Bharathidasan University

Tiruchirappalli, Tamil Nadu

Programme: M. Tech Geoinformatics

Course: Microwave and Hyperspectral Remote Sensing

Title: Hyperspectral Imaging

Dr. C. Bhuvaneswaran, M.sc., M.Tech., Ph.D
Guest Faculty
Department of Geography
Bharathidasan University

HYPERSPECTRAL REMOTE SENSING

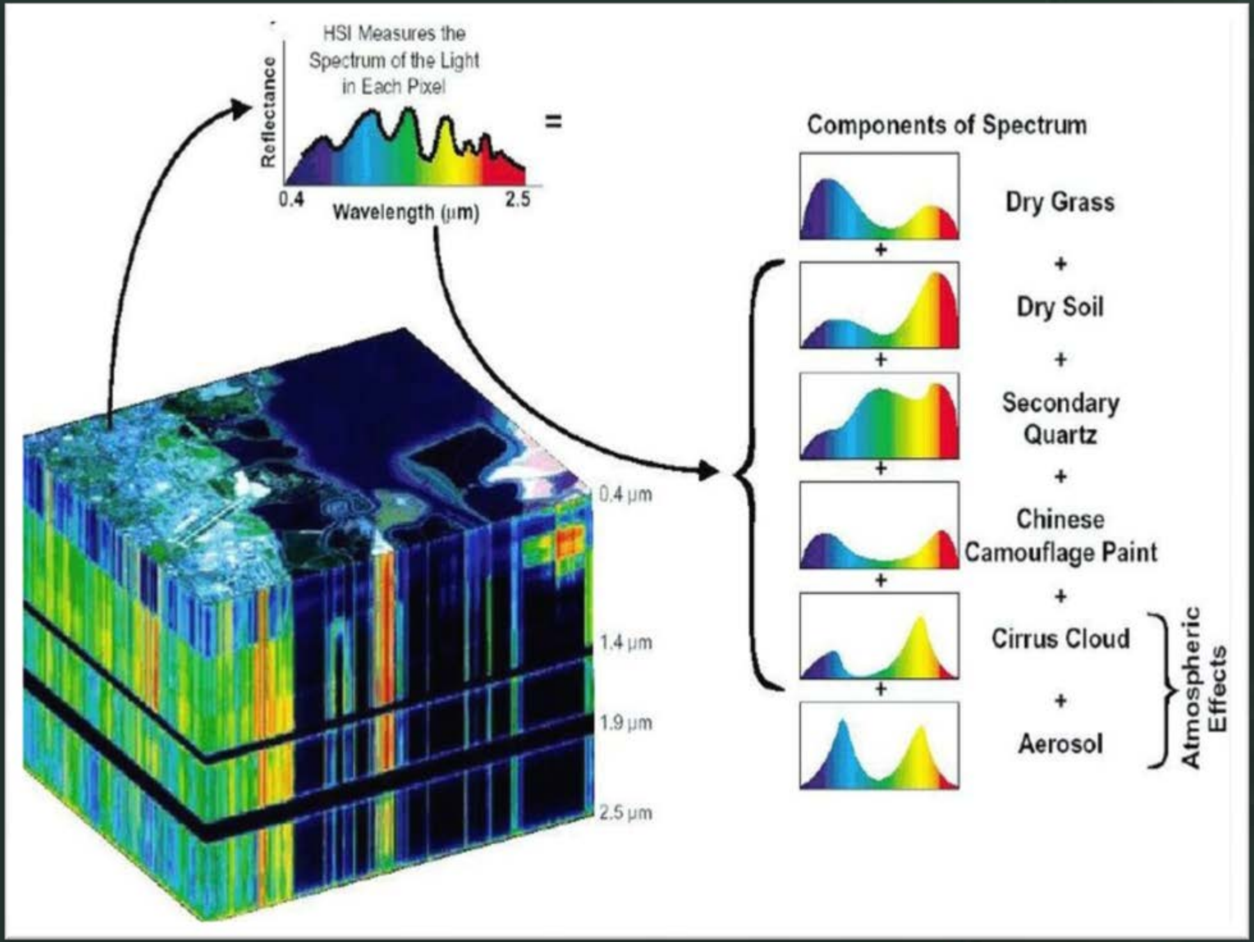
CONTENTS

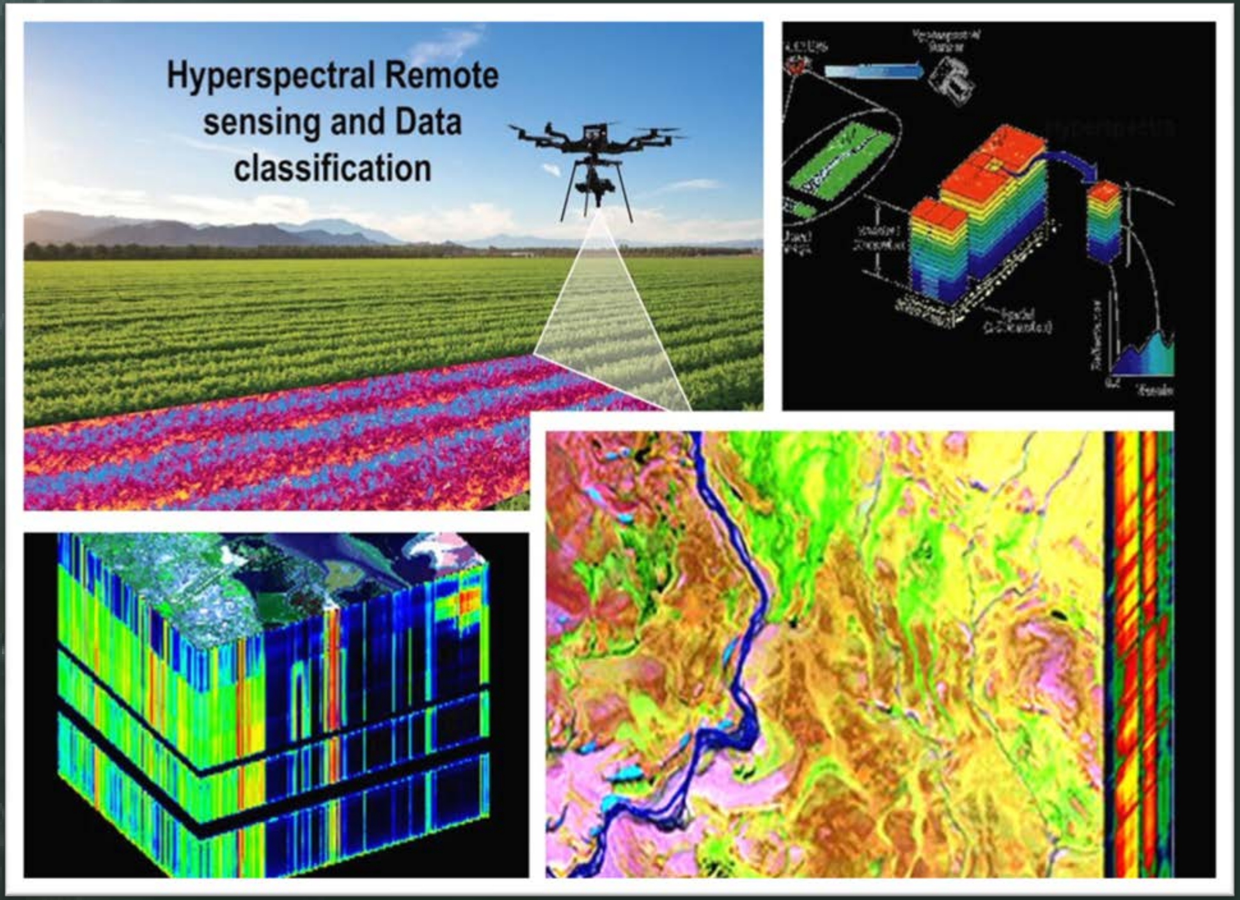
01

Description of Hyperspectral Imaging

Introduction

Hyperspectral remote sensing is a technique used in Earth observation and remote sensing that involves capturing and analyzing a wide range of wavelengths across the electromagnetic spectrum. Hyperspectral sensors capture data across hundreds or even thousands of narrow and contiguous spectral bands. This high spectral resolution allows for detailed characterization and analysis of materials and substances based on their unique spectral signatures.





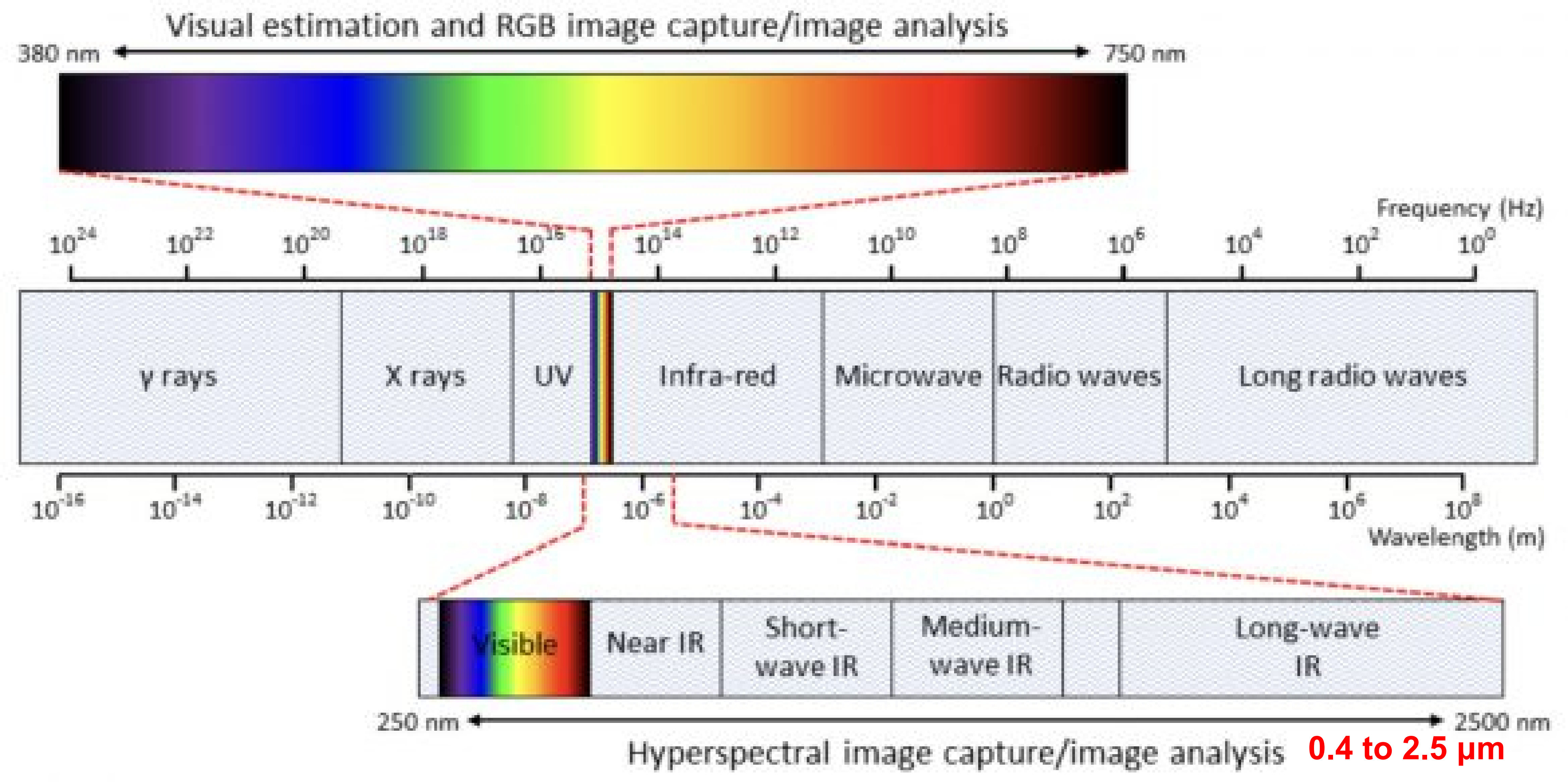
01 It is also called as a imaging spectometry or spectroscopy.

02 Hyperspectral sensors covers the continuous data of electromagnetic spectrum.

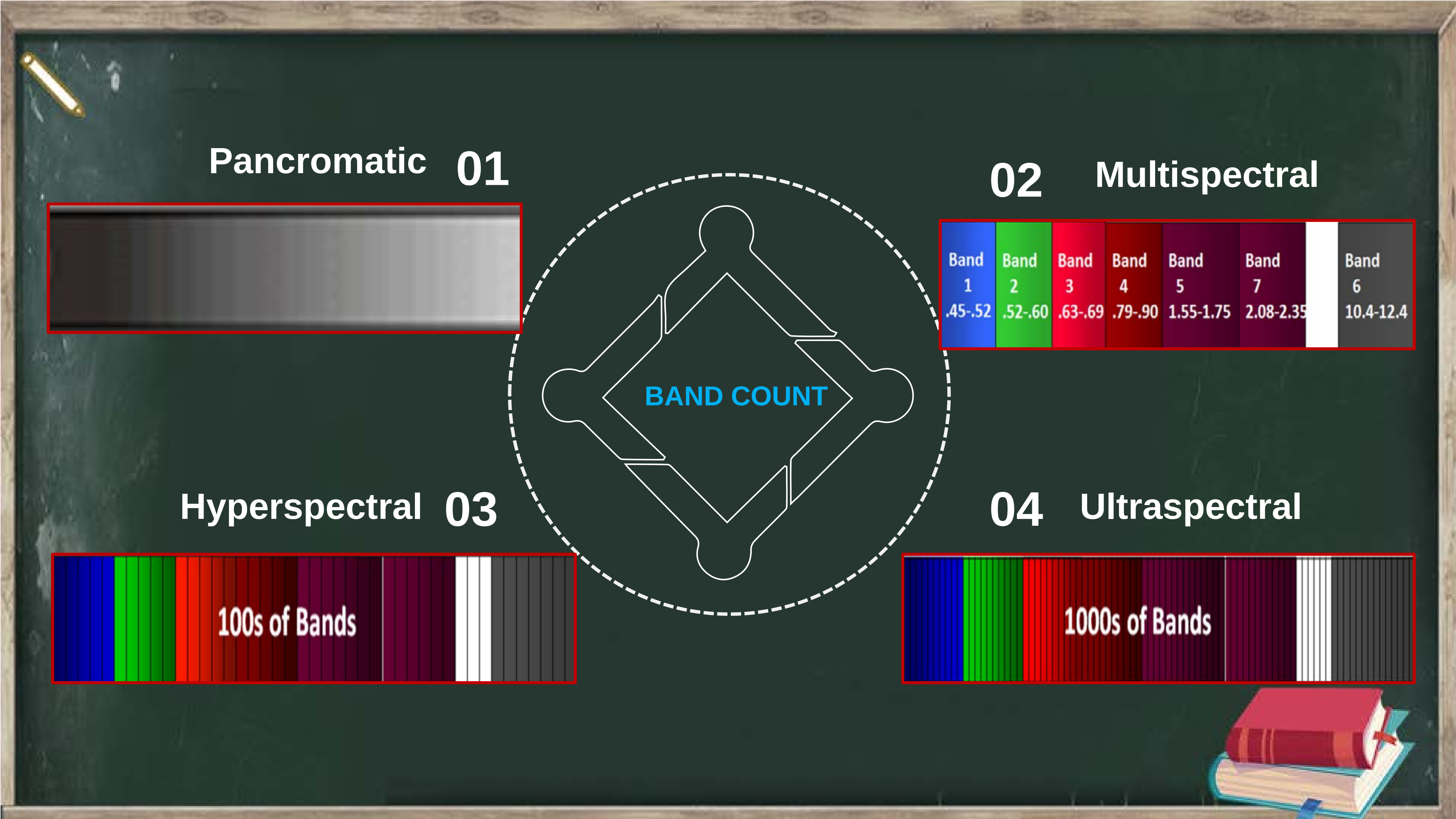
03 It contains a more than hundereds of bands and sometimes 240+ bands.

04 Hyperspectral imagine having very narrow bands and the band width was thin in nannometers(5-10nm) .

Range in EMR



0.4 to 2.5 μm


Pancromatic 01
02 Multispectral
Band 1 .45-.52
Band 2 .52-.60
Band 3 .63-.69
Band 4 .79-.90
Band 5 1.55-1.75
Band 7 2.08-2.35
Band 6 10.4-12.4
BAND COUNT
Hyperspectral 03
100s of Bands
04 Ultraspectral
1000s of Bands

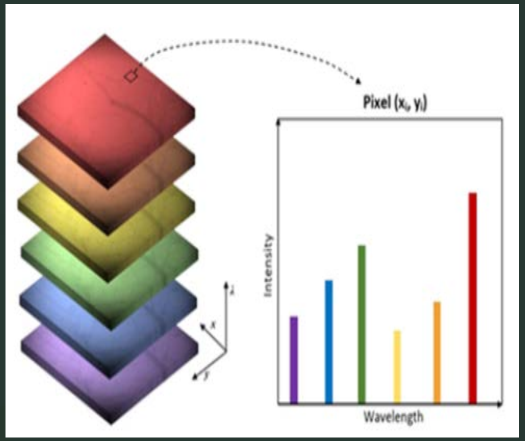
Multispectral:

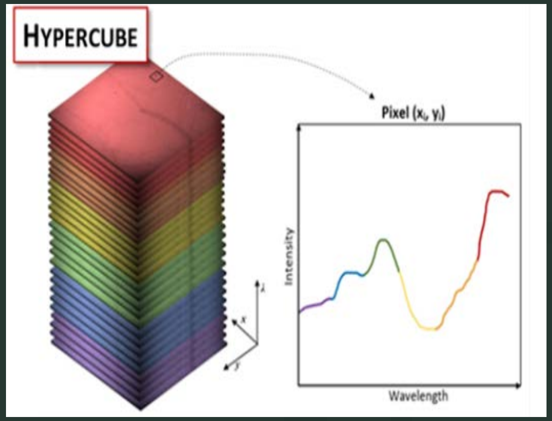
#Popular sensors such as Landsat and MODIS MSS,TM

#Limited number of spectral bands

#high Image resolution

#Global spatial extent





Hyperspectral:

#Limited in numbers of satellite sensors

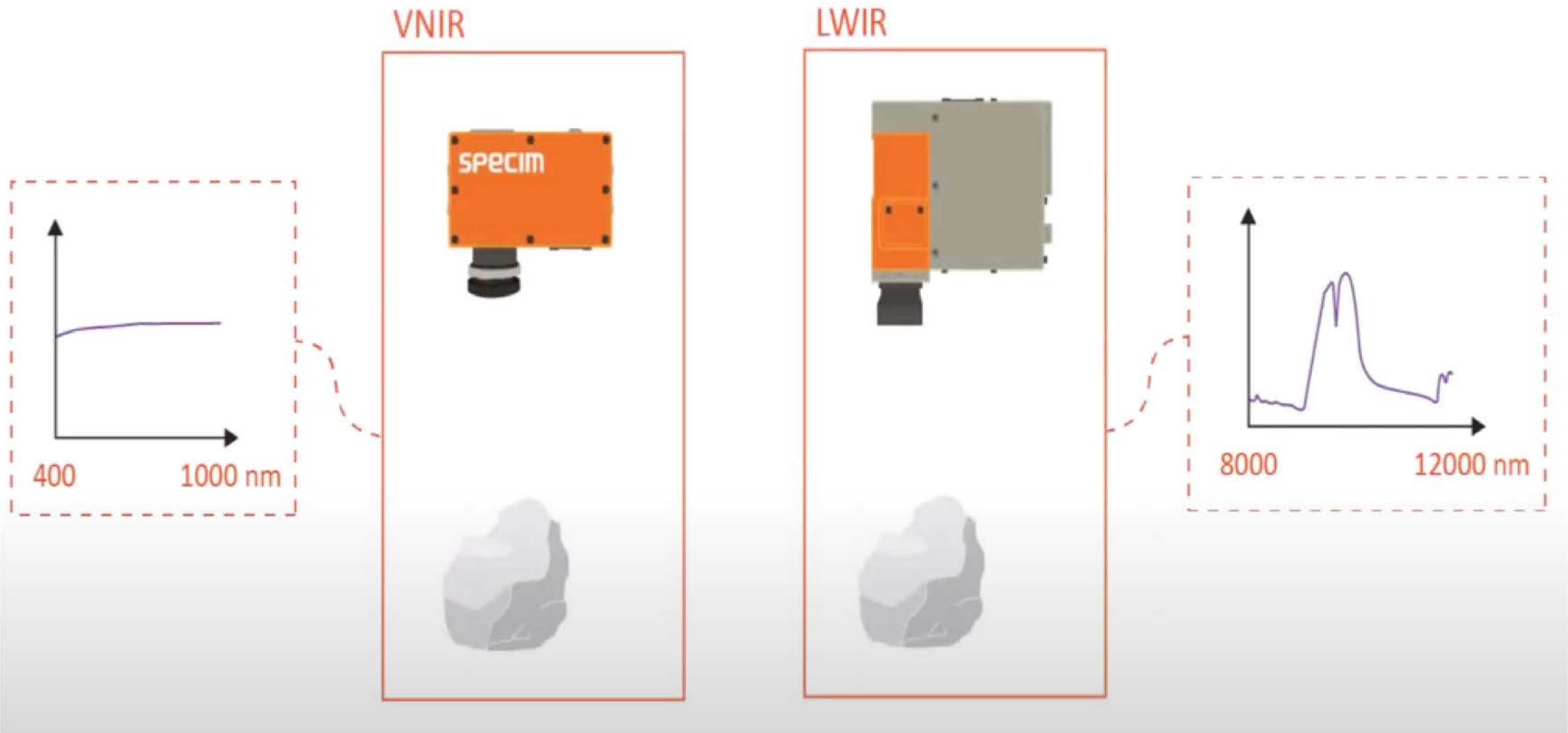
#Narrow bands that measure more characteristics of surface reflectance

#high pixel resolution

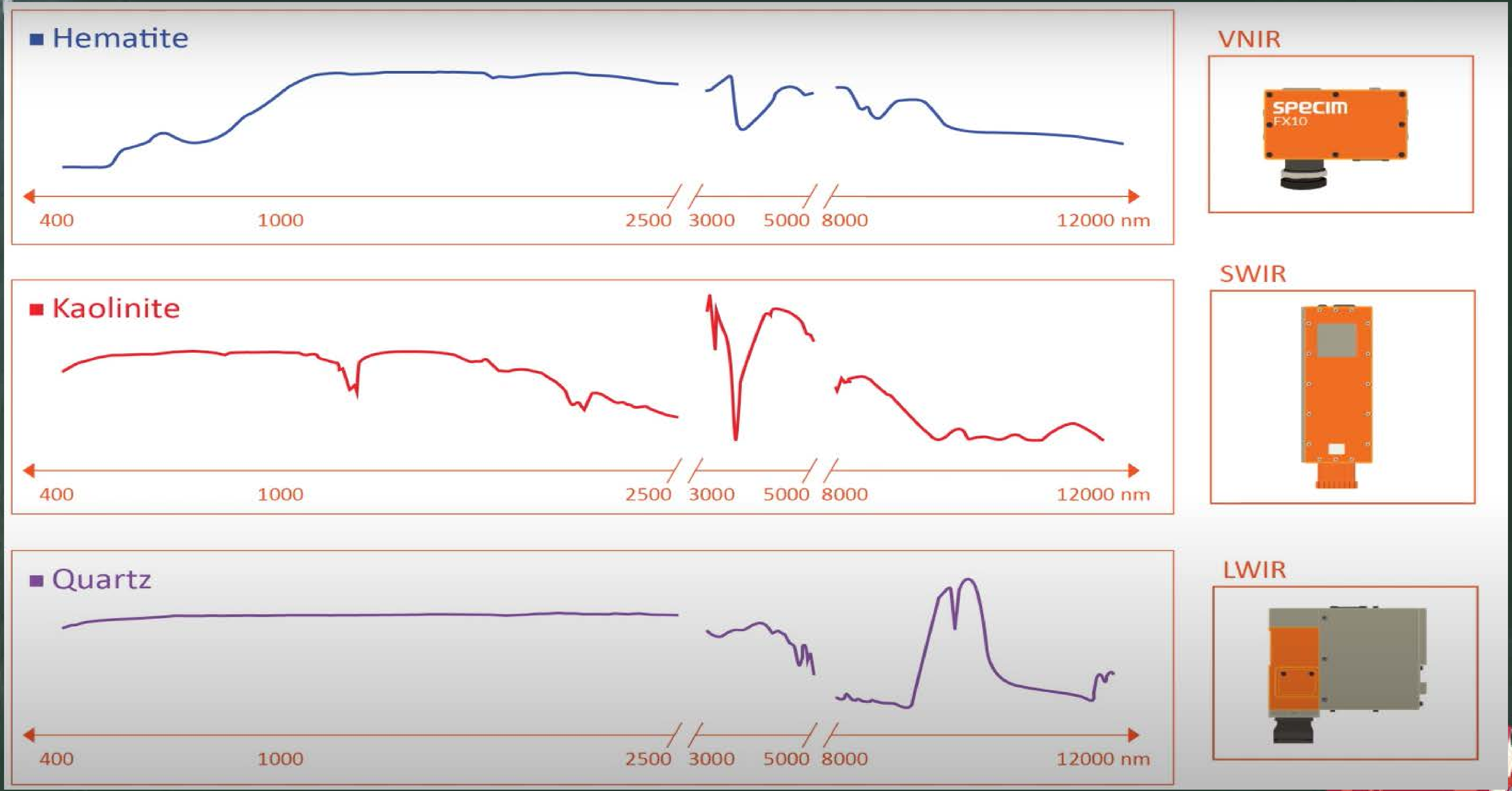
#Less spatial coverage

HyperSpectral Imaging (HSI) is based on the utilization of an integrated hardware and software (HW&SW) platform embedding conventional imaging and spectroscopy to attain both spatial and spectral information from an object. Although HSI was originally developed for remote sensing, it has recently emerged as a powerful process analytical tool, for non-destructive analysis, in many research and industrial sectors.

SPECRAL SIGNATURE OF HYPERSPECTRAL CAMERAS



VNIR
LWIR
specim
400
1000 nm
8000
12000 nm



Hematite
Kaolinite
Quartz
400
1000
2500
3000
5000
8000
12000 nm
VNIR
SWIR
LWIR
specim
FX10

02

Development of Hyperspectral Imaging

Development of Airborne hyperspectral remote sensing

@Airborne HRS has a long history of development dating back to 1983. Airborne Imaging Spectrometer (AIS) -1, the first generation imaging spectrometer was born in this year. The spectral range is from 0.99µm to 2.4µm, at 9.3nm spectral resolution in 64 contiguous spectral bands.

@The second generation imaging spectrometer was AVIRIS, at the same time, it was the first imaging sensor. The AVIRS can measure solar reflectance spectroscopy from 0.4µm to 2.5µm with 224 bands.

@Subsequently, in 1989 ITRES Corporation, Alberta, Canada introduced a pushbroom imaging spectrograph, Compact Airborne Spectrographic Imager (CASI), which covers the region (0.43~ 0.86µm) in 288 spectral bans.

@In 1994, the GER launched the Digital Airborne Imaging Spectrometer (DAIS) series, DAIS3715, DAIS7915, DAIS16115, and DAIS21115, HyMAP has also been developed in Australia in 1996. Following the CHRIS was launched on ESA'S PROBA platform in October 2000.

@China began to develop hyperspectral imaging system in 1980's, the first Modual Airborne Imaging Spectral (MAIS) ran in 1991. It is a sign that China has made a great breakthrough in technology and applications of airborne imaging spectral.

@And then, the Chinese Academy of Sciences successfully developed operational modular imaging spectrometer (OMIS) on the basis of MAIS, including OMIS-1 and OMIS-2, which belonged the Pushbroom Hyperspectral Imager (PHI), with 128 and 68 spectral bands from visible to TIR wavelength at the spectral region 0.46~12.5μm

@Chinese Moderate Resolution Imaging Spectrometer (CMODIS), as an ocean color satellite measure spectrometer, was launched on 25 March 2002 onboard the "Shenzhou-3" spaceship. In addition, the interference imaging spectrometer, researched by Xi'an institute of optics and precision mechanics of Chinese Academy of Sciences (CAS), was lift off onboard Chang'E-1 in October 2007, the Environmental disaster reduction satellite(Env-DD) in September 2008, and the GF-5, will be taken in the near future.

@A variety of imaging spectrometers in our country, OMIS and PHI represent the technical level of the imaging spectrometer in Asia, and also occupy an important position in the world.

Development of Spaceborne hyperspectral remote sensing

@The history of spaceborne HRS is shorter than airborne HRS, the first HRS satellite launched in 1997 named LEWIS (Failure). The plans of high resolution imaging spectrometer (HIRIS) and Orbview-4 were also failed. However, it develops very well in recent 30 years, and its value has been put forward.

@MODIS was launched successfully in December 1999, every 1 to 2 days, theMODIS pay a return visit the earth and acquires data, the spectral range of which is from 0.4μm to 14μm with 36 bands. These data can help us to well comprehend the global dynamics of earth.

@ASTER is an imaging instrument flying on Terra. The goal of ASTER is to discover how the earth is changing by observing and modeling the earth system, and understand the importance of life on earth. MightySat-II was launched on 19 July 2000, which was the third generation imaging spectrometer, sun-synchronous orbit

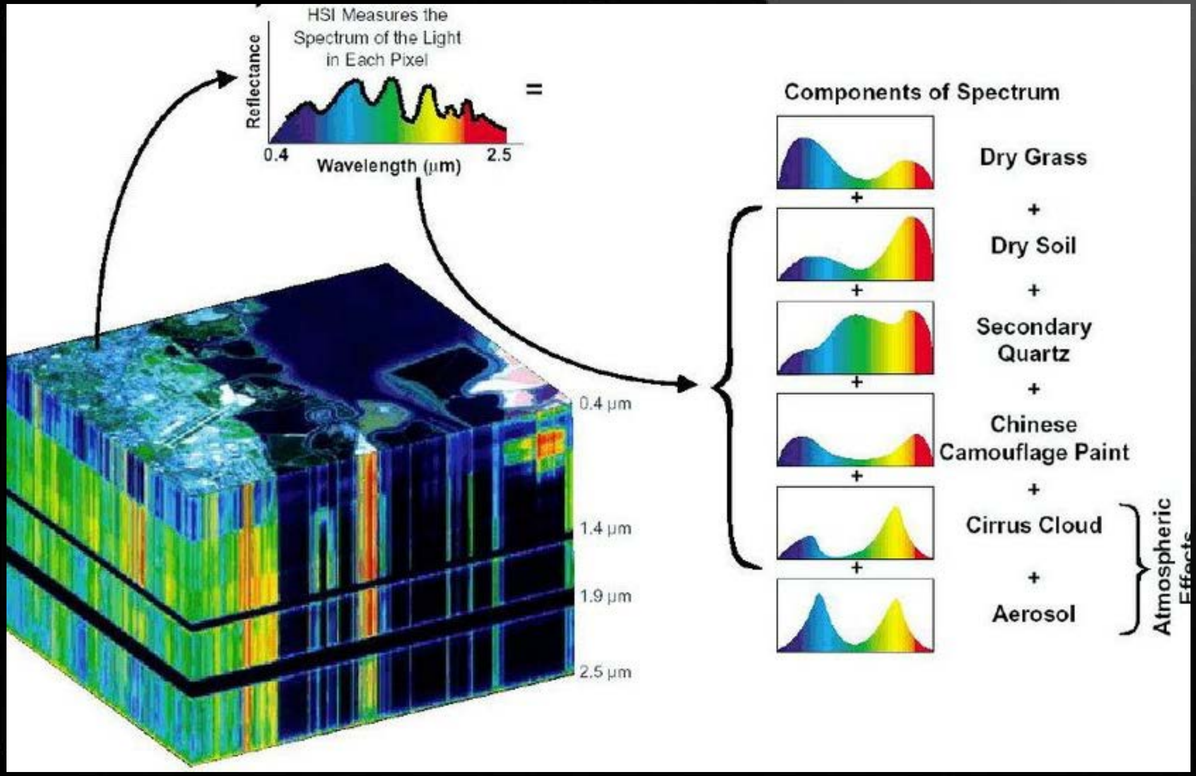
@The space technology of China develops rapidly, the HJ-1A satellite was launched in September 2008. The hyperspectral imager provides earth imagery at 100m spatial resolution and 5nm spectral resolution, and it spectral range is from 0.45μm to 0.95μm. Tiangong-1(TG-1) spacecraft with the spaceborne hyperspectral Image of China was lunched from the Jiuquan spaceport boarded the Changzheng-2F rocket in September 29, 2011. The spaceborne hyperspectral image has the highest spectral and spatial resolution, and its spectral region is from VIS to SWIR. The hyperspectral images data are widely used in various fields, such as in land resources investigation, forestry, agriculture, exploration of oil and gas, mineral, marine, urban heat island effect, detection of atmospheric and environment, materials science and so on.

03

Spectral Radiometry & spectral library

Spectral Radiometry

Spectral radiometry is the study of the measurement and interpretation of electromagnetic radiation over a range of wavelengths. It plays a crucial role in fields such as remote sensing, astronomy, and environmental monitoring. Understanding spectral radiometry is essential for interpreting data from hyperspectral imaging systems.



Spectral Radiometry Types

01

Reflectance Spectroscopy

Measures the amount of light reflected by a material across different wavelengths.

02

Fluorescence Spectroscopy

Investigates the fluorescence emitted by substances upon excitation with light.

03

Transmittance Spectroscopy

Studies the light transmitted through a substance to analyze its properties.

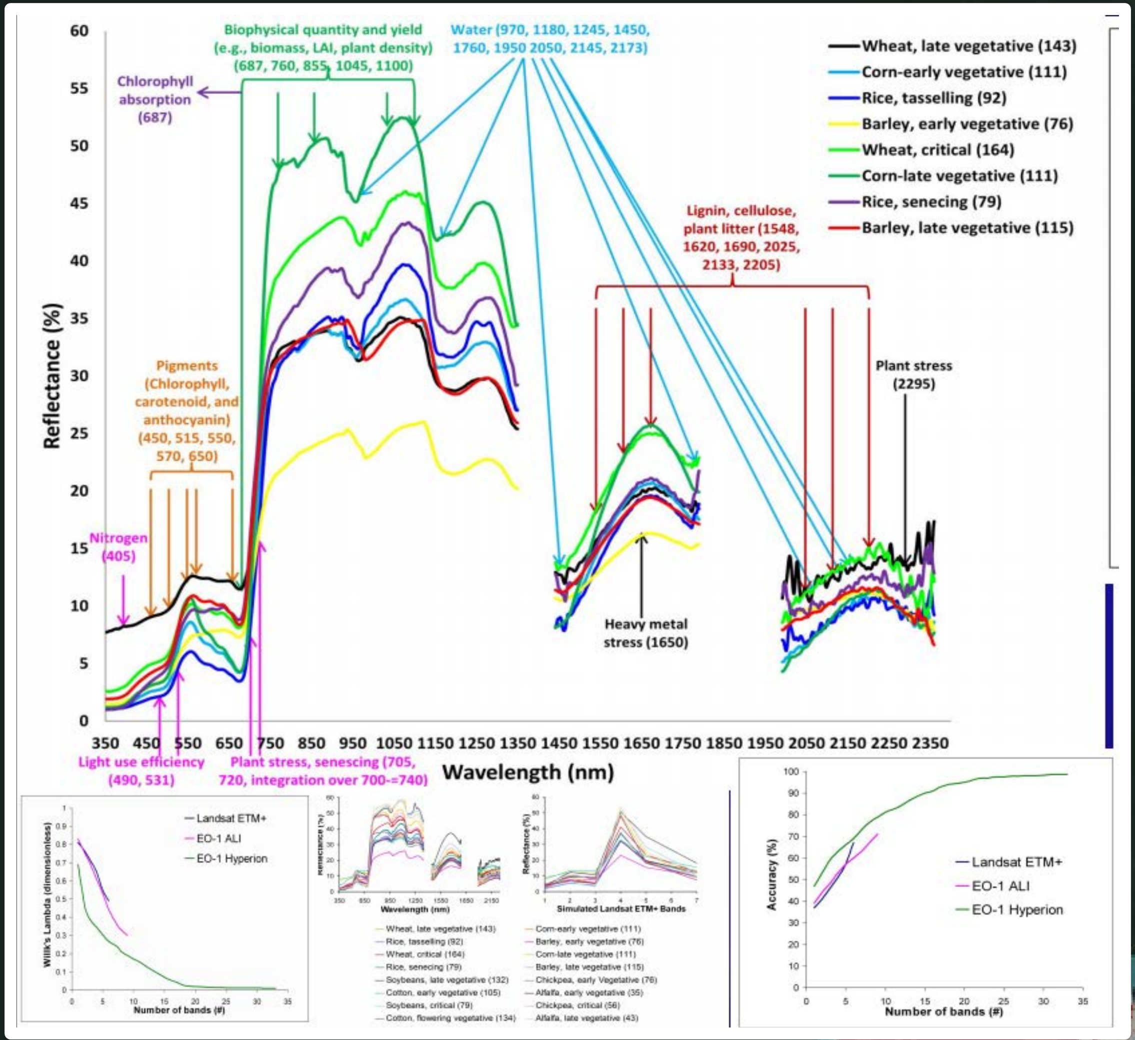
SPECTRAL RADIOMETER

SRI2000 Spectrometer

A spectroradiometer is a tool that measures the wavelength and amplitude of light emitted from a light source. It is used in many applications, including planetary remote sensing, where it detects and quantifies light intensity and its associated parameters, such as wavelength and amplitude. Spectral reflectance and transmittance data are recorded digitally, which facilitates spectral analysis

SPECTRAL LYBRARY

A spectral library refers to a collection of spectral signatures or spectra obtained from various materials or substances. These libraries are crucial for hyperspectral image analysis, as they serve as reference databases against which the spectral signatures observed in the hyperspectral data can be compared.By allowing comparison and matching of spectral signatures, it enhances the accuracy of material identification.



Types of Spectral Libraries

01 Database

A database spectral library contains pre-measured spectra for comparison.

02 Handheld

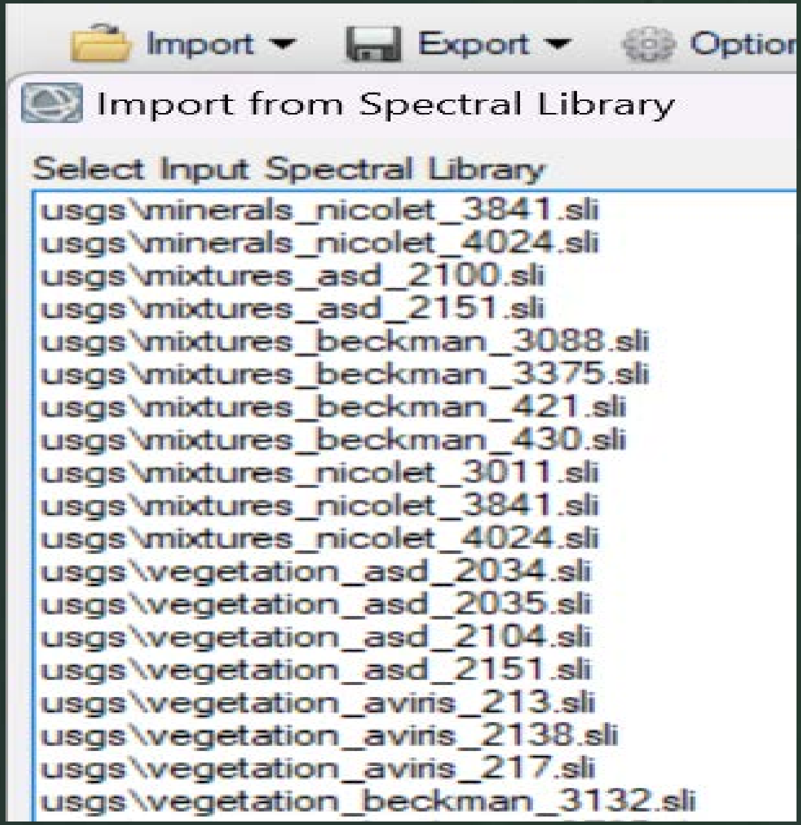
Handheld spectral libraries are portable and used for in-field analysis.

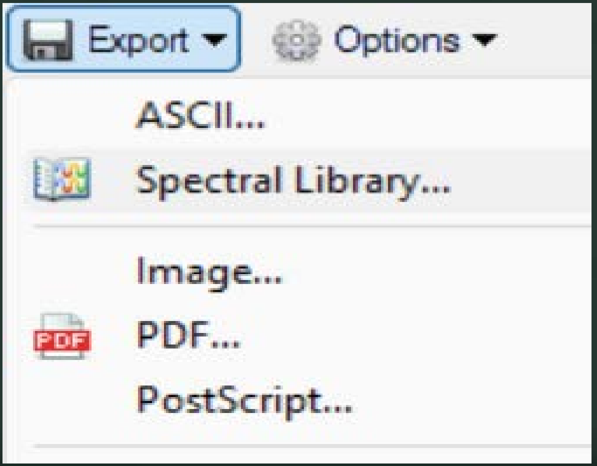
03 Community

Community spectral libraries are crowdsourced and collaborative in nature.

HOW TO CREATE SPECTRAL LYBRARY

Creating a spectral library involves acquiring spectral data from various materials under controlled conditions, typically using laboratory spectroscopy instruments. These spectra are then stored in a database along with metadata such as material type, conditions of measurement, and relevant properties. Some commonly used spectral libraries include the USGS Spectral Library, the ASTER Spectral Library, and the SPECCHIO Spectral Database.



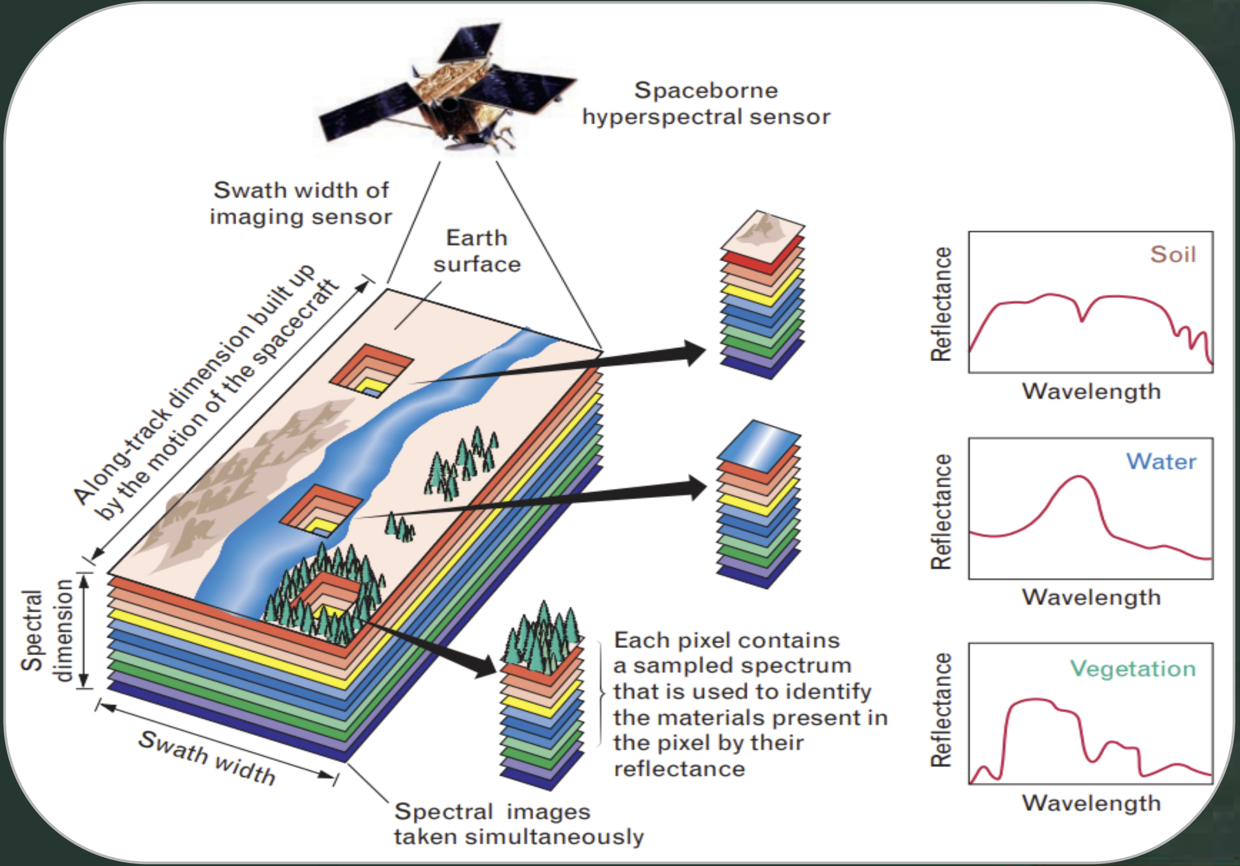


04

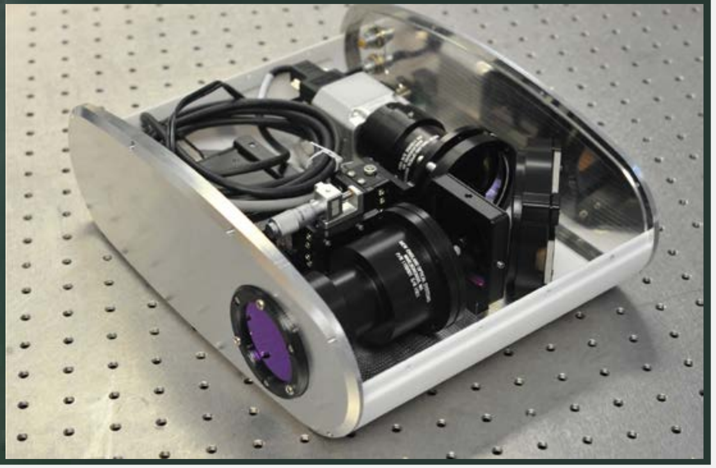
Imaging Spectrometers handheld–aerial–space

Imaging Spectrometers

Hyperspectral imaging spectrometers are advanced optical instruments capable of capturing and analyzing the spectral signatures of materials across a wide range of wavelengths. Hyperspectral imagers collect information across hundreds or even thousands of contiguous narrow spectral bands. This results in highly detailed spectral data for each pixel in an image.



Hyperspectral imaging spectrometers

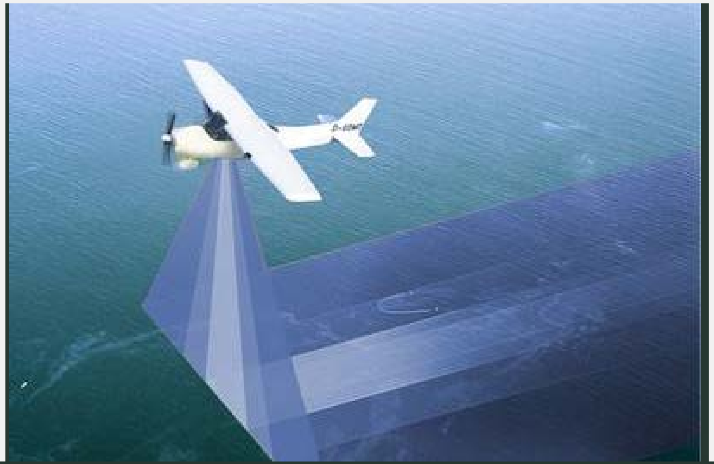


AERIAL

Mounted on aircraft for large-scale data collection.

HANDHELD

Portable devices for on-the-go spectral analysis.



SPACE

Deployed on satellites for global monitoring.

HANDHELD SPECTROMETERS

OCI-1000 series VIS-NIR hyperspectral imaging cameras are extremely compact, light, and rugged. They cover visible – near-infrared (VIS - NIR) spectral range from 470 – 1000 nm. Unlike conventional hyperspectral imagers which rely on intensive software effort on hyperspectral image cube construction, the innovative design of the OCI-1000 series imagers feature true push broom and ultrafast data transfer rates, with automatic data capturing and processing, they can move to scan at random speeds.

HANDHELD SPECTROMETERS

OCI-2000HH handheld snapshot hyperspectral imaging camera brings for the high-performance hyperspectral imaging in a handheld form within 1 lbs. (450 g). This handheld snapshot hyperspectral camera acquires full and continuous visible - near infrared (VIS - NIR) hyperspectral / multispectral data with simple point-and-shoot operation.

HANDHELD SPECTROMETERS

GoldenEye the ultra-miniature snapshot hyperspectral camera covers visible – near infrared (VIS - NIR) spectral range from 400 to 1100nm. BaySpec continues ground-breaking development of extremely precise snapshot hyperspectral camera. this novel snapshot hyperspectral imager features native spectral resolution of 8 - 60 nm with 140 active spectral bands.

AERIAL SPECTROMETERS

Airborne Imaging Spectrometer (AIS)

1982;
spectral resolution (9.6-nm-wide bands between 0.9 and 2.4 µm)
128 continuous spectral bands
wavelength range 1.2 to 2.4 µm
Bandwidth: < 10 nm

AERIAL SPECTROMETERS

Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)

- Jan. 1, 1993;current
- Flown in North America, Europe, portions of South America, and Argentina
- 224 continuous spectral bands
- 400 to 2500 nm
- Bandwidth: < 10 nm

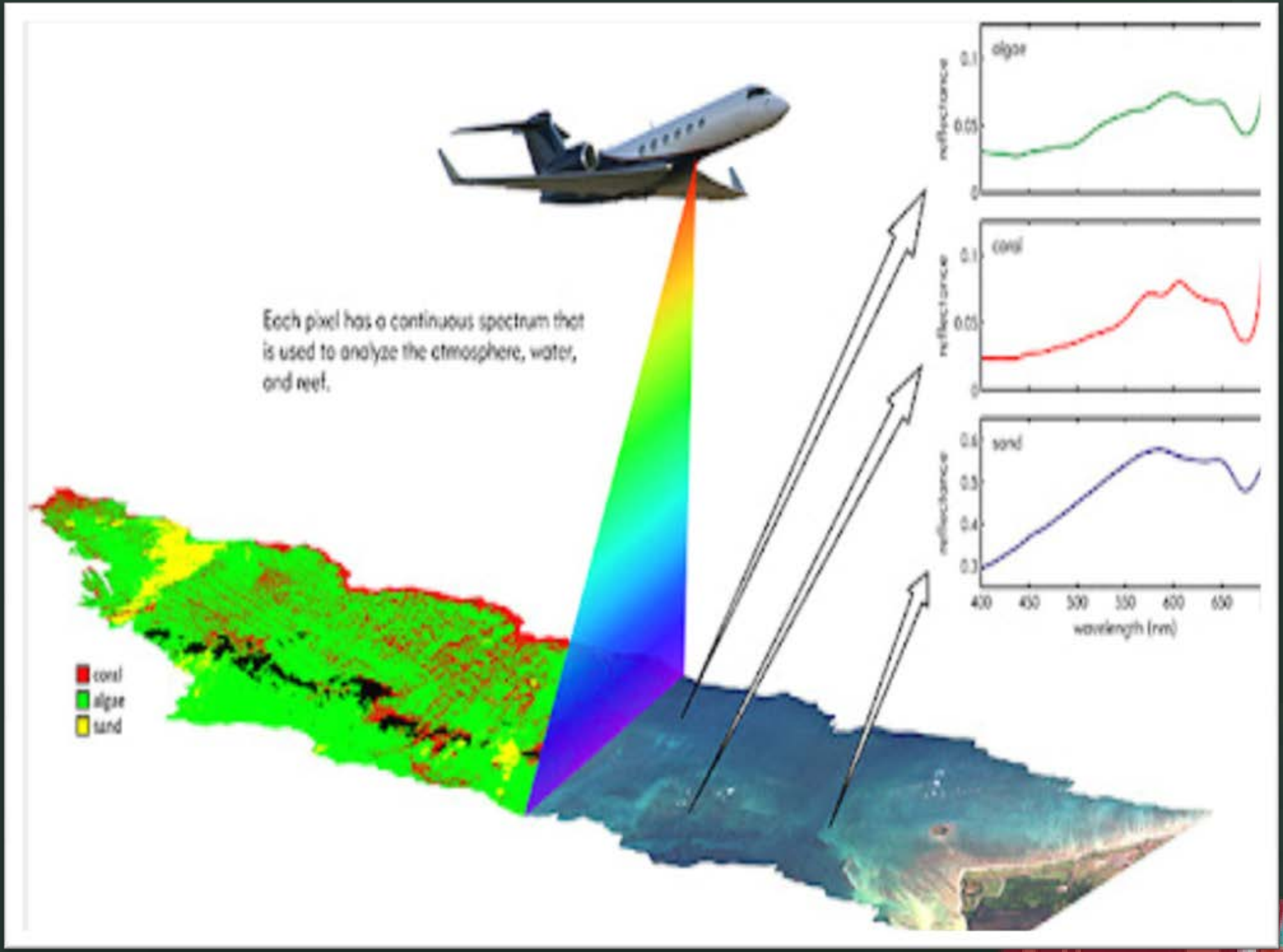
AERIAL SPECTROMETERS

COral Reef Airborne Laboratory (CORAL)

Airborne mission flown using the Portable Remote Imaging Spectrometer (PRISM) to evaluate health and conditions of coral reef ecosystems

Date Range: 2016-2019

Spectral Resolution: 349.9-1053.5 nm (3.5 nm sampling)



Parameters	FLI	CASI	SFSI
Period of Operation	1984-1990	Since 1989	Since 1992
Country	Canada	Canada	Canada
Operation mode	pushbroom	pushbroom	pushbroom
Detector array format	385×288	612×288	512×488
# of detector arrays (i.e. spectrometers)	5	1	1
Spectral range (nm)	430 – 805	418 – 926	1200 – 2400
# of spectral elements	288	288	122
Spectral sampling interval (nm)	1.3	1.8	10
# of spatial pixels	1925	512	512
Field-of-view (°)	70	35	11.7
IFOV (mrad)	1.3	1.2	0.4
Airplane altitude (km)	2	2	2
Swath width (km)	4.8	1 – 5	0.26
Spatial resolution (m)	2.5	2 – 5	0.5
Digitization	12	12	12

SPACE SPECTROMETERS

EO-1
Hyperion

Date Range:

2000-2017

220 spectral bands

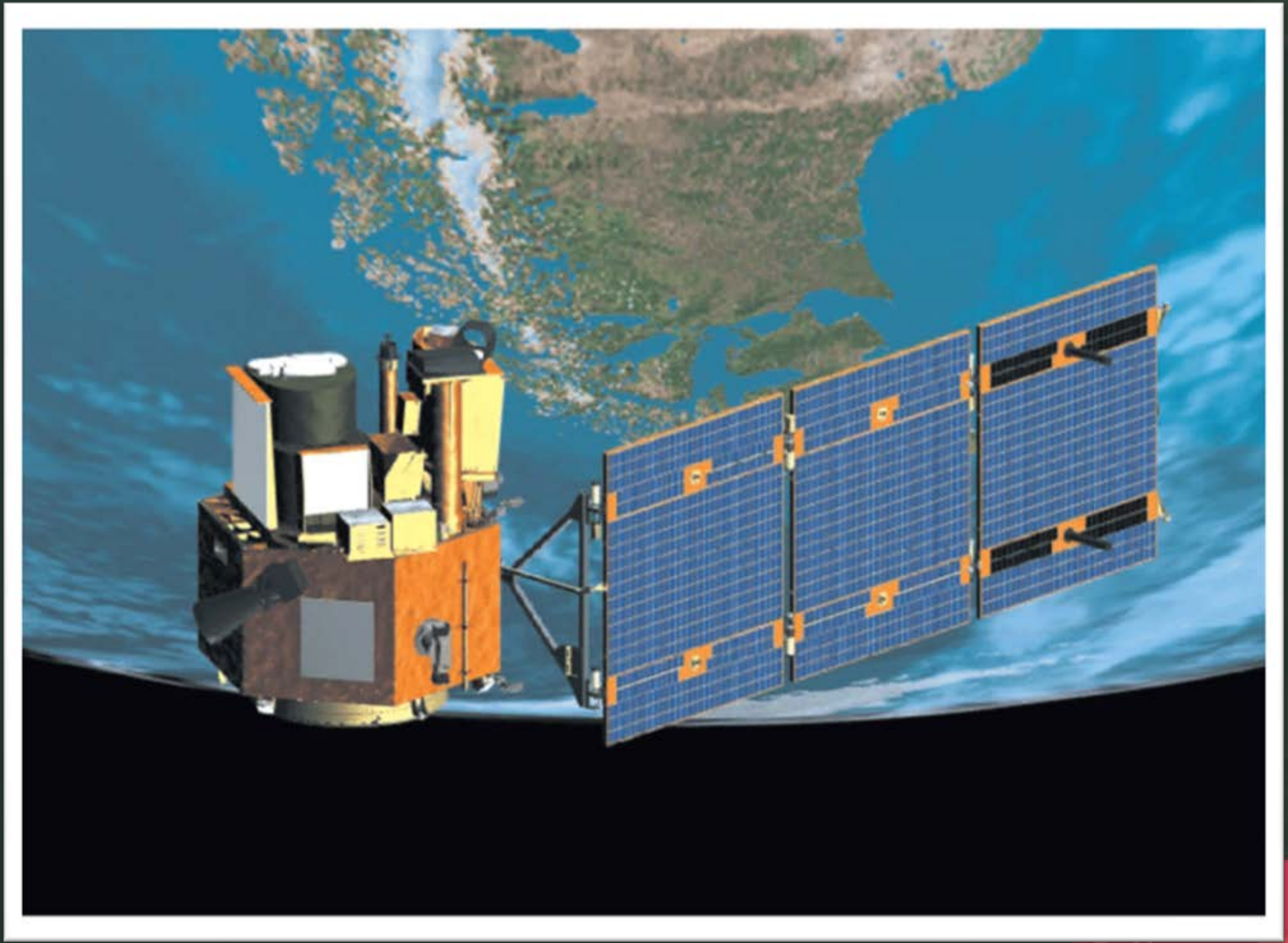
357 to 2567 nm

10 nm bandwidth

30 m spatial resolution

7.75 km swath

12-bit



SPACE SPECTROMETERS

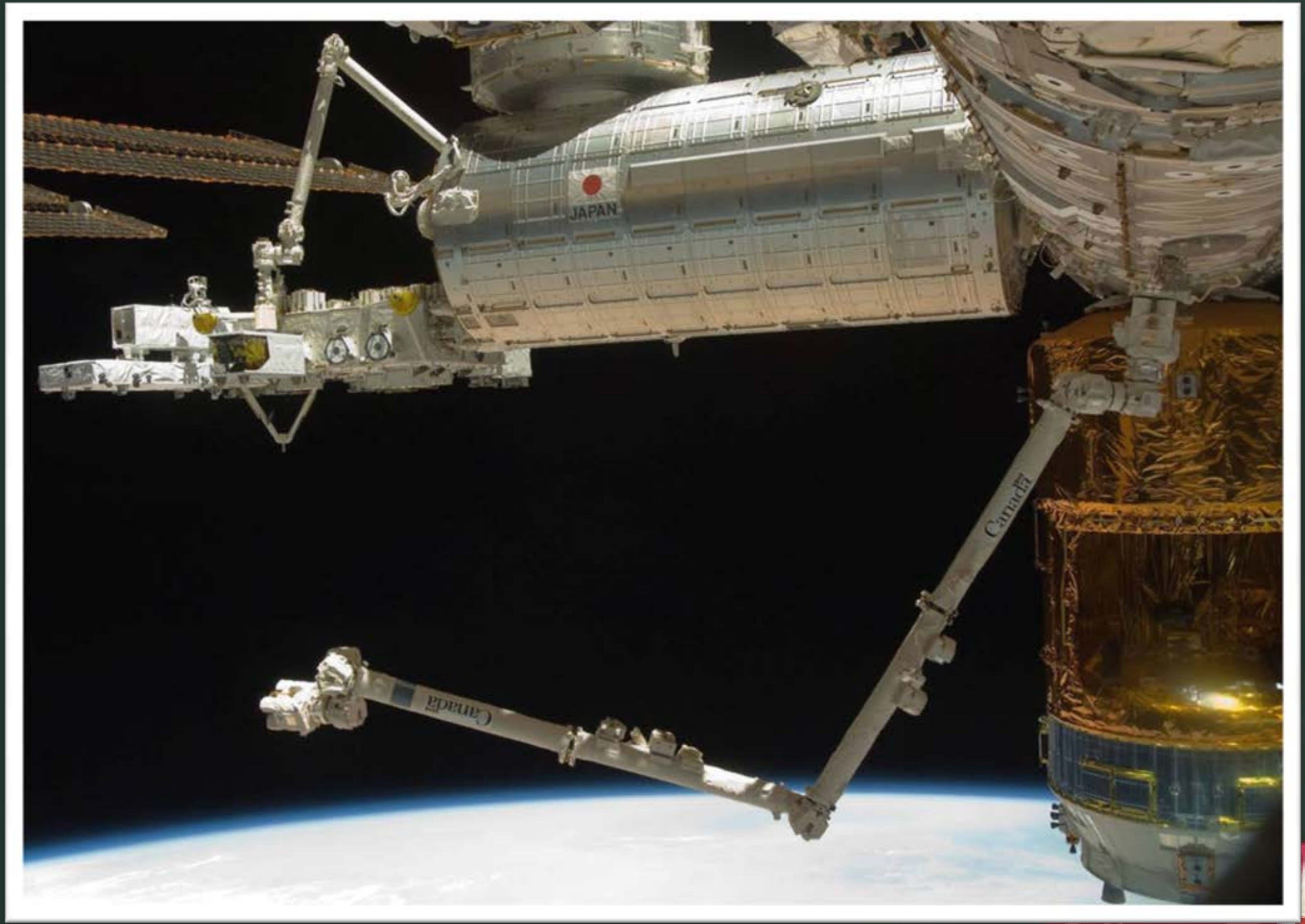
HICO - Hyperspectral Imager for the Coastal Ocean

Date Range: 2009-2014

Spatial Resolution: 90 m

Spectral Resolution: 128 bands (400-900nm every 5.7nm)

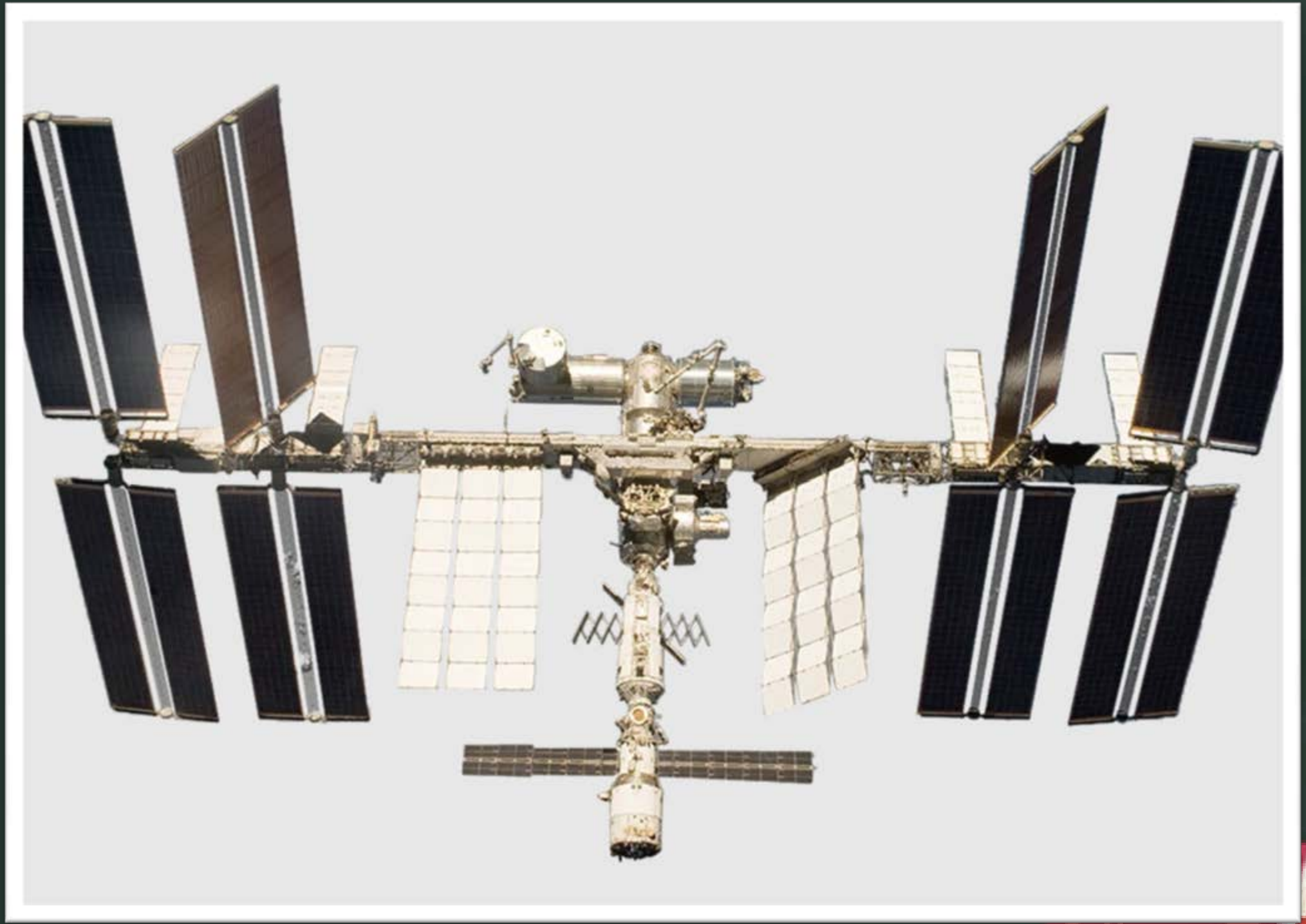
Temporal Resolution: ~3 days

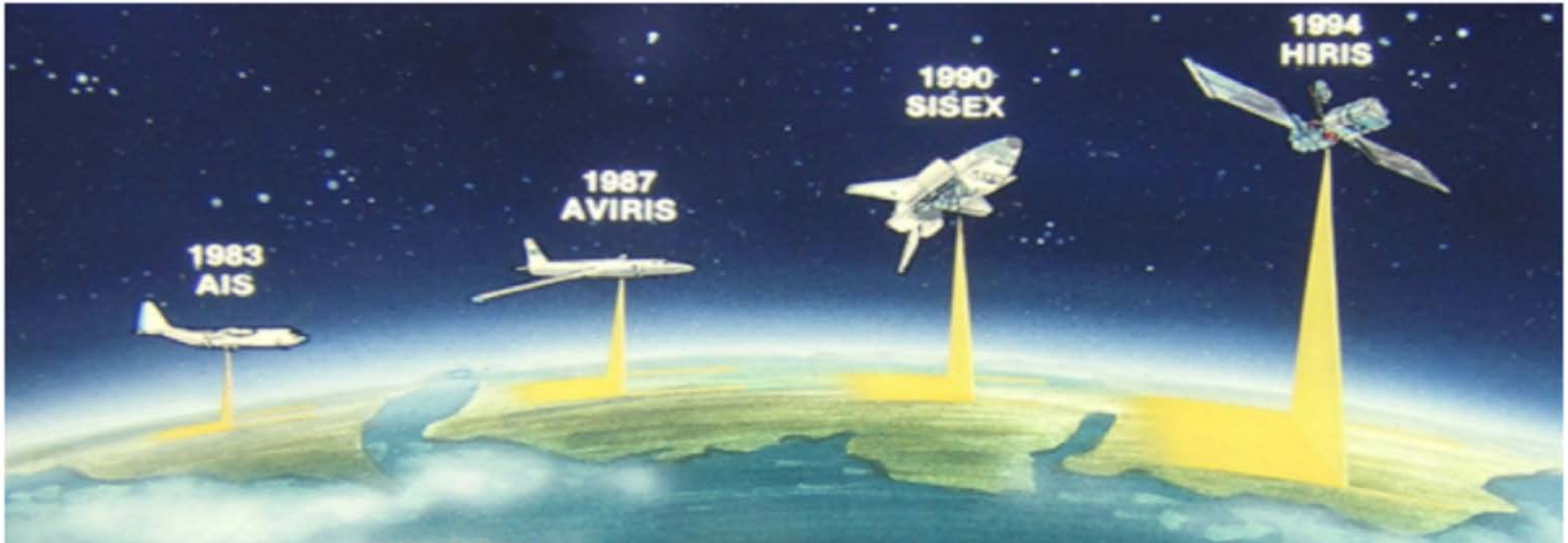


SPACE SPECTROMETERS

ECOSTRESS-ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Date Range: Aug 2018-Present
Spatial Resolution: 70 m
Spectral Resolution: 6 bands (160-1200 nm)
Range: 53.6° N latitude to 53.6° S latitude





	SPECTRAL REGION, μm	No. BANDS	WIDTH nm	SWATH	IFOV
AIS	1.2 – 2.4	128	9.6	320 m	10 m
AVIRIS	0.4 – 2.4	224	9.6	11 km	20 m
SISEX	0.4 – 2.5	196	11	12 km	30 m
HIRIS	0.4 – 2.5	196	11	50 km	30 m

DEVELOPMENT MISSIONS

#Pixxel Hyperspectral Imaging Constellation

#CHIME (Copernicus Hyperspectral Imaging Mission for the Environment)

#CLARREO (Climate Absolute Radiance and Refractivity Observatory)

#NACHOS (Nano-satellite Atmospheric Chemistry Hyperspectral Observation System)

#PREFIRE (Polar Radiant Energy in the Far-InfraRed Experiment)

#GHOSt (Global Hyperspectral Observation Satellite)

MightySat Program

#TacSat-3 (Tactical Satellite-3)

#Resurs-p(Resurse Prospective)

#PRISMA(Hyperspectral Precersor and Application Mission)

#PACE(Plankton,Aerasol,Cloud,Ocean,Ecosystem Mission)

#EnMAP(Environmental Mapping Analysis Program)

DATA SOURSES

United States Geological Survey (USGS) Earth Explorer:

USGS provides access to a wide range of remote sensing data, including hyperspectral imagery from satellites such as Landsat, Sentinel-2, and EO-1 Hyperion.
Website: Earth Explorer

NASA Earth Observing System Data and Information System (EOSDIS):

NASA EOSDIS offers access to various hyperspectral datasets collected by NASA's Earth observing satellites, including Hyperion, MODIS, and ASTER.
Website: NASA EOSDIS

European Space Agency (ESA) Earth Observation Data:

ESA provides access to free hyperspectral data from satellites such as Sentinel-2, which includes a multispectral instrument with some hyperspectral capabilities.
Website: ESA Earth Observation

DATA SOURSES

Commercial Satellite Imagery Providers:

Several companies offer commercial hyperspectral imagery with high spatial and spectral resolution. These providers may offer data for purchase or through subscription services. Some examples include:

%Maxar Technologies (WorldView-3)
%Planet Labs (PlanetScope with hyperspectral capabilities)
%Satellogic
%GeoVantage
%HySpex

Hyperspectral Data Repositories: There are several online repositories and archives dedicated to hyperspectral data,
SpecTIR: SpecTIR Data Corporation
AVIRIS: Jet Propulsion Laboratory (JPL) AVIRIS Data
SPECCHIO: Spectral Information System (SPECCHIO)

DATA ANALYSIS SOURSES

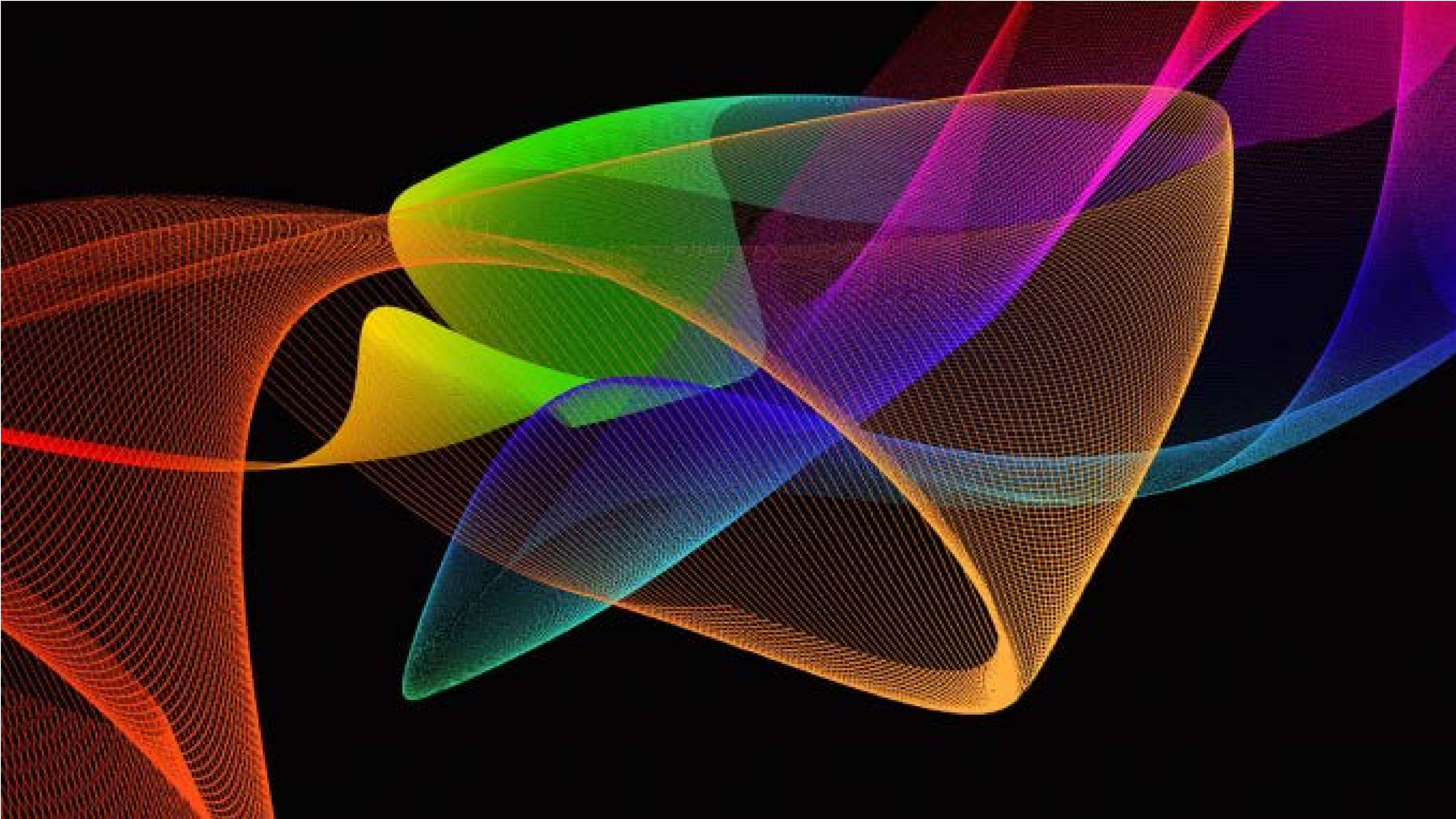
Open source:

- HyperSpy(software) Python Hyperspectral Toolbox.
- Gerbil (software) hyperspectral visualization and analysis framework.

Commercial:

- Erdas Imagine, a remote sensing application for geospatial applications.
- ENVI a remote sensing application.
- MIA Toolbox multivariate image analysis.
- MicroMSI a remote sensing application.
- A Matlab Hyperspectral Toolbox.
- Other Hyperspectral tools in MATLAB.
- MountainsMap HyperSpectral, a version of MountainsMap dedicated to the analysis of hyperspectral data in microscopy.
- Opticks a remote sensing application.
- Scyllarus, hyperspectral imaging C++ API, MATLAB Toolbox and visualize

some hyperspectral images



PRE PROCESSING TECHNIQUES
ALGORITHMS FOR CLASSIFICATION
FEATURE EXTRACTION METHODS

Radiometric errors caused by the change in DN value

Geometric errors caused by change in position of DN value

Atmospheric error caused by interaction with atmostpheric components.

Errors can be also classified into **internal or external**. Errors are also known as systematic errors and it is predictable whereas external errors are non systematic errors which cannot be predicted

RADIOMETRIC ERRORS

Radiometric errors are caused by the changes or noise in the brightness values of the digital numbers

This is introduced by the sensor system itself when the individual detectors do not function properly or are improperly calibrated

Some common remote sensing system introduced radiometric errors are

- Random bad pixel
- Line start or stop problems
- Line or column dropouts
- Line or column stripping

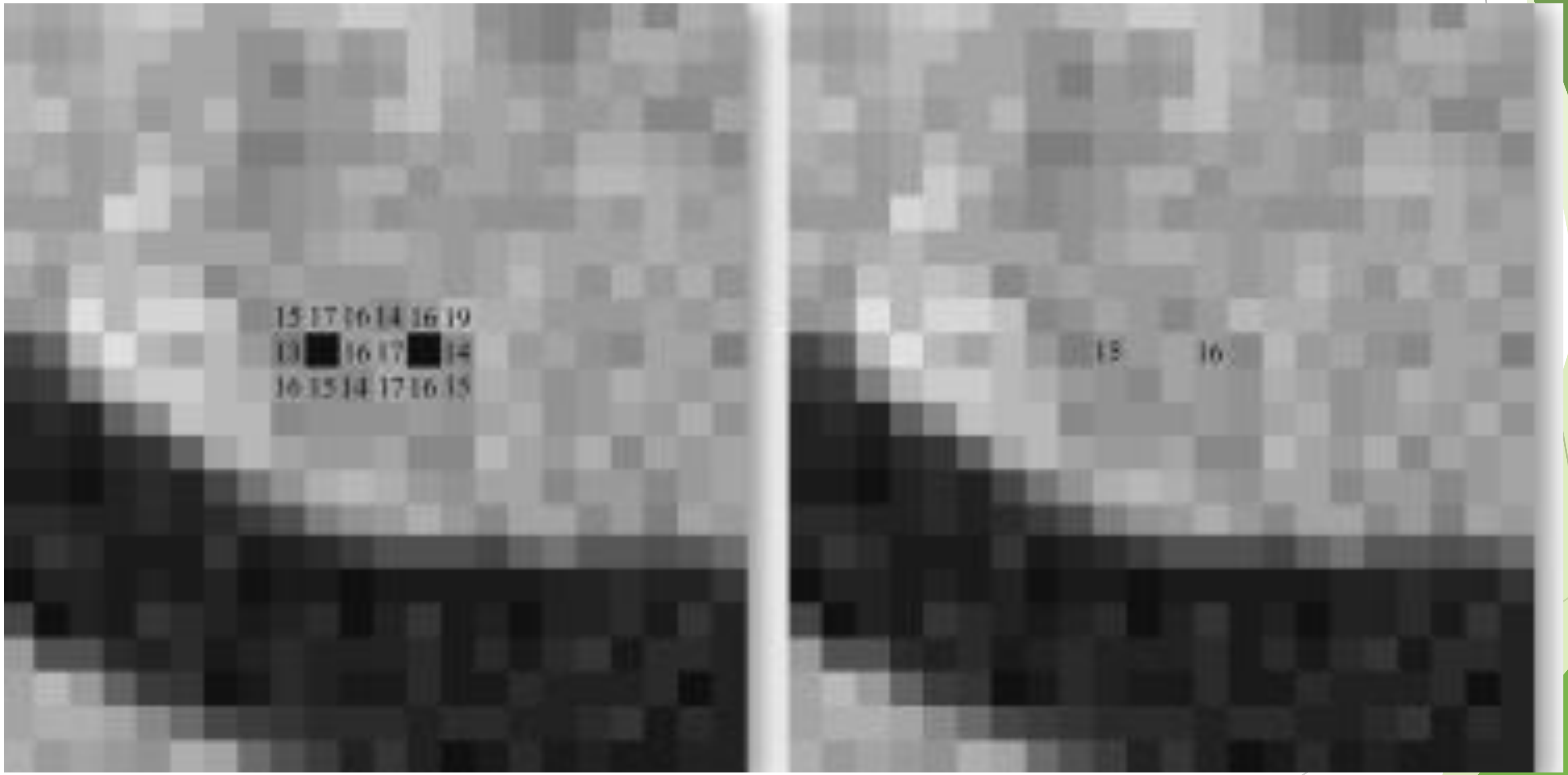
Random bad pixel(Shot noise)

The DNS values for a random pixel will not be available or missing for more than one bands

Correction process

1. Identify the missing pixels
2. Record the 8 pixels surrounding the missing pixel
3. Calculate the average of all the 8 surrounding pixels to fill the value of the mixing pixel

$$BV_{i,j,k} = \text{int}\left[\frac{\sum_{n=1}^{8} BV_n}{8}\right]$$


15 17 16 14 16 19
13 16 17 14
16 15 14 17 16 15
15 16

Line or Column drop out

When an entire line contains no spectral information is produced when an individual detector fails to function properly, it is known as line dropout

This error is corrected by averaging the pixel values above and below to record in each missing pixel or try to fill the values with another image of the same location location

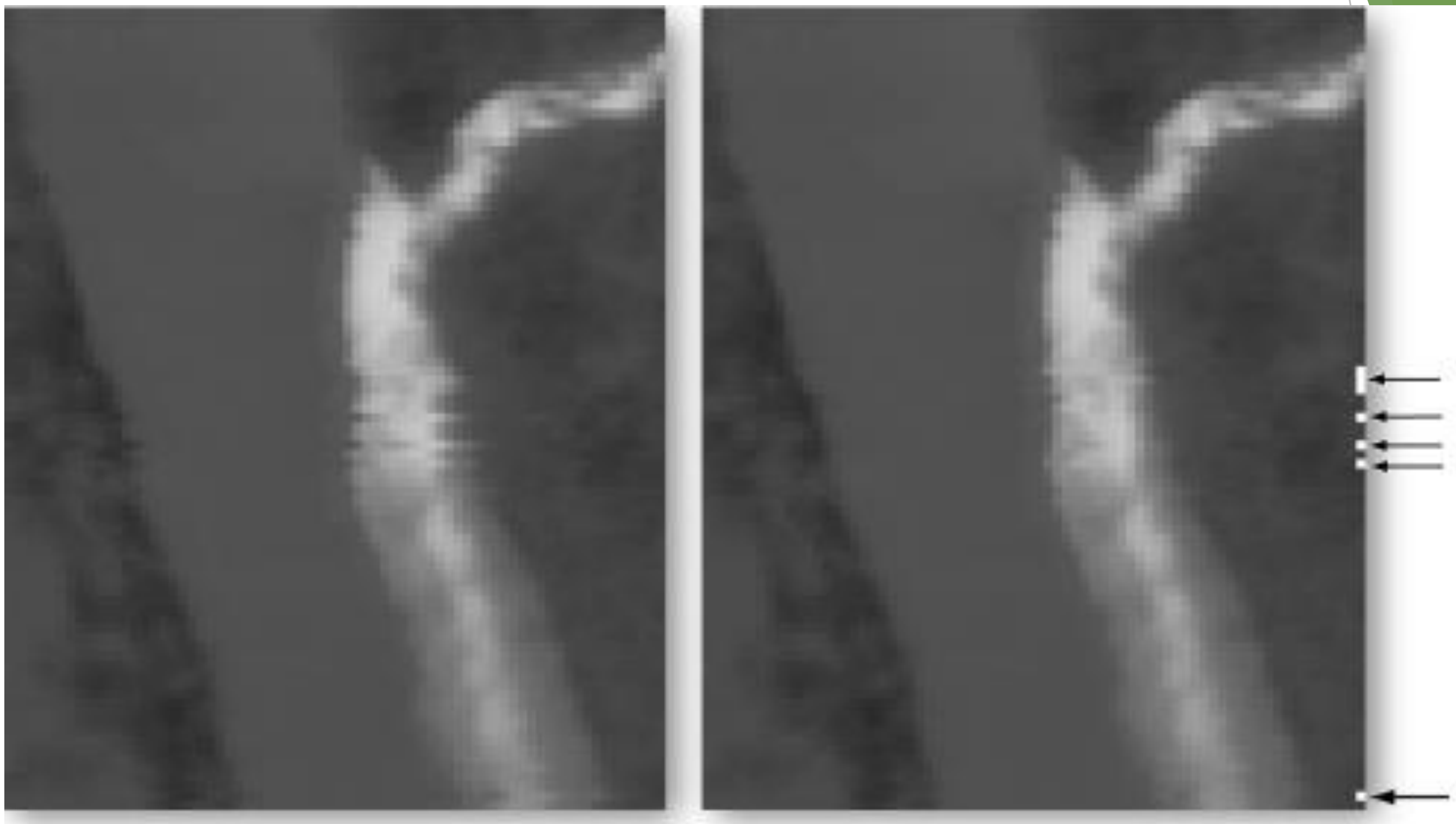
$$BV_{i,j,k} = \text{int}\left[\frac{BV_{i-1,j,k} + BV_{i+1,j,k}}{2}\right]$$

Bad line start or Stop error

Occasionally, scanning systems fail to collect data at the beginning of a scan line, or they place the pixel data at inappropriate locations along the scan line.

For example, all of the pixels in a scan line might be systematically shifted just one pixel to the right. This is called a line-start problem.

Also, a detector may abruptly stop collecting data somewhere along a scan and produce results similar to the line or column drop-out



a. Predawn thermal infrared imagery of the Savannah River with line-start problems.

b. Seven line-start problem lines were translated one column to the left.

N Line stripping

Sometimes editor does not feel completely but simply goes out of radiometric adjustment. The result of this error would be an image with systematic and noticeable lines that are brighter than the adjacent lines. This Error is known as n line stripping.

The Error line contains valuable information but it should be corrected to have approximately the same radiometric scale as the data collected by properly calibrated detectors associated with the same band

DESTRIPING PROCESS

ATMOSTPHERIC CORRECTIONS

Atmospheric corrections are done in order to reduce the atmospheric errors

The two main processes of atmospheric corrections are **atmospheric parameter estimation** and **surface reflectance retrieval**.

1. conversion of DNA values to spectral radiance
   Radiance =bias+ (DN * Gain).

2. Conversion of spectral radiance to apparent reflectance
   Apparent reflectance=Radiance *A

3. Estimation of atmospheric effect due to scattering and absorption moving the particular value from reflectance

4. Calculation of the target reflectance at the earth surface

Scene to scene normalization

Invariant object method

- In this particular method, a set of pixels are selected whose reflectance value does not change with respect to time and the atmospheric conditions. Such pixels are selected as reference, and it is used for normalizing the two or more images. It is a normalizing method rather than a correction method

Internal average relative reflectance

- In this method the mean radiance is taken as a correction factor and it individual radiance value of each pixel is divided by this mean radiance to estimate the reflectance.

Flat field method

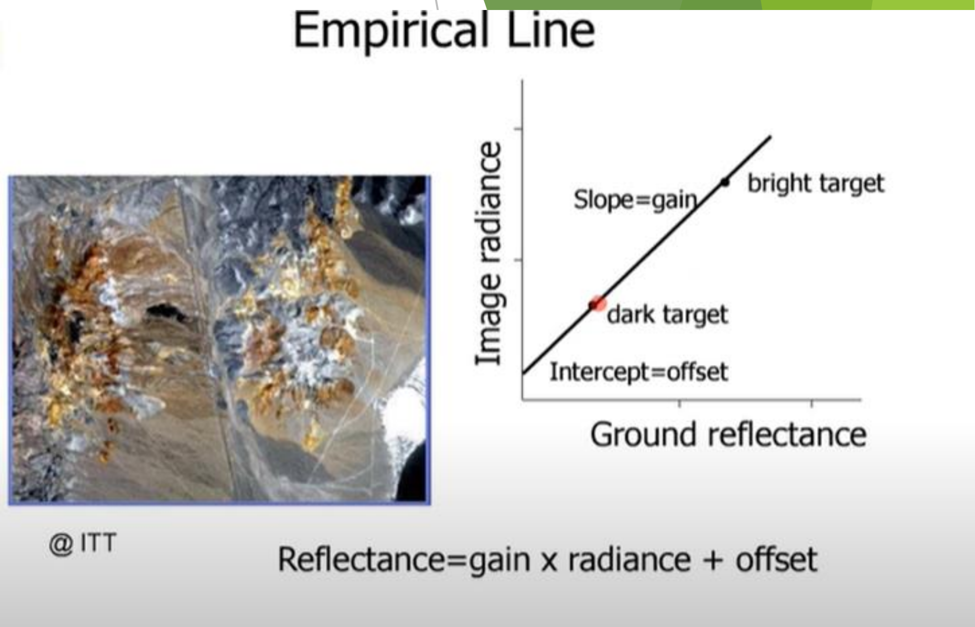
- Individual radiance value in each pixel or divided by mean radiance of a flat field
- For this particular method we require a flat field with large and homogeneous texture

Dark object method

- Dark object subtraction is one of the most common radio metric correction techniques used for remotely sensed data. It assumes that some of the atmospheric effects such as scattering can be removed by finding the darkest pixels in an image and subtracting their values from all other pixels

Ground Truth Verification (Traditional method)

- Also known as **Empirical line approach**
- For this particular method, larger homogeneous surface with high reflectance value and also a surface with low reflectance value simultaneously in the same image.
- Instruments such as spectroradiometers taken to the ground and spectral reflectance of the two contrast features are measured manually. A graph is plot with ground reflectance in X axis and image radiance in the Y axis. The slope and intercept obtained from the graph is substituted in the formula and reflectance is calculated.



Radiative transfer based atmospheric correction

- **Look up table approach** which is data intensive
- **Online radiative transfer approach** which is computationally expensive

Atmospheric Correction Models

- FLAASH (Fast line of site atmostpheric analysis of Spectral Hypercubes)
- ATREM (Atmospheric Removal Programme) (Uses 6S)
- ATCOR (Atmospheric and Topographic Correction (Uses MODTRAN)
- ACORN (Atmospheric Correction Now) (Uses MODTRAN)
- HATCH (High accuracy Atmospheric Correction for Hyperspectral Data)
- QUAC (Quick Atmospheric Correction)
- SMAC (Simplified Model for Atmospheric Correction (Semi-empirical method)
- 6S (Second Simulation of the Satellite Signal in the Solar Spectrum
- MODTRAN (Moderate Resolution Atmospheric Transmission

GEOMETRIC CORRECTIONS

Digital images often contain systematic and non systematic geometrical errors that arise from earth curvature, platform motion, relief displacement, non-linearities in scanning motion, earth rotation etcetera. Removing all such errors are known as geometric correction.

Systematic errors include scan skew mirror velocity variation, cross track distortion, earth rotation skew platform altitude variation and platform velocity variation.

It can be corrected by applying formulas derived by modeling the sources of distortion mathematically or by means of ortho rectification.

Orthorectification is the process of removing image distortions or displacements caused by sensor tilt and topographic relief.

Orthorectification aims to ensure that every point on the image is represented as if it were captured directly below the sensor. Orthorectification places image features in their true ground position while ensuring a uniform scale.

NON SYSTEMATIC CORRECTIONS

Non systematic corrections can be done by establishing the relationship between 2 coordinate systems

Image to ground Geo correction or georeferencing

- Georeferencing is a transformation between the image space to the geographical coordinate space
- Forward transformation is used for georeferencing
- GCP are required for the process of georeferencing
- GCP should be easily identifiable on both Image and ground

Image to image Geo correction or registration

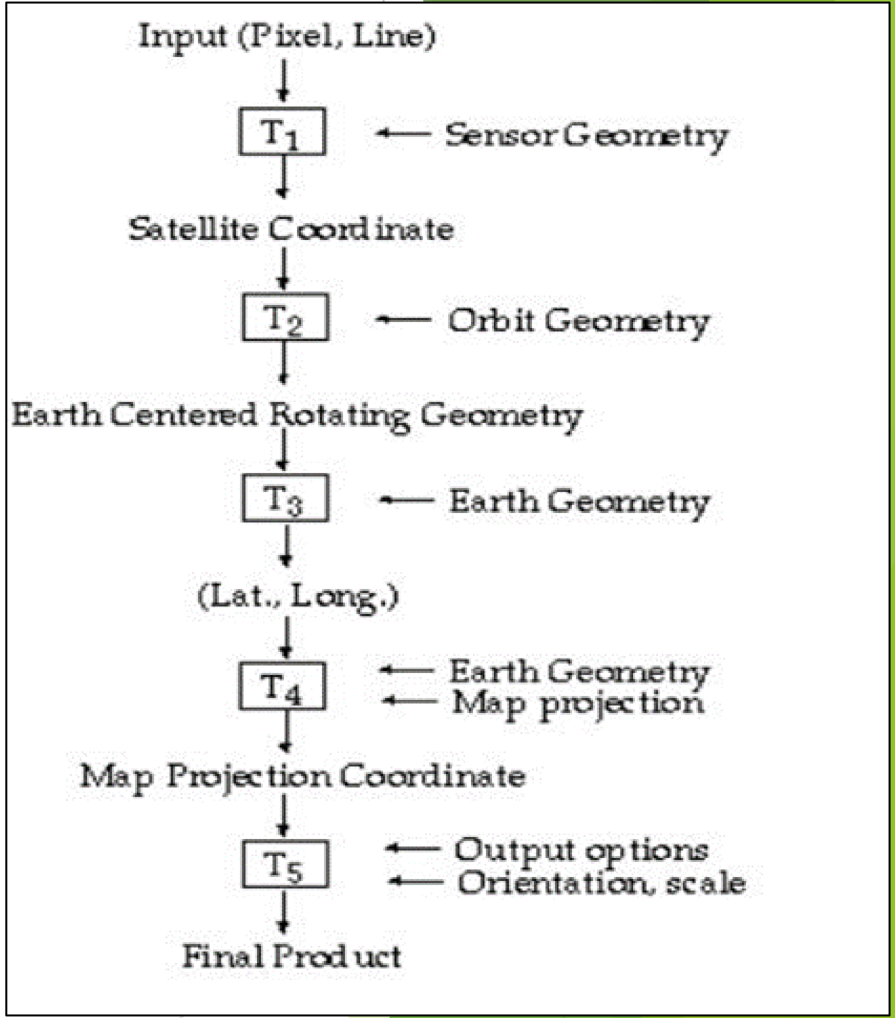
- Assigning a co ordinate system of one image to another image of same area

STEPS OF GEOMETRIC CORRECTIONS

1.Spatial Interpolation

- It is defined as establishing a mathematical relationship between the image coordinate system and geographical coordinate system
- Polynomial transformation is used to define the relationship between the pixel coordinate system and the image coordinate system.
- The minimum number of control points required is calculated by (t+1)(t+2) /2

t is the order of polynomial transformation



2.Intensity Interpolation (Resampling)

Resampling is a method in transformation is used to determine the digital values to place in the new pixel locations of the corrected output image.

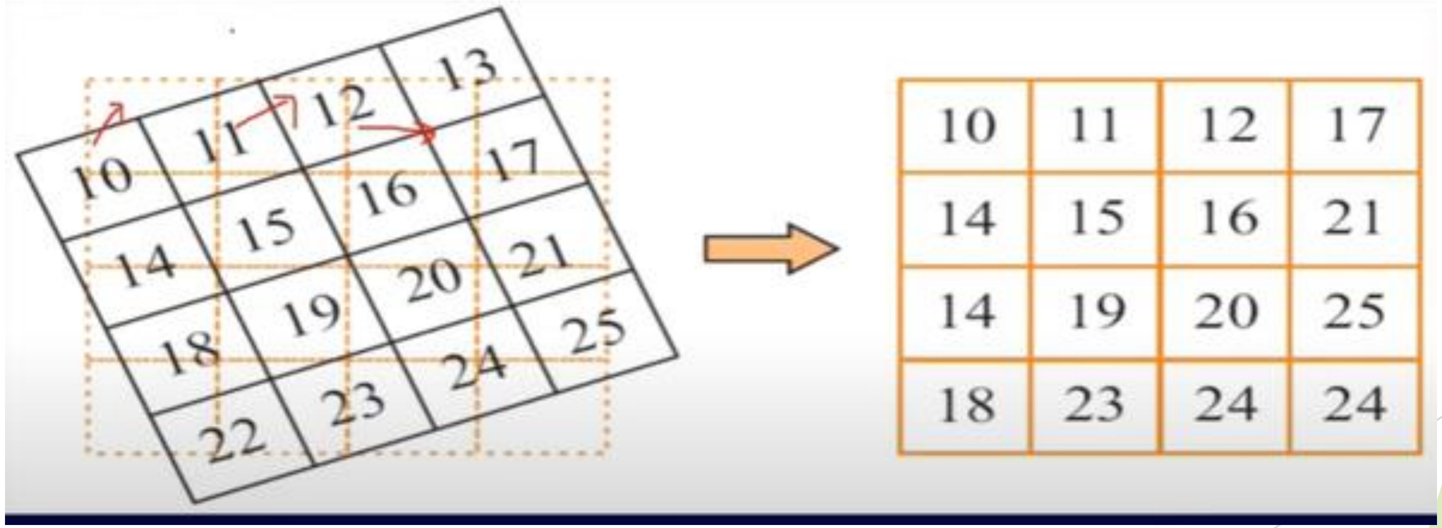
It is a process of fitting 1 raster grid to the new rectified raster grid.

The three main methods of resampling are

- nearest neighbor method
- bilinear interpolation method
- cubic convolution method.

Nearest Neighbour Technique

Nearest neighbour uses the input cell value closest to the output cell as assigned value to the output cell. It is the most fast method and original pixel value are maintained.



Bilinear Interpolation method

Bilinear interpolation calculate the output cell value by calculating the weighted average of the four closest input cell based on distance. This method is usually spatially accurate and shows smooth transition but the original pixel value integrity will be lost

$$\text{Bilinear}_{BV_{wt}} = \frac{\sum_{k=1}^{4} \frac{Z_k}{D_k^2}}{\sum_{k=1}^{4} \frac{1}{D_k^2}},$$

Cubic Convolution method

This method or technique of resampling is the same as the bilinear resampling method, except that the weighted value of the pixel is assigned by computing the 16 input pixel values surrounding the location of the desired x’, y’ pixel.

$$\text{Cubic Convolution}_{BV_{wt}} = \frac{\sum_{k=1}^{16} \frac{Z_k}{D_k^2}}{\sum_{k=1}^{16} \frac{1}{D_k^2}},$$

ALGORITHMS FOR IMAGE CLASSIFICATION FOR HYPER SPECTRAL REMOTE SENSING

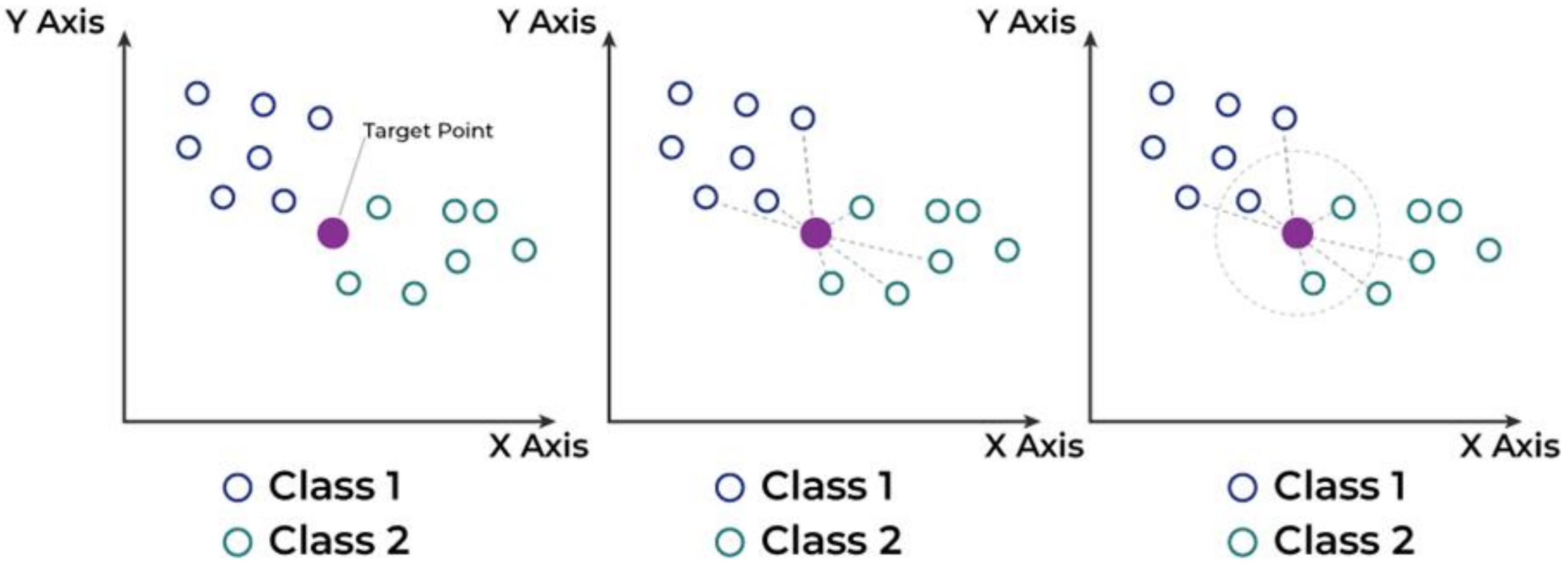
K-Nearest Neighbors Algorithm

KNN is one of the most basic yet essential classification algorithms in machine learning. It belongs to the supervised learning domain and finds intense application in pattern recognition, data mining, and intrusion detection.

KNN algorithm helps us identify the nearest points or the groups for a query point

Euclidean distance can also be visualized as the length of the straight line that joins the two points

Manhattan Distance metric is generally used when we are interested in the total distance traveled by the object instead of the displacement. This metric is calculated by summing the absolute difference between the coordinates .


Y Axis
Target Point
X Axis
Class 1
Class 2
Y Axis
X Axis
Class 1
Class 2
Y Axis
X Axis
Class 1
Class 2

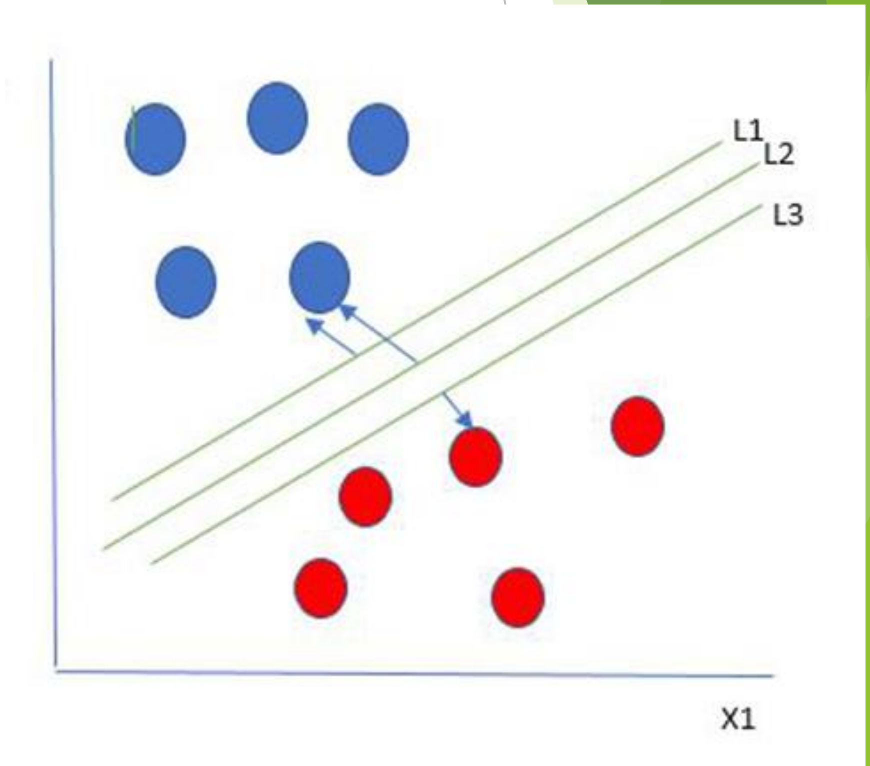
ALGORITHMS FOR IMAGE CLASSIFICATION FOR HYPER SPECTRAL REMOTE SENSING

Support Vector Machine

Support Vector Machine (SVM) is a supervised machine learning algorithm used for both classification and regression.

The main objective of the SVM algorithm is to find the optimal hyperplane in an N-dimensional space that can separate the data points in different classes in the feature space.

The hyperplane tries that the margin between the closest points of different classes. The best hyperplane is the one that represents the largest separation or margin between the two classes.

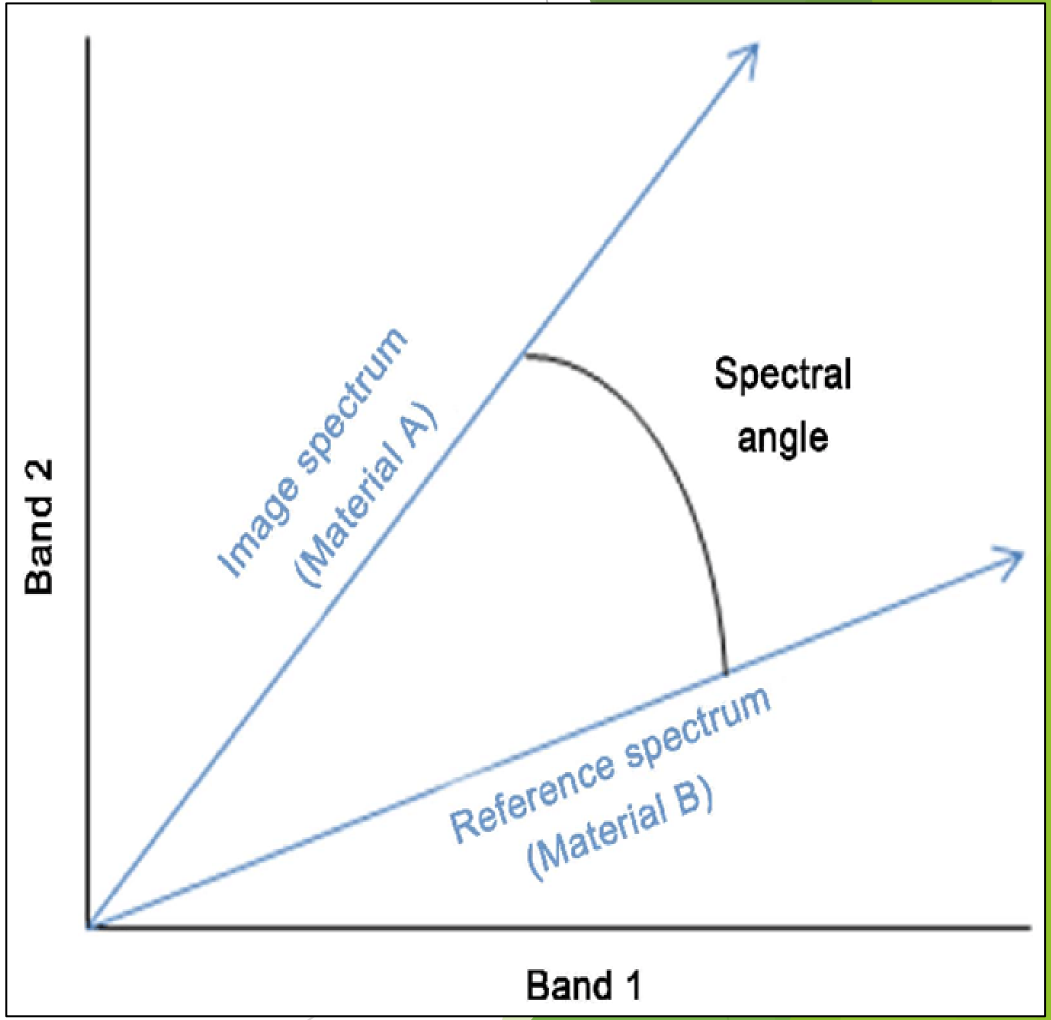


ALGORITHMS FOR IMAGE CLASSIFICATION FOR HYPER SPECTRAL REMOTE SENSING

Spectral Angle Mapper(SAM)

SAM is a physically-based spectral classification that uses **spectral angle** to match pixels to reference spectra.

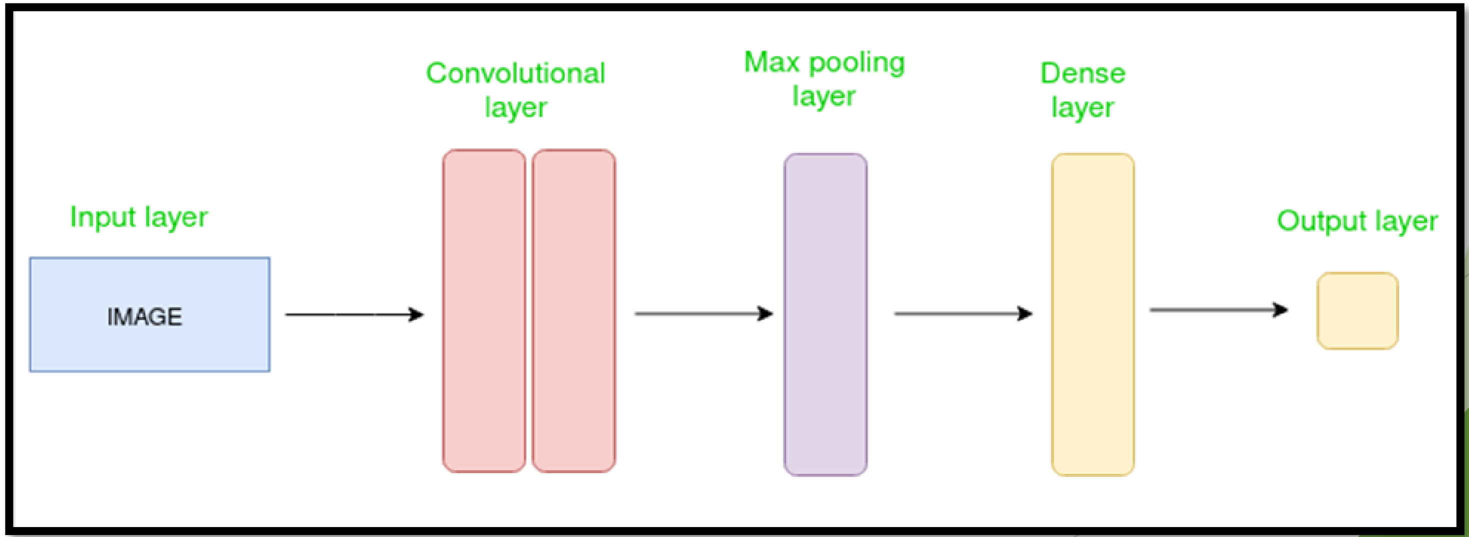
The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands.



ALGORITHMS FOR IMAGE CLASSIFICATION FOR HYPER SPECTRAL REMOTE SENSING

Convolutional Neural Network (CNN)

Convolutional Neural Network consists of multiple layers like the input layer, Convolutional layer, Pooling layer, and fully connected layers. The Convolutional layer applies filters to the input image to extract features, the Pooling layer downsamples the image to reduce computation, and the fully connected layer makes the final prediction.



ALGORITHMS FOR IMAGE CLASSIFICATION FOR HYPER SPECTRAL REMOTE SENSING

DECISION TREE ALGORITHM

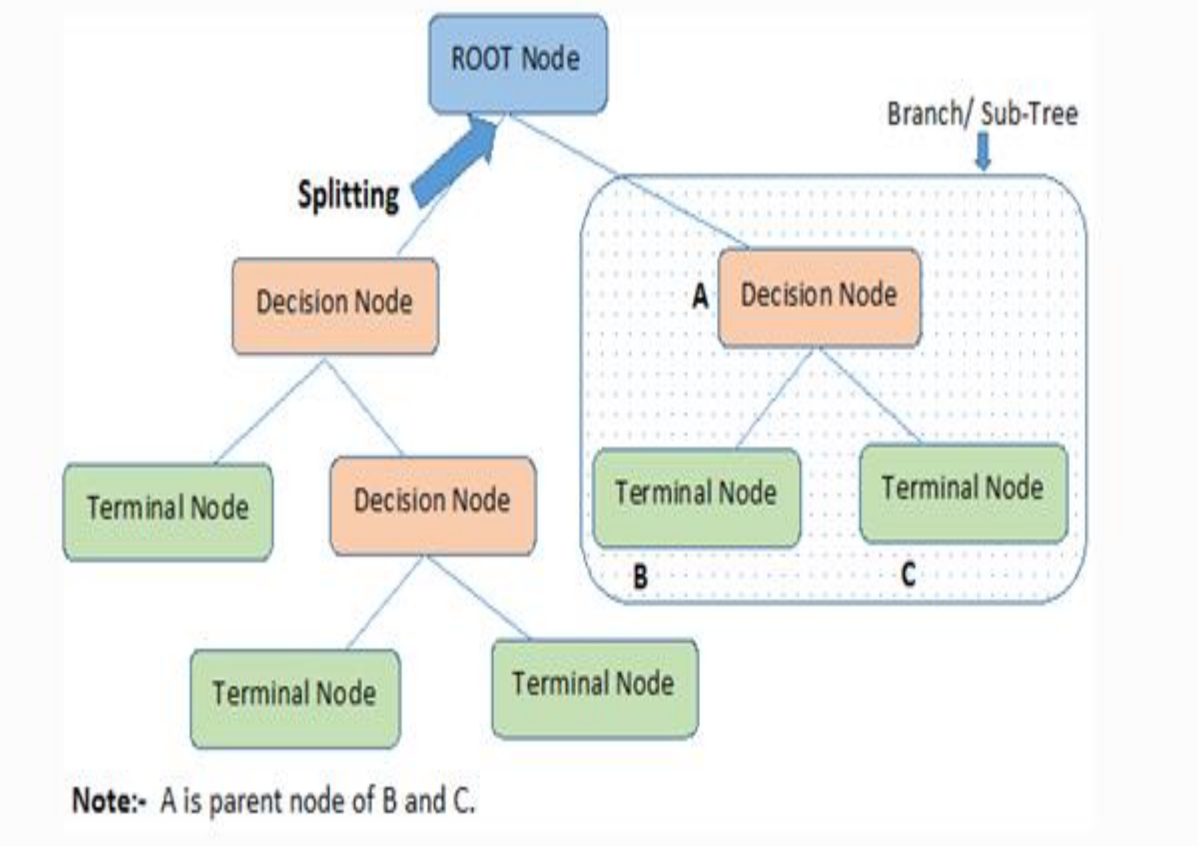
Root Node: It is the topmost node in the tree, which represents the complete dataset. It is the starting point of the decision-making process.

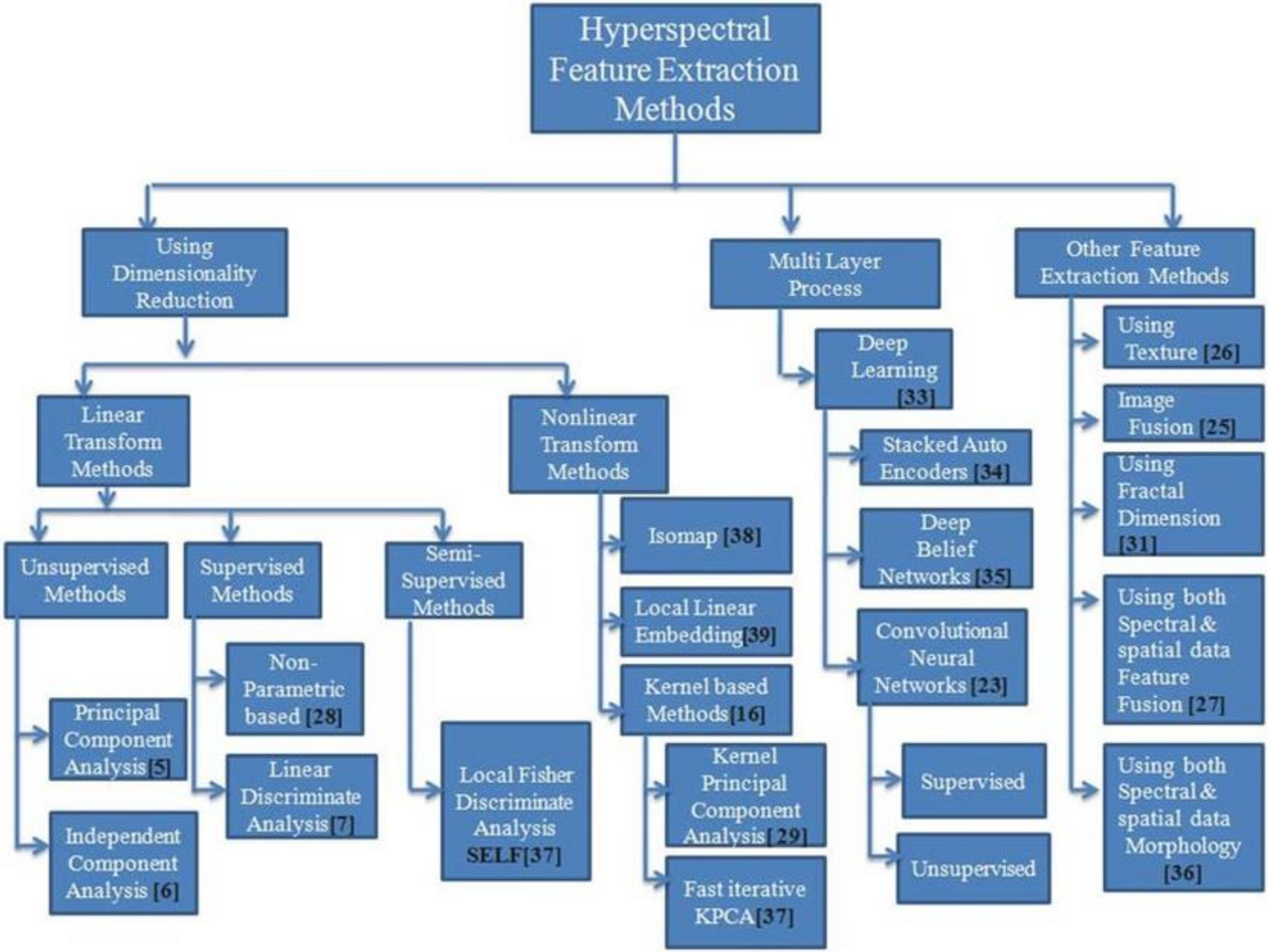
Decision/Internal Node: A node that symbolizes a choice regarding an input feature. Branching off of internal nodes connects them to leaf nodes or other internal nodes.

Leaf/Terminal Node: A node without any child nodes that indicates a class label or a numerical value.

Splitting: The process of splitting a node into two or more sub-nodes using a split criterion and a selected feature.

Pruning: The process of removing branches from the tree that do not provide any additional information or lead to overfitting




Hyperspectral Feature Extraction Methods
Using Dimensionality Reduction
Multi Layer Process
Other Feature Extraction Methods
Linear Transform Methods
Nonlinear Transform Methods
Deep Learning [33]
Using Texture [26]
Image Fusion [25]
Stacked Auto Encoders [34]
Using Fractal Dimension [31]
Isomap [38]
Deep Belief Networks [35]
Unsupervised Methods
Supervised Methods
Semi-Supervised Methods
Local Linear Embedding[39]
Convolutional Neural Networks [23]
Using both Spectral & spatial data Feature Fusion [27]
Non-Parametric based [28]
Kernel based Methods[16]
Principal Component Analysis[5]
Linear Discriminate Analysis[7]
Local Fisher Discriminate Analysis SELF[37]
Kernel Principal Component Analysis[29]
Supervised
Using both Spectral & spatial data Morphology [36]
Independent Component Analysis [6]
Fast iterative KPCA[37]
Unsupervised