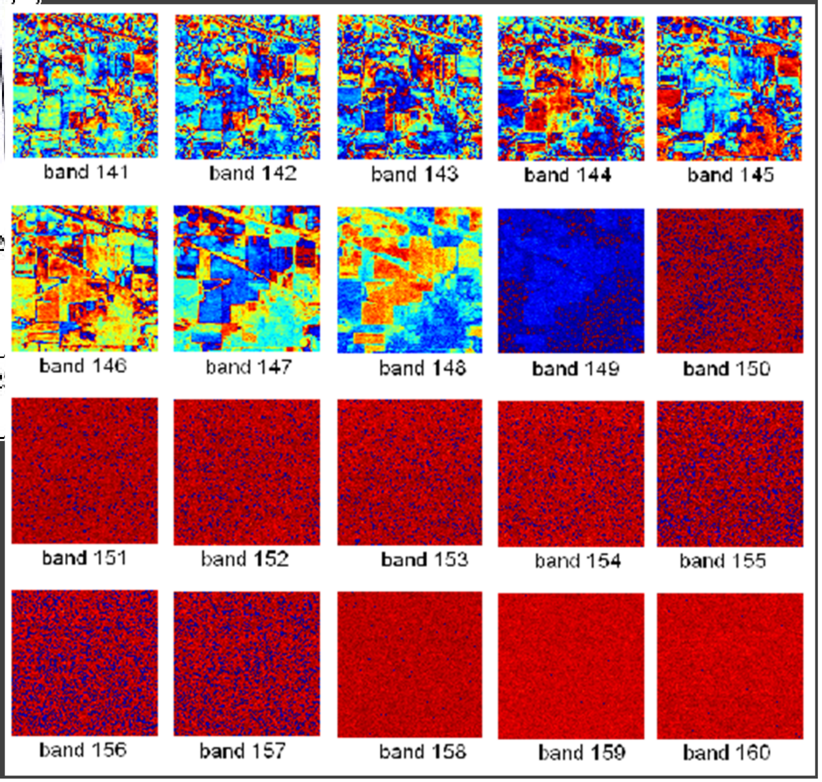


Hyperspectral Remote Sensing

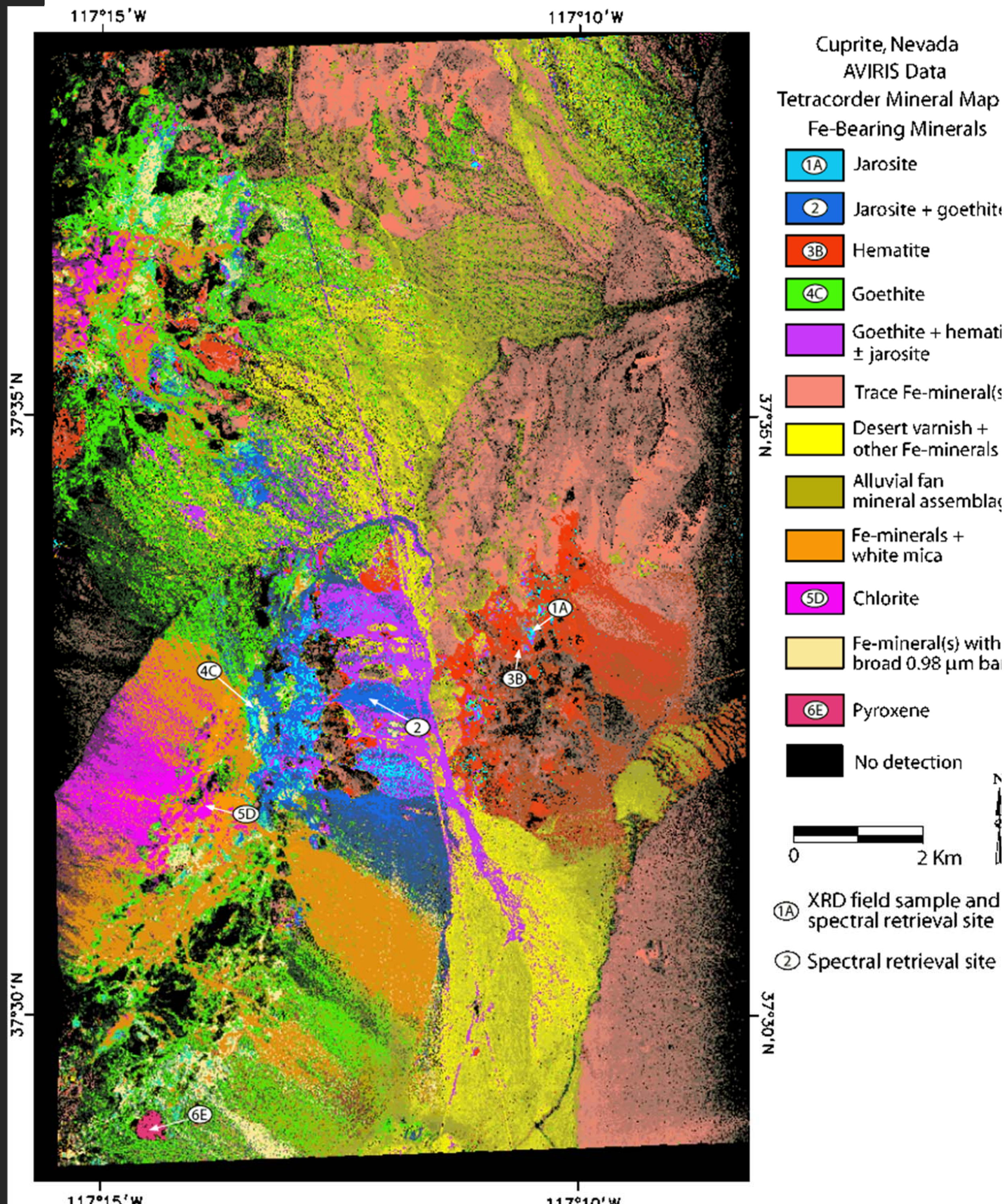
- Recent advances in remote sensing and geographic information has led the way for the development of hyperspectral sensors.
- hyperspectral remote sensing uses hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum. This sensor’s very high spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.
- Hyperspectral data sets are generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths (5-10 nm)
- Hyperspectral deals with imaging narrow spectral bands over a continuous spectral range, producing the spectra of all pixels in the scene.

AVIRIS


224 AVIRIS Spectral Channels (10nm)
Scattering
O3
H2O
H2O
O2
H2O
H20
O2
H20
CO2
H2O
CO2
CH4
Example Atmospheric Transmittance Spectrum
MODIS Multi-Spectral Bands
Transmittance
Wavelength (nm)
1
0.8
0.6
0.4
0.2
0
400
700
1000
1300
1600
1900
2200

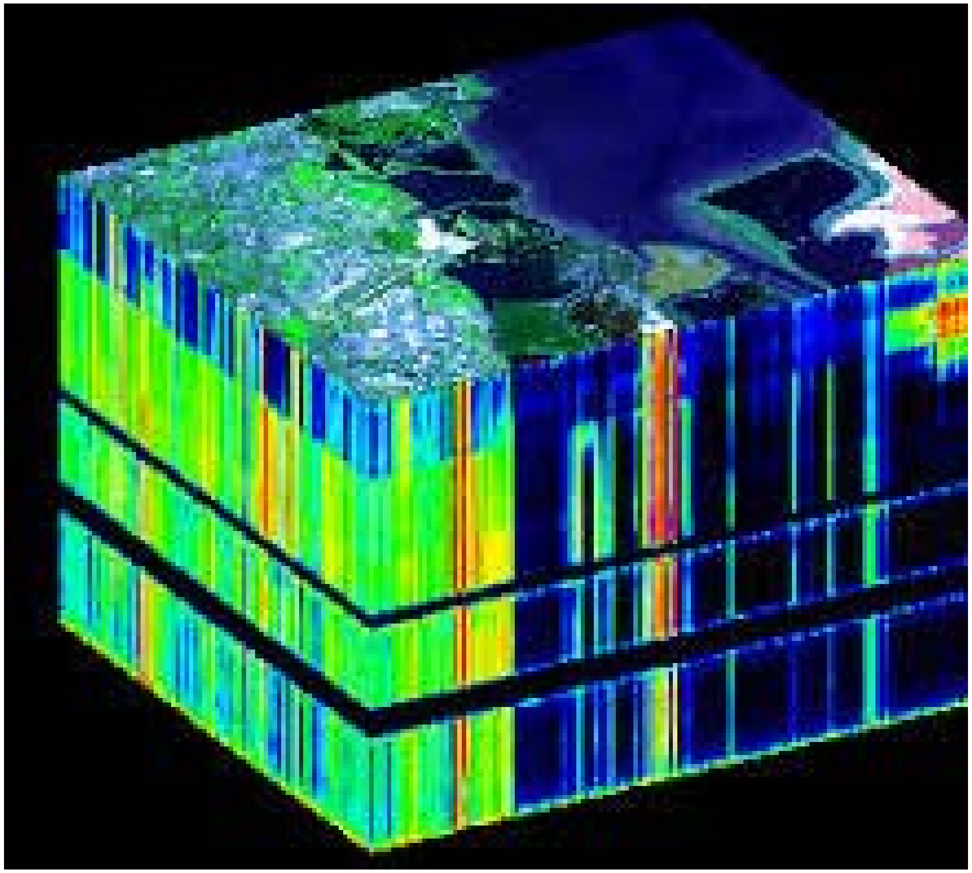

band 141
band 142
band 143
band 144
band 145
band 146
band 147
band 148
band 149
band 150
band 151
band 152
band 153
band 154
band 155
band 156
band 157
band 158
band 159
band 160

AVIRIS Application

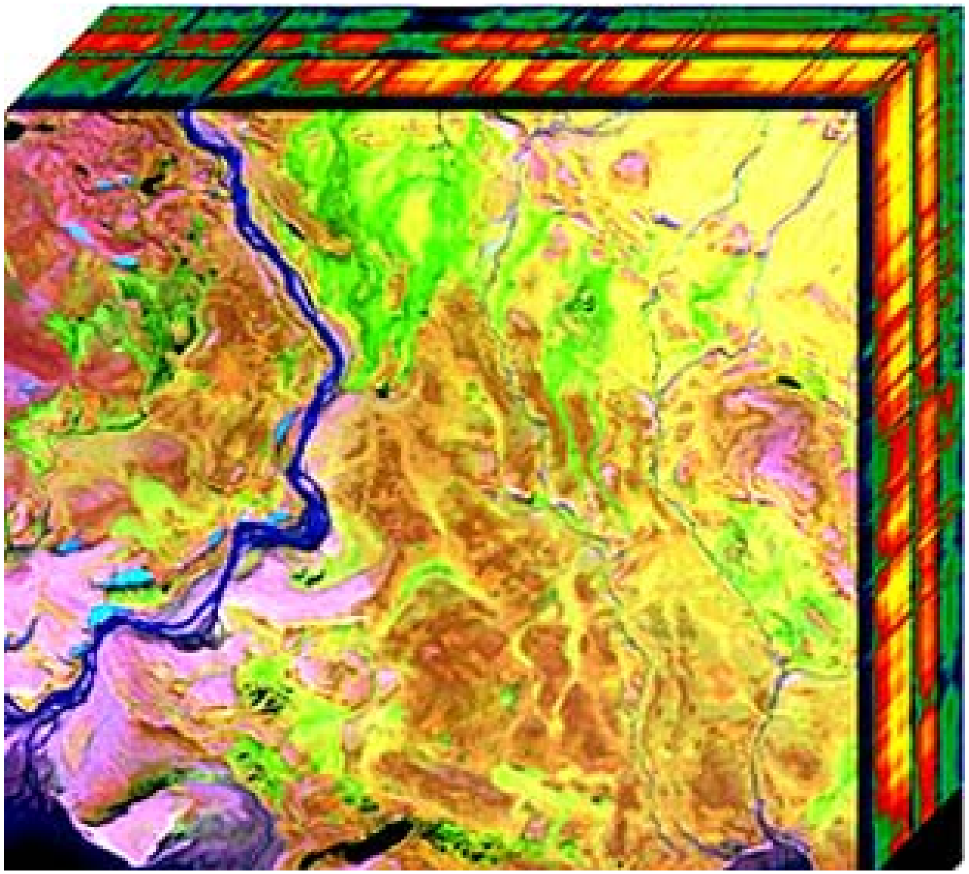


Hyperspectral remote sensing cube

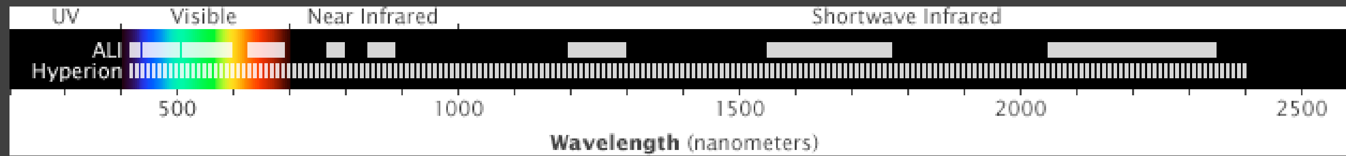
- There are four ways for sensors to sample the hyperspectral cube: Spatial scanning, spectral scanning, snapshot imaging, and spatio-spectral scanning



AVIRIS hyperspectral data cube over Moffett Field, CA



Hyperion



https://www.nanosats.eu/sat/hyperion

- Hyperion measures reflected light like many other satellite imagers, recording more than 200 wavelengths, it can detect the fingerprints of the materials on Earth's surface.
- The hundreds of bands in hyperspectral imagery enable researchers to differentiate minerals and rocks that appear similar in visible light.

Largest database of nanosatellites

Nanosats Database

DATABASE FIGURES COMPANIES TABLES ECOSYSTEM ABOUT CUBESAT CONTACT

World's largest database of nanosatellites, over 2500 nanosats and CubeSats

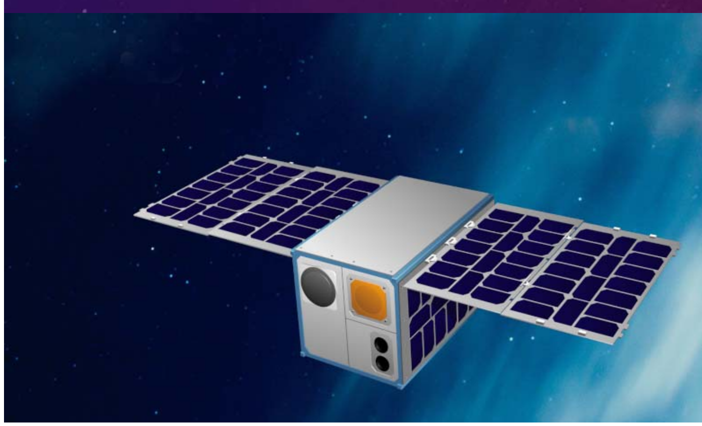
CubeSat constellations, companies, technologies, missions and more

Sister websites **www.factoriesinspace.com** and **www.newspace.im**

"I believe the big future of nanosatellites is still to come!"

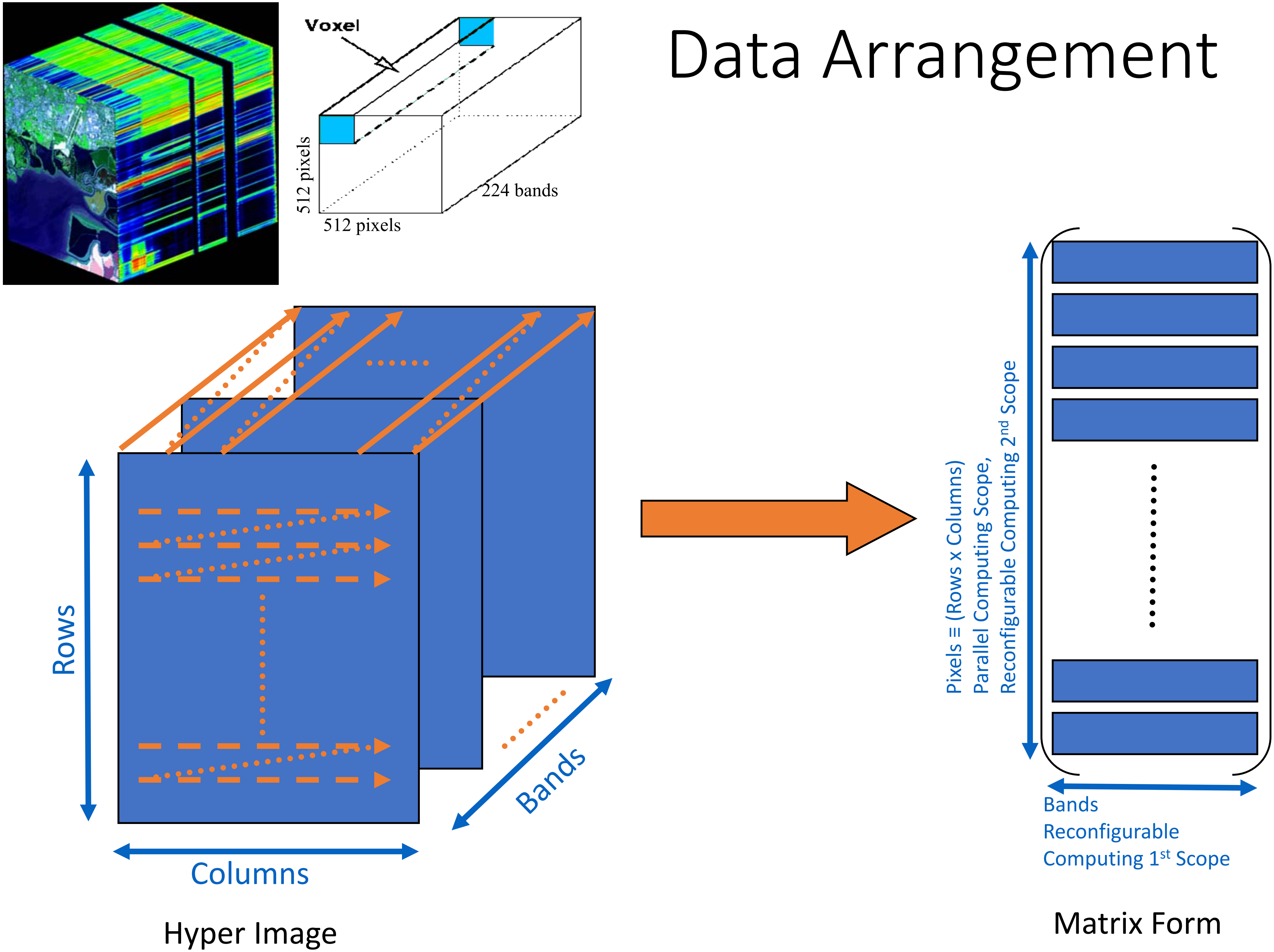
Facts as of 2020 April 19

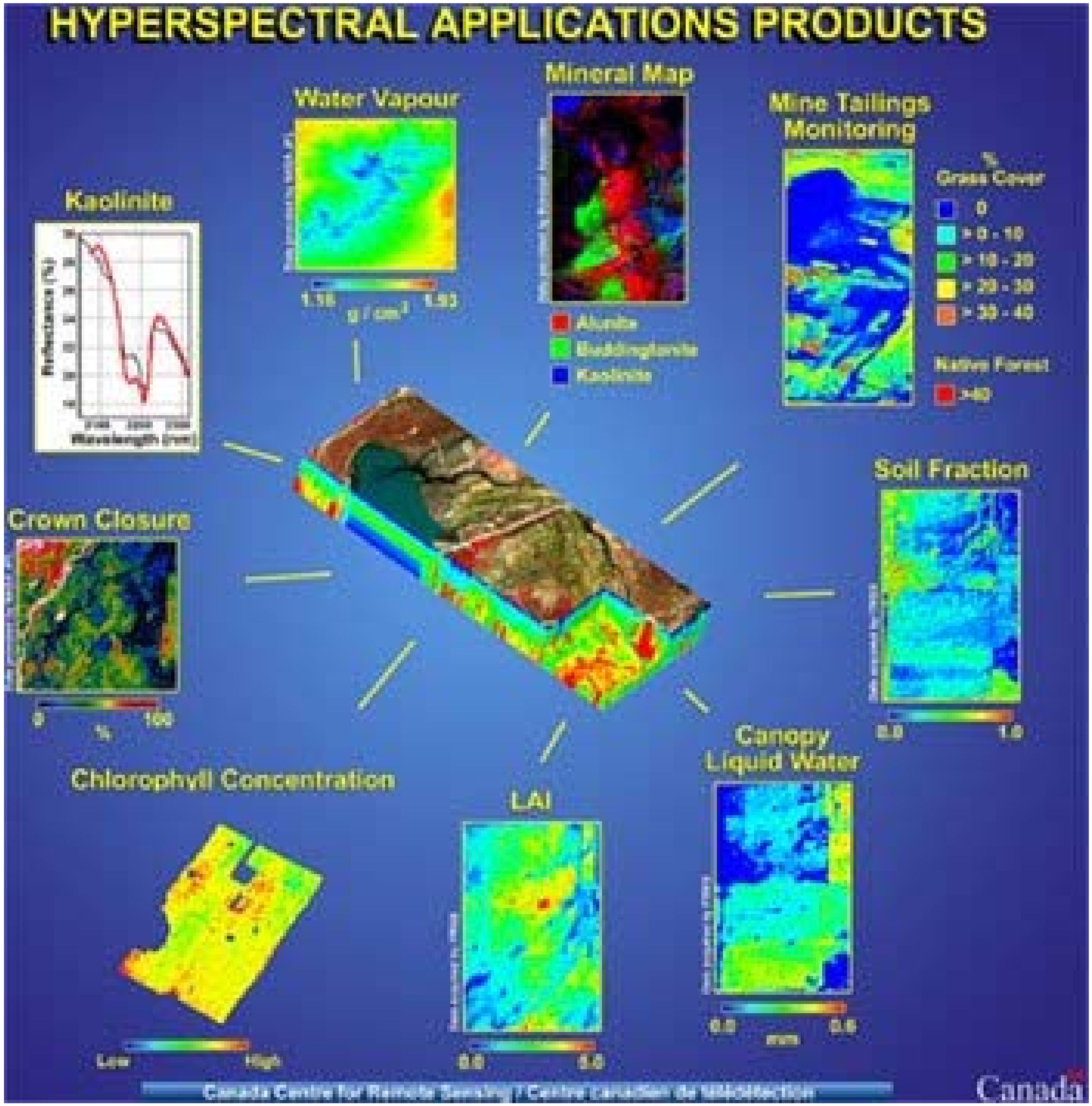
Nanosats launched: 1317
CubeSats launched: 1210
Interplanetary CubeSats: 2
Nanosats destroyed on launch: 87
Most nanosats on a rocket: 103
Countries with nanosats: 66
Companies in database: 495
Forecast: over 2500 nanosats to launch in 6 years



https://www.nanosats.eu/

Data Arrangement




HYPERSPECTRAL APPLICATIONS PRODUCTS
Water Vapour
g / cm³
Mineral Map
Alunite
Buddingtonite
Kaolinite
Mine Tailings Monitoring
% Grass Cover
0
> 0 - 10
> 10 - 20
> 20 - 30
> 30 - 40
Native Forest
>40
Kaolinite
Reflectance (%)
Wavelength (nm)
Soil Fraction
0.0
1.0
Crown Closure
0
%
100
Canopy Liquid Water
0.0
mm
0.6
Chlorophyll Concentration
Low
High
LAI
0.0
5.0
Canada Centre for Remote Sensing / Centre canadien de télédétection
Canada

Hyperspectral Remote Sensing Applications

Hyperspectral data has been used to identify and distinguish spectrally similar materials having characteristic reflectance spectra. Due to the capability of distinguishing various ground objects in detail, hyperspectral datasets are able to detect and map a wide variety of materials.

- Mineral Targeting: Spectral reflectance in visible and near-infrared offers a rapid and inexpensive technique for determining the mineralogy of samples and obtaining information on chemical composition.
- Soils: Obtaining quantitative information about soil chemistry, its genetic and fertility classification. Study of soil parameters such as organic matter, soil moisture, particle size distribution iron oxide content, soil structure etc. The hyperspectral data with improved radiometric and spatial resolution will help in deriving an improved vegetation/soil indices that will maximize sensitivity to plant biophysical parameters, increase sensitivity to the vegetation signal and normalize atmosphere and ground contamination noise influence.
- Vegetation: Study of species diversity, environmental stress, physiological features such as photosynthetic activity, plant productivity, canopy biochemistry, biomass and plant transpiration. Also for evaluation of vegetation stress, nutrient stress, moisture stress and crop growth models.
- Atmosphere: Study of atmospheric parameters such as clouds, aerosol conditions and water vapor monitoring, large scale atmospheric variations as a result of environmental change.
- Oceanography: Measurement of photosynthetic potential by detection of phytoplankton, detection of yellow substance and detection of suspended matter. It also helps in investigations of water quality, monitoring coastal erosion.
- Snow and Ice: Spatial distribution of various types of snow cover, surface albedo and snow water equivalent. Calculation of energy balance of a snowpack, estimation of snow properties-snow grain size, snow depth and liquid water content.
- Oil Spills: When oil spills in an area affected by wind, waves, and tides, a rapid and assessment of the damage can help to maximize the cleanup efforts. Environmentally sensitive areas can be targeted for protection and cleanup, and the long-term damage can be minimized. Time sequence images of the oil can guide efforts in real-time by providing relative concentrations and accurate locations

Advantages and disadvantages of Hyperspectral remote sensing

- The primary advantage to hyperspectral imaging is that, because an entire spectrum is acquired at each point, the operator needs no prior knowledge of the sample, and postprocessing allows all available information from the dataset to be mined.
- Hyperspectral imaging can also take advantage of the spatial relationships among the different spectra in a neighbourhood, allowing more elaborate spectral-spatial models for a more accurate segmentation and classification of the image.
- The primary disadvantages are cost and complexity. Fast computers, sensitive detectors, and large data storage capacities are needed for analyzing hyperspectral data.
- Significant data storage capacity is necessary since hyperspectral cubes are large, multidimensional datasets, potentially exceeding hundreds of megabytes.
- All of these factors greatly increase the cost of acquiring and processing hyperspectral data.

Active and Passive Satellites and possible applications

Comparing Active and Passive Microwave Sensors

Passive Microwave Remote Sensing	Active Microwave Remote Sensing
Sensor Examples	
AMSU-A & -B, MHS, AMSR-E, SSM/I/T1/T2, SSMIS, TRMM-TMI, WindSat, NPOESS MIS*, and ATMS	QuikSCAT, TRMM-PR, RADARSAT, MetOp ASCAT, CloudSat, U.S. Navy GFO, Jason-1 and 2, ERS-2 SCAT & SAR, Envisat ASAR, and RA-2
Measurement Capabilities	
Sense emitted microwave energy from terrestrial sources	Send and receive electromagnetic pulses of energy
Cloud and precipitation information from layers	Cloud and precipitation information from discrete levels
Sea surface wind vectors (WindSat, MIS*), salinity	Sea surface wind vectors, salinity
Precipitation (rain rate and snowfall)	Precipitation (rain rate and snowfall)
Cloud properties (microphysics, cloud top and base)	Cloud properties (microphysics, cloud top, and base)
Atmospheric temperature and moisture profiling	
Snow and sea ice coverage and extent, sea ice age	Snow and sea ice coverage and extent, river ice movement
Snow cover characteristics	Snow cover characteristics
Soil moisture / surface wetness	Soil moisture / surface wetness
	Vegetation, biomass, land use, surface roughness, topography, and geology (SAR, SCAT, ASCAT, RADARSAT)
Sea surface temperature	Ocean surface topography, sea surface state, heat storage and transfer (from radar altimeters)

*NPOESS microwave imager/sounder capabilites TBD