PDH Academy

Remote Sensing for Surveyors

3 hours

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Remote Sensing For Surveyors Final Exam

1. In the 1840's, where did balloonists take pictures of the ground using a photo capable camera?
   A. Africa
   B. United States
   C. Europe
   D. Belize

2. What year was the first official camera publicly released?
   A. 1839
   B. 1950
   C. 1975
   D. Has not yet been released.

3. Which type of bird was used for aerial photography, although considered a novelty?
   A. Bald Eagle
   B. Pigeon
   C. Penguin
   D. Blue Jay

4. What decade was GIS introduced?
   A. 1900-1910
   B. 1910-1920
   C. 1920-1930
   D. 1960-1970

5. Which country launched a satellite named SPOT?
   A. Russian
   B. USA
   C. France
   D. Italy

6. What does LiDAR stand for?
   A) Light Detection and Ranging
   B) Light Radar
   C) False Light Radar
   D) Light Beaming and Ranging

7. What decade did the Landsat program begin?
   A) 1960’s
   B) 1940’s
   C) 1950’s
   D) 1920’s

8. Radiant Flux is measured in?
   E) Watts
   F) Inches
   G) Feet
   H) Joules

9. Which Landsat Satellite was the first to fail at launch?
   A) Landsat 1
   B) Landsat 2
   C) Landsat 3
   D) Landsat 6

10. What does GCP stand for?
    A) Ground Common Point
    B) Ground Control Point
    C) Great Common Point
    D) Great Control Point

BIOGRAPHY

Robert T Loane III, is a Professional Land Surveyor currently located in the Denver, Colorado area. Robert has around twelve years of various experience in the Surveying and Mapping industry. He has worked on high profile construction projects across the United States from Florida to Alaska, most notably the Port of Miami Tunnel Project and the Urenco USA Uranium Enrichment Facility. Robert has been featured in both “The American Surveyor” and “POB” magazines for projects throughout the United States. He has completed his Bachelor’s of Science in Geomatics Engineering from Florida Atlantic University, Graduate Certificate in Geospatial Analysis from the University of Florida and will obtain his Master’s of Science from the University of Florida after the spring 2018 semester.

Course Description -

This course was designed as an introduction to Remote Sensing technology and how it applies to the Surveying and Mapping industry. Remote Sensing is one of the most revolutionizing technologies to be integrated with surveying since GPS. This course will expand the students’ knowledge of how Remote Sensing and Aerial Photography work and integrate into the map-making process.

After review of all course material, a final exam (included with course) must be completed. A score of 70% or better must be achieved to pass the assessment and receive the certificate of completion.

Learning Objectives –

Upon completion of this course, the student will be able to:

1. Summarize the history of Remote Sensing and how the technology was developed.

2. Explain the camera and how it functions within a Remote Sensing system.

3. Identify space borne photography and the systems used to collect the data.

4. Discuss how Remote Sensing works and how it translates into the Surveying and Mapping industry.

Remote Sensing for Surveyors

Introduction

Today, the role of technology plays a huge and increasing importance to almost every aspect of human life. The dependence upon the capability of technology to conduct work as well as daily affairs and the demands placed upon people in the modern world can only be met with the aid of technology. The world we currently live in requires the use of technology in order to function, utilizing electronics in every aspect of life, from communication, to entertainment to conducting scientific experiments. Over the last 30 years, technology has grown at an exponential rate and it's our duty to progress along with it. We must learn from past mistakes and use technology as a tool to progress the future generations.

When relating technology to Remote Sensing, there has been a great amount of effort put into developing quality and efficient ways to gather aerial photography and imagery. Some of the most readily used applications of technology are GPS and digital maps which allow people to navigate almost anywhere on the entire planet. Because of the success of these applications through the massive amounts of work and research being put into this field, the precision of the technology is becoming increasingly accurate and versatile. This advancement, which allows us to access everyday tools such as maps and directions, is achieved through Remote Sensing and aerial imaging in many forms. One of the most important tools developed in the past 25 years is Google Earth, which serves many purposes and incorporates many images derived from Remote Sensing techniques.

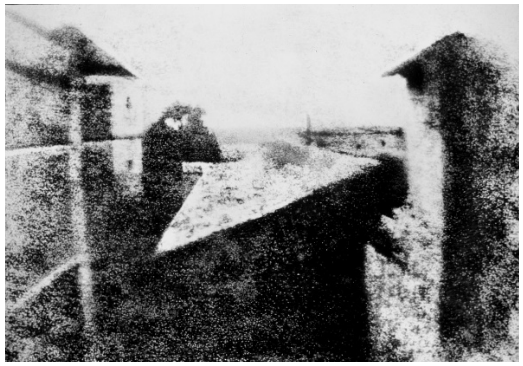
Remote Sensing has many uses and advantages. Not only is it used when dealing with maps and GPS, but it can also be utilized to forecast weather through the use of satellites and ground based methods. Being able to access such information means that Remote Sensing also provides accurate identification and measurements including the location of storms, weather patterns, cloud types and atmospheric conditions. Remote Sensing techniques can also be used to predict hazardous weather conditions such as tornadoes, hurricanes, forest fires, floods and earthquakes. This tool has been crucial for expedited responses to severe storms. The sensors can also be used to predict long-term and short-term climate patterns by measuring and monitoring things such as surface temperature and glacial melting. This technology aids in human safety and disaster relief planning through almost instantaneous image acquisition.

Resource Management is also an important topic when dealing with Remote Sensing. Multispectral imaging can be used to determine overall forest health and estimate crop yields, which is beneficial to agriculture, conservation, and a multitude of other industries. The mapping industry has greatly evolved with the addition of Remote Sensing data as well. High resolution space borne imagery has basically redefined how we view mapping data. Knowing the many uses of Remote Sensing, we can see that it has a vast and extensive benefit in most scientific fields that benefit for high quality and high-resolution imagery. It is difficult to find a scientific field that does not benefit directly from Remotely Sensed data.

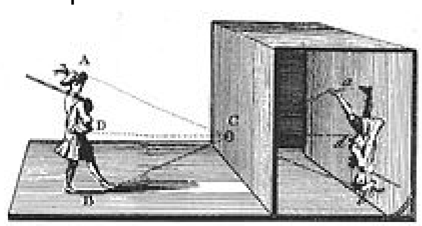
History of Remote Sensing

The history of Remote Sensing dates back to the 1840's when balloonists in Europe took pictures of the ground using a photo-capable camera. At this time, it was a simple mechanism that was experimental in practice but also successful and lead to vast future developments and capabilities in the technology of aerial imaging. Prior to aerial imaging, mapmaking was an extremely difficult task. It was incredibly hard to portray an accurate representation of the land without the use of some sort of aerial photography. Early maps were not accurate or precise portrayals of the land and waters. Cartography, which can be defined as the production of maps, was a term that was coined around the same time the first camera was invented. Below is a map from the 17th century and it is clear to see that some of the land features are distorted due to the lack of accurate knowledge regarding the shape and size of the land. This map also shows a split view of the eastern and western hemispheres, as well as the northern and southern hemispheres. Remote Sensing aerial imagery has helped a great deal with map distortions and projections.

The original device was called the Daguerrotype (the first official) camera and was publicly released in 1839, being invented by Louis Daguerre and Joseph Nicéphore Niépce. Even Though the first camera was designed in 1685 by Johann Zahn, Nicéphore Niépce is credited with taking the first photograph in the year 1814. The Daguerrotype was the most commonly used camera until about 1960, when new and less expensive processes were being used to provide faster and readily available images. This type of camera was extremely bulky and not practical for aerial photography. When using the Daguerrotype camera, it was a common occurence to utilize a polished sheet of silver-plated copper in order to produce the photo. The earliest surviving photograph was titled View from the Window at Le Gras, although 1839 is regarded as the birth year of practical photography.



The Daguerrotype is an example of a Camera Obscura which translates to dark chamber. The origin of the name tells the story of how the ability of the camera was discovered and further developed. Below is an example of the fundamentals of the Camera Obscura.



Camera Obscura was also referenced as “pinhole imaging” which can be understood as: “the natural optical phenomenon occurring when an image of a scene at the other side of a screen can be projected through a small hole (pinhole) as a reversed and inverted image (left to right and upside down) on a surface opposite to the opening. In order for the image to be clear, the surroundings of said projected image have to be dark (obscura) for anything to be visible.” (Wikipedia, Camera Obscura). This simple process basically inverts the image on the other side of the display.

The process of early photography was composed of a multitude of steps, including Polishing, Sensitization, Exposure, Development and Fixing. All of these steps work together in phases to produce an image. This camera typically used laterally reversed images that are viewed from the side. Photographic data quickly became an essential element in Remote Sensing due to its advancement and the ability to produce accurate visuals. Below is a picture of a common Daguerreotype camera. Although technology has come a long way since the invention of the first camera, this device led to great advancements in imaging and data gathering technology and created way for Remote Sensing. Although simple in design, the Daguerrotype camera was considered cutting edge technology when it was invented.

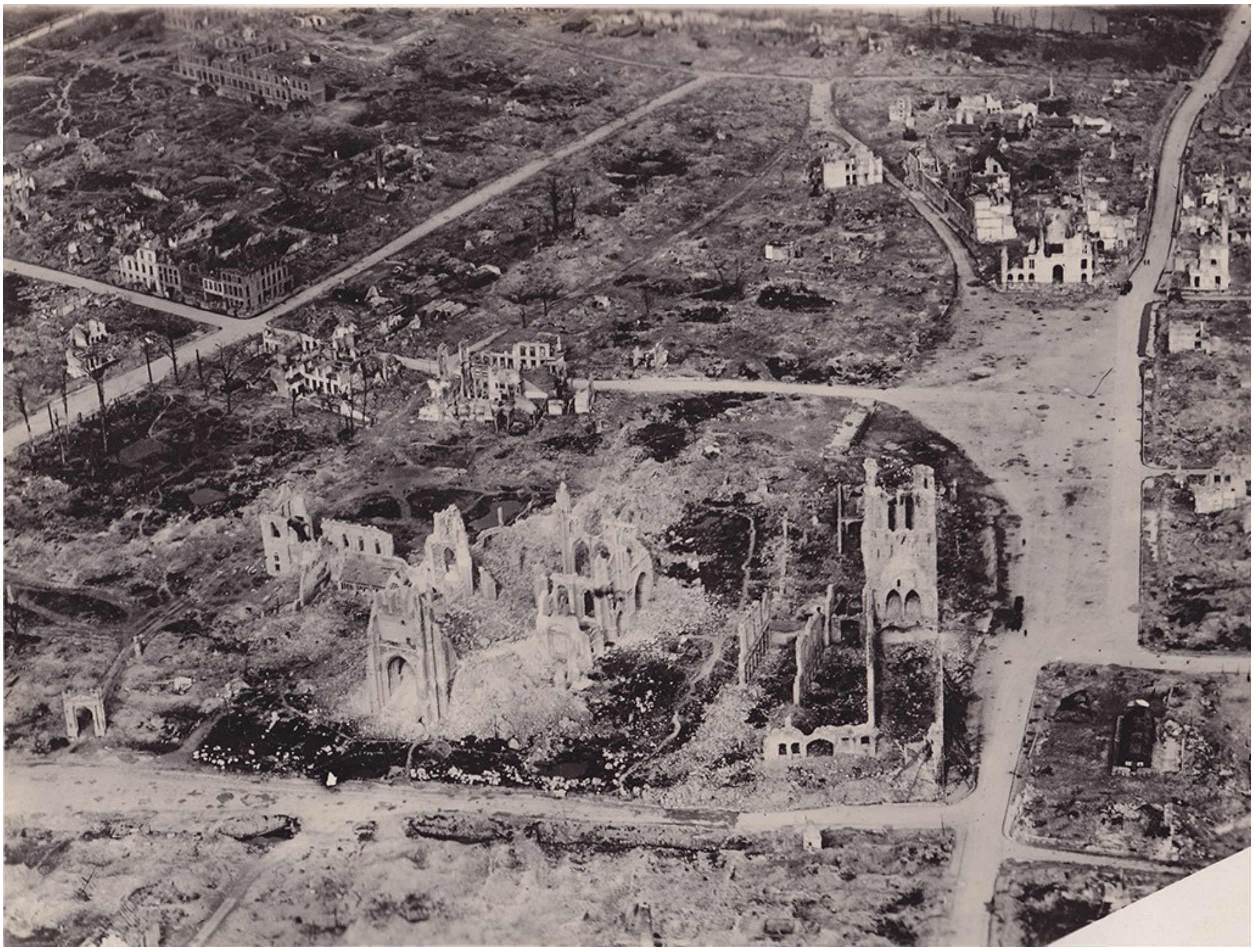
Remote Sensing is technically defined as “the science of gathering data on an object or area from a considerable distance, as with radar or infrared photography, to observe the earth or a heavenly body.” (1) Remote Sensing is made up of four major components that are categorized as: energy source, sensor, interaction with the surface of the earth and interaction with the earth’s atmosphere. It is used to detect non-visible characteristics and cover a large region of view. It’s also very effective in creating time-lapse imagery in a cost-efficient manner. For example, Google Earth has an excellent function that allows you to view past aerial photography of the same location. These images range from black and white to color depending on the aerial photography that was taken.

Many different vessels have been used to gather data, but none have the notoriety of the pigeon fleet used in Europe at the turn of the last century. Although, this method was thought of as a novelty, these birds flew above ground with cameras mounted on their breasts to capture images of the ground below. This was not the most practical method because the camera was extremely large to be mounted on a small bird. This pigeon photography was a technique invented in 1907 by German-born Julius Neubronner who also was associated with developing a technique for pigeons to deliver medications. Pigeons were used because they were easy to train on flight patterns. Another example of intelligent techniques used in the past to gather ground data is that of 1906, when photographs of the San Francisco earthquake were obtained from a kite. These are just a few of a substantial number of important occurrences, however we can see that photographic technology has made huge strides in the last century. A pigeon fleet is pictured below with cameras strapped to their front.

During the First World War, Remote Sensing and Aerial photography became an important reconnaissance tool due to the increased necessity to gain information through aerial visuals. “By this time, sophisticated aerial photography from kites, balloons and pigeons had already developed significantly thanks to a century of experiments by scientists and militaries. In “The Balloon Prospect,” Caren Kaplan writes that balloons were used for military reconnaissance as early as June 26th, 1794, when the French Revolutionary Army floated balloons over their engagement with the Austrian-Dutch coalition in Fleurus, Belgium.” (2) World War 1 was a major contributor which led to the advancement of Remote Sensing technology. The methods of collecting aerial intelligence would continue to evolve after the first World War.

The benefits of aerial photography and Remote Sensing for surveillance purposes became more and more evident after the war. Cameras were then mounted on aircrafts and pilots more regularly. Aside from serving military purposes, the photos captured during that time frame began to also be used in a variety of different fields, such as soil surveys, forest inventory and mapping. The years between World War 1 and World War 2 was a period of advancement in Remote Sensing. Military and nonmilitary groups combined forces and worked together to advance the beneficial technology. This technology evolved at a rapid rate and the quality of the aerial imagery started to become more and more useful.

The first comprehensive use of aerial imagery in battle occurred in 1915 during the Battle of Neuve, where British intelligence gathered and distributed around 1,500 photographed maps of Germany's trenches. The aerial photograph was the primary tool used for surface depiction from World War 1 until the 1960's. Getting a so called “bird's eye view” on your enemy was extremely advantageous in planning attacks and setting up defense. The advancement of this technology allowed for strategic planning in battle and gained popularity in the military field. Below is an early aerial photograph taken in World War 1 and a perfect example of early Remote Sensing technology.



During the Second World War, aerial photography became a key militaristic asset and photo recognition became a highly valuable skill. Photogrammetric equipment began to evolve at a rapid rate and color infrared imagery began being used for camouflage detection. RADAR was then introduced, and Remote Sensing technology became classified. RADAR being a detection system that uses radio waves to determine the velocity, angle and range of objects. It was used to detect ships, spacecraft, guided missiles, aircraft, motor vehicles, terrain and weather formations. Much like the global positioning system, also known as GPS, the Remote Sensing technology was being used more often and at an increasing rate for militaristic purposes at this time.

After World War 2, interpreters began to evaluate these photos for other uses such as engineering, mapping and geology. U-2 Spy planes became popular vessels that were applying this technology. Soon after, rockets and satellites were also being used for Remote Sensing. New imaging systems began to emerge replacing the previous film-based devices. The U-2 Spy plane was the topic of an international diplomatic crisis in 1960, when USSR shot down an American U-2 in Soviet airspace and captured the pilot.

Satellite Remote Sensing dates to the beginning of the space age with attachments of several different types of sensors on spacecrafts. Both Russian and American space programs are credited with using this technology. Although Remote Sensing was around prior to this, the term was not coined until the 1950's by Naval Research Officer Evelyn Pruitt. The first non-military satellites emerged in the 1960's for monitoring weather patterns.

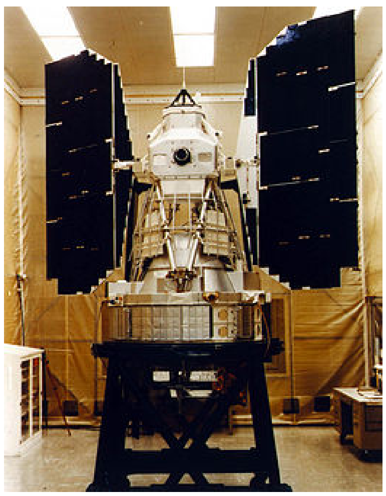
Another major technological advancement came along in the 1960's. This was the Geographical Information Systems, also known as GIS. GIS was developed in both Canada and the United States. Systems such as CGIS, SYMAP and DIME began to emerge as functional data systems after branching from GIS. Roger Tomlinson is known as the father of GIS, and it's first system was developed in Canada. His system (CGIS) was unique from the others because it involved a layering schema. Tomlinson's system became fully operational in 1971, and was used by the Canadian Government to inventory used soil, drainage and climate characteristics. Technology began to evolve quickly from the year 1970 through the mid 1980's with multiple types of satellite sensors being launched, as well as, GIS software commercialization.

The Landsat program began in the early 1960's in the United States when USGS (U.S. Geological Survey) director William Pecora made a proposition to initiate a Remote Sensing program in order to gather information on natural resources. After a few years of methodical investigations, NASA had received the go-ahead to build a satellite for this purpose. Landsat 1 only took around two years to build and was successfully launched by the Thor-Delta rocket in 1972. Below is a sketch of Landsat 1, which closely resembled a weather satellite. This satellite had a liftoff weight of 2,101 pounds.

At the time, Landsat 1 was known as ERTS or Earth Resources Technology Satellite and was the first satellite launched to monitor Earth and its landmasses. Landsat 1 carried a camera system called RBV or Return Beam Vidicon and a Multispectral Scanner. This satellite was a modified version of a Nimbus 4 meteorological satellite and was a near-polar orbiting spacecraft. Although only designed to function for around 1 year, Landsat 1 was functional until 1978 and greatly exceeded all quality and longevity expectations. The success of this satellite helped NASA realize that this technology would be beneficial and worth investing in for years to come.

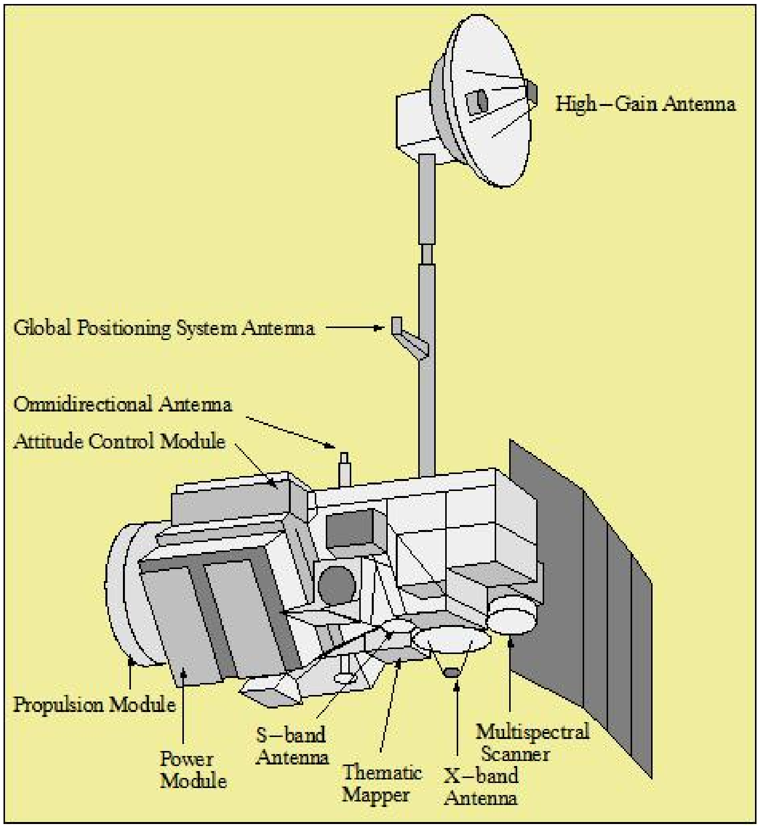
Landsat 2 was launched approximately two and a half years after Landsat 1 and carried the same equipment. This satellite had the capability to store around 30 minutes of data on two wide-band video recorders. Landsat 2 was very similar in size and weight to Landsat 1, being 3 meters tall and 1.5 meters in diameter. It had two solar panel arrays (one on each side) that were around 4 meters long. It was functional for around seven years, but had control issues (faulty yaw thruster) and was removed from operations.

Three years after Landsat 2 launched, Landsat 3 was introduced with improved cameras and a larger spectral band. Landsat 3 was functional for around five years. This satellite also had the same storage capabilities of Landsat 2. It was slightly heavier than the two predecessors and was able to orbit the Earth 14 times per day. The data obtained from this satellite was used in 31 different countries. Below is an artist rendering of the Landsat 3 satellite.



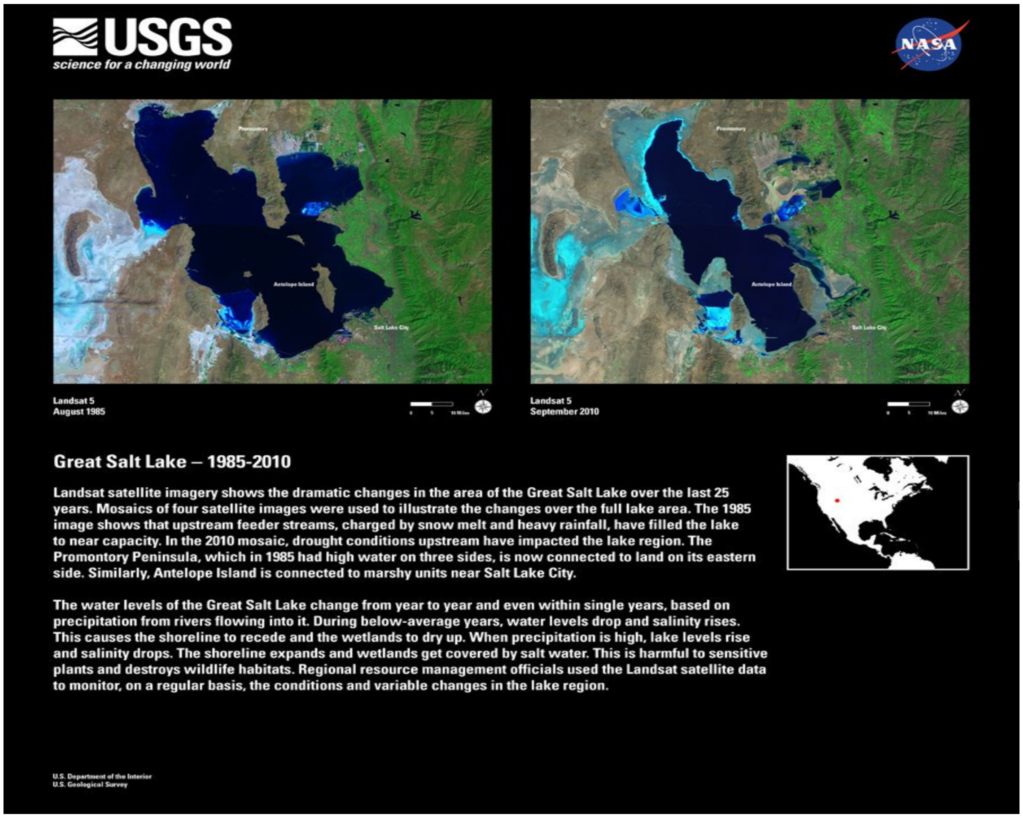
Landsat 4 was launched in 1982 and had significant changes from the previous three satellites. Landsat 4 had an improved sensor that could see better ground detail with a wider range. The Thematic Mapper took the place of the RBV instrument providing a larger spectral band. Landsat 4 was functional for nearly 20 years until it was finally decommissioned in 2001.

In 1984, NASA launched Landsat 5 which was designed with the same Thematic Mapper and Multi-Spectral Scanning System as Landsat 4. Landsat 5 performed extremely well and was functional for over 28 years. This was a great feat considering it was designed to last only three years. Landsat 5 is known as the longest-operating Earth observation satellite.



"On Dec. 21, 2012, the USGS announced Landsat 5 would be decommissioned after the failure of a redundant gyroscope. The satellite carries three gyroscopes for attitude control and needs two to maintain control. In January 2013, Landsat 5's instruments were powered off and the satellite was moved in to a lower orbit. Mission operators conducted several burns to use all the excess fuel, and put the satellite into a disposal orbit in June 2013. They sent the last command to power off the transmitter on June 5, 2013." (3)

In 1984, Congress decided that satellites could be privatized through the Land Remote Sensing Commercialization Act. EOSAT or the Earth Observation Satellite Company was selected through the National Oceanic and Atmospheric Administration (NOAA). NOAA eventually directed EOSAT to decommission the satellites in 1989 because of lack of interest in the data, but the Vice President stepped in to save the program. The government eventually stepped in and took control of Landsat 4 and Landsat 5 once again.



Landsat 6 was the first Landsat satellite to fail at launch because it couldn't reach the minimum velocity to obtain orbit of the earth. This satellite carried an enhanced version of the Thematic Mapper that was aboard Landsat 4 and Landsat 5. The enhanced mapper allowed for an eighth spectral band and increased spatial resolution from the previous Landsat models.

In 1999, Landsat 7 was launched carrying an even more enhanced Thematic Mapping System with new features such as a panchromatic band, on-board absolute radiometric calibration, on-board data recorder and a thermal IR channel. Landsat 7 reached accuracy standards that surpassed all of its predecessors. It was the most stable earth observing satellite to be placed in orbit for the four years it was functional.

Landsat 8 was designed by both NASA and USGS with an OLI Operational Land Imager and a TIRS Thermal Infrared Sensor. It was launched in 2013 on an Atlas-V 401 rocket and acquires 112 more scenes per day than Landsat 7 with better cartographic accuracy. It is still functional today, but was designed with a five-year estimated shelf life.

As remote sensing technology evolved SeaSat was introduced in June of 1978 with the hopes of monitoring the earth's oceans through SAR or synthetic aperture radar. This technology was used to observe all aspects of the ocean’s such as surface temperature, wave heights, surface winds, atmospheric waves and general ocean topography. The five major components that make up the SeaSat are the radar altimeter used to measure height above the ocean surface, synthetic aperture radar to measure the wave field, radiometer to identify specific features, microwave radiometer to measure temperature and the scatter meter to measure wind speed and direction. Since most of the earth is covered by water, SeaSat was a very important step in the history of Remote Sensing. Seasat was also able to detect wakes of underwater submarines which was not anticipated from the design. Below is a picture of the Seasat satellite.

In October of 1978, the first AVHRR or Advanced Very High-Resolution Radiometer was launched. These space-borne sensors measure the earth's reflectance with five very wide spectral bands. Most of these sensors are carried and managed by NOAA. These sensors are primarily used to measure the earth's thermal emissions and cloud patterns.

One month later the TOMS or Total Ozone Mapping Spectrometer was introduced to measure ozone values from space. Out of the five of these spectrometers built, only four of them wound up reaching orbit. TOMS-EP was launched in 1996 and is capable of measuring sulfur dioxide released from volcanic eruptions. The TOMS program is managed by the Goddard Space Flight Center in Maryland.

Between the years 1986 and 1999, commercialization emerges in Remote Sensing technology with France launching the first non-US, non-Russian satellite named SPOT. GIS and

GPS technology begins to evolve to better interpret the Remote Sensing data. GIS or geographical information system was designed to integrate Remote Sensing, surveying, photogrammetry and various other technologies. GPS or global positioning systems were originally designed to enable location awareness for the military, but provides good information to be used in conglomeration with the other technologies as well. Drones and LiDAR are new technologies that are being integrated into Remote Sensing technology. The relatively low cost of a drone makes it easier for the general public to gather and interpret aerial photography.

Prior to the 1960's, the only platform used was the photograph which was simple and inexpensive, but was reliant on human interpretation. Since then many new technologies have emerged providing automated analysis. The technology will continue to evolve and become more important and invasive at the same time.

Recently, Facebook had a post about a dead body discovered in a field on Google Earth. This shows the capabilities that this emerging technology has and will continue to produce. Another example of the capabilities of this technology come from a British firm named SA Catapult. This firm provided information to police that helped in a murder case. In this instance, anomalies were searched for on the ground and a wide range of land could be investigated at an exponential rate. This satellite imagery was sensitive enough to pick up small animals under bushes.

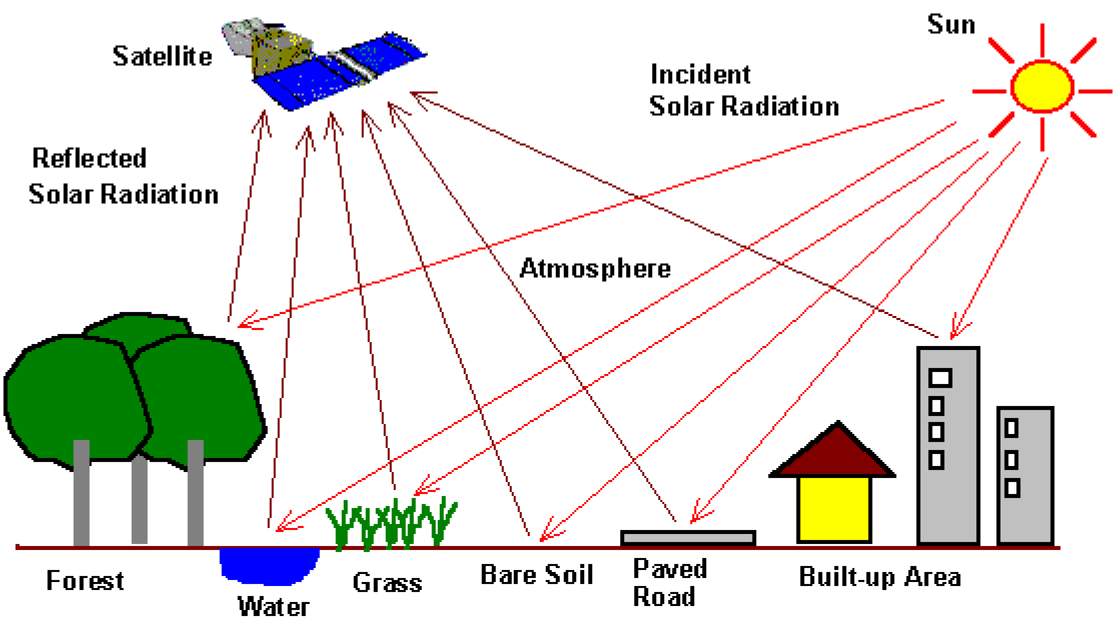
Many funny things can be seen on Google Street view in metro city areas. By taking a virtual ride through any downtown area one can see a number of interesting things. We are at the point where you can't do much without the possibility of being on camera, either from Remote Sensing satellites or through other means.

Principles of Remote Sensing

Remote Sensing data is collected through either a passive or active sensor. The passive sensor typically collects electromagnetic energy that's either emitted or reflected from the earth. Active sensors use a man-made signal and record the amount of light or flux that gets deflected back to the sensor. The sensor then produces a gray level or digital number for each ground resolution cell. The value of the digital number cell can range from zero to two hundred fifty-five.

Many variables interact within the IFOV or Instantaneous Field of View. These include wavelength, polarization of energy recorded by the sensor, radiometric resolution, angles between surface and sensor, time and the location and size of the pixel being mapped. Remote Sensing starts with an energy source and from there goes to atmospheric absorption, surface absorption, cloud absorption, atmospheric scattering or surface reflection. The portion that goes to surface absorption winds up as surface emission. The portion that is reflected and absorbed by the clouds gets bounced back into the atmosphere. Only the portions that are scattered through the atmosphere and reflected from the earth's surface reach the sensor.

Distinct types of surfaces reflect light at different rates which can help with land and object identification. Typically surfaces like concrete reflect at a much higher rate than surfaces like asphalt or dirt. “Reflectance is the process whereby radiation “bounces off” an object like the top of a cloud, a water body, or the terrestrial earth. Actually, the process is more complicated, involving reradiation of photons in unison by atoms or molecules in a layer approximately one-half wavelength deep. Reflection exhibits fundamental characteristics that are important in Remote Sensing.” (7) Reflectance percentage is typically measured in wavelengths. Through the reflectance percentage of electromagnetic energy within specific bandwidths, valuable spectral information can be acquired. Spectral response is used to identify single objects on a photograph or image.



Spectral resolution pertains to the value and size of the band of which the instrument is sensitive. Commercial cameras have bands 1 through 3 and range from 400-700 nanometers in bandwidth. Band 1 is blue in color and represents energy with wavelengths between 400-500 nanometers. Band 2 is green in color and represents the 500-600 nanometers part of the spectrum. Band 3 is red in color and ranges from 600-700 nanometers. Landsat 4 and 5 satellites could see 7 different bandwidths in comparison ranging from 450-2350 nanometers. The first three bands are near the same range as the commercial camera and the additional four bands range from Near to Mid Infrared.

Spatial resolution has to do with separation angles or distances between individual objects monitored through an Instantaneous Field of View. This is measured by multiplying the altitude of the sensor above ground by the angular field of view to obtain the diameter on the ground through which your image pixel size is calculated. Sampling theory states that your resolution should be smaller than half the smallest object dimension that you are trying to observe.

“The temporal resolution of a Remote Sensing system generally refers to how often the sensor records imagery of a particular area.” (7) Temporal resolution is calculated by the frequency a sensor picks up and records imagery within a given field of view. The resolution is measured in depth by the revisit time of the sensor. This creates a time-lapse effect where different photos of the same area can be viewed for changes being a major benefit of Remote Sensing data. Some of these sensors can be aimed at a specific location which cuts down the time between the images of the same objects.

Radiometric resolution has to do with the precision a signal can be detected and recorded by the sensor. This plays a significant role in the precision of the measurement calculated from the surface striking energy at each pixel location. Radiometric resolution is measured in bits in which a digital number is calculated for an individual pixel value.

Through this gathered data the image display system is generated and calculated based on the bandwidths and digital image number. Color images are then formed through a combination of three grey band levels of a multispectral image.

Landsat Applications

A variety of new applications arise with the introduction of satellite imagery from Landsat data. As the technology evolves so does the uses of it. Landsat has many different applications and continues to evolve. Many different fields have made great advancements through Remote Sensing and aerial photography.

This data is used in Agriculture, Forestry and Range Resources to identify vegetative crop and timber types and measure crop and timber area and acreage. Precision farming and land management is now a realistic capability. This technology is also used to monitor crop harvest, determine range and readiness of biomass and health and determine soil conditions.

Landsat is also used for land use mapping. Some applications are land classification and cartographic mapping and updating. It is also used to monitor urban growth, categorize land capability, regional planning and mapping transportation networks. Very accurate DTM’s or digital terrain models can be achieved through aerial photography and Remote Sensing data. This data can replace or be used in aggregate with traditionally gathered land surveying data.

Geologists are also using Landsat data to map major geological features. They can revise geologic maps based off the acquired data and map geologic landforms. Some other geologic uses are mapping volcanic surface deposits, classification of rock types and delineation of rock and soil formations.

Landsat data also plays an important role in the evolution of Hydrology which is the study of the earth's water in relation to the land. The data is used to determine water boundaries and surface areas and map floods and floodplain characteristics. This technology allows for better interpretation of determining extents of snow and ice coverage. Landsat data has been key in interpreting damage done by major hurricanes and tornadoes.

This data also can be used for Coastal Resource Management. It can help determine patterns and extent of turbidity and help with mapping changes in the shoreline. The data is valuable for mapping shoals, reefs and shallow water areas. It can also be used to map and monitor sea ice in freight shipping lanes, monitoring coral reef health and tracking beach flooding and erosion.

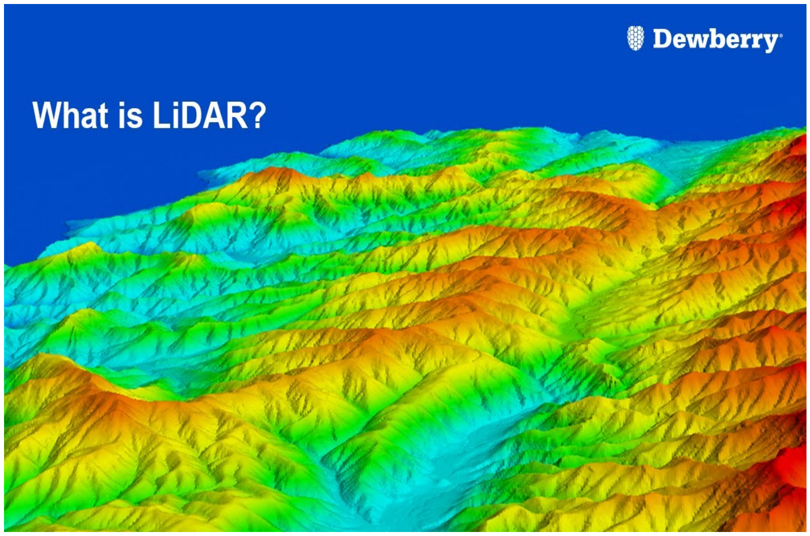
Landsat data is also a valuable tool for Environmental Monitoring because it can help monitor deforestation and volcanic flow activity. It can also be used to assess drought impact and determine the effects of natural disasters. Landsat data is also helpful in mapping and monitoring water pollution and tracking oil spills.

Landsat data is a tool that has played a major part in conservation efforts over the last 40 years. New and exciting ways to use the data continue to develop. As technology grows, so does the demand for high accuracy satellite data.

LiDAR History and Applications

LiDAR, or Light Detection and Ranging is an active form of Remote Sensing in which a transmitter sends out a signal that's reflected by a target and the signal is then sent back to the source. LiDAR systems are typically airborne, but some are space-borne. When accessing LiDAR data, three types of information are typically obtained. Range to target information is gathered through topographic LiDAR and laser altimetry. Chemical properties of a target are gathered through Differential Absorption LiDAR and Velocity of target is typically gathered through Doppler LiDAR.

LiDAR was first developed in the 1960's with the invention of the laser and it's first instruments came to fruition by the 1970's with lunar laser ranging and satellite laser ranging. During the 1980's, the first altimetry laser systems were developed. These systems were called the ATM or Airborne Topographic Mapper and the AOL (Atmospheric and Oceanographic LiDAR) developed by NASA. The first airborne commercial LiDAR system wasn't developed until 1995.



LiDAR differs from Radar primarily because it primarily uses optical signals which are near IR (infrared), while Radar uses microwave signals that have much longer wavelengths. The shorter wavelengths used by LiDAR allows for it to detect much smaller particles. One benefit of Radar is that it functions better than LiDAR with cloud coverage.

There are two typical operating principles for topographic LiDAR systems. The pulse system has a transmitted signal composed of a series of laser pulses. The CW or Continuous Wave system works by transmitting a sinusoidal signal with a known wavelength from which the range this calculated from a number of waveforms and the phase difference between the received and transmitted signal. The CW system is not a very common LiDAR technique.

“A LiDAR instrument principally consists of a laser, a scanner, and a GPS/INS system receiver. Airplanes and helicopters are the most commonly used platforms for acquiring LiDAR data over broad areas. Two types of LiDAR are topographic and bathymetric. Topographic LiDAR typically uses a near-infrared laser to map the land, while bathymetric lidar uses water-penetrating green light to also measure seafloor and riverbed elevations.” (4)

Optical Radiation Model

Two ways to model electromagnetic energy from passive remote sensing systems would be using the wave theory and the particle theory. The wave theory basically states that two vectors of electric and magnetic energy, being perpendicular to travel direction, are at right angles. The speed of light being equal to the product of the wavelength and frequency of electromagnetic radiation with the stipulation that the two are inversely proportionate.

The particle theory calculates the energy of a quantum (measured in joules) by taking the product of Planck’s constant (6.626 x 10^-34 J s) and the speed of light and dividing by the wavelength. The theory states that the interaction between electromagnetic energy and matter causes particles or photons with physical properties like momentum and energy. The wavelength being inversely proportionate to the energy. This theory states that more energy is carried in shorter wavelengths.

Electromagnetic radiation is affected by the earth's atmosphere and is susceptible to diversion from refraction. Refraction being the bending of transferred light through two or more bodies with different densities. The index of refraction is calculated as a ration between the speed of light in a substance versus the speed of light in a vacuum.

"Snell's law, in optics, a relationship between the path taken by a ray of light in crossing the boundary or surface of separation between two contacting substances and the refractive index of each. This law was discovered in 1621 by the Dutch astronomer and mathematician Willebrord Snell (also called Snellius). The account of Snell's law went unpublished until its mention by Christiaan Huygens in his treatise on light." (5)

Scattering is a little different than reflection because the pattern of the atmospheric particles is random and unpredictable. The three types of scattering include mie, molecular and non-selective. "Mie scattering is associated with dust or smoke molecules. Molecular or Rayleigh scattering is associated with gas molecules and Non-Selective scattering focuses on water vapor. Molecular scattering takes place between 2 and 8 kilometers above the ground and is responsible for sunrise, sunset and sky colors." (7)

Mie scattering typically exists in the lower 4.5 kilometers of the earth's atmosphere and is greatly made up of pollution containing smoke or dust. The higher density of smoke and dust causes scattering of the violet and blue light causing red and orange light to become more visible. The particle size being closely related to the wavelength of the energy in this lower part of the atmosphere.

Non-selective scattering takes part where the particles are less than ten times the wavelength at the lowest portion of the earth's atmosphere. All the light is scattered with ice crystals and water droplets making up clouds causing everything to appear white. Not much contrast exists between different objects making them difficult to distinguish borders.

The process where radiant energy is transformed into other forms of energy is called absorption. Some portions of the spectrum called atmospheric windows is transmitted effectively. Substances such as water, carbon dioxide and nitrous oxide absorb radiant energy in absorption bands.

Absorption and scattering combined can cause a reduction in radiation making it to the earth. Two passes through the atmosphere are typically required for the satellite sensor to gather the energy. Specular and diffuse reflectance requires an angle of incidence and an angle of exitance around an object where radiant energy bounces off a surface. The angle of exitance or angle of reflection is very close to the angle of incidence.

Various types of reflective surfaces are typical when dealing with Remote Sensing data acquisition. Specular reflection occurs when the surface is very smooth. Examples of this would be a calm lake or pond. Near perfect specular reflection occurs when only a few imperfections exist like a body of water that is relatively calm. Diffuse reflection happens when the radiant energy is deflected in many different directions because of a larger surface height with regard to the wavelength. Lambertian surfaces is much like a diffuse surface, but allows radiant energy to be deflected at a constant angle.

Radiant flux is measured in watts (W) and pertains to the rate of energy flow deflecting on, off or through a surface. This is a key component for Remote Sensing. Flux or radiant energy is conservative. It has to be transferred or transmitted through either reflection, absorption or transmittance. “The principle of conservation of energy states that energy cannot be created or destroyed, although it can be changed from one form to another. Thus, in any isolated or closed system, the sum of all forms of energy remains constant. The energy of the system may be interconverted among many different forms—mechanical, electrical, magnetic, thermal, chemical, nuclear, and so on—and as time progresses, it tends to become less and less available; but within the limits of small experimental uncertainty, no change in total amount of energy has been observed in any situation in which it has been possible to ensure that energy has not entered or left the system in the form of work or heat. For a system that is both gaining and losing energy in the form of work and heat, as is true of any machine in operation, the energy principle asserts that the net gain of energy is equal to the total change of the system's internal energy. There are many ways in which the principle of conservation of energy may be stated, depending on the intended application. Of particular interest is the special form of the principle known as the principle of conservation of mechanical energy which states that the mechanical energy of any system of bodies connected together in any way is conserved, provided that the system is free of all frictional forces, including internal friction that could arise during collisions of the bodies of the system. In view of the principle of equivalence of mass and energy in the restricted theory of relativity, the classical principle of conservation of energy must be regarded as a special case of the principle of conservation of mass-energy. However, this more general principle need be invoked only when dealing with certain nuclear phenomena or when speeds comparable with the speed of light (1.86 × 105 mi/s or 3 × 108 m/s) are involved.” (6)

Radiant flux density calculates the amount of energy that’s intercepted through the plane surface. Exitance is the radiant flux that actually leaves the surface with hopes of returning to the sensor. Radiance is the easiest and most precise measurement calculation when dealing with Remote Sensing.

Once the radiant flux is emitted or reflected, it interacts with particles, gases and water vapor and is subject to reflection, scattering, absorption or refraction before sensor interaction. Once at the sensor, the energy or flux has interactions before it can enter. Atmospheric corrections are often a necessity before using data. Models and algorithms are created to enhance the quality of the data that enters the sensor.

Resolution Concepts and Digital Image Formation

Three different types of scanning methods have been applied to create the images. The line scanner acquires data in-track and cross-track over the field of view while the push broom and whiskbroom scanners focus on a single direction. These sensors usually have components that degrade or lessen the quality of the signal of interest. These degradations can be accounted for by applying equations and algorithms to the interpreted results.

Sensor design is crucial for dealing with distortion of Remote Sensing data. A resolution is typically calculated based off how the data ends up at the sensor. No sensor is perfect because some type of signal distortion or variation is unavoidable. The spatial properties are modified by the sensor through distortion of the figures geometry and blurring due to the optic system built into the sensor.

The scene's image is never perfect or a complete representation of what's been measured in the field of view. Smaller more intricate figures are typically blurred more than larger more recognizable features. This is calculated through the Point Spread Function. The output of most sensors can be written as a function of the output signal. The Point Spread Function is basically the spatial responsivity of the Remote Sensing sensor treated as a function for spatial convolution. The physical signal is measured and integrated over the response function range to calculate an output value. The limit of the function is known as the spatial extent.

The Point Spread Function is made up of several different components such as electronics, detector, image motion and optics. The parameters are typically found in reports generated through the contractor. This function is only able to be measured once the sensor is built and its capabilities are known. The optical Point Spread Function has to do with the flux distribution of the image and can be calculated through a Gaussian function. The detector Point Spread Function figures the blurring caused by the sensor detector in the measurable non-zero spatial set. This function being separable and uniform.

The Image Motion Point Spread Function needs to be taken into account when image movement caused by the detector causes blurring of pixels. This does not affect the line scanner because it can only be measured in one direction. The whiskbroom scanner smear can be calculated by multiplying the velocity of the scan by the integration time. The push broom scanner smear is measured by multiplying the velocity of the platform by the time of integration.

The whiskbroom scanner uses the product of the scan velocity and sample time to calculate. The push broom scanner takes the product of the platform velocity and the sample time to calculate. The Electronic Point Spread Function has to do with filtering the signal acquired from the detectors in order to reduce noise.

All of these scanning systems show a typical response that is broader than the individual detector. The extraction of images weighs heavily on these comparisons. The field of view is typically larger than the quoted field of view because of a blurring effect. Ground projected sample interval or GSI relates to the distance between two samples that are adjacent to one another. This is determined by both cross-track and in-track sampling compared to the in-track platform velocity and is based off space of the interdetector. The Ground Instantaneous Field of View or GIFOV is a projection of a detector's length and width on the ground.

The Optical Point Spread Function is typically calculated under controlled conditions using a special target where the image scanned is used to produce a two-dimensional line spread function or one-dimensional edge spread function. The line or edge being the part measured using the Point Spread Function. Pixel sampling is also a key component when dealing with the Point Spread Function as a whole.

The energy measured per band is a function that takes into account the radiance of the image over the individual band. The product of the net radiance that reaches the sensor and the individual wavelength response will provide you with the weighted spectral distribution from which the total effective radiance can be calculated. The individual band placement is as crucial as the individual bandwidth to maximize the efficiency of a Remote Sensing sensor to identify spectral objects. Hyperspectral sensors have a huge selection of bands that can be placed contiguously over a vast spectral range.

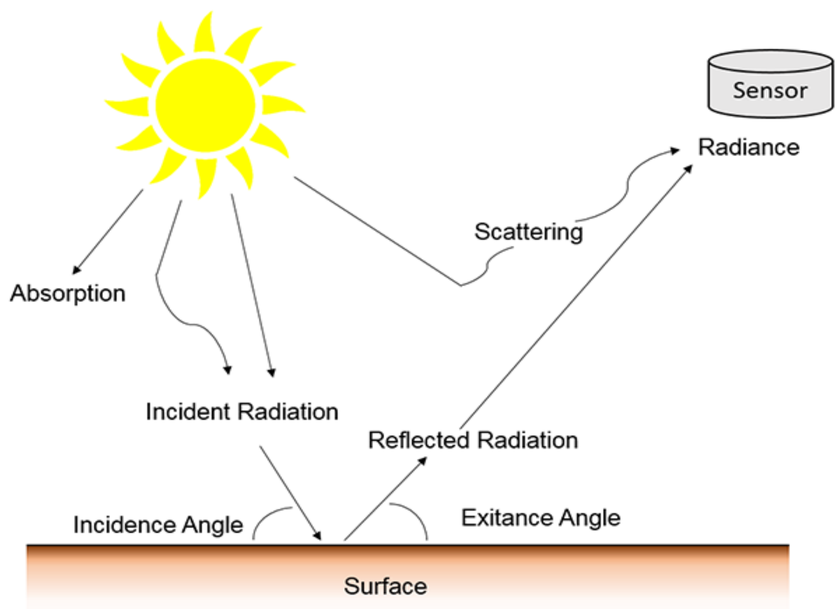
Signal level is necessary for quantization so amplifications to a signal are often applied at the design stage for the sensor. This calculation is an estimation of the maximum radiance range within a scene and the output range of the corresponding detector. A digital number range is yielded through gain and offset values applied to the electronics. Amplified signal is a function of the gains and offsets. A linear quantizer uses both the filtered and amplified signal to generate the digital number of the individual pixel. The radiometric resolution of the Remote Sensing system is determined by the bits per pixel value.

The sensors spectral response is quantitated as a constant value over an effective band. The spatial response being a constant over a ground instantaneous field of view. This spatial response relates the at sensor radiance value to the images direct number and integrates it above the ground instantaneous view and the spectral band. Sensor calibration is basically an inversion of this equation to obtain band radiance values from the direct numbers. A scene calibration or calibration to reflectance is achieved through the conversion of radiance value to reflectance value. These calibrations can be hard because you must have a basic knowledge and understanding about certain atmospheric conditions and surface terrain.

Radiometric Corrections

The majority of errors occurring in Remote Sensing data come during the image pre-processing steps. The two most common being radiometric and geometric errors. "Radiometric correction is done to reduce or correct errors in the digital numbers of images. The process improves the interpretability and quality of remote sensed data. Radiometric calibration and correction are particularly important when comparing data sets over multiple time periods. The energy that sensors onboard aircrafts or satellites record can differ from the actual energy emitted or reflected from a surface on the ground. This is due to the sun's azimuth and elevation and atmospheric conditions that can influence the observed energy. Therefore, in order to obtain the real ground irradiance or reflectance, radiometric errors must be corrected for." (19) The geometric correction is more concerned with putting the measurements in their proper location, so they can be related to other forms of spatial information.

Two major error types that a radiometric correction is applied to are internal and external. The internal being introduced from within or inside the system. Typically, these are generally predictable errors which are fixed with calibrations done before the system is launched. External errors are more variable errors that tend to occur naturally over space and time.



Radiometric errors within the Remote Sensing system includes shot noise, line and/or column drop-outs, start and stop line problems, partial drop-outs and column or line striping. Noise is a problem that can affect the data-collection system at many stages. Bad pixels occur when an individual detector fails to record spectral data for that individual pixel. Shot noise occurs when random bad pixels are found within an individual scene. To correct for shot noise, each individual bad pixel must be identified and repaired. Once the bad pixel is identified, an evaluation of the surrounding pixels takes place. The average of the surrounding pixels is then calculated and applied to the flagged pixel.

When an entire line doesn't contain spectral information, you have a line drop-out. This line has value of zero for brightness. This type of error occurs when an individual detector fails to properly function. A column drop-out occurs when a detector fails to function in a linear array. Line-start problems occur when the system fails to collect data at the start or beginning of a scan line. Line striping occurs when a detector goes out of radiometric adjustment. This is not a complete failure from the detector. This line still contains valuable information, but it's necessary to correct the radiometric scale of the collected data.

At times, it's important that Remote Sensing data be atmospherically corrected. Slight differences in reflection among the crucial constituents can be lost if the data is not corrected or not corrected properly. These corrections are made through algorithms. There are many ways to atmospherically correct Remote Sensing data, some being complex and others straight forward. Atmospheric models are sometimes applied to correct the Remote Sensing data. The use of these models along with in situ atmospheric measurements can greatly increase the quality of the data collected by the sensor. Multiple views of the same object from different vantage points can minimize your atmospheric attenuation. "Atmospheric attenuation is the sum of the energy lost through the interaction of the solar radiation and the earth's atmosphere scattering and absorbing portion of the radiation." (7) Atmospheric radiative transfer models are able to provide estimates of the effects of absorption and atmospheric scattering on the satellite imagery.

The radiance recorded by the detector or camera ideally should be a function of the total amount of radiance exiting the target terrain within the IFOV with respect to a specific solid angle. Different radiant energy could enter the field of view through many other paths and introduce noise throughout the Remote Sensing process. Additional variable definitions are necessary to properly identify the paths and major sources of this energy.

The analyst is required to understand the absorption and scattering taking place and how these affect the radiant energy transmittance through various paths of irradiance. The manual absolute atmospheric correction is possible, but it is a very labor intensive mathematical process that requires a lot of steps. This can be done for each individual band within the data.

Atmospheric corrections can also be based on radiative transfer models. Fundamental atmospheric characteristic information such as radiance data, individual band information, atmospheric visibility, model information, altitude of image acquisition, date and time of collection, average elevation and latitude and longitude of the scene. The parameters are then put into a selected atmospheric model and used to calculate absorption and scattering characteristics. These characteristics are then applied to invert the radiance to scaled surface reflection. Based off these radiative transfer principles, a number of atmospheric correction algorithms are developed.

Polishing constitutes an adjustment to the reflectance data. This allows the spectra to more closely resemble the spectra of actual materials as they are recorded on the ground. Radiative transfer-based atmospheric correction algorithms are also used to suppress artifacts among the corrected data. In situ Spectro radiometer measurements are incorporated through the radiative transfer atmospheric correction programs. Through this, the analyst can provide an accurate in situ spectral reflectance curve for a known region and provide coordinates of the location of the known area.

Another method that can be used for absolute atmospheric correction is the empirical line calibration. The method forces the image data to match the in situ spectral reflection measurements which were hopefully collected at approximately the same date and time of the overflight. The majority of multispectral datasets are able to be calibrated using this method.

Relative radiometric correction techniques have been developed because of the lack of accurate surface reflectance data. This can be applied to normalize the intensities of different bands within a single date image. It can also normalize the band intensities in multiple dates of imagery to a single standard scene. Another correction technique involves using a histogram for single image normalization. This technique is a simple one based on the fact that infrared data are mostly free of scattering effects. Various histograms of different bands are evaluated.

Multiple date image normalization starts with selecting a base image and then transforming other images spectral characteristics to be close to the same radiometric scale as the base image. This method also involves selecting radiometric ground control points know as Pseudo Invariant Features. These features should be in a relatively flat area, contain only a small amount of vegetation, consistent over time and be close to the same elevation as the neighboring land features included in the scene. It is extremely important that the quality of the PIF's is high in order to apply this image regression method.

Regression is applied to relate the PIF's spectral characteristics within the base image with the PIF spectral characteristics at other dates. Different sun angels, atmospheric and soil moisture conditions can become a problem associated with historical data. The accuracy is contingent on a robust connection between the actual surface conditions and the brightness value. Normalization could allow the pixel classification logic from a base year to be applied to the other normalized scenes.

The recorded signal may be subject to radiometric distortion because of topographic slope. Slope aspect correction is applied to remove topographically induced illumination variation so that the objects will have the same brightness value in the image despite different orientation with regard to the position of the sun. This correction is based off illumination. A digital elevation model of the scene is necessary to apply the slope aspect topographic correction. The gathered information is then modeled to enhance or subdue the brightness values of the data.

The cosine correction is a function that is associated with the amount of irradiance that reaches a pixel on a proportional slope to the cosine of the incident's angel. This correction assumes that there is a steady distance between the earth and the sun, a stable amount of solar energy and the surface is Lambertian. This correction forgets to take into account light reflected from the general proximity of the mountainside or diffuse skylight which could illuminate the pixel. In 1982, the Minnaert constant was introduced to this function.

Image Data Models

Image data models are used to provide a connection between the design of an image processing algorithm and the physics of Remote Sensing. These models are designed to relate to physical process models. Each individual model contains metadata information and are not image only. This metadata can be in binary or asci formats. Binary data typically precedes the digital number of the actual pixel value. The processing software must be capable of reading this data and have knowledge of the format. The three primary organization methods used to arrange individual pixel values (digital numbers) are Band Sequential (BSQ), Band Interleaved by Pixel (BIP) and Band Interleaved by Line (BIL).

Band sequential (BSQ) is one of three primary methods for encoding image data for multiband raster images that are in the geospatial domain (example: images obtained from satellites). BSQ is not an image format, but rather, it is a method for encoding the actual pixel values of an image in a file to make available for further use. “The format of BSQ is a very simple one - where each line of the data produced is followed immediately by the next line in the same spectral band. This format is optimal for spatial (x, y) access of any part of a single spectral band. The BSQ data organization can handle any number of bands, and thus accommodates black and white, grayscale, pseudo color, true color, and multi-spectral image data.” (19)

Band interleaved by pixel (BIP) is another one of three primary methods for encoding image data for multiband raster images in the geospatial domain. Like BSQ, BIP also a method for encoding the actual pixel values of an image in a file and not an image format. The difference is that images stored in BIP format have the first pixel for all bands in sequential order, they are then followed by the second pixel for all bands, and eventually followed by the third pixel for all bands, and continue in this fashion. interleaved up to the number of pixels. The BIP data organization can handle any number of bands. In doing so, BIP accommodates black and white, grayscale, pseudo color, true color, as well as multi-spectral image data. (20)

Band interleaved by line (BIL) is the last of the three primary methods for encoding image data for multiband raster images in the geospatial domain. As in the case of BSQ and BIP, BIL is a scheme for storing the pixel values of an image and not a format. For example, given a three-band image, all three bands of data are written for row one, all three bands of data are written for row two, and so on. The BIL encoding is a compromise format, allowing fairly easy access to both spatial and spectral information. (21)

When the Data Models are in accordance with the necessary methods required to manage the pixel values, remote sensing can manage the design of an image processing algorithm and the physics of Remote Sensing. This allows for retrieval of contained data and for further usage and information extraction.

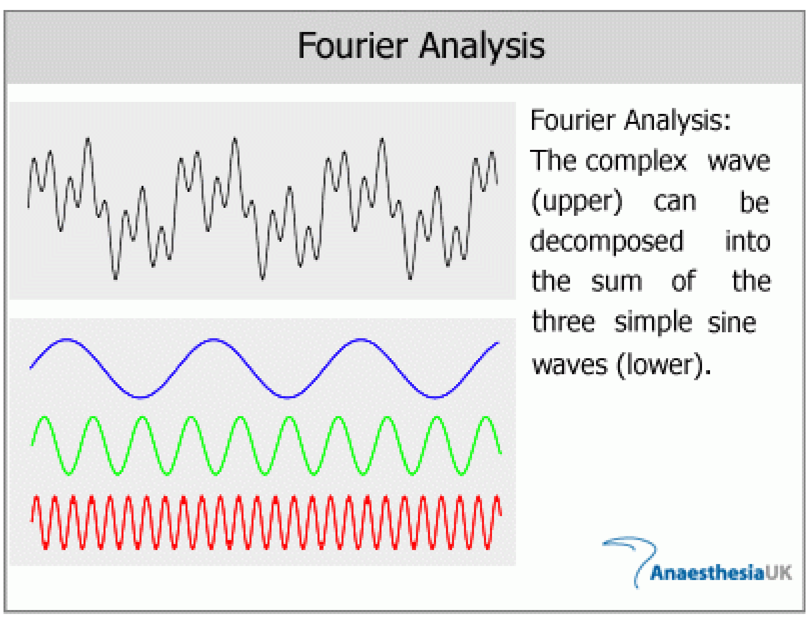
Univariate statistics apply to a single band image. Multivariate statistics apply to multispectral images. In this case, the digital numbers of a pixel become measurement vector.

Noise models are designed to interpolate the variation in the sensor output. A simple global noise model takes into account a single independent component for each individual pixel. The most likely occurrence related to scanning is known as periodic noise. Signal to noise ratio or (SNR) is a calculation in which the signal is divided by noise. A signal is noiseless and can refer to at sensor radiance or reflectance.

"The image is presented at two levels - logical and physical. The logical level contains the global description and content-based sublevels. The global description level consists of the meta and the semantic attributes of the image. The content-based layout contains the object features connected with color, texture, shape, and spatial object characteristics. The physical level contains the image header and the image matrix." (8)

Image Transformations

Image transformations are typically used to improve the image for human or machine analysis. Spatial transforms are used to extract or change spatial information within a Remote Sensing image. Local transformations refer to small pixel neighborhoods while global spatial content takes into account the entire image. "Spatial frequency in remotely sensed imagery may be enhanced or subdued using two different approaches. The first is spatial convolution filtering based primarily on the use of convolution masks. The procedure is relatively easy to understand and can be used to enhance low and high frequency detail, as well as edges in the imagery. Another technique is Fourier analysis, which mathematically separates an image into its spatial frequency components." (7) The convolution method applies to the local transform while the Fourier method applies to the global spatial content. All the scales in between local and global are known as scale space filters.



Any individual image can be described as the sum of two images. The Low-Pass contains the large area of variations and the High-Pass contains the small area. The Low-Pass filter is designed to preserve slowly varying spatial details and the High-Pass filter is used to filter the low frequencies and let the higher frequencies Pass through. The High-Boost filter is used to enhance the overall detail of the image. Band-Pass filters are used to filter out frequency within a certain range and can be constructed as a sequence of Low-Pass Filters and High-Pass Filters.

When dealing with border regions, issues can arise while using the moving window approach. These issues are due to the convolution filters not having neighbors to the pixel's edge. One resolution to this issue is to just simply ignore the border pixels by setting the digital number to zero. Also, one can reflect the input pixels to the outer border to rectify any dilemmas that arise. The final solution in avoiding this issue is to place the digital number to the digital number mean of the given image. Any of these practices will ensure that the border regions maintain their integrity, keeping the edge effect cleanly intact.

A common filter that can be used is the Box Filter. "Box filtering is basically an average-of-surrounding-pixel kind of image filtering. It is actually a convolution filter which is a commonly used mathematical operation for image filtering. In convolution filtering, *image sample* and the *filter kernel* are multiplied to get the *filtering result*. The filter kernel is like a description of how the filtering is going to happen, it actually defines the type of filtering. The power of filtering is one can write a general image filter that can do sharpen, emboss, edge-detect, smooth, motion-blur, etcetera. Provided appropriate filter kernel is used." (9) A visual example of a filter kernel would be to consider a window larger than the size of a pixel, then imagine this window sliding over a given sample image constantly calculating the average of what it is viewing.

A sequence of linear filters can be added to a given image by cascading a net filter. This single net filter must be equivalent to the convolution of the filter. This then allows the single equivalent net filter to be used once, rather than having to use multiple filters on the given image. It is important to keep in mind that the filter size is usually much smaller than the size of the image.

Another type of filter that can be used is Statistical Filters. These particular filters are similar to convolution filters, in that, they can also use the moving window approach. However, the output is a common statistical amount. These can be described as minimum, median, and maximum, along with standard deviation and variance. Also, Morphological filters can be applied for use. "Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image, such as boundaries, skeletons, etc. In any given technique, we probe an image with a small shape or template called a structuring element, which defines the region of interest or neighborhood around a pixel." (10) This process of filtering can be described as dilation and erosion, as well as, opening and closing.

"Spectral transformations alter the spectral space and spatial transformations alter the image space. Many of these transformed spaces are useful for thematic classification and are collectively called feature spac*es* in that context. A variety of spectral transformations are examined, ranging from nonlinear spectral band ratios to linear transformations of various types. Some are designed to improve quantitative analysis of remote-sensing images, while others simply enhance subtle information so that it is visible." (11) Spectral transformations are used to improve images for both human and machine analysis.

"A very useful image processing technique is band ratioing. For each pixel, we divide the DN value of any one band by the value of another band. This quotient yields a new set of numbers that may range from zero (0/1) to 255 (255/1) but the majority are fractional (decimal) values between 0 and typically 2 - 3 (e.g., 82/51 = 1.6078; 114/177 = 0.6440)." (12) Band ratioing is typically computed in matrix form to find the output ratio value for a pixel.

Vegetation characteristics and transformations are also two important factors in considering image enhancement. These characteristics can be broken down into three categories: reflection, absorption, and transmission. Reflection can be described as simply as the light reflecting off of an object to reveal its color. An example of this is viewed when we look at plants. The chlorophyll produced within plants reflects green light, thus making plants green in color to the human eye. Absorption transformed to another form. For instance, we see this in plants through the process of photosynthesis. Transmission is revealed when the energy uses a medium and is neither reflected nor absorbed. There are a few dominating factors controlling the act of leaf reflectance. Water content within the leaf and the chlorophyll pigment amounts are a few of these controlling factors.

A common practice of analysis used to simplify noted uncorrelated variables is Principal Component Analysis. "Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components (or sometimes, principal modes of variation). The number of principal components is less than or equal to the smaller of the number of original variables or the number of observations. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables." (12) The four steps in this analysis process are as follows: first start with the original data, then the mean must be subtracted, next the covariance matrix must be calculated, then lastly one must determine the eigenvectors and eigenvalues for the covariance matrix. "PCA is mostly used as a tool in exploratory data analysis and for making predictive models. It's often used to visualize genetic distance and relatedness between populations. PCA can be done by eigenvalue decomposition of a data covariance (or correlation) matrix or singular value decomposition of a data matrix, usually after mean centering (and normalizing or using Z-scores) the data matrix for each attribute. The results of a PCA are usually discussed in terms of component scores, sometimes called factor scores (the transformed variable values corresponding to a particular data point), and loadings (the weight by which each standardized original variable should be multiplied to get the component score). PCA is the simplest of the true eigenvector-based multivariate analyses. Often, its operation can be thought of as of this object when viewed from its most informative viewpoint. This is done by using only the first few principal components so that the dimensionality of the transformed data is reduced, revealing the internal structure of the data in a way that best explains the variance in the data. If a multivariate dataset is visualized as a set of coordinates in a high-dimensional data space (1 axis per variable), PCA can supply the user with a lower-dimensional picture, a projection of this object when viewed from its most informative viewpoint. This is done by using only the first few principal components so that the dimensionality of the transformed data is reduced." (12)

Texture transformations another important image analysis technique to consider. It is key to note the first law of geography as stated by Waldo Tobler, "everything is related to everything else, but near things are more related than distant things." Points within a close proximity of one another vary less than points that are farther apart. "Spatial autocorrelation is the correlation among values of a single variable across a two-dimensional surface that are locationally referenced or tied together by an underlying spatial structure, introducing a violation of the independent observations assumption of classical statistics. Its many interpretations include a nuisance parameter, self-correlation, map pattern, a diagnostic tool, a missing variable surrogate, redundant information, a spatial process mechanism, a spatial spillover, and the outcome of areal unit demarcation." (14)

Discrete Tonal Feature refers to the connected set of resolution cells on a digital image that have approximately the same image intensity. Texture is the dominate property of a region having a large variety of discrete tonal features. The Co-occurrence matrix or CM is a two-dimensional matrix. This matrix used to calculate probabilities between pixel pairs separated to a distance and direction. Two common problems with the Co-occurrence matrix is that it requires a great deal of computation and that features are not always consistent with regard to the scale or rotation change in the texture.

Geometric Corrections

The two types of Geometric Errors are internal and external. "Any remote sensing image, regardless of whether it is acquired by a multispectral scanner on board a satellite, a photographic system in an aircraft, or any other platform/sensor combination, will have various geometric distortions. This problem is inherent in remote sensing, as we attempt to accurately represent the three-dimensional surface of the Earth as a two-dimensional image. All remote sensing images are subject to some form of geometric distortions, depending on the manner in which the data are acquired." (15) There can be many factors that attribute to these errors. The movement of the scanning system and the possible instability of the platform can affect the outcome and create errors. Also, the rotation of the earth, as well as, the Earth's curvature can cause spatial distortion. In order to collect accurate measurements, one must account for these errors and correct the given imagery.

Remote Sensing images are often skewed by the rotation of the Earth. The Earth rotates around its axis on an equatorial plane. Earth observing sun synchronous satellites are on predetermined orbits and they are designed to collect imagery from north to south or south to north. “Some Earth observation satellites are equipped with instruments able to analyze all possible colors on the surface of the Earth. In order to show how such instruments operate, we may compare them to our own sense organs, for instance, sight and hearing. By means of these senses we are also equipped for observing at a distance.” (16) These satellites are the primary tool used to collect Remote Sensing data. Deskewing refers to a systematic displacement of pixels (westward) in an image frame. It is a method designed to correct for interaction of the velocity of the earth’s surface and the angular velocity of a satellite sensor system. The earth’s surface velocity being a function of the earth’s rotational velocity, the radius of the earth and a specific latitudinal value. “This adjustment places all of the pixels in the scan in their proper positions relative to adjacent scans. Null values are added to the data set to maintain the integrity of the raster format. The amount of shift or displacement to the West is a function of the relative velocities of both the satellite and the Earth in the length of the image frame that is recorded.” (7)

It is important to note a few types of scanning systems that promote change in surface resolution cell size. “Fortunately, an orbital multispectral scanning system scans through just a few degrees off-nadir as it collects data hundreds of kilometers above the Earth’s surface. This configuration minimizes the amount of distortion introduced by the scanning system.” (7) In contrast, sub-orbital scanning can function only tens of kilometers above the Earth’s surface. This can produce several acts of geometric distortion that is very hard to correct.

The ground swath width or (gsw) is defined as the total length of the terrain strip that is sensed during a single across-track sweep with the scanning mirror. “Most scientists using across-track scanner data use only approximately the central seventy percent of the swath width (thirty-five percent on each side of nadir) primarily because ground resolution elements have larger cell sizes the farther they are away from nadir.” (7)

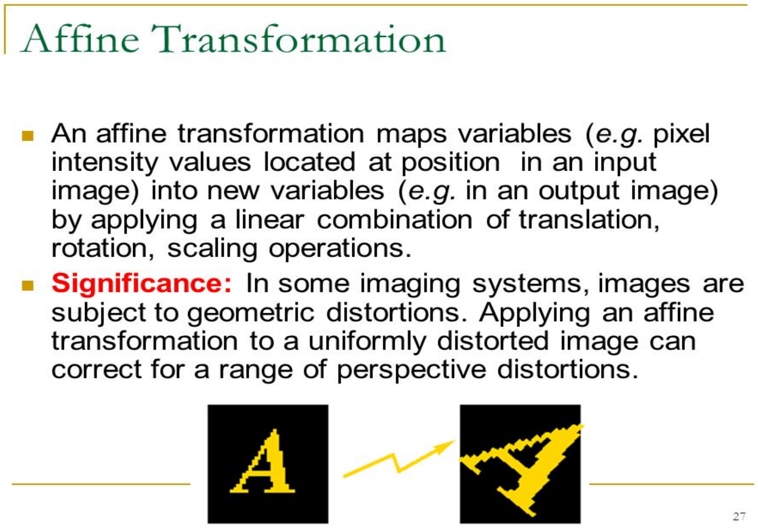
Some of the external geometric errors that can occur are a result of natural phenomenon through time and space. The important variables to consider that cause these errors in remote sensor data are sporadic unplanned movements by the aircraft at the same moment of data collection. This occurrence will typically involve changes in altitude and/or changes in attitude such as: roll, pitch, and yaw. “A remote sensing system is ideally flown at a constant altitude above ground level (AGL) resulting in imagery with a uniform scale all along the flatline.” (7) Even if the sensing platform stays at a constant altitude, it can at times rotate about three different axes that are known as roll, pitch and yaw. “High quality satellite and aircraft remote sensing systems often have gyro-stabilization equipment that, in effect, isolates the sensor system from the roll and pitch movements of the aircraft. Remote sensing systems without stabilization equipment introduce some geometric error into the remote sensing data set through variations in roll, pitch, and yaw that can only be corrected using ground control points.” (7)

Ground Control Points are fixed locations on the Earth's surface that are identifiable on the aerial image and can be accurately located on a map. "The image analyst must be able to obtain two distinct sets of coordinates associated with each GCP: image coordinates specified in *i* rows and *j* columns, and map coordinates (e.g., x, y measured in degrees of latitude and longitude, feet in a state plane coordinate system, or meters in a Universal Transverse Mercator projection)." (7) Ground Control Points should have the following qualities: High color contrast in each image, small feature size, fixed over time and be closed to the same elevation of the nearby ground.

Image to map rectification in remote sensing, is a process where the geometry of a given image is made planimetric. This process of map rectification typically includes selecting ground control points pixel coordinates and their map coordinates that correspond. "GPS collection of map coordinate information to be used for image rectification is especially effective in poorly mapped regions of the world or where rapid change has made existing maps obsolete." (7)

Geometric image rectification creates an image from either a single or a set of perspective projections to orthographic rectification. The characteristics for perspective projection are as follows: they are in variant scale, the angels are not kept, distances are not constant, and tall objects tend to lean. Conversely, orthographic projection is on a constant scale, angels and distances are kept, and tall objects do not lean.

"Affine transformation is a linear mapping method that preserves points, straight lines, and planes. Sets of parallel lines remain parallel after an affine transformation.
The affine transformation technique is typically used to correct for geometric distortions or deformations that occur with non-ideal camera angles. For example, satellite imagery uses affine transformations to correct for wide angle lens distortion, panorama stitching, and image registration. Transforming and fusing the images to a large, flat coordinate system is desirable to eliminate distortion. This enables easier interactions and calculations that don't require accounting for image distortion." (17) Six distortions can arise from this type of translation including translation in x and y, scale differences in x and y, skew, and rotation.



It is very important that Ground Control Points are uniformly dispersed throughout your mapping area. The smallest number of points needed for each order of polynomial (t) used in the transformation can be solved with the formula ((t+1) ((t+2)) / 2. It also should be noted that you should always use greater than the minimum to achieve the best rectification. When Ground Control Points are tightly bunched together, you will have map distortions within the area that is lacking control. In order to calculate errors within the transformation model, the Root Mean Squared (RMS) error is calculated at each individual ground control point.

The Geometric rectification is achieved through pixel identification within the image with corresponding known coordinate values. Forward mapping uses straight forward logic and closed form equations, while Inverse mapping is a process that requires an equation inversion. Inverse mapping logic to collect, but it is a more difficult process than Forward mapping. For remote sensing, it is better to use Inverse mapping.

“If we take pictures of a planar scene, such as a large wall, or a remote scene (scene at infinity), or if we shoot pictures with the camera rotating around its center of projection, we can stitch the pictures together to form a single big picture of the scene. This is called *image mosaicking*.” (18) Mosaicking a rectified image requires six (6) steps: each image should be rectified in accordance to the same map datum and projection, some sort of image overlap must exist, matching overlap areas, a matching system from the base image and feathering which promotes pixel overlap.

<u>Field Uses for Remote Sensing and Aerial Photography</u>

A lot of Government Agencies are now providing a huge amount of geospatial data free to the public. Google Earth which was acquired in 2001 from Keyhole Inc., has basically evolved the way we survey. Being able to view an aerial of the survey area is one of the most essential tools for project planning and bidding. Most of the guesswork on what to expect in the field is basically taken out of the equation. It's now much easier for survey companies to turn a profit with the aid of Remotely Sensed aerial photography.

These tools derived from Remote Sensing and Aerial Mapping are changing the way we look at common maps and evolving our perspective of the world. This is just the beginning of three-dimensional mapping and it continues to evolve day by day. Just the changing from Landsat 7 imagery to Landsat 8 has been monumental in the level of mapping precision that can be acquired from this satellite based imagery.

Having geo-rectified images to use is an awesome tool for planning field and office surveying methods. Almost all companies are now using these correctly placed images behind their CAD drawings and using them as a basis for checking and reference. One thing surveyors must be cautious with is solely relying on these images instead of measuring the site. This causes serious issues and is an ethical violation in most cases. Sometimes these images can be out of date which can cause issues with site changes and new construction.

Aerial images often have embedded coordinates or can be fit to GCP's or ground control points which were surveyed using traditional methods and matched in the aerial photograph. These points are then typically best fit using a least squares method and a RMSE (root mean squared error) is produced to see the overall accuracy and how well the data fits.

Fitting these images often takes time and patience. The process would be picking a point on the photograph and a point in the topographically shot data and holding that as your origin or common point. Then you would find another reference point that was easily recognizable in the photo and rotate the photo to the second point. It is important to try and rotate the image before prior to creating a unique scale factor for the Remotely Sensed aerial image.

Scaling an image is basically shrinking it or making it larger to fit a topographic area. This can be done in many ways but the best way to do it is too pick points that are on opposite ends of the photograph and topographic area. This allows for more accurate scaling and produces better results in most cases. Scaling must be done when your data is in two different reference systems. An example of this would be state plane coordinates and ground coordinates. Ground differs from State Plane based off of the elevation of the site. You will have the greatest difference in areas with heights well above sea level.

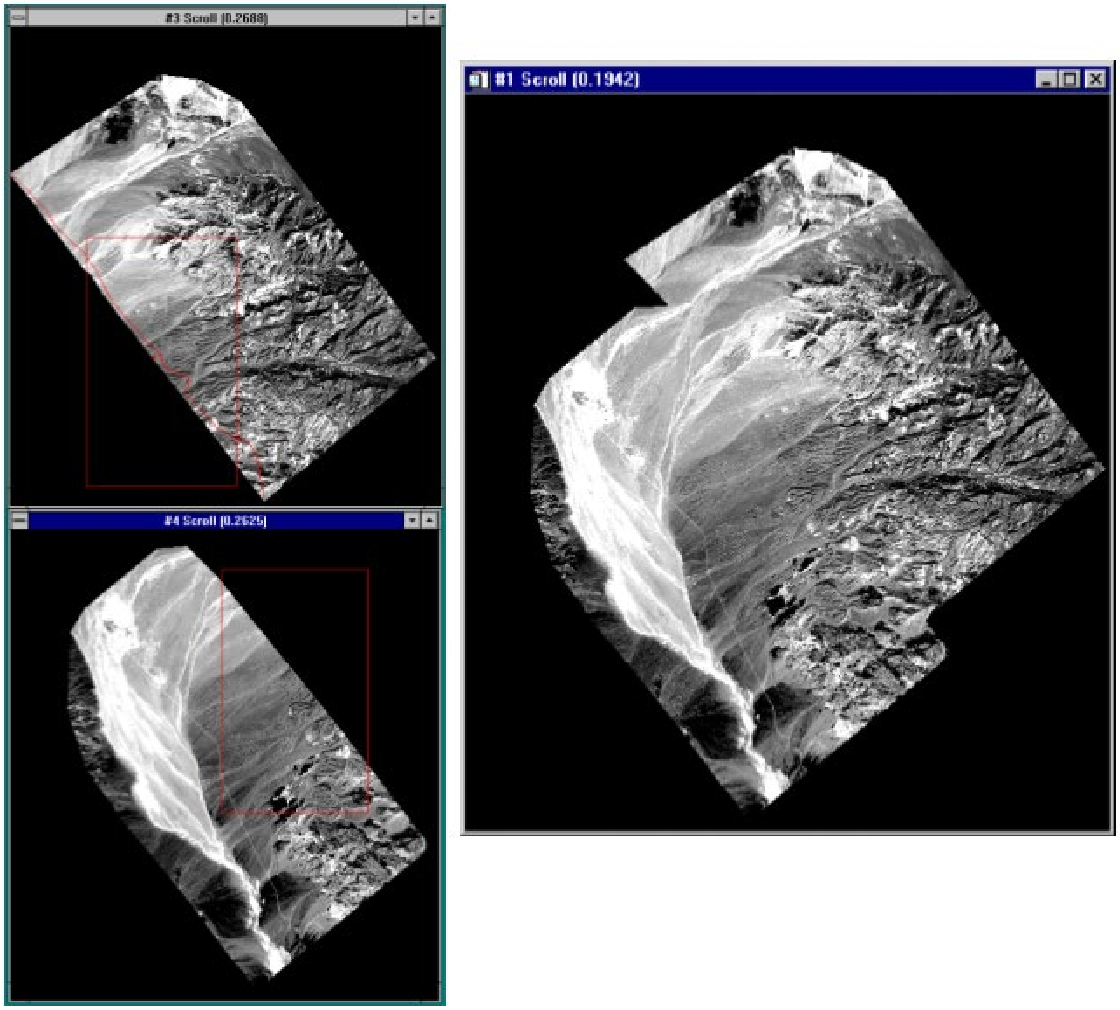
Google Earth's platform is basically a digitally referenced globe that provides a great deal of spatially referenced data. From this program, such things as latitude and longitude, terrain height and topography are readily available. Prior to the launch of Landsat 8, Google Earth's primary source of aerial photography was Landsat 7 imagery. This source of imagery was not fully reliable and would leave large gaps in between frames. In 2008, the company made Street View which is an excellent tool for Surveying. Current Street View maps are extremely convenient to provide to the field crews in the field packet, so they are aware of what has to be located at each survey area. This advancement in technology has been a great aid to field staff, as well as, office staff that can use Street View to basically drive the corridor and check to see if the images match what was located. Street View is not available everywhere in the United States, but one would think it's going to be in the very near future.

Google Earth typically displays it's coordinates in latitude and longitude which makes it easy to convert to other coordinate systems using a supplemental software. Some counties throughout the United States will provide you with GIS overlays for Google Earth. These files include a variety of useful tools for surveying and mapping.

This Street View mapping is being acquired using mobile mappers. This technology has been around since 2007 and continues to grow. Basically, when using the program, you look for the streets that have a thick blue line and you can drop your figure on the line and scroll up and down the street and get perspective of what's out there. This Street View is often updated at separate times than the traditional aerial view, so you have a distinct perspective of what's out there. Sometimes the Street View is newer than the aerial satellite imagery, but then again sometimes it's the other way around with the satellite imagery being more current than the Street View. It is good to check the date on the imagery you are using as sort of a quality control method to determine which dataset is more useable than the other.

One of the most accessible Remote Sensing software packages is called Erdas Imagine. This software has become the most widely used Remote Sensing software worldwide. This product is made available through Hexagon Geospatial. It is common for most students and new users to begin on this program. Another software common to Remote Sensing is ENVI embedded with IDL, which is its programming language.

This ENVI software allows the user to adjust bandwidths and colors for various images and manipulate images with a few different transforms. Through this software and the tutorials, users are able to learn a variety of ways to deal with image distortion and rectify images. This product also has a unique tool where different images of the same location can be linked and manipulated at the same time. ENVI is not the most user friendly software, but it has a great deal of benefits and capabilities.



Above is an example of mosaicking in ENVI software. You can see the different scroll values on each of the image windows. These images can be linked to other images through geo-referencing. Most of the images we worked with were derived from satellites.

The most common way to collect aerial data now is drone or UAV mapping. These Unmanned Aerial Vehicles are very small and accessible to a significant percentage of the population. These drones can be purchased for a little over a hundred dollars, so it's becoming affordable to all. They are being equipped now with LiDAR technology to produce Remotely Sensed data. Georgia Tech University was one of the first places that started experimenting with attaching LiDAR to drones. They experimented using this technology around a pool and achieved excellent results. With the addition of the LiDAR on drones, Remote Sensing with UAV's will become an everyday tool used in a variety of ways.

NASA is planning on launching it's James Webb telescope in 2019 as part of it's Next Generation Space Telescope Program. This telescope is designed to produce never before seen high-resolution images from space. With this technology, we will be able to see further into the galaxies then we ever imagined and acquire data that was once though as impossible to gather. This will be used in conjunction with the Hubble telescope which has been relied on for many years to produce high quality space-borne images.

This will differ from the Hubble because of it's distinct abilities to see red-shift objects. It was named after James Webb who was NASA's second administrator who played a major roll in the Apollo program. NASA's plan was to try and extend the life of the Hubble until the Webb telescope was fully online and functional.

One of the coolest thing Remote Sensing data has done so far is help archaeologists locate old tombs and ruins. They basically used the satellite imagery to locate underground formations and find the sites. These tombs and ruins were in Mexico and were not discovered until Remote Sensing technology was applied to find differences in the make-up of the ground.

Remote Sensing data can also be used to predict forest patterns and figure out a lot of different problems related to overharvesting and deforestation. Drones have been employed in certain areas of the Rainforest and from those images, plant and animal species could be properly identified and accounted for. This tool could be essential in conservation and preservation methods moving forward in both the forests and oceans.

This Remote Sensing technology was also used to determine different species and makeups of trees, as well as, used in conjunction with GIS and Surveying data to produce a large asset inventory of forest health and overall well-being. Remote Sensing technology has become a staple in the Forestry industry and is being used all over the world.

Drones equipped with LiDAR will change the way we view the forest. This technology will aid in producing some of the most accurate and intensive maps the Forestry industry has ever seen. These maps will aid in selective logging and many other processes that will establish an overall health and well being of one of our most significant resources. Drone mapping has become prevalent for species mapping.

This Remote Sensing technology will aid in the conservation and preservation of our natural resources. This technology is producing high resolution maps of the coastal regions throughout the world and will aid in a tool for reef management and regeneration. These drones can be used in monitoring things like water temperature and overall water clarity, so we can come up with conservation and preservation techniques for the reefs. It is estimated that over 90 percent of the ocean species live among the reefs and we must do all we can to protect that environment.

At the University of Florida, the Geomatics program is part of the Forestry department, so you see how Surveying, GIS, Forestry and Remote Sensing interact with each other to scientifically investigate the land. These sciences are closely related, and the data is interchangeable. The biggest take away from these sciences is figuring out how to accurately inventory the land and develop methods to conserve and preserve our natural resources for the generations to come.

Aerial Mapping and Remote Sensing technologies are changing the way we view oceans, forests, wetlands and mountainous terrain. It is becoming an emerging technology that is developing at an exponential rate and will continue to evolve. Remote Sensing and Aerial Mapping have a symbiotic relationship and depend on each other's advancements for the other technology to advance as well. These technologies are changing the way the world is mapped and it is extremely interesting to see what's to come.

Conclusion

The observation of the simple method and device that camera obscura provided in the creation of imaging and photography lead to firm advancements in technology and the ability of the human mind to perceive, gather and discernment insight and findings. Remote Sensing has proven to be a valuable tool in a variety of industries. This technology has evolved at such an exponential rate that it is hard to predict what its capabilities will be, even in the near future.

Some countries are now using aerial imagery to determine boundary lines and property ownership. This was unheard of years ago, but a reality today with aerial photography and Remote Sensing technology. The accuracy of the data being achieved through drones and other UAV's is improving at an exponential rate. Some coastal regions in the United States, such as North Carolina, are now using drone technology for wetland delineation.

With advancements of imaging and manners of observing land and area further away; in various formats, and with available insights leads to a technological velocity that allows for improved communications, efficiencies and ultimately quality of life. Data collection methods are key to verifying and then establishing new frameworks in which knowledge and progress is built.

Producing new and effective technological advancements is key in Remote Sensing, GIS and Surveying. Over the last 50-60 years, GPS, Robotics, Drones and LiDAR have become extremely effective and efficient technologies that have basically changed the way we view the world. Technological advancements are speeding up and it doesn't look like we have a slow down anytime in the future.

Moving forward, traditional methods of mapping are becoming obsolete with the furthering advancements in Remote Sensing and aerial photography. A day could soon come where traditional data collection becomes unnecessary. The world continues to evolve, and Remote Sensing technologies are becoming the forefront of technology. The ownership of personal drones has greatly increased and becoming a pilot is an easier process than it was before. Drones are now being equipped with LiDAR which is even more exciting. It is hard to believe how much progress has been made just in the last five years. I believe that in the next 20 years or so, Remote Sensing and drone technology will evolve so much that even a toddler will be able to successfully take aerial images. It is amazing how technologically advanced our children are compared to us at that age.

This past year, I was able to purchase a drone for my 10-year-old daughter and she was able to successfully fly it within 30 minutes of opening the package. It's amazing that the new generation of kids are so technically advanced. I don't even remember being able to operate a cell phone when I was 10. The cell phone and apps are becoming more prevalent with younger children and they are gaining experience working with electronics.

Remote Sensing is a field that I have enjoyed following over the last decade while in school and I see the LiDAR equipped drones as the biggest advancement over that time period. These drones will be able to produce real time data in which trees and forests can be mapped. It will become basically like a video game where you are flying around a forest and doing

investigation and asset inventory at the same time. We will be able to map at such an exponential rate that everywhere in the world will have up to date mapping. The ocean floors will be mapped using new technologies and we will probably be able to have a sort of an Ocean View on Google Earth, quite possibly a Forest View too. Could you imagine picking your hiking trail and route before you even step into the forest?

The way drone mapping will change the world is exciting and I can't wait to see it evolve over the next 10-15 years. We will have enormous data sets of extremely detailed maps at our disposal. I think this is going to change the phone industry as well. In my opinion, Remote Sensing data is going to be used for real time 3 dimensional projected maps.

Remote Sensing technologies are giving computers the ability to basically look back at you. This technology is giving computers the tools to discern many changes in surroundings. Many scientists believe that this technology will give computers a sensory network with the ability to put the environment itself online.

Of course, the most far reaching profiles will come from satellite based data derived from space. Sort of an "eye in the sky", where a vast amount of data will have derived from multiple satellites orbiting the planet Earth. As stated before, we already have sensors measuring climate issues, environmental changes, forests and coral reefs. This data is being infused with GIS and Survey technology to create a super-rich data base.

In closing, I am extremely excited to see what's in store for us with this growing technology and I think that it is important that we evolve with it. The human race is becoming more dependent on technology for things such as resource management, conservation and preservation and Remote Sensing technology can add a great deal of value to it. Worldwide - technology races are taking place and this competition is great for advancement. As we continue to evolve as a species, the advancements made will alter our perception of our individual selves. Thanks to Remote Sensing, our view of the world is now achievable through space borne photography. We now have the ability to view ourselves from space; that in itself is amazing.

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