# HYPERSPECTRAL REMOTE SENSING IMAGE ACQUISITION THROUGH AVIRIS SENSOR

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## ABSTRACT

Remote sensed data have different resolutions of space, radiometry, spectrum, and time. Knowing the strengths and weaknesses of various sensor data types is important for selecting correct remote sensed object classification data. Selecting acceptable remote sensed information involves consideration of factors such as end-user needs, research area size and characteristics, usable image data and their characteristics, cost and time constraints, and the analyst's experience using the selected images. The important factor affecting the collection of remote sensing data is atmospheric condition; another important factor influencing the selection of remote sensing data is atmospheric condition. Monetary costs are often an important factor that affects remotely sensed data selection. Airborne imagery taken by aero-transported platforms can overcome some of the difficulties of satellite images, mostly because they can be acquired in optimal climate and illumination conditions. Their spatial resolution can be adapted to different sensor configurations, flight plan and altitude, along with ground and atmospheric parameters. Airborne Visible Infrared Imaging Spectometer (AVIRIS) is one such sensor hence Hyperspectral Remote Sensing Image Acquisition is done here by using AVIRIS Sensor.

**Key words :** AVIRIS (Airborne Visible Infrared Imaging Spectrometer), HIS (Hyperspectral Sensing and Imaging) , EMAC (European Multi-sensor Airborne Campaign), ETM (Enhanced Thematic Mapper).

## 1. INTRODUCTION

Remote sensing imaging has enormous potential impact in the fields of geography, land surveying and most disciplines of Earth science (e.g., hydrology, ecology, meteorology, oceanography, glaciology, geology); it also has military, intelligence, commercial, political, planning and humanitarian disciplines and has become widely accepted through specific applications such as Google Earth ArcGis, among others. Vehicles carrying instruments operating in different acquisition modes may acquire images. We can specifically mention various satellite missions and constellations, airborne platforms and fixed platform cameras.

Each platform and acquisition mode has specific advantages and disadvantages. Due to the highly expensive acquisition sensors that are mounted on them, but are only freely available with low spatial and temporal resolution, satellite imagery has high-quality parameters and better spectral calibration and is therefore often inadequate for certain studies. Also, adverse weather and atmospheric conditions (fog, rain, smoke and other factors that may influence sensor measurements) often seriously impair them.

High-resolution satellite images are extremely expensive for most uses, making them prohibitive. Airborne images taken by aero-transported vehicles can overcome some of the difficulties with satellite images, primarily because they can be captured under optimal conditions of lighting and climate.

Their spatial resolution can be adjusted to various sensor settings, flight plan, and altitude along with ground and atmospheric parameters. Their main disadvantage is the high cost of operation and deployment. On board image processing is not readily available and it is only after each flight that the quality of each run is assessed. Mobile verification and correction of real-time image is once again highly prohibitive. Because of hardware limitations fixed camera imagery is typically of average or low quality and involves very complex processing to be useful for precise quantitative measurements [1].

Remote sensing image data is more than just a video-they are Electro Magnetic Energy measurements. The ‘quality’ of image data is determined primarily by the sensor-platform device characteristics. Such characteristics of the sensor system are usually referred to as Spectral resolution and radiometric resolution, relating respectively to the measured portion of the electro-magnetic spectrum and energy variations, Spatial resolution means the minimum size of items that can be chosen, referring to the smallest unit area measured and Review time, time between two successive acquisitions of images over the same location [2].

Several remote sensing satellites are presently on the market, providing imagery applicable for various forms of applications. Each of these satellite-sensor platform is characterized by the wavelength bands utilized in image acquisition, spatial resolution of the device, the coverage area and thus the temporal coverage, i.e. how frequent a given location on the earth surface could also be imaged by the imaging system.

In terms of the spatial resolution, the satellite imaging systems could also be classified as Low resolution systems (approx. 1 km or more), Medium resolution systems (approx. 100 m to 1 km), High resolution systems (approx. 5 m to 100 m) and Very high resolution systems (approx. 5 m or less)

In terms of the spectral regions used in data acquisition, the satellite imaging systems could also be classified as Optical imaging systems (include visible, about to infrared, and shortwave infrared systems), Optical/thermal imaging systems could also be classified in step with the number of spectral bands used, Synthetic aperture measuring device imaging systems could also be classified in step with the mixture of frequency bands and polarization modes used in data acquisition, Multiple polarization (Combination of two or further polarization modes), Monospectral or panchromatic (single wavelength band, "black-and-white", grey-scale image) systems and Multiple frequency (Combination of two or more frequency bands).

## 2. PRE-PROCESSING OF REMOTE SENSING DATA

### Geometric and Atmospheric Correction

Images were corrected geometrically using ground control points collected during the winter field campaign and a geo-rectified spatial coverage of the forest compartments located in the catchment.

### Data Reduction

Data reduction techniques are used to modify data sets with high spectral resolution, to minimize high data dimensionality and the difficulty of applying statistical classifiers to these data sets [3].

## 3. OVERVIEW OF HYPERSPECTRAL REMOTE SENSING AND IMAGING

Hyperspectral Sensing and Imaging (HIS) exploits the fact that all materials reflect, absorb and emit electromagnetic energy at specific wavelengths due to differences in their molecular composition in distinctive patterns. This feature is called the signature of the spectrum.The spectral signature can, in theory, be used to classify and distinguish any substance in a sufficiently large spectral band [4].

Hyperspectral data / images acquired through selected wavebands are made up of spectral information that can cover dozens or even hundreds of contiguous narrow bands for signature analysis purposes. Spatially and spectrally digitized information can be regarded as a three-dimensional data cube with two-dimensional spatial coordinates and a third spectral band dimension. Developing proper processing algorithms to analyze the data cube with high resolution has become the key to the success of many applications for hyperspectral sensing and imaging.

Based on their functions, the processing algorithms can be divided into four types: target detection, change detection, classification and unmixing. Detection of targets means looking for a particular spectral signature belonging to some object or substance. The aim of detecting change is to find significant differences between two hyperspectral scenes in the same geographic area. The classification objective is to label each pixel in a hyperspectral image into clusters of pre-specified category (class) types. Unmixing involves determining the fraction of the pixel area covered by each material in the scene or decomposing a mixed pixel into a series of spectra usually used in remote sensing.

The typical procedures in HIS analysis includes:

- Image display, that shows a view of the data set in the image space so that the analyst can easily illustrate and mark data classes
- Class definition, this process was designed to identify information in the appropriate groups
- Feature extraction that uses algorithms to determine a function subspace that is optimal for distinguishing between given groups. Typically a initial collection of data training is needed
- Reformatting, in this step, a new data set with reduced dimensionality is generated based on the subspace of the feature
- Initial classification, classifiers are used to divide the data cube into classes defined
- Finalize training; it involves reviewing the outcomes of the initial assessment and identifying potential changes. If required, new features will be added to the training set and
- Final classification, this step involves reclassifying data on the basis of the new training set [5].

## 4. HYPERSPECTRAL REMOTE SENSING SENSORS

Hyperspectral remote sensors have the ability to acquire images in many specific spectral bands in the electromagnetic spectrum from visible, near infrared, medium infrared to thermal infrared.

Hyperspectral sensors capture energy in 200 or more bands, thus constantly covering the reflective spectrum for each pixel in the scene. Bands characteristic of these types of sensors are continuous and narrow, allowing an in-depth study of the characteristics and features of Earth that would be missed with multispectral sensors.

Hyperspectral records are based on spectroscopy in the range 0.40 to 2.5 μm where hyperspectral sensors work and where absorption has three fundamental characteristics : the absorption of the transferred cargo, which occurs mostly in the visible part of the electromagnetic spectrum, causes the electrons to be transferred between atoms. For example, between atoms Fe2+ and Fe3+, an atom is moved from atom Fe2+ to Fe3+ due to the action of light causing the appearance of oxidized artifacts in red. Although this phenomenon can be identified with multispectral sensors such as Landsat, hyperspectral sensors can better expose it; in the case of atoms with an incomplete electronic wrapper, transmitted electron absorption occurs when light with certain wavelength can bombard electrons from different positions in the coating. This absorption appears to extend beyond the transferred cargo at more narrow intervals and the wavelength where the absorptions are rendered is influenced by the location and heterogeneity in the vicinity of atoms, not by the form of atom. This feature is used, especially in geology where atomic mineral arrangement is well defined; vibration absorption occurs when light with or part of a molecule having the same wavelength strikes the molecule and causes a vibration that leads to light absorption [6,7].

Generally speaking, this energy absorption is very small, while depths are sufficiently varied. Multi-spectral detectors can sense a lot of this absorption.

Hyper-spectroscopy applies to the image spectroscopy as images can be obtained for each narrowband. Hyperspcetral remote sensing is the term used for devices that take images with high spectral resolution.

Hyperspectral remote sensing is a relatively new technology used in rocks, plants, artificial materials and soil background detection and identification [8].

The remote hyperspectral emerged in the mid-80s and has since been widely used for mapping minerals by geologists, detection of the type of material depends on the range and spectral resolution, the spectrometers signal to noise ratio of the sample density and the frequency of the product absorption in the wavelength of the measurements [9].

| **Hyperspetral Sensors on Satellites** | | | |
|---|---|---|---|
| **Types of sensors** | **Producer** | **Number of bands** | **Spectral range (µm)** |
| **FTHSI on MightySat II** | **Air Force Research** | **256** | **0.35 – 1.05** |
| **Hyperion on EO-I** | **NASA Guddard Space Flight Center** | **242** | **0.40 - 2.50** |
| **Hyperspectral sensors on aircrafs** | | | |
| **AVIRIS (Airborne Visible Infrared Imaging Spectrometer)** | **NASA Jet Propulsion Lab.** | **224** | **0.40 – 2.50** |
| **HYDICE (Hyperspectral Digital Imagery Collection Experiment)** | **Naval Research Lab.** | **210** | **0.40 – 2.50** |
| **PROBE – 1** | **Earth Search Sciences** | **128** | **0.40 – 2.50** |
| **CASI (Compact Airborne Spectrographic Imager)** | **ITRES Research Limited** | **Over 228** | **0.40 – 1.00** |
| **HyMap** | **Integrated Spectronics** | **100 1a 200** | **Visible to termal infrared** |
| **EPS – H (Environments Protection System)** | **GER Corporation** | **VIS / NIR (76),<br>SWIR1 (32),<br>SWIR 2 (32),<br>TIR (12)** | **VIS / NIR (0.43-1.05)<br>SWIR 1 (1.50 – 1.80)<br>SWIR 2 (2.00 – 2.50)<br>TIR (8 – 12.50)** |
| **DAIS 7915 (Digital Airborne Imaging Spectrometer)** | **GER Corporation (Geophysical and Environmental Research Imaging Spectrometer)** | **VIS / NIR (32),<br>SWIR1 (8),<br>SWIR 2 (32),<br>MIR (1),<br>TIR (12)** | **VIS / NIR (0.43 -1.05)<br>SWIR 1 (1.50 – 1.80)<br>SWIR 2 (2.00 – 2.50)<br>MIR (3.00 – 5.00)<br>TIR (8.70 – 12.30)** |
| **DAIS 21115 (Digital Airborne Imaging Spectrometer)** | **GER Corporation** | **VIS / NIR (76),<br>SWIR1 (64),<br>SWIR 2 (64),<br>MIR (1),<br>TIR (12)** | **VIS / NIR (0.40 -1.00)<br>SWIR 1 (1.00 – 1.80)<br>SWIR 2 (2.00 – 2.50)<br>TIR (8.00 – 12.00)** |
| **AISA (Airborne Imaging Spectrometer)** | **Spectral Imaging** | **Over 288** | **0.43 – 1.00** |

**Table 4.1 Main Hyperspectral Sensors on Aircraft and Satellites**

There are two types of systems taking images in the hyperspectral field: on aircraft and on satellites [10]. The majority of hyperspectral sensors are installed on air platforms and less on the satellite which is tabulated in Table 4.1.

## 5. AVIRIS SENSORS

For the first time in 1986, AVIRIS was flown (first airborne images), first scientific data in 1987, fully operational since 1989. As part of the European Multi-Sensor Airborne Campaign (EMAC), the instrument was flown over numerous European test sites in June / July 1991. Across 224 contiguous spectral bands, AVIRIS uses scanning optics and a team of four spectrometers to simultaneously view a swath size of 677 pixels. A spatial image is constructed through the motion of the scanner, which defines a line of image 677 pixels wide perpendicular to the direction of the aircraft and through the motion of the aircraft, which defines the length of the image frame. Sensor : Whiskbroom optimechanical scanner (12 Hz) which uses line detector arrays to image a 677-pixel-wide swath in 224 contiguous bands (four grating spectrometers). Spectral range : 360 – 2500 nm with 224 bands in total.

AVIRIS is now a robust radiometric and spectral measurement operating instrument. AVIRIS typically takes pictures at an altitude of 20km with a pixel scale from a NASAER-2 aircraft. On the surface, the swath width is about 12 km. At spatial resolutions of 1-4 m with decreased swath widths, AVIRIS can also obtain images from a low-altitude aircraft.

### 5.1 Sensor Specifications

The sensor has 224 adjacent spectral bands that range from 400 to 2.5 µm each 1µm long. AVIRIS is a whiskbroom scanning device that collects data in a 12 bit (0 to 4095) quantization. The sensor flies on a few aircraft at a high altitude of 20 km including the NASA / ARC ER-2 and the turboprop of the Twin Otter International at a lower altitude of 4 km.

Spatial image resolution can vary depending on the aircraft’s altitude. High-altitude flights are 20 m x 20m in resolution, while low-altitude flights are 4 m x 4m in higher resolution.

**Image footprint or swath width :** 11 km long, swath at high altitude (20km), 1.9km wide swath at low altitude (4km). The functional block diagram of AVIRIS sensors is shown in Figure 5.1.

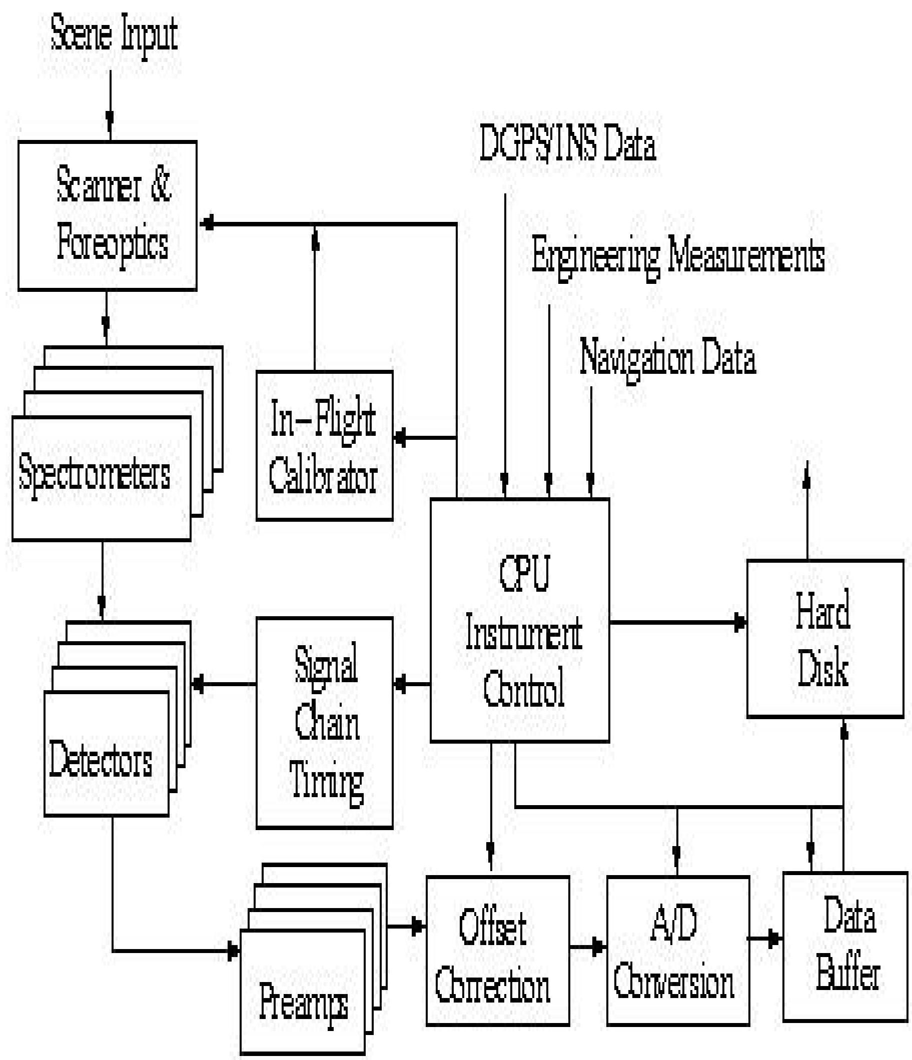


**Figure 5.1 : AVIRIS functional block diagram**

AVIRIS consists of six optical subsystems and five electrical subsystems as shown in Figure 5.2, of modular construction. Optical subsystems (a whiskbroom scanner, four spectrometers and a source of calibration) are combined via optical fibers.

Whisk broom scanners, sometimes also called spotlight scanners or cross-track scanners, use a mirror to reflect light on a single detector. The mirror moves back and forth to take measurements in the image from one pixel at a time. The moving parts make it expensive and more likely to wear out this sort of sensor. A spectrometer is an analytical tool used to isolate and quantify physical physical phenomenon spectral components. Spectrometer is a broad term that is often used to describe instruments that measure a continuous variable of a phenomenon that somehow blends the spectral components. A spectrometer can isolate white light in visible light and measure individual narrow color bands, called a spectrum.

Data : the recorded data set form an object cube containing two axes of spatial dimensions and a spectral dimension is defined by the third. The AVIRIS data recorder was upgraded in 2005 (storage capacity of 73 GByte) [11].

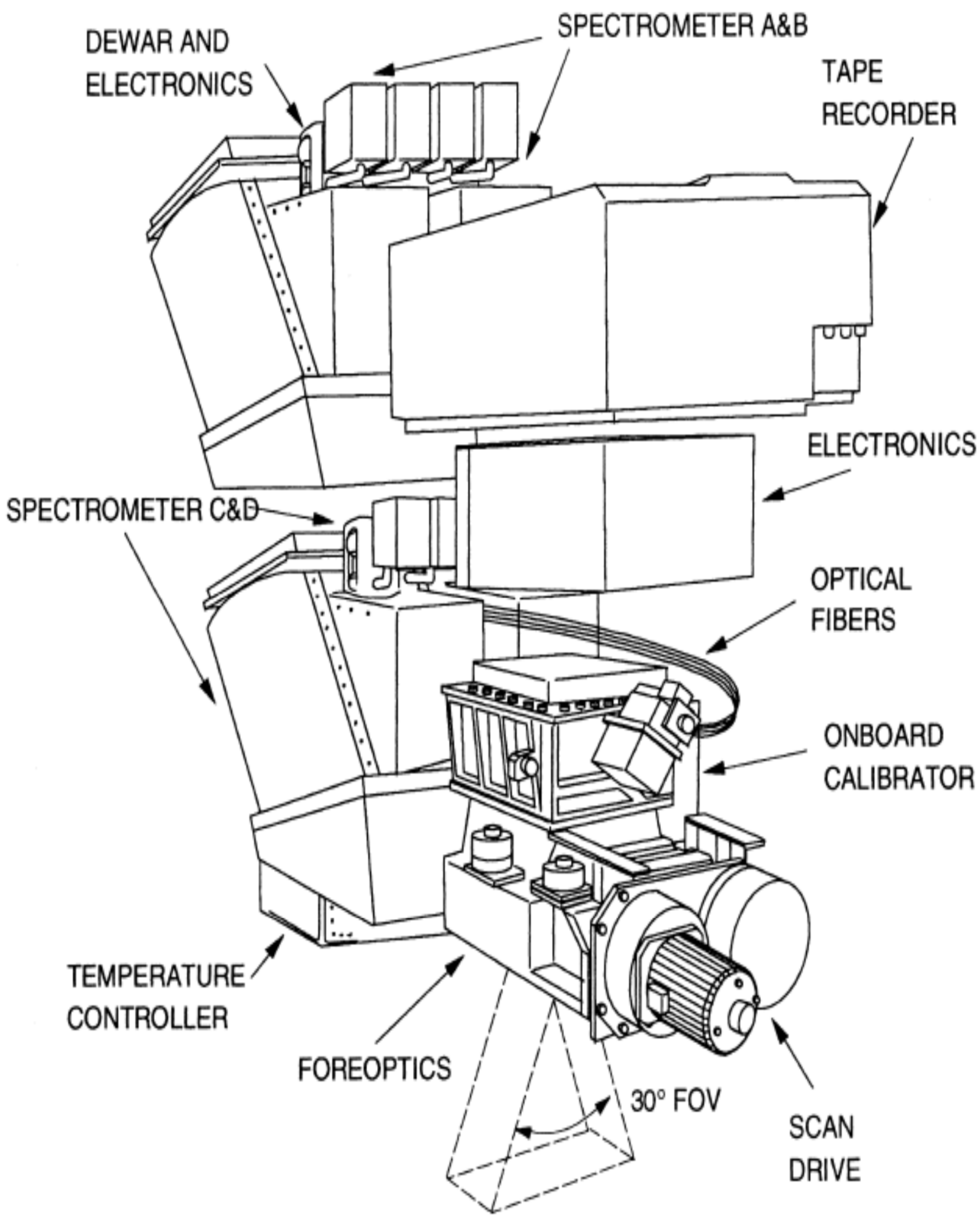


**Figure 5.2 : Schematic view of the AVIRIS instrument**

### 5.2 Sensor Characteristics

The characteristics of AVIRIS sensor is listed in Table 3.2 and data characteristics in Table 5.1.

| | |
|---|---|
| **Imager Type** | **Whiskbroom scanner** |
| **Scan rate** | **12 Hz** |
| **Dispersion** | **Four Grating Spectrometers (A,B,C,D)** |
| **Detectors** | **224 Detectors (32,64,64,64) Si and Insb** |
| **Digitization** | **12 bits** |
| **Data rate** | **20.4 Mbits/s** |
| **Spectrum rate** | **7300 Spectra/s** |
| **Data Capacity** | **>10GB (>8000 Km$^2$)** |

**Table 5.1 Characteristics of AVIRIS Sensor**

The AVIRIS sensor receives white light in the foreoptics, disperses the light into the spectrum, converts the photons into electrons, amplifies the signal, digitizes the signal and records the data density tape. Nominal AVIRIS data Characteristics are tabulated in Table 5.2.

| **Spectral** | |
|---|---|
| **Wavelength range** | **400 – 2500 nm** |
| **Sampling** | **10 nm** |
| **Spectral response (fwhm)** | **10 nm** |
| **Calibration accuracy** | **< 1 nm** |
| **Radiometric** | |
| **Radiometric range** | **0 to maximum lambertian radiance** |
| **Sampling** | **~1 DN noise RMS** |
| **Absolute calibration** | **≥ 96%** |
| **Inter flight stability** | **≥ 98%** |
| **Signal-to-noise** | **Exceeding 100 :1 requirement** |
| **Polarization sensitivity** | **≤ 1%** |
| **Spatial (at 20 km altitude)** | |
| **Field of view** | **30 degrees (11 km)** |
| **Instantaneous FOV** | **1.0 mrad (20 m)** |
| **Calibration accuracy** | **≤ 0.1 mrad** |
| **Flight line length** | **800 km total** |

**Table 5.2 Nominal AVIRIS Data Characteristics**

Scanning mirror, foreoptics, spectrometers, detectors, onboard calibrators and electronic signal chain are the core subsystems of the sensor [12].

### 5.3 Comparison of AVIRIS with other Sensors

In [13] AVIRIS is compared with Hyperion and the following characteristics in Table 5.3 are determined which shows that AVIRIS is best.

| HIS Sensor | Spectral Resolution | Spatial Resolution | Swath Width | ShortWave InfraRed Signal to Noise Ratio | Imager Type |
|---|---|---|---|---|---|
| AVIRIS – High Altitude | 10nm | 20m | 12km | 500:1 | Whiskbroom |
| Hyperion | 10nm | 30m | 7.5km | 50:1 | Pushbroom |

**Table 5.3 Comparison of AVIRIS with Hyperion Sensor**

AVIRIS was more accurate to define land use at the Urban Fringe than on of Synthetic Landsat ETM+. The factors that may affect the accuracy of classification are the Ground Sampling Distance (GSD), the number of spectral bands and a sensor’s signal-to-noise ratio [14]. The comparison is tabulate in Table 5.4.

| | AVIRIS | LandSat TM/ETM+ |
|---|---|---|
| Platform | Airborne | Spaceborne |
| Ground Sampling Distance | 20m | 30m |
| Number of Bands (excluding thermal) | 224 | 6 |
| Signal-to-Noise Ratio | High | Moderate |
| Launch | 1987 | 1982 |

**Table 5.4 Comparison of AVIRIS with LandSat TM/ETM+**

Due to the increasing number of companies and agencies operating hyperspectral scanners, airborne and spaceborne hyperspectral imaging is becoming increasingly available. Airborne data acquisitions benefit significantly from satellite-based missions as the user controls the task in terms of time schedules, flight line arrangements, calibration measurements, spectral / spatial resolutions and appropriate weather conditions [15].

### 5.4 Image Acquisition through AVIRIS Sensors

AVIRIS is a complex and sophisticated optical sensor system that includes a number of major subsystems, modules and functions [16].

A supervised AVRIS classification is more reliable than one of the artificial Landsat ETM (Enhanced Thematic Mapper) for Urban Fringe land use classification. With a combination of soil and plants, AVIRIS reduce false positives for land use [14].

AVIRIS's narrow bands would track the effect of spectral reflection in a narrow spectral area and have higher radiometric quality [17].

AVIRIS is an airborne detector that collects images with 224 spectral bands from visible, close to infrared to short wave infrared. Spatial resolution ranges from meters to dozens of meters and the swath ranges from several kilometers to dozens of kilometers, depending on the satellite platforms and the data collected latitude [18].

To test the reflective portion of the electromagnetic spectrum, the hyperspectral sensors are produced. The entire inspection spectrum spreads through the near infrared from the visible region and is divided into hundreds of overlapping small bands. The spectrum interval in wavelength can be as narrow as nanometers, resulting in obtaining more than 100 spectral channels at the same time. Because image data is considered to be two-dimensional, the hyperspectral data can be interpreted as a three-dimensional data cube by adding a new dimension of "spectrum" information as shown in Figure 5.3.

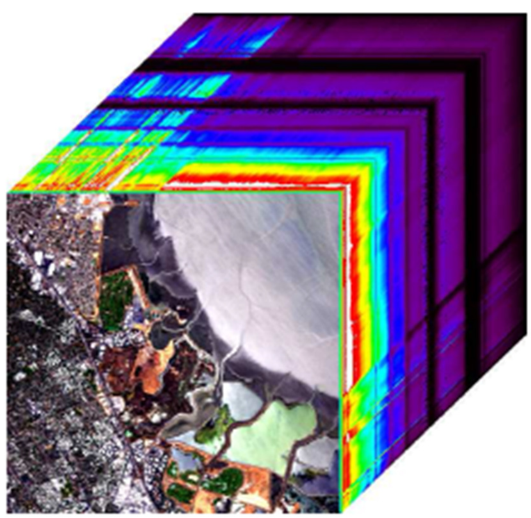

**Figure 5.3 Representation of a sample data cube for a hyperspectral image with 224 bands, covering the range of 365 nm – 2500 nm**

Hyperspectral data / images collected by selected wavebands are made up of spectral information that can span dozens or even hundreds of contiguous narrow bands for signature analysis purposes. Spatially and spectrally digitized information can be viewed as a three-dimensional data cube with two-dimensional spatial coordinates and a third spectral band dimension. The development of appropriate processing algorithms to analyze the high-resolution data cube has become the key to the success of many applications for hyperspectral sensing and imaging [5].

| **Features** | **AVIRIS** |
| --- | --- |
| **Technology** | **Whisk broom linear array** |
| **Sampling Interval** | **10 nm** |
| **Field of View** | **30 degrees** |
| **Instantaneous Field of View** | **1.0 mrad** |
| **Scan Rate** | **12 Hz.** |
| **Spectral Channels** | **224** |
| **Wavelength Range** | **400 – 2500 nm** |

**Table 5.5: Features of AVIRIS Sensors**

Table 5.5 summarizes AVIRIS sensor features that include AVIRIS sensor using more spectral channels, wavelength range, scanning rate, etc. Image acquisition is therefore carried out using AVIRIS sensors and the steps to acquire image are

Step 1: Record the visible and near-infrared spectrum.

Step 2: Frame a data cube with two or more spatial and one or more spectral dimension.

Step 3: Consider each pixel to identify spectral and spatial signature.

Step 4: Use spectral and spatial images for identification purposes.

**CONCLUSION**

Hyperspectral sensors capture images using two systems, aircraft and satellites out of which aircraft system capture images by considering time schedules, flight line arrangements, calibration measurements, spectral / spatial resolutions and acceptable weather conditions.

AVIRIS is an airborne sensor collecting images with 224 spectral bands with spectral range of 0.40 – 2.50 µm, uses whiskbroom scanner, having data rate 2..4 Mbits/s, spectrum rate 7300 spectra/s and data capacity greater than 10 GB.

AVIRIS is compared with Hyperion sensor and it shows that AVIRIS is better because of having large swath width and less Signal-to-Noise ratio.

AVIRIS is compared with Synthetic Landsat ETM+ and it is proved that AVIRIS is more accurate because of having large spectral bands. Hence the image captured by AVIRIS sensors is considered for this research work.

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