**Modern Surveying Techniques**

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**Lecture - 9**

**Sensor and Platform**

In my previous session, I had introduced to you those space-borne sensors based on spatial resolution.

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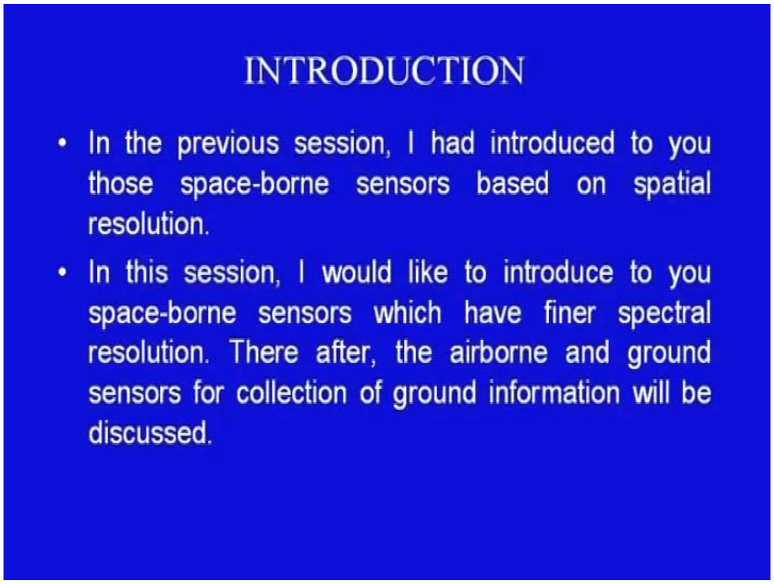


In this session, I would like to introduce to you space-borne sensors which have finer spectral resolution. Thereafter, the airborne and ground sensors for collection of ground information will be discussed. First of all, earth observing 1 mission or in short EO – 1.

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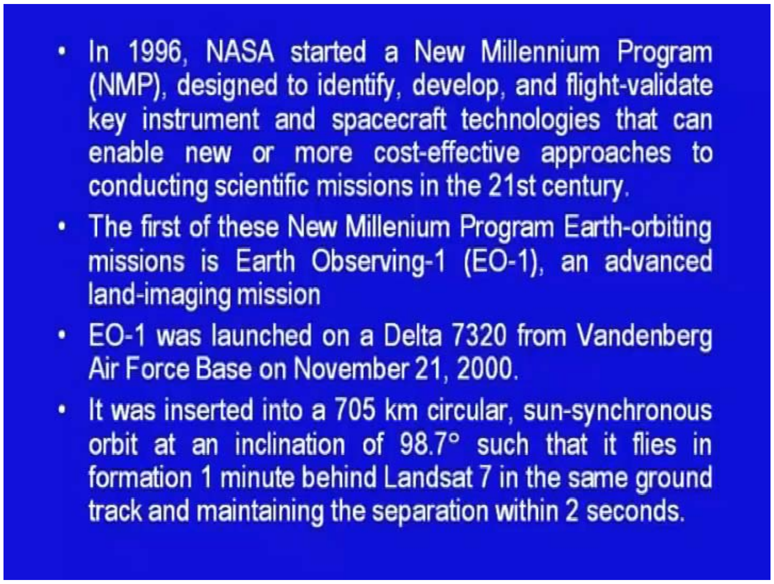


In 1996, NASA started a New millennium program designed to identify, develop and flight validate key instruments and spacecraft technologies that can enable new or more cost effective approaches to conducting scientific missions in the 21 century.

The first of these New Millennium Program Earth-orbiting missions is earth Observing-1, an advanced land-imaging mission. EO-1 was launched on Delta 7320 from Vandenberg Air Force Base on November 21, 2000. It was inserted into a 705 kilometer circular, sun synchronous orbit at an inclination 98.7 degrees such that it flies in formation in1 minute behind Landsat 7 in the same ground track and maintaining the separation within 2 seconds.

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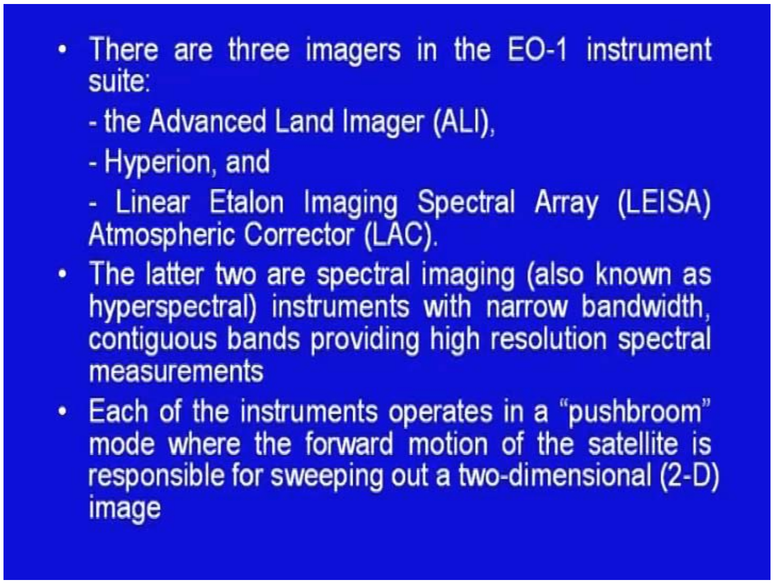


There are 3 imagers in the EO-1 instruments suite: the Advanced Land Imager or in short called as ALI, Hyperion and Linear Etalon imaging spectral array, atmospheric corrector. The latter two are spectral imaging known as hyperspectral instruments with narrow bandwidth, contiguous bands providing high resolution spectral measurements. Each of the instruments operates in a "pushbroom" mode where the forward motion of the satellite is responsible for sweeping out a 2-dimensional image.

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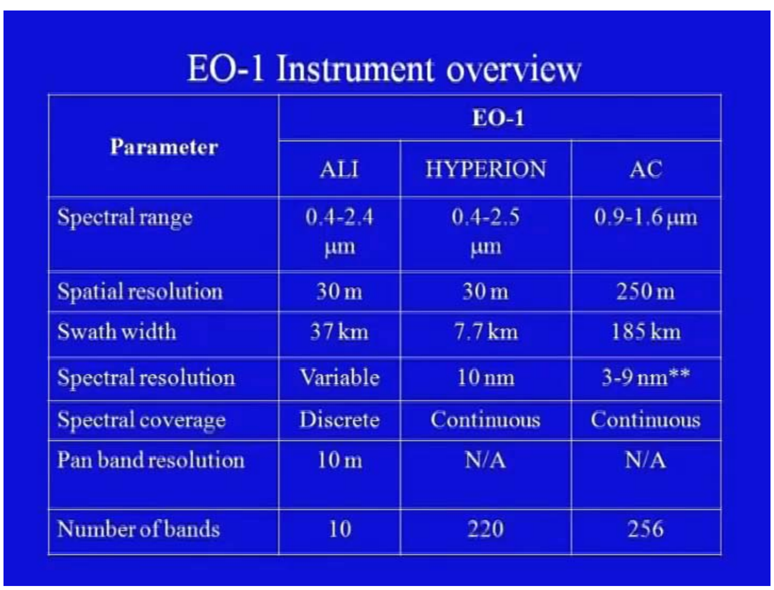

EO-1 Instrument overview

| **Parameter** | **EO-1** | | |
|---|---|---|---|
| | ALI | HYPERION | AC |
| Spectral range | 0.4-2.4 µm | 0.4-2.5 µm | 0.9-1.6 µm |
| Spatial resolution | 30 m | 30 m | 250 m |
| Swath width | 37 km | 7.7 km | 185 km |
| Spectral resolution | Variable | 10 nm | 3-9 nm** |
| Spectral coverage | Discrete | Continuous | Continuous |
| Pan band resolution | 10 m | N/A | N/A |
| Number of bands | 10 | 220 | 256 |

Now, let us look at the EOI instrument. EOI has, as I have said, has 3 instruments; ALI, Hyperion and LAC. The spectral range of ALI is between 0.4 to 2.4 mu meters, whereas, for Hyperion it is 0.4 to 2.5 mu meters and for LAC, it is between 0.9 to 1.6 mu meters.

The spatial resolutions are 30, 30 and 250 meters respectively, with a swath width of 37 kilometers for ALI, 7.7 kilometer for Hyperion and 185 kilometers for LAC. Spectral resolution is variable in case of ALI. However, for Hyperion it is 10 nanometers and for LAC it is between 3 to 9 nanometers.

The spectral coverage is discrete in ALI, whereas, it is continuous in Hyperion and LAC. The pan band resolution in ALI is 10 meters, whereas, Hyperion and LAC do not have any pan band resolution. The number of bands in ALI is 10, 220 for Hyperion and 256 for LAC.

Now, let us look at each of the equipment one by one. First is advanced land imager or ALI.

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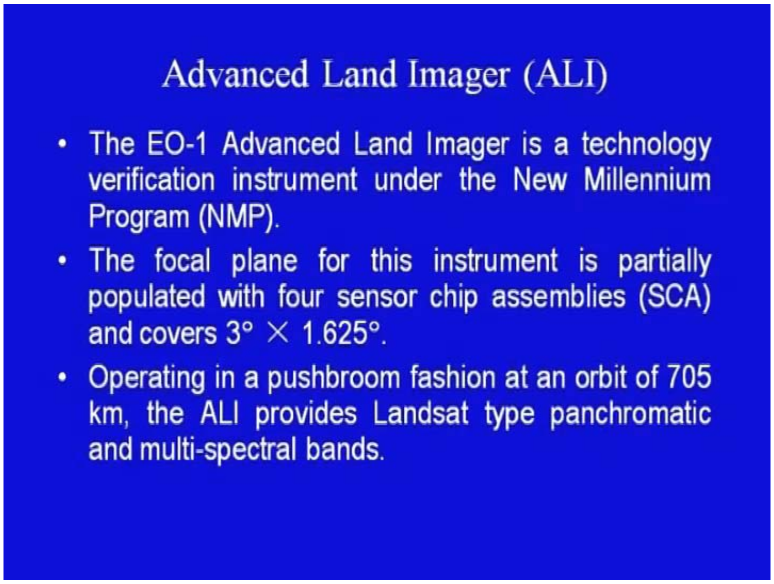


The EO- 1 advanced land imager is a technology verification instrument under the new millennium program. The focal plane of this instrument is partially populated by 4 sensor chip assemblies or SCA and covers 3 degrees by 1.625 degrees coverage. Operating in a pushbroom fashion at an orbit of 705 kilometer, the ALI provides Landsat type panchromatic and multi-spectral bands.

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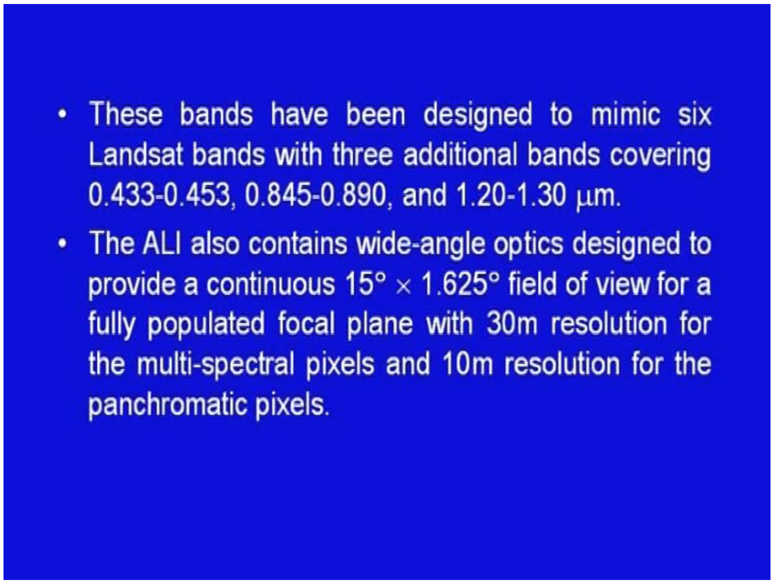


These bands have been designed to mimic the 6 Landsat bands with 3 additional bands covering the region of 0. 433 to 0.453, 0.845 to 0.890 and 1.2 to 1.3 mu meters. The ALI also consist of a wide angle optics designed to provide a continuous 15 degrees by 1.625 field of view for fully populated focal length with 30 meter resolution for multi-spectral pixels and 10 meter resolution for panchromatic pixels.

Now, we come to the next equipment in the EO-1 and that is Hyperion.

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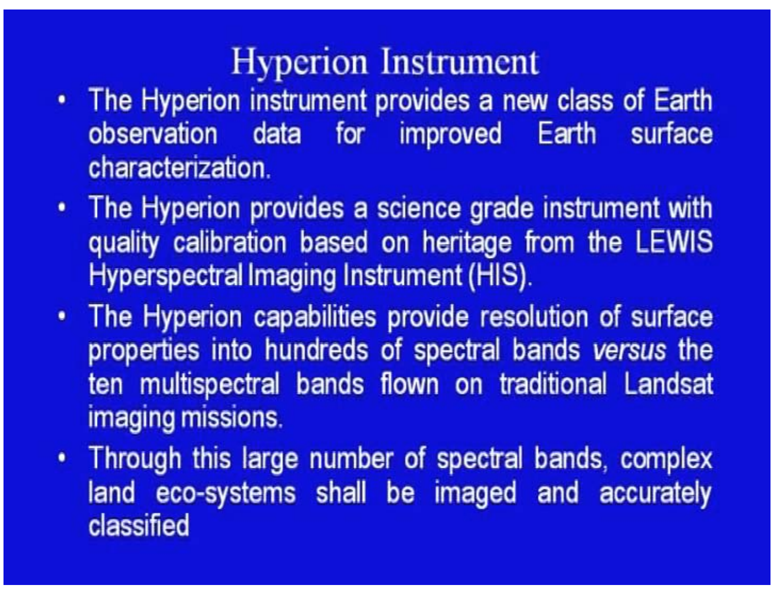

The Hyperion instrument provides a new class of earth observation data for improved earth surface characterization. The Hyperion provides science grade equipment with quality calibrations based on heritage from the LEWIS hyperspectral imaging instrument. The hyper Hyperion capabilities provide resolution of surface properties into hundreds of spectral bands versus the 10 multispectral bands flown on any traditional Landsat imaging missions. Though this large number of spectral bands, complex land eco-systems shall be imaged and accurately classified.

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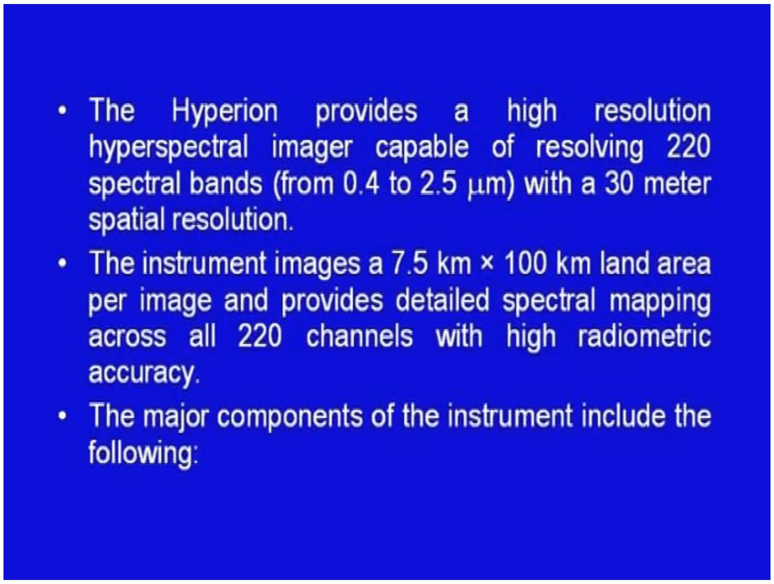


The Hyperion provides a high resolution hyperspectral imager capable of resolving 200 spectral bands between 0.4 to 2.5 mu meters with a 30 meter spatial resolution. The instrument images an area of 7.5 kilometers by 100 kilometers land area per image and provides detail spectral mapping across all 220 channels with high radiometric accuracy.

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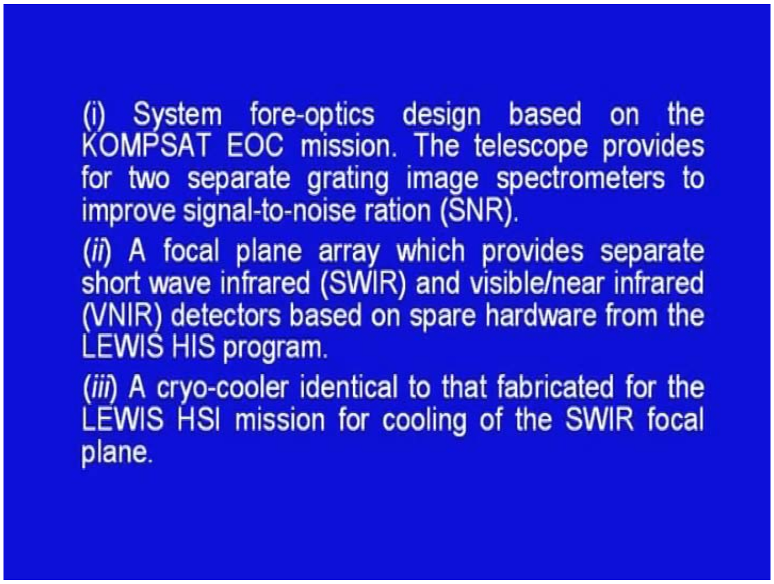


The major components of the equipment include the following: System fore-optics design based on KOMPSAT EOC mission. The telescope provides for 2 separate grating image spectrometers to improve signal to noise ratio. A focal plane array which provides separate short wave infrared and visible or near infrared detectors based on spare hardware from the LEWIS HIS program. A cryo-cooler identical to that fabricated for the LEWIS HIS mission for cooling of the SWIR focal plane.

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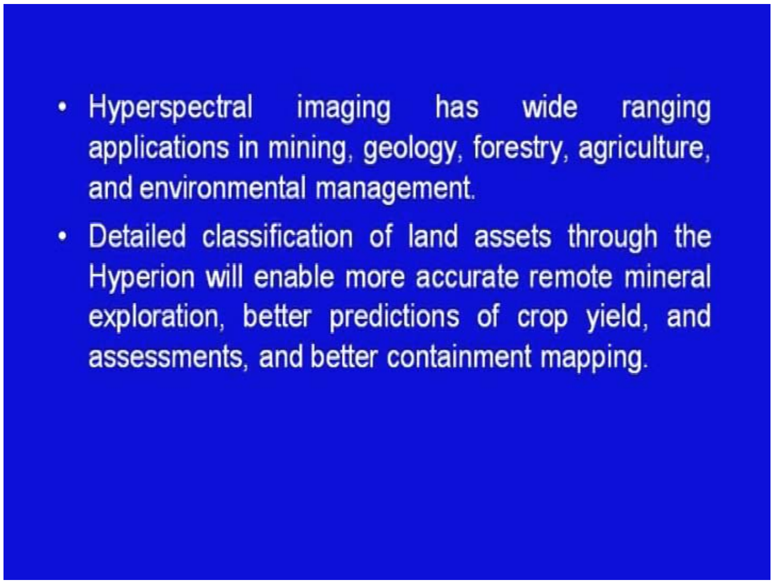


Hyperspectral imaging has wide ranging applications in the area of mining, geology, forestry, agriculture and environmental management. Detailed classification of land assets through Hyperion will enable more accurate remote mineral exploration, better prediction of crop yield and assessments and better containment mapping. Then we come to the next instrument which is LAC or in short called as the atmospheric corrector.

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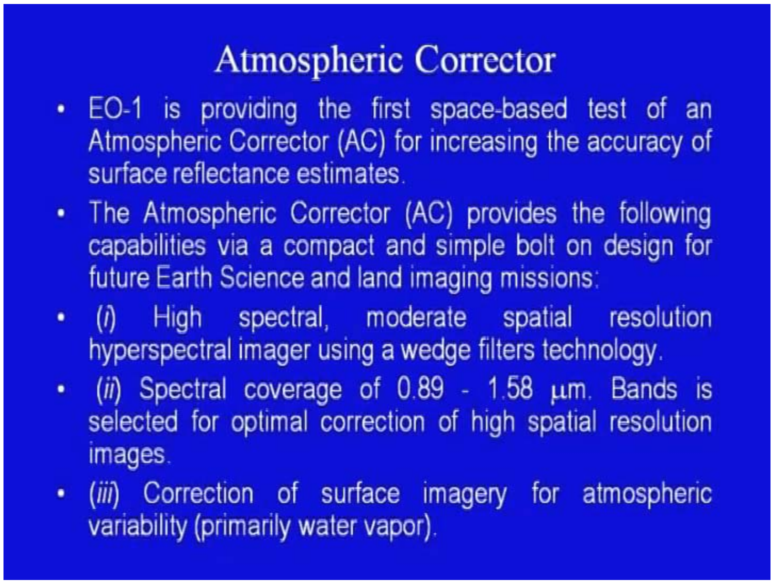


EOA - 1 is providing the first space -based test of an atmospheric corrector for increasing the accuracy of surface reflectance estimates. The atmospheric corrector provides the following capabilities via a compact and simple bolt on design for future earth and land imaging missions: first, high spectral moderate spatial resolution hyperspectral imager using a wedge filter technology, spectral coverage of 0.89 to 1.58 mu meters. The bands are selected for optimal. Correction of high spatial resolution images correction of surface imagery for atmospheric variability primarily water vapor.

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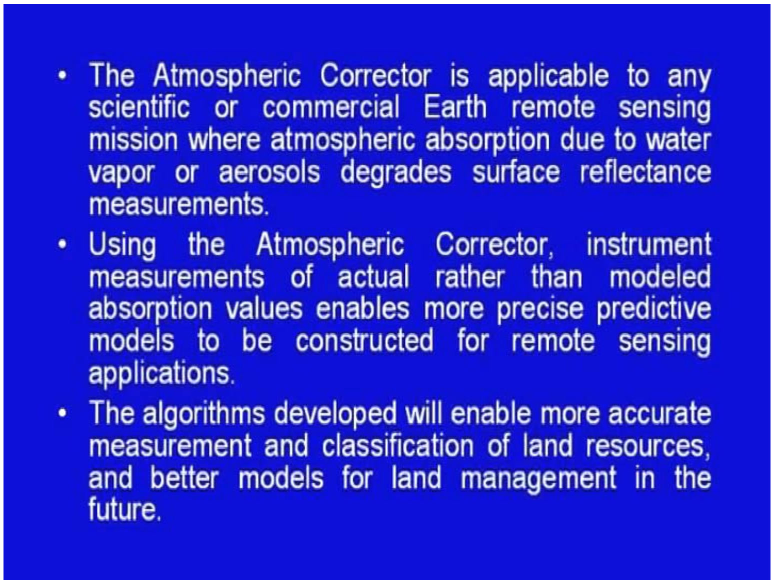


The atmospheric corrector is applicable to any scientific or commercial earth remote sensing mission, where atmospheric absorption due to water vapor or aerosols degrades surface reflectance measurements. Using the atmospheric corrector equipment instrument measurements of rather than modeled absorption values enables more precise predictive models to be constructed for remote sensing applications. The algorithms developed will enable more accurate measurements and classification of land resources and better models for land management in the future. Now, we look at the next finer spectral mission known as the ASTER mission.

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ASTER is a cooperative effort between NASA and Japan's ministry of economy trade and industry with the collaboration of scientific and industry organizations in both the countries. ASTER captures high spatial resolution data in 14 bands from the visible to the thermal infrared wavelengths and provides stereo viewing capabilities for digital elevation model creation.

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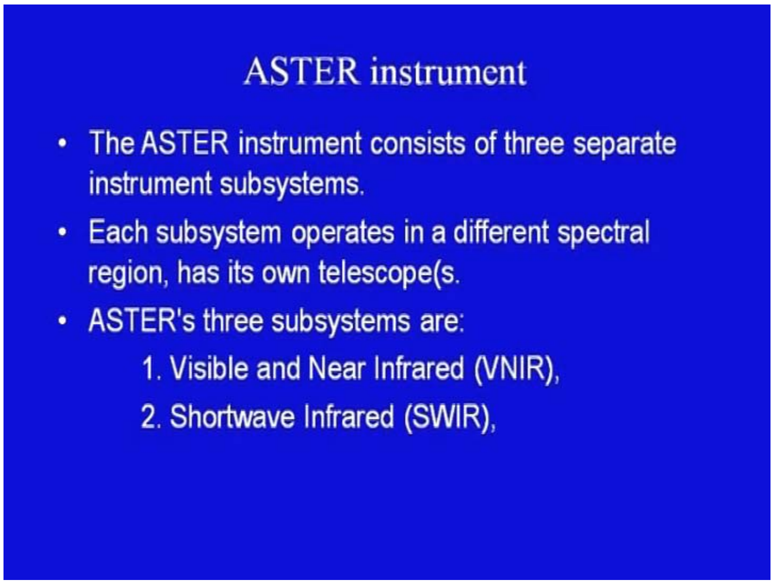


The ASTER instrument consists of 3 separate instrument subsystems. Each subsystem operates in a different spectral region and has its own telescope. The 3 subsystems in which the ASTER operates are the visible and near infrared or in short known as VNIR, shortwave infrared - SWIR and thermal infrared - TIR. So, now let us look at the 3 subsystems that we have. First is VNIR.

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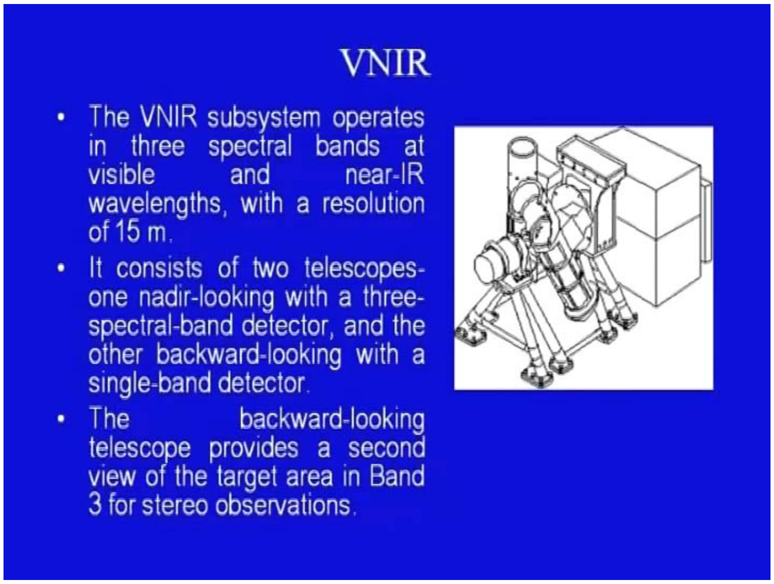


The VNIR subsystem operates in 3 spectral bands at visible and near infrared wavelengths with a resolution of 15 meters. It consists of 2 telescopes; 1 nadir looking with a 3 spectral band detector and the other backward looking with a single band detector. The backward looking telescope provides a second view of the target area in band 3 for stereo observations.

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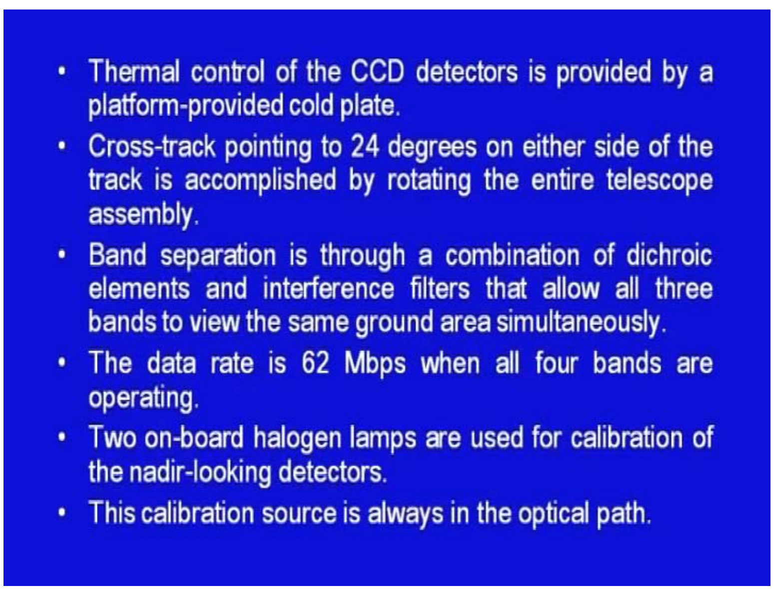


The thermal control of the CCD detectors is provided by a platform provided cold plate. Across track pointing up to 24 degrees on either side of the track is accomplished by rotating the entire telescope assembly. Band separation is through a combination of dichroic elements and interference filters that allow for all the 3 bands to view the same ground area simultaneously.

The data rate is 32 Mbps when all the 4 bands are operating. The 2 on board halogen lamps are used for calibration of the nadir-looking instruments. This calibration source is always in the optical path. The next subsystem is the SWIR.

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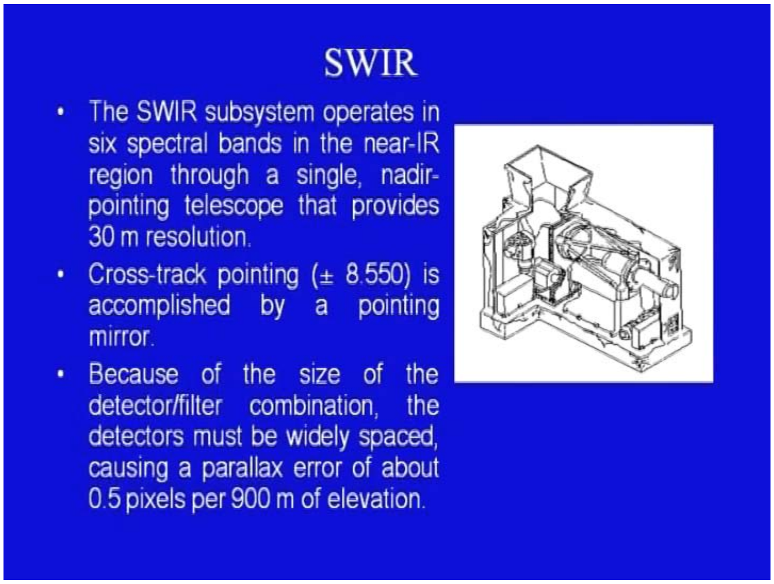


The SWIR subsystem operates in 6 spectral bands in the near infrared region through a single nadir pointing telescope that provides 30 meter resolution. The cross track pointing that is plus minus 8.55 degrees is accomplished by a pointing mirror. Because of the size of the detector or filter combination, the detectors must be widely spaced causing a parallax error of about half a pixel for per 900 meter elevation.

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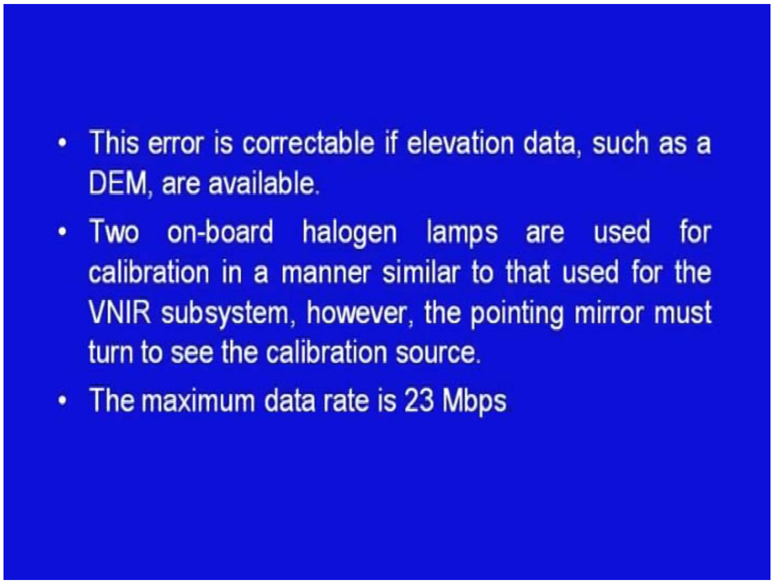


This error is correctable if the elevation data such as a DEM are available. The 2 on-board halogen lamps are used for calibration in a manner similar to that used for VNIR system. However, the pointing mirror must turn to see the calibrated source. The maximum data rate here is 23 Mbps.

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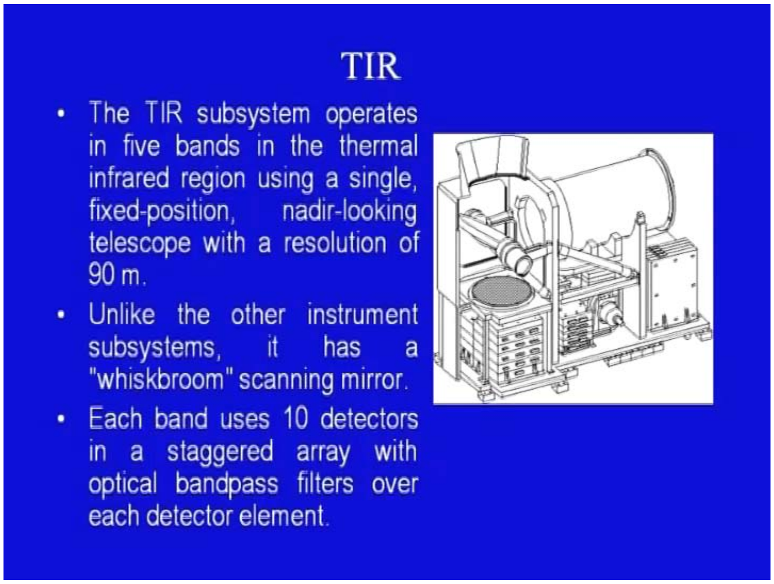


Then we come to the third subsystem which is TIR or the thermal infrared. The TIR subsystem operates in 5 bands in this thermal infrared region using single fixed position, nadir looking telescope with a resolution of 90 meter. Unlike the other system, instrument subsystems, it has a whiskbroom scanning mirror. Each band uses 10 detectors in a staggered array with optical band pass filters over each detector element.

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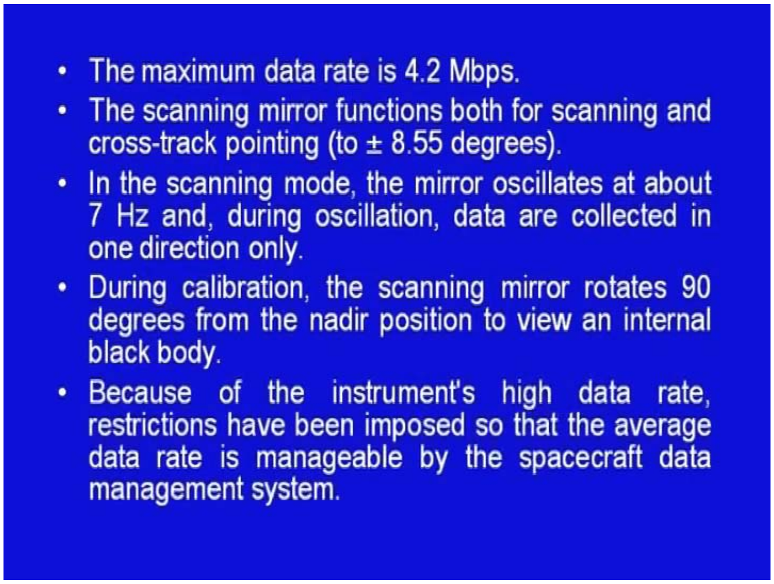


The maximum data rate is 4.2 Mbps. The scanning mirror functions both for scanning and cross track pointing that is between 0 to plus minus 8.55 degrees. In the scanning mode, the mirror oscillates at about 7 hertz and during 1 oscillation; data are collected in 1 direction only.

During calibration, the scanning mirror rotates 90 degrees from the nadir position to view an internal black body. Because of the instrument's high data rate, restrictions have been imposed so that the average data rate is manageable by the spacecraft data management system.

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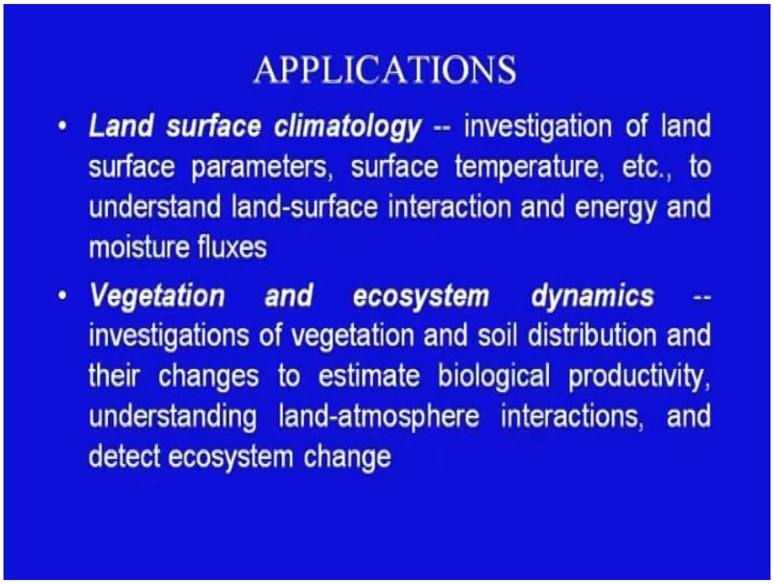


Now, we come to the applications of ASTER data. First is land surface climatology. It allows for the investigation of land surface parameters such as surface temperature to understand land surface interaction and energy and moisture fluxes. Vegetation and ecodynamics: investigations of vegetation and soil distribution and their changes to determine biological productivity, understanding land atmospheric interactions and detect eco ecosystem changes.

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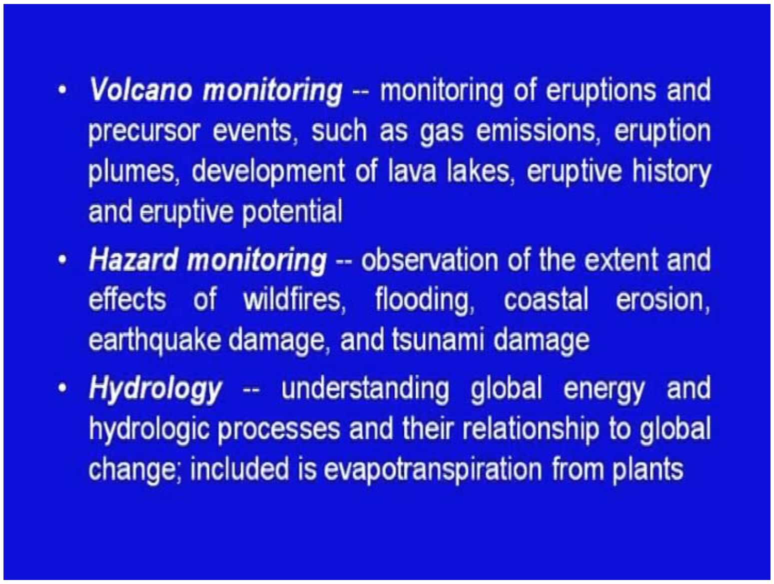


It can be used for volcanic monitoring in order to monitor the eruptions or the precursor events such as gas emissions, eruption of plumes, development of lava lakes, eruptive history and eruptive potential. In the area of hazard monitoring, it provides observation to the extent and effect of wildfires, flooding, coastal erosion, earthquake damage and tsunami damages.

In the area of hydrology, it provides understanding of the global energy and the hydrological processes and their relationship to global change; including is evapotranspiration from plants.

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Zoology and soils is the next area where ASTER can provide ample opportunities. It gives the detailed composition and geomorphological mapping of the surface soils and bedrocks to study land surface processes and earth's history. The land surface and land cover change can be also monitored with the help of ASTER. At present, monitoring, desertification, deforestation, urbanization; is providing data for conservation managers to monitor protected areas and national parks and wilderness areas.

Now, we come to the next type of satellite mission which is known as AVIRIS.

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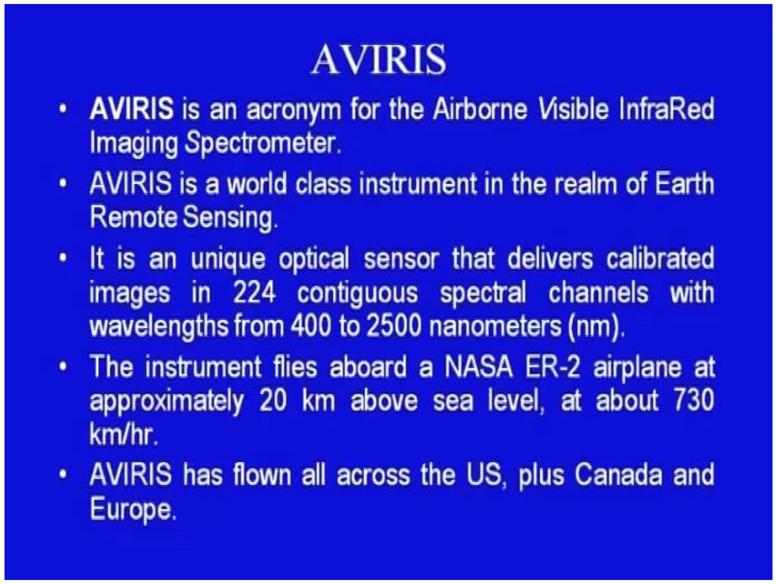


AVIRIS is an acronym of Airborne Visible Infrared Imaging Spectrometer. AVIRIS is a world class instrument in the realms of earth remote sensing. It has a unique optical sensor delivers calibrated images in 244 contiguous spectral channels with wavelength ranging from 400 to 2500 nanometer.

The instrument flies aboard a NASA ER - 2 airplane at approximately 20 kilometers above the earth surface with a speed of about 730 kilometers per hour. AVIRIS has flown all over USA plus Canada and the Europe.

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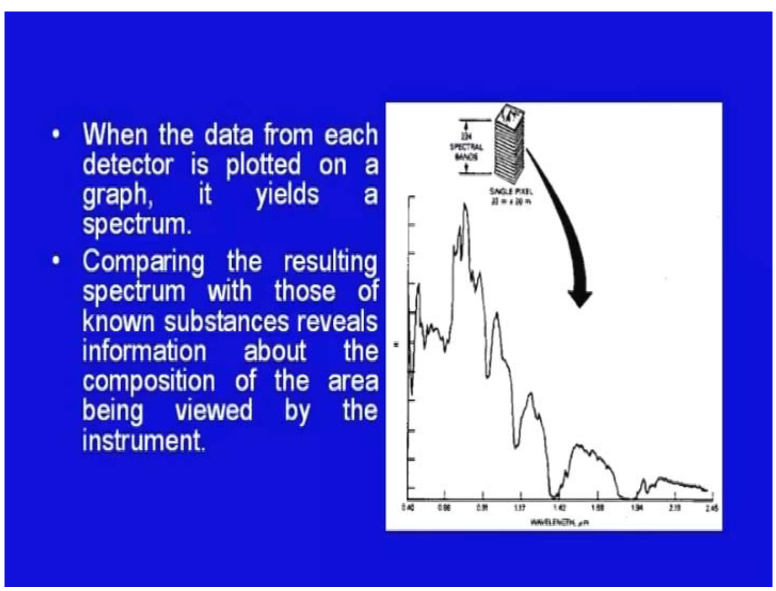

When the data from each detector is plotted on a graph, it yields a spectrum. The adjoining figure shows a such a profile of a single pixel whose data has been collected in 24 bands and what we can see is on the x axis, the wavelength has been plotted, whereas, on the y axis the amount of energy reflected at each wavelength from a single pixel has been generated. Comparing the resulting spectrum with those of known substances reveals information about the composition of the area being viewed by the instrument.

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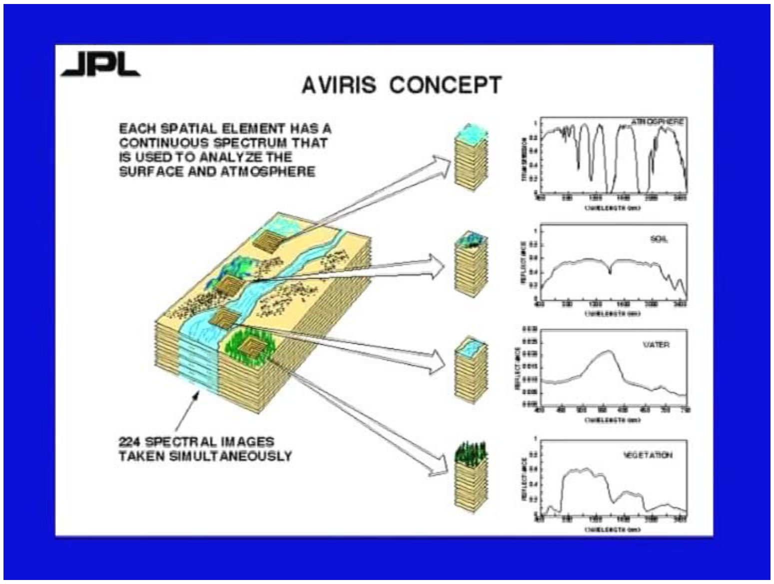


So finally, we can say that the AVIRIS is a system or a concept where each spatial element has a continuous spectrum that is used to analyze the surface and atmosphere.
One can see 4 such sample information’s related to atmosphere, soil water and vegetation and one can see the manner in which the information is available by taking continuous bands and not discrete bands. The next sensor is MODIS.

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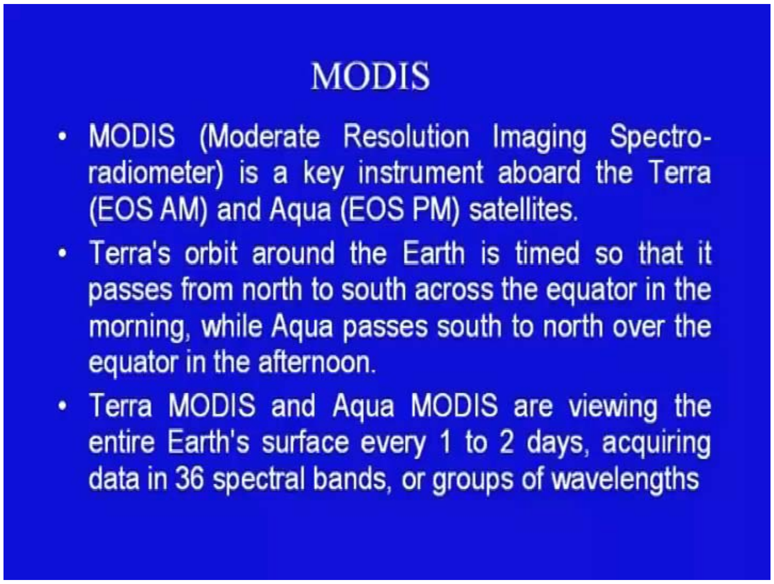


MODISm the full form is Moderate Resolution Imaging Spectro- radiometer is a key instrument abroad the Terra EOS AM and Aqua EOS PM satellites. EOS means Earth Observing Satellites, AM means in the morning, PM means in the afternoon.

Terrra’s orbit around the earth is timed so that it passes from north to south across the equator in the morning, while, aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire earth’s surface every 1 to 2 days acquiring data in 36 spectral bands or group of wavelengths.

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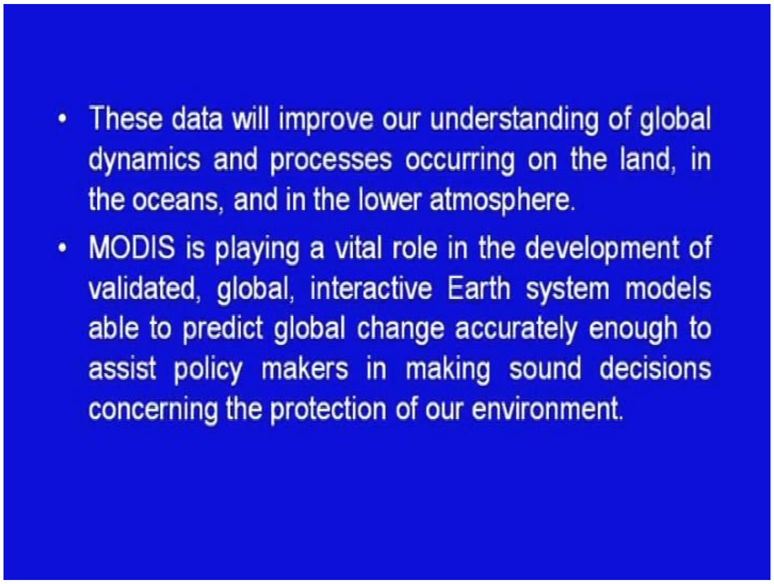

These data will improve our understanding of global dynamics and processes occurring on the land in the oceans and in the lower atmosphere. MODIS is playing a vital role in the development of validated global interactive earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment. Now, let us look at the characteristics of MODIS.

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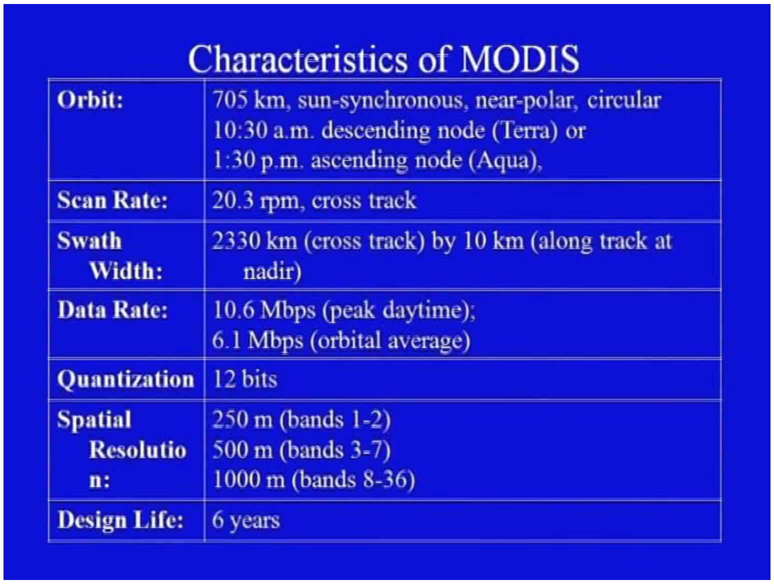

Characteristics of MODIS

| | |
|---|---|
| **Orbit:** | 705 km, sun-synchronous, near-polar, circular 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), |
| **Scan Rate:** | 20.3 rpm, cross track |
| **Swath Width:** | 2330 km (cross track) by 10 km (along track at nadir) |
| **Data Rate:** | 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average) |
| **Quantization** | 12 bits |
| **Spatial Resolution:** | 250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36) |
| **Design Life:** | 6 years |

The orbit of MODIS is a sun-synchronous near polar circular 1 at an altitude of 705 kilometers. It the Terra satellite on its descending node, passes the equator at 10:30 AM; While, the aqua satellite on its ascending node passes the equator at 1:30 PM. It has a scanned rate of 20.3 rpm cross track, having a swath width of 2330 kilometer by 10 kilometers at nadir.

The data rate is 10.6 Mbps peak daytime, while it is 6.1 Mbps orbital average. The data is having a radiometric resolution of 12 bits and a spatial resolution which is variable for from band to band. For the first 2 band; 1 and 2, it is 250 meters, for bands 3 to 7, it is 500 meters and from bands 8 to 36, it is 1000 meters. This particular sensor has a design life of 6 years.

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| Primary Use | Band | Bandwidth (nm) |
|---|---|---|
| Land/Cloud/Aerosols Boundaries | 1 | 620 - 670 |
| | 2 | 841 - 876 |
| Land/Cloud/Aerosols Properties | 3 | 459 - 479 |
| | 4 | 545 - 565 |
| | 5 | 1230 - 1250 |
| | 6 | 1628 - 1652 |
| | 7 | 2105 - 2155 |

Now, let us look at the primary uses of these MODIS instrument. For the first 2 bands, that is band 1 and 2 operating in the wavelength region of 620 to 720 nanometers and 841 to 876 nanometers are being used for land, cloud, aerosol, boundary determination while, bands 3 to 7 are providing information's regarding the land, cloud, aerosol properties.

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| Primary Use | Band | Bandwidth (nm) |
|---|---|---|
| Ocean Color/ Phytoplankton/ Biogeochemistry | 8 | 405 - 420 |
| | 9 | 438 - 448 |
| | 10 | 483 - 493 |
| | 11 | 526 - 536 |
| | 12 | 546 - 556 |
| | 13 | 662 - 672 |
| | 14 | 673 - 683 |
| | 15 | 743 - 753 |
| | 16 | 862 - 877 |
| Atmospheric Water Vapor | 17 | 890 - 920 |
| | 18 | 931 - 941 |
| | 19 | 915 - 965 |

The bands 8 to 16 are being utilized for ocean color phytoplankton and biogeochemistry. The band widths can be seen to be varying between 10 to 20 nanometers. Bands 17 to 19 are being used for atmospheric vapor.

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| Primary Use | Band | Bandwidth (µm) |
|---|---|---|
| Surface/Cloud Temperature | 20 | 3.660 - 3.840 |
| | 21 | 3.929 - 3.989 |
| | 22 | 3.929 - 3.989 |
| | 23 | 4.020 - 4.080 |
| Atmospheric Temperature | 24 | 4.433 - 4.498 |
| | 25 | 4.482 - 4.549 |
| Cirrus Clouds Water Vapor | 26 | 1.360 - 1.390 |
| | 27 | 6.535 - 6.895 |
| | 28 | 7.175 - 7.475 |

Bands 20 to 23 are being used for surface and cloud temperature while, bands 24 and 25 provide information regarding the atmospheric temperature. Bands 26, 27and 28 are used for mapping cirrus clouds and water vapor.

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| Primary Use | Band | Bandwidth (µm) |
|---|---|---|
| Cloud Properties | 29 | 8.400 - 8.700 |
| Ozone | 30 | 9.580 - 9.880 |
| Surface/Cloud Temperature | 31 | 10.780 - 11.280 |
| | 32 | 11.770 - 12.270 |
| Cloud Top Altitude | 33 | 13.185 - 13.485 |
| | 34 | 13.485 - 13.785 |
| | 35 | 13.785 - 14.085 |
| | 36 | 14.085 - 14.385 |

Band 29 is used for ascertaining cloud properties, band 30 is dedicated for ozone measurements, band 31 and 32 provide information to the surface and cloud temperatures; while band 33, 30 to 38, it provides information regarding the cloud top altitude.

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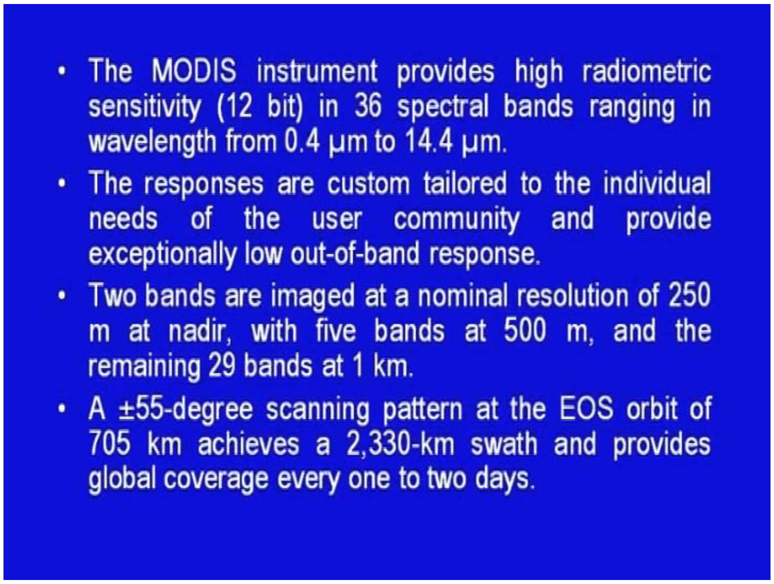


The MODIS instrument provides high radiometric sensitivity that is at 12 bits in 36 spectral bands ranging in the wavelength from 0.4 mu meters to14.4 mu meters. The responses are custom tailored to the individual needs of the user community and provide exceptionally low out of band responses. 2 bands are imaged at a nominal resolution of 250 meters at nadir with 5 bands at 500 meters and the remaining 29 bands at 1 kilometer.

A plus minus 55 degree scanning pattern at the EOS orbit of 705 kilometers achieves a 2330 kilometer swath width and provides global coverage every 1 to 2 days.

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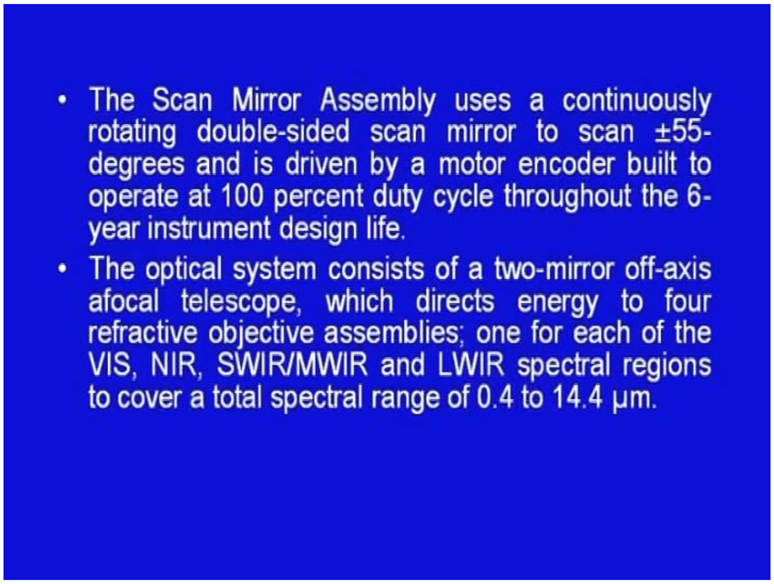

The scan mirror assembly uses a continuously rotated double-sided scan mirror to scan a plus minus 55 degree and is driven by a motor encoder built to operate at 100% duty cycle throughout the 6 year instrument design life.

The optic system consists of 2 off axis if a focal telescope which directs energy to 4 refractive objective assemblies; one each for the visible, near infrared, SWIR and middle WIR and LWIR spectral regions to cover the total spectral range of 0.4 to 14.4 mu meters.

Now, we focus our attention to those type of data collection systems which can which are placed on an aircraft and this is what we call it as the airborne data collection system.

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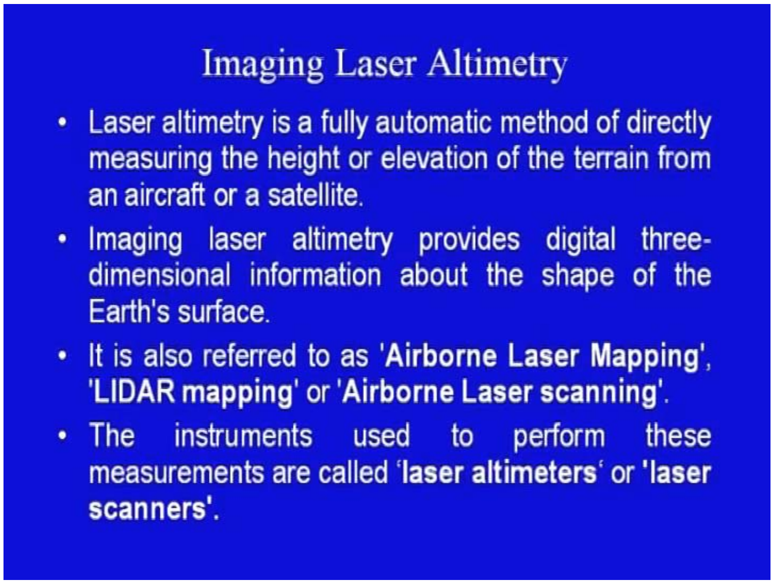


First is imaging laser altimetry. Laser altimetry is a fully automated method of directly measuring the height or elevation of the terrain from an aircraft or a satellite. Imaging laser altimetry provides digital 3 dimensional information about the shape of the earth's surface. It is also referred as Airborne Laser Mapping or LIDAR mapping or the Airborne Laser Scanning. The instruments used to perform these measurements are called laser altimeters or laser scanners.

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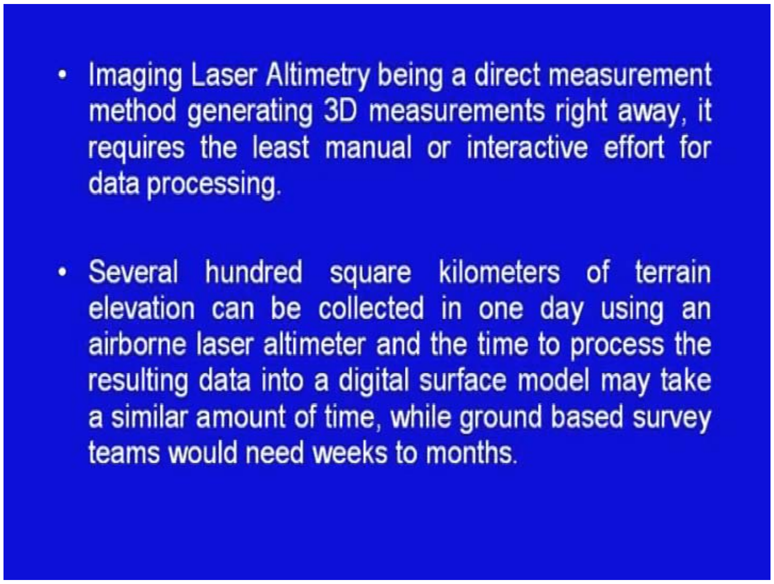


Imaging laser altimeter being a direct measurement method generating 3 D measurements right away, it requires the least manual or interactive effort of data processing. Several 100 square kilometers of terrain elevation can be collected in 1 day using airborne laser altimeter and the time to process the resulting data into digital surface model may take a similar amount of time; while, ground base surveying method teams would need weeks to months.

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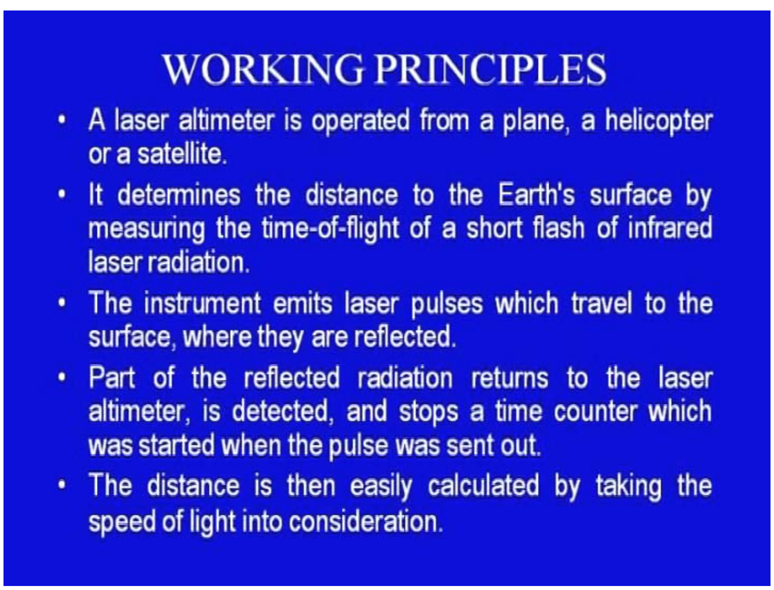


Let us look at the working principle of a laser altimeter. A laser altimeter is operated from a plane or a helicopter or from a satellite. It determines the distance of the earth's

surface by measuring the time-of-flight of a short flash of infrared laser radiation. The instrument emits laser pulses which travel to the surface where they are the reflected.
Part of the reflected radiation returns to the laser altimeter is detected and stops a time counter which was started when the pulse was sent out. The distance is then easily calculated by taking the speed of the light into consideration.

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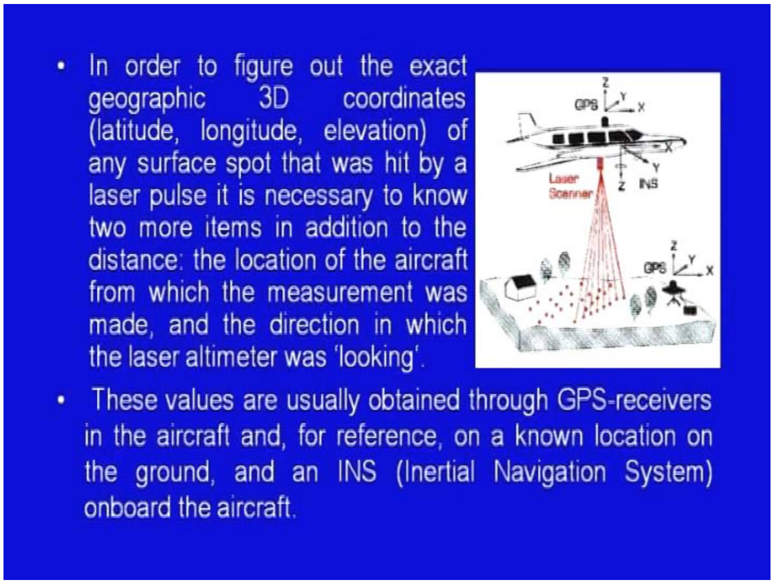


In order to figure the exact geographic 3D coordinates that is latitude, longitude and elevation of any surface spot that was hit by a laser pulse; it is necessary to know 2 more items in addition to the distance - the location of the aircraft from which the measurement was made and the direction in which the laser altimeter was looking. These values are obtained through GPS receivers in the aircraft and for reference on a known location on the ground and an INS, inertial navigation system onboard the aircraft.

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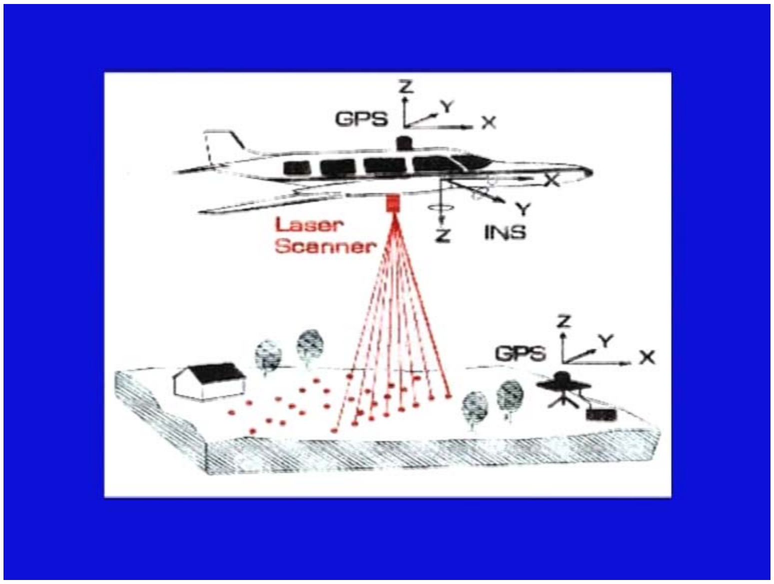


This particular graphic shows the 3 basic informations required to further argument the data being collected by the laser altimeter. Laser altimeter has lot of applications. So, let us look at the applications of laser altimetry.

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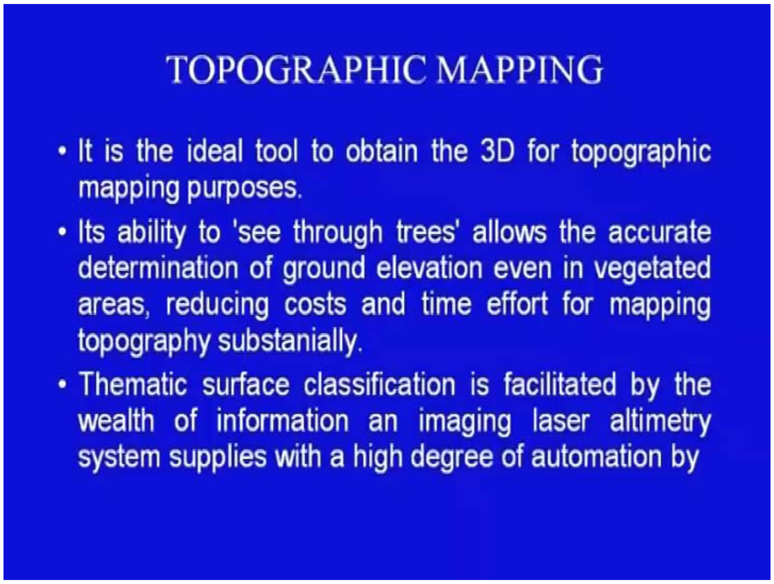


First is topographic mapping. It is the ideal tool to obtain 3D for topographic mapping purposes. Its ability to see through trees allows the accurate determination of the ground elevation even in vegetated areas reducing cost and time effort for mapping topography substantially. The thematic surface classification is facilitated by the wealth of the information and laser altimetry system supplies with a high degree of automation by establishing and updating topographic maps with accurate 3D information.

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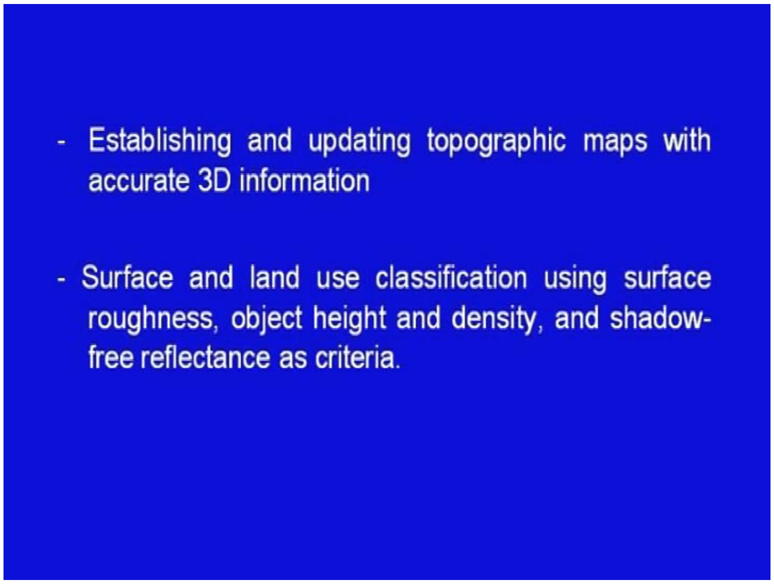


Surface and land use classification using surface roughness, object height, density and shadow free reflectance as criteria.

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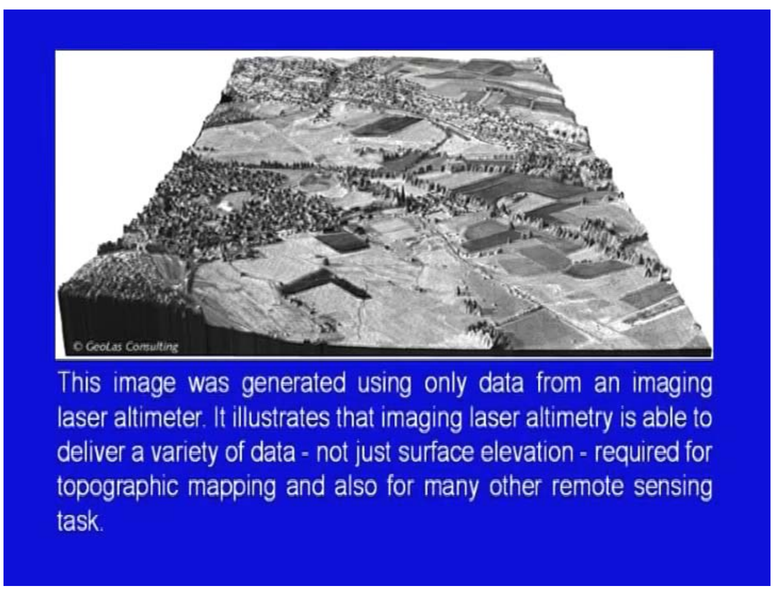


In this particular image which has been generated using data only from an image laser altimetry, it illustrates that the laser imaging laser altimeter is able to deliver a variety of data- not only surface elevation required for topographic mapping; it also for many other remote sensing task. One can see the wealth of information that has been collected by laser altimeters.

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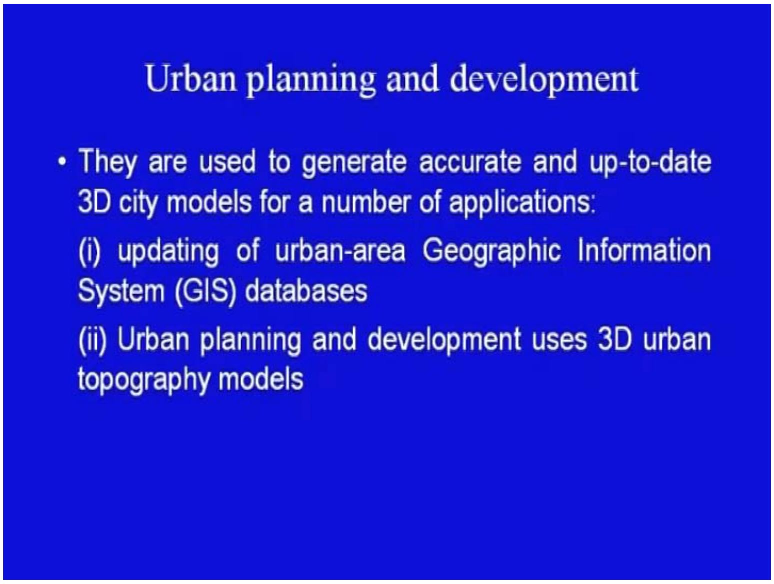


Another area is in urban planning and development. They are used to generate accurate and upto date 3D city models for a number of applications such as updating of urban area, geographic information system databases, urban planning and development uses 3 D urban topography models.

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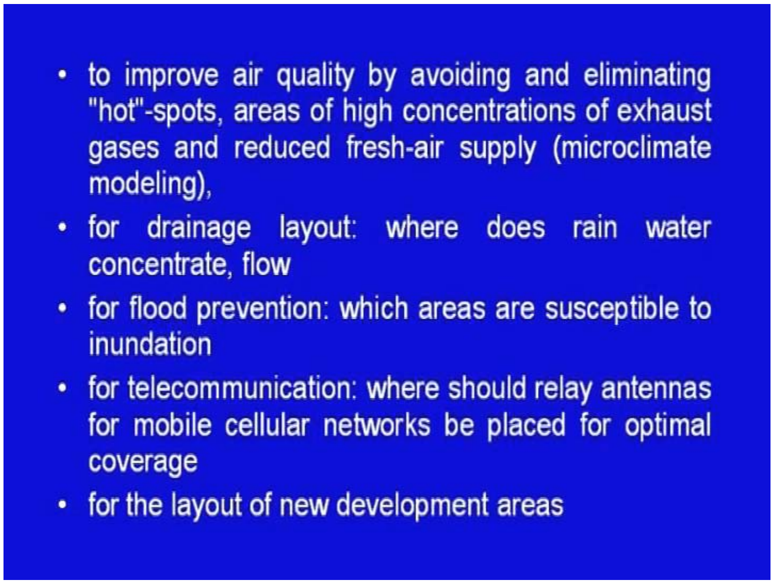

It can be used to improve air quality by avoiding and eliminating hot spots area of high concentration of exhaust gases and reduced fresh air supply that is it can be used for microclimate modeling.

For drainage layout: where does the rain water concentrate or flow, for flood prevention: in identifying areas that are susceptible to inundation, for telecommunication so that where should the relay antennas for mobile cellular networks be placed for optimal coverage, for the layout of new development areas. It is also having large application for infrastructure construction, maintenance and management.

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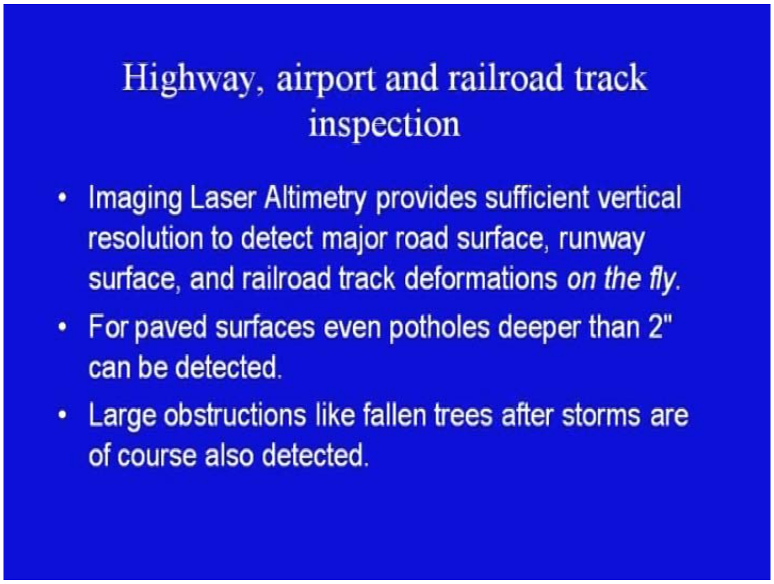
For layout and construction of infrastructure, it provides accurate and upto date digital 3D terrain maps, even in forested areas provide input to optimize design and construction processes and logistics. For environmental impact simulations using digital surface models help to find the solution with least adverse effect on the landscape, vegetation and hydrology.

(Refer Slide Time: 36:20)




In the area of highway and rail track inspection, laser altimetry provides sufficient vertical resolution to detect major road surface, runway surface and rail track deformations on the fly. For paved surfaces, even potholes deeper than 2 inches can be detected. Large obstructions like fallen trees after storms are of course can be detected.

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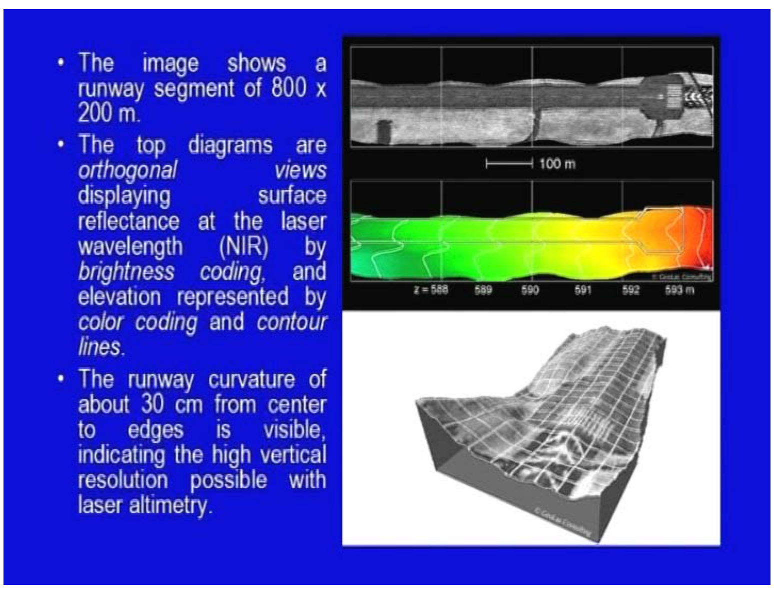


In this particular graphics, it shows the image of a runway segment of 800 by 200 meters. The top diagrams are the orthogonal views displaying the surface reflectance at the laser wavelength that is NIR by brightness coding and the elevation represented by color coding and contour lines. The runway curvature of about 30 centimeter from the center to the edges is visible, indicating the high vertical resolution possible with laser altimetry.

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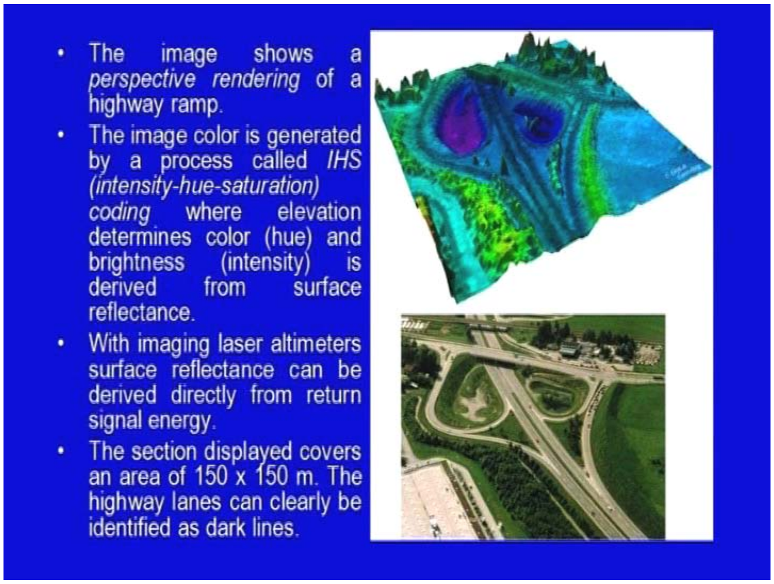


This particular slide shows the perspective rendering of a highway ramp. If the image color is generated by a process called IHS that is intensity hue saturation coding, where elevation determines the color that is hue and the brightness that is intensity is derived from the surface reflectance.

With imaging laser altimeters, surface reflectance can be derived directly from the return signal energy. The section displayed here covers an area of 150 meters by 150 meters. The highway lanes can be clearly be identified as dark lines in the image.

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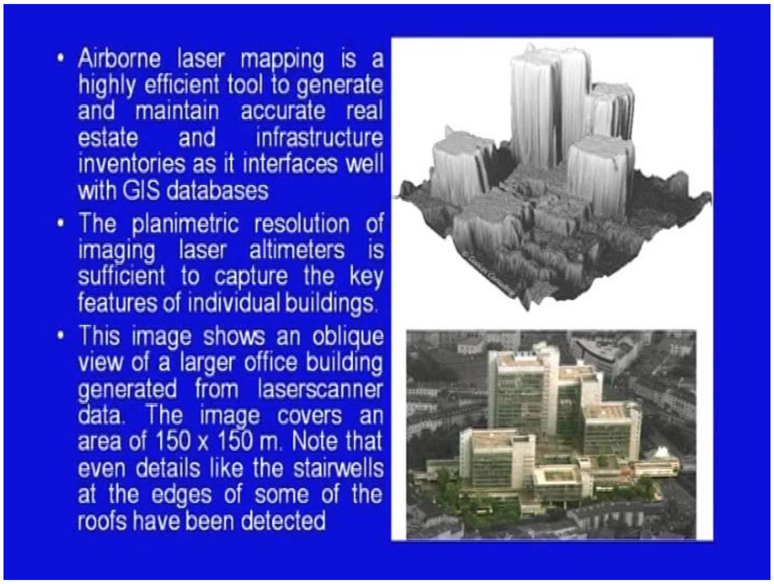


Airborne laser mapping is a highly efficient tool to generate and maintain accurate real estate and infrastructure inventories as it interfaces well with GIS databases. The planimetric resolution of imaging laser altimeters is sufficient to capture the key features of individual buildings. In the adjoining image, it shows a oblique view of a larger office building generated by laser scanner data. The image covers an area of 150 meters by 1 150 meters. One can note that even details like stairwells at the edges of some of the roofs have been detected. It has very wide applications in the area of ecology and environment.

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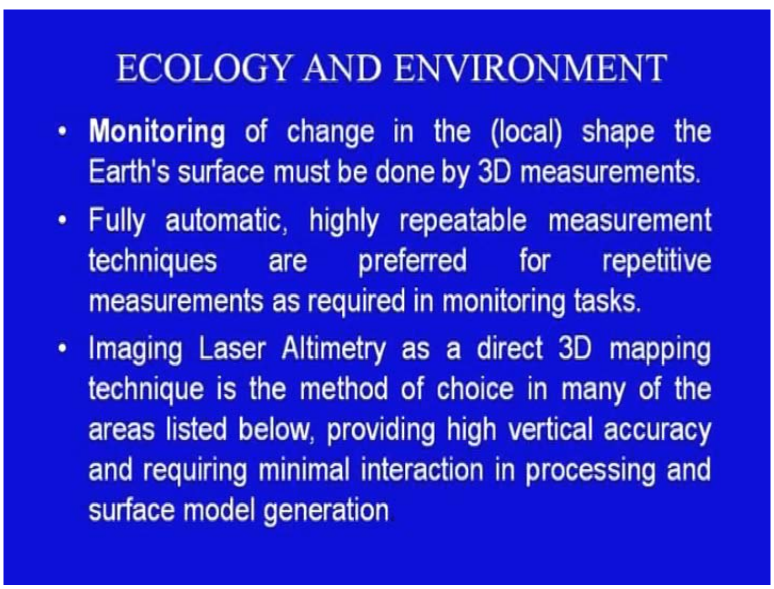

Monitoring of change in the local shape of the Earth's surface must be done by 3D measurements. Fully automatic highly repeatable measurement techniques are preferred for repetitive measurements as required in monitoring tasks. Imaging laser altimeter is a direct 3D mapping technique is the method of choice in many of the areas listed providing high vertical accuracy and requiring minimal interaction in processing and surface model generations. So, let us look at which are these application areas.

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These are ice sheets and glaciers, erosion, volcanic activity, tree height, canopy density and biomass, beaches and sand dunes, water depth in rivers and coastal zones, tidal flats wetlands. Here, one can see a information which has been generated for a open coast mine.

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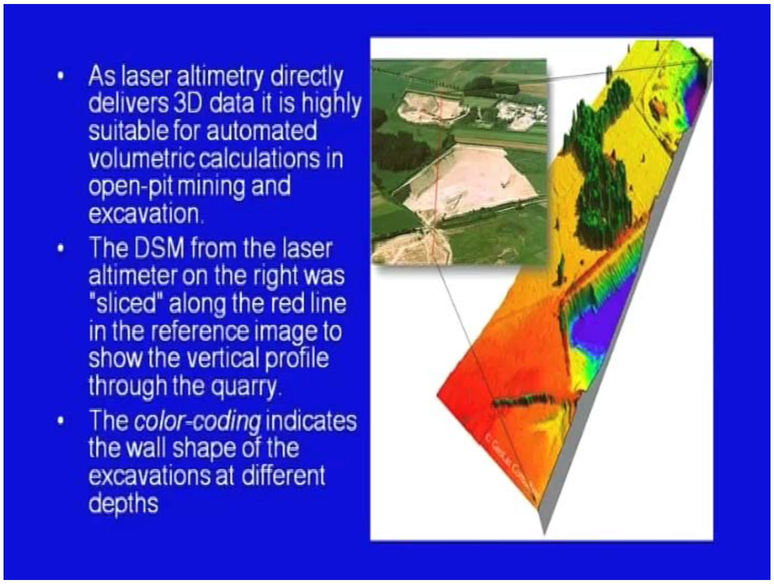
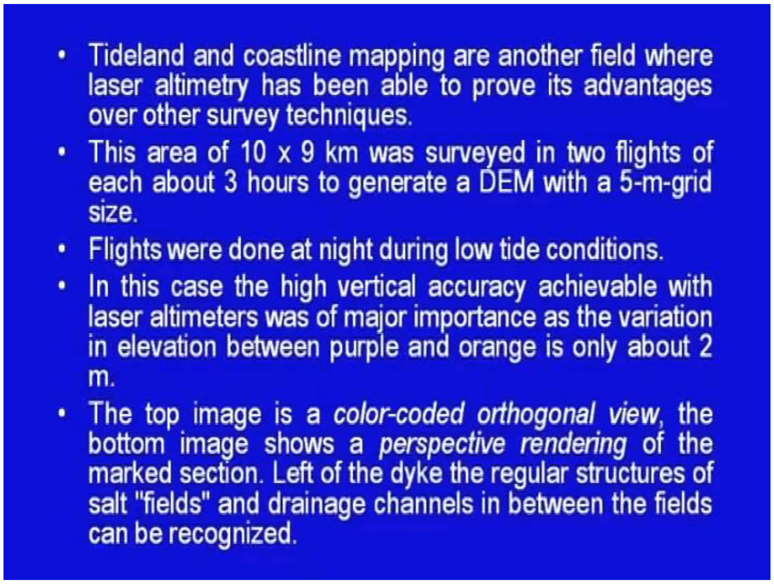



As laser altimetry directly delivers a 3D data, it is highly suitable for automated volumetric calculations in a open pit mining and excavation. The digital surface model from the laser altimeter on the right was sliced along the red line in the reference image to show the vertical profile through the quarry. The color coding indicates the wall shape of the excavation at different depths.

(Refer Slide Time: 41:02)




Tideland and coastal line mappings are another field where laser altimetry has been able to prove its advantage over the other surveying techniques. In this area of 10 by 9 kilometers which was surveyed in 2 flights each of 3 hours to generate a DEM of 5meter grid size. Flights were done at night time during low tide condition.

In this case, the high vertical accuracy achievable with laser altimeters was one of the major importance as the variation in elevation between purple and orange is about 2 meters. The top image is a color coded orthogonal view of the bottom image while the bottom image shows a perspective rendering of the marked section. Left of the dyke, the regular structures of the salt fields and the drainage channels in between the fields can be recognized. Another area where laser altimetry is providing is in mathematical modeling.

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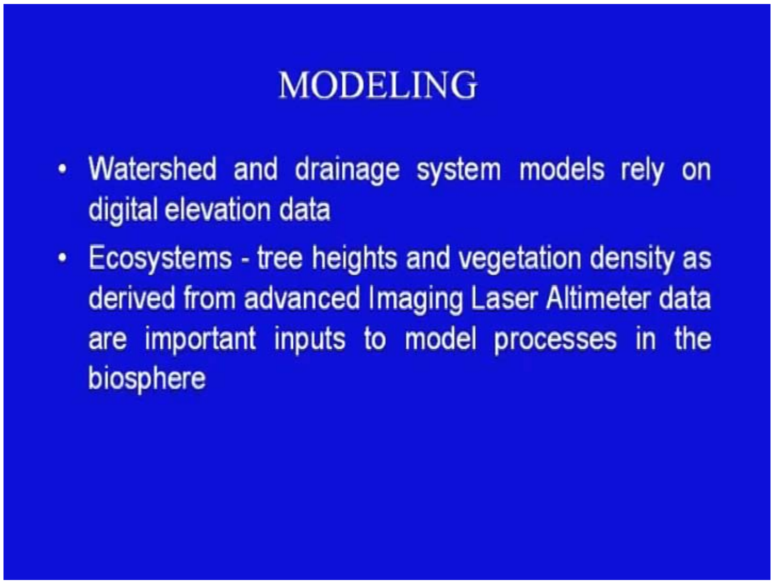


Watershed and drainage system models rely on digital elevation data. In ecosystems, tree heights and vegetation density as derived from advanced imaging laser altimeter data are important inputs to model processes in the biosphere.

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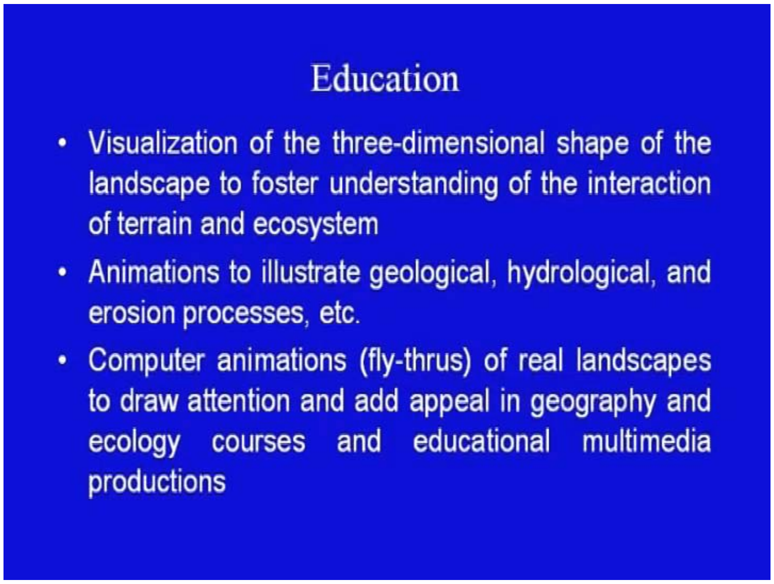


It has found lot of use in the area of education as it can provide visualization of the 3 dimensional shape of the landscape to foster understanding of the interaction of terrain and ecosystem. Animations to illustrate geographic geological, hydrological and erosion processes. Computer animations that is fly-thrus of real landscape to draw attention and add appeal in geography and ecological courses and educational multimedia productions.

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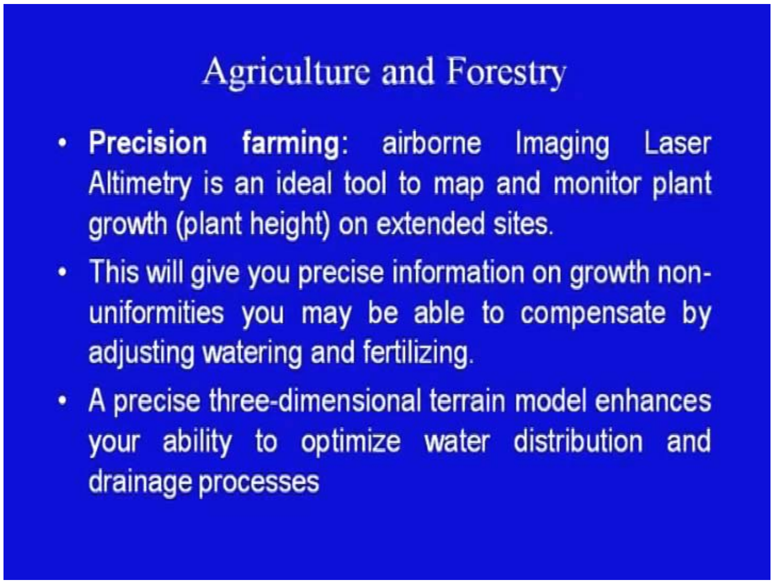


In the area of agriculture and forestry, it has found its use in the following areas: precision farming - airborne imaging laser altimetry is an ideal tool to map and monitor plant growth that is plant height on extended sites. This gives you the precise information on the growth and non-uniformities you may be able to compensate by adjusting watering and fertilization. A precise 3 D terrain model enhances your ability to optimize water distribution and drainage processes.

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Forest and park management - monitoring of canopy density and tree heights is one of the major applications of advanced imaging laser altimeter which cannot be achieved by any other automatic means as efficiently. The results may, for example, may be used to detect vegetation disease or to asses the impact of storms and to respond rapidly.

As above, digital terrain models of the forest grounds are useful to study drainage paths and for planning pathways. Laser altimetry is essentially the only technology able to provide terrain maps in forested areas.

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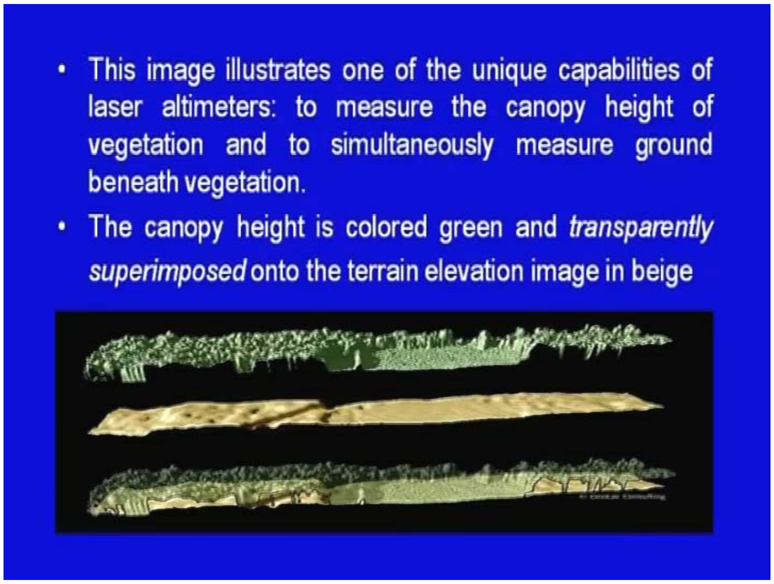


This image illustrates one of the unique capabilities of laser altimeters that is to measure the canopy height of the vegetation and to simultaneously measure ground beneath the vegetation. The canopy height is colored green and the transparently superimposed onto the terrain elevation map in beige color.

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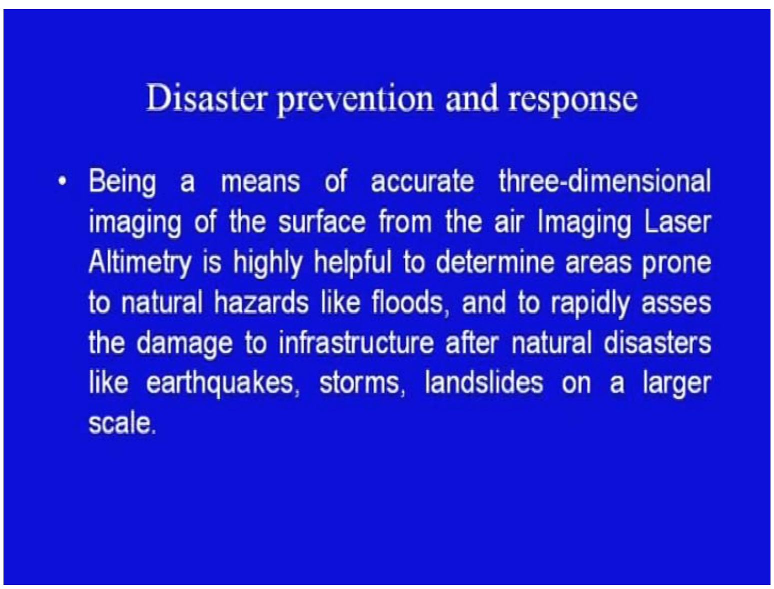


In the area of disaster response, prevention and response, it is being used as a means of accurate 3D mapping of the surface from the air. Imaging laser altimetry is highly helpful to determine areas prone to natural hazards like floods and to rapidly asses the damage to the infrastructure after natural disasters like earthquake, storms, landslides on a large scale.

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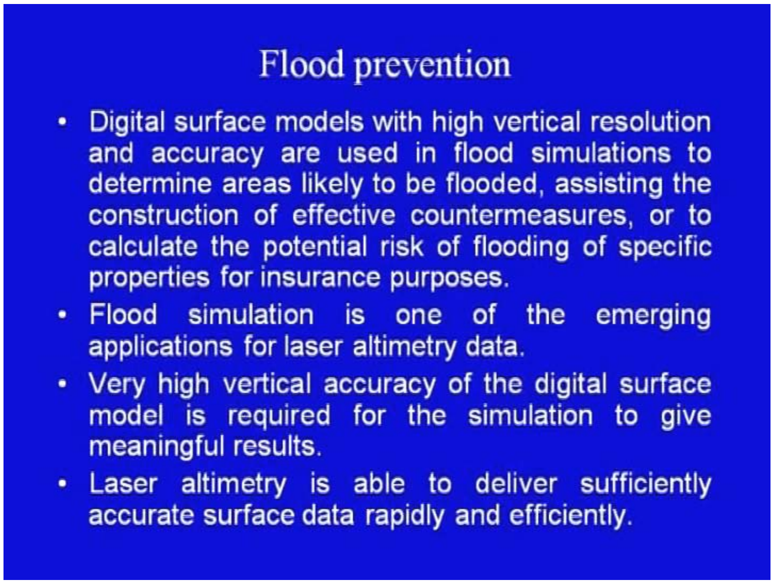


For flood prevention, digital surface models with very high vertical resolution and accuracies are used in flood simulation to determine areas to be flooded assisting the construction of effective countermeasures or to calculate the potential risk of flooding of specific properties for insurance purposes.

Flooding simulation is one of the emerging applications of laser altimetry data. Very high vertical accuracy of the digital surface model is required for the simulation to give meaningful results. Laser altimetry is able to deliver sufficiently accurate surface data rapidly and efficiently.

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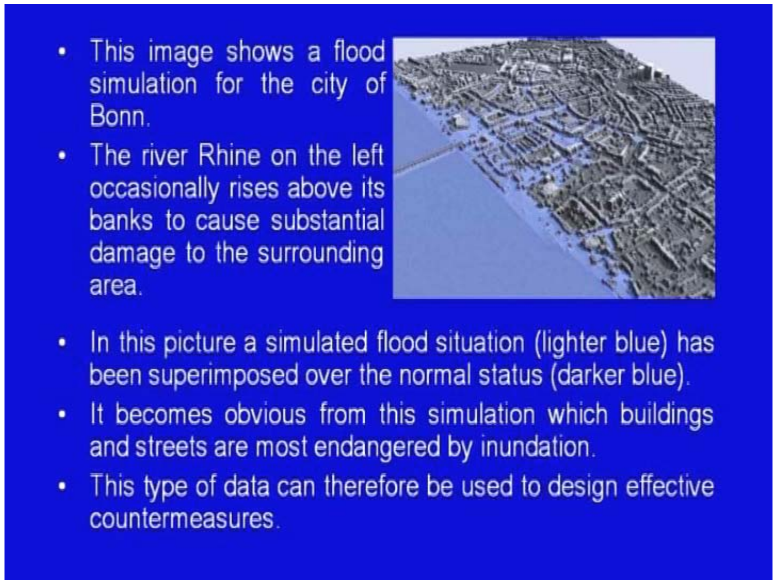


This image shows a flood simulation for the city of Bonn. The river Rhine on the left occasionally rises above its banks to cause substantial damage to the surrounding area.
In this picture, a simulated flood situation that is a light blue has been superimposed over the normal status which is dark blue. It becomes obvious from this simulation which buildings and streets are most endangered by inundation. This type of data can therefore be used to design effective countermeasures.

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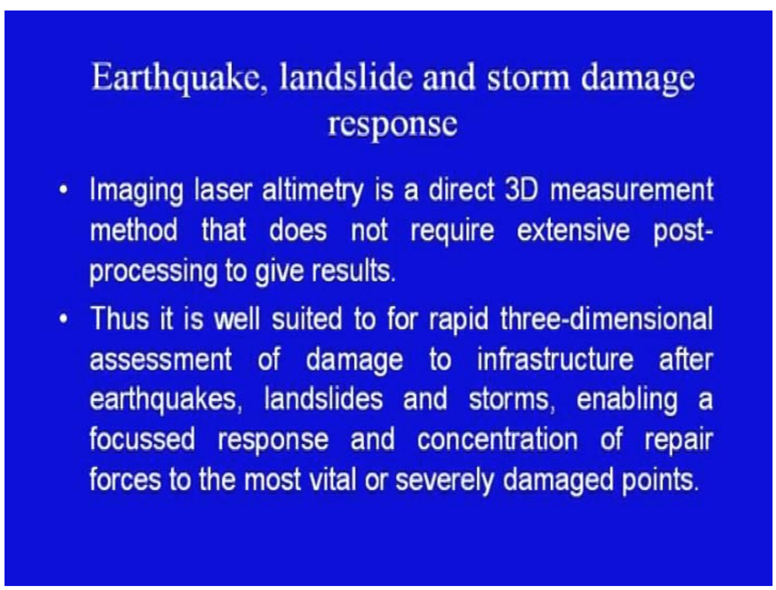


In case of earthquake, landslides and storm damage response, the imaging laser altimetry is a direct 3D measurement method that does not require extensive post processing to give results. Thus, it is well suited for rapid 3D dimensional assessment of damage to infrastructure after earthquakes, landslides and storms enabling a focused response and concentration of repair forces to the most vital or severely damaged points.

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In the area of architecture and landscape design, automatic integration of an architecture design with its surrounding represented by a high resolution 3D landscape model that includes existing vegetation, facilitates the design process and gives an accurate impression of how the design interacts with the surrounding, more realistically than the generalized terrain model generally used today.

In the area of virtual landscape sculpturing can be done on the computer based on a digital surface model that may even include existing vegetation to optimize and accelerate the design process and to give a realistic image of the results before one can use a shovel.

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By applying plant growth and erosion simulation models to an accurate current terrain model can give show you how your design may be evolved in 10 years time. Below is a example of the same. It has also found its utility in non-conventional engineering areas such as multimedia, advertising and art.

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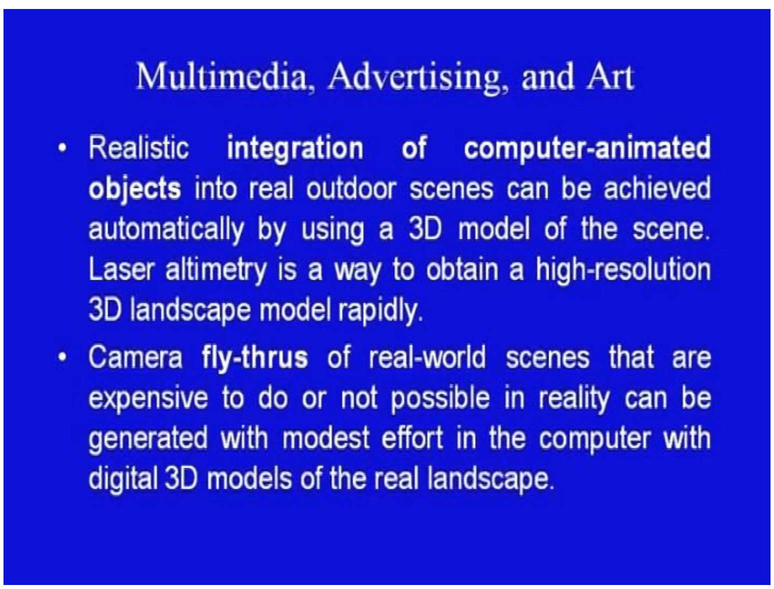


Realistic integration of computer animated objects into real outdoor scenes can be achieved automatically by using a 3D model of the scene. Laser altimetry is a way to obtain high resolution 3D landscapes model rapidly. Camera fly-thrus of the real world scenes that are expensive to do or not possible in reality can be generated with modest effort in the computer with digital 3D models of the real landscape.

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Accurate surface models of the real-world sites add excitement to computer video games: topography of real golf courses in virtual golf games even below vegetation, fantasy games situated in real forest and well known locations, flight simulation over recognizable landscapes, eye catching visual effects involving neighborhood landscape enhance the appeal of advertising media to local customers.

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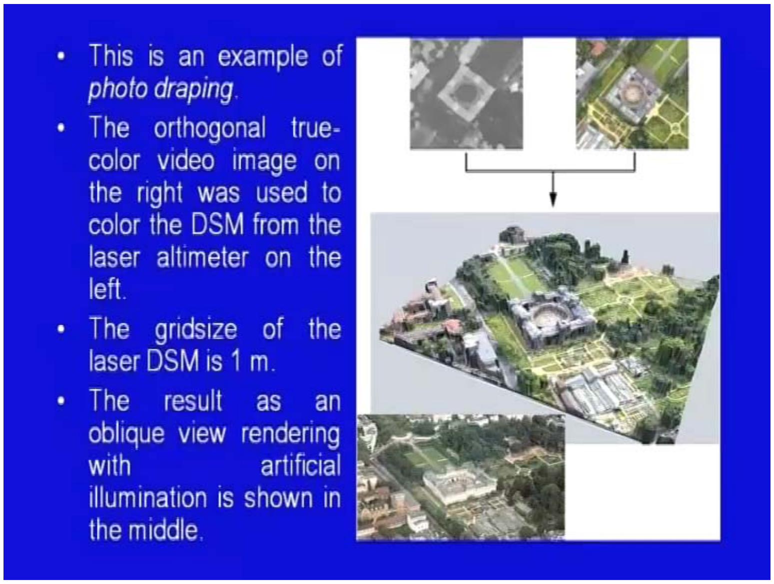

This is an example of photo draping commonly carried out in the area of multimedia. The orthogonal true color video images on the right have been used to color the digital surface model from the laser altimetry on the left. The grid size of the laser DSM is 1 meter. The result this results as an oblique view rendering with artificial illumination as shown in the middle.

Now, we come to the next type of data collection which is LIDAR.

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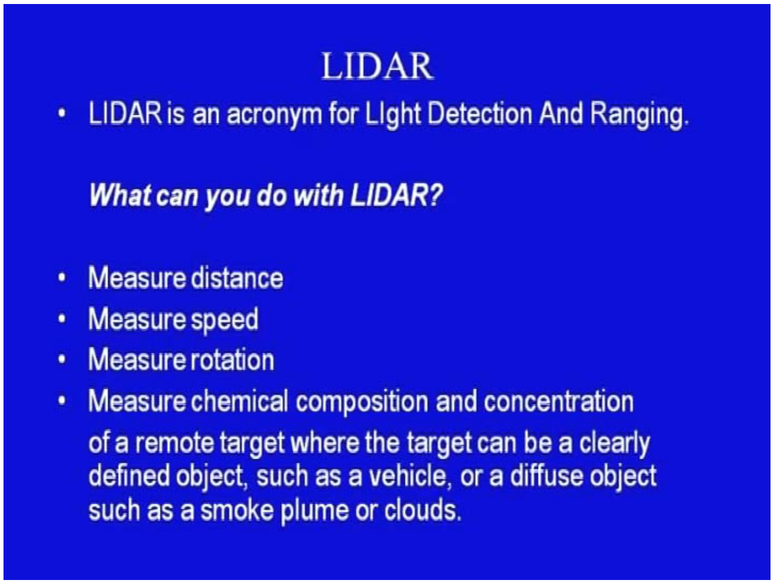


LIDAR is an acronym for light detection and ranging. Well, what can you do with a LIDAR? You can measure distance, you can measure speed, you can measure rotation, you can measure chemical composition and concentrations of a remote target where the target can be a easily defined object such as a vehicle or a diffused object such as a smoke plume or clouds.

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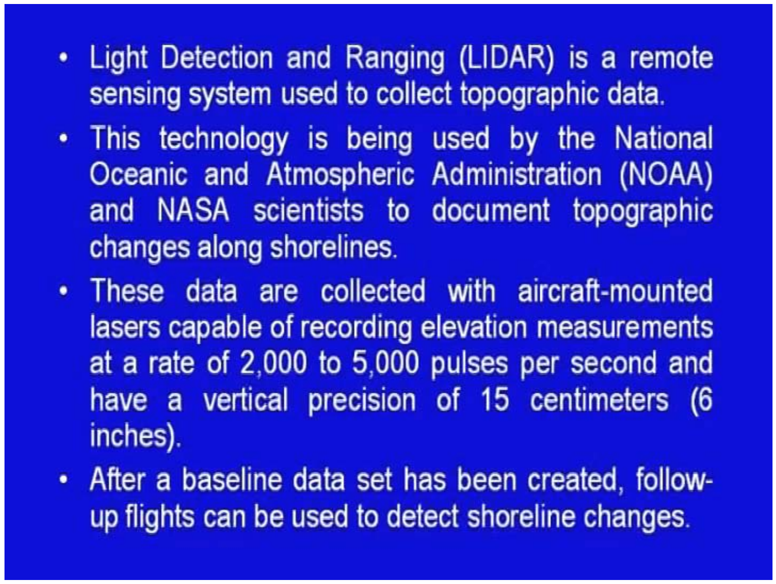


Light detection and ranging that is LIDAR is a remote sensing system used to collect topographic data. This technology is being used by NOAA and NASA scientists to document topographic changes along shorelines. These data's are collected with aircraft mounted lasers capable of recording elevation measurements at a rate of 2000 to 5000 pulses per second and have a vertical precision of about 15 centimeters that is 6 inches.
After a baseline data has been created, follow up flights can be used to detect shoreline changes. Let us look at the working principle of LIDAR.

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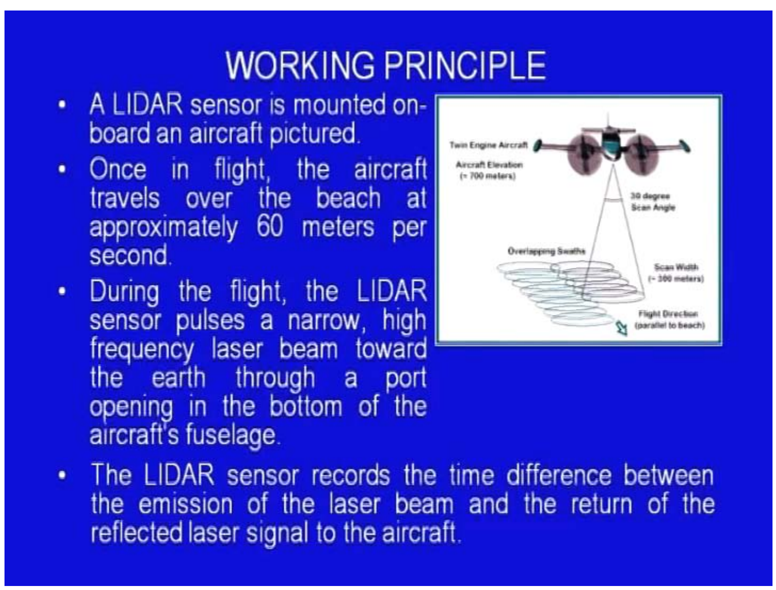

A LIDAR sensor is mounted on board and aircraft as pictured besides. Once in flight, the aircraft travels over the area approximately at 50 meters per second. During the flight the LIDAR sensor pulses a narrow high frequency laser beam towards the earth through a port opening at the bottom of the aircrafts fuselage. LIDAR sensor records the time difference between the emission of the laser beam and the return of the reflected laser signal to the aircraft.

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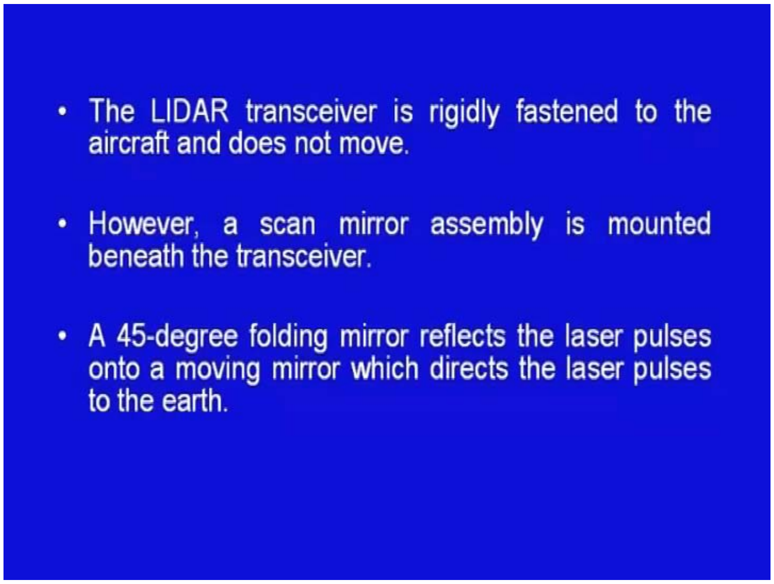


The LIDAR transceiver is rigidly fastened to the aircraft and does not move. However, a scan mirror assembly is mounted below the transceiver. A 45 degree folding mirror reflects the pulse laser pulses onto a moving mirror which directs the laser pulses to the earth.

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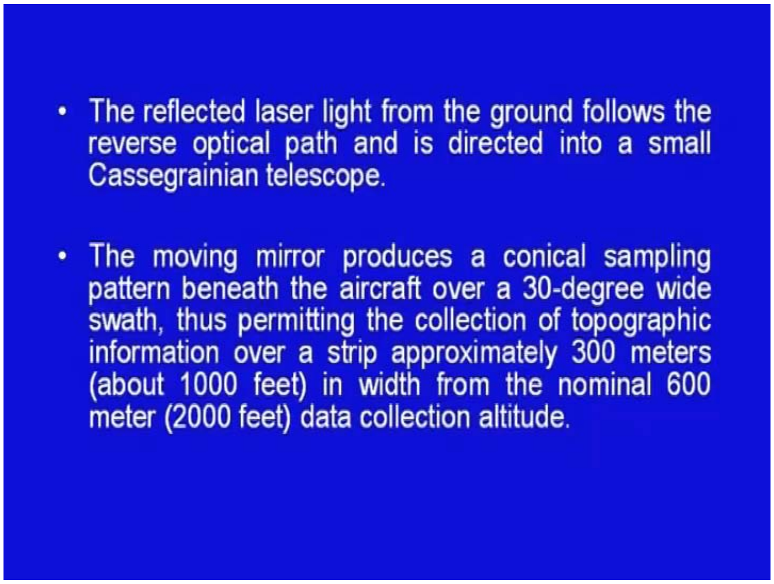


The reflected laser path from the ground follows the reverse optical path and is directed into a small Cassegrainian telescope. The moving mirror produces a conical sampling pattern beneath the aircraft over a 30 degree wide swath; thus, permitting the collection of topographic information over a strip approximately 300 meters in width and from a nominal height of 600 meters above the ground.

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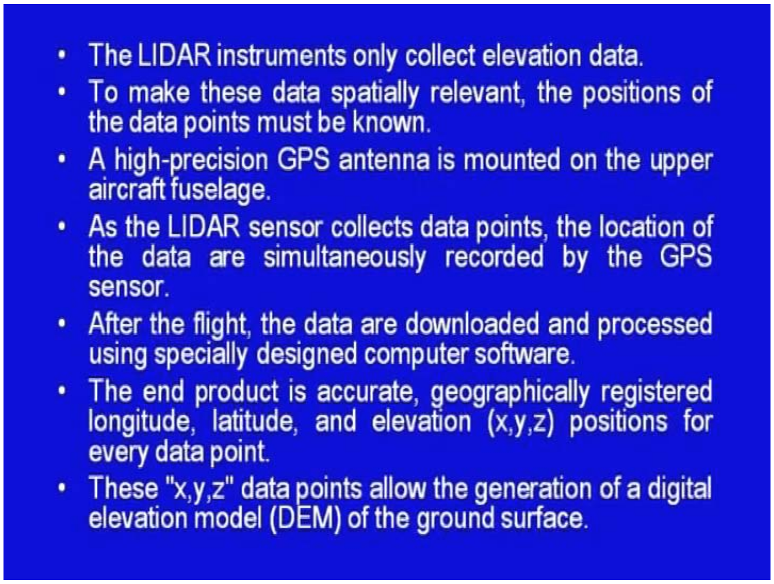


LIDAR instruments only collect elevation data. To make these data spatially a relevant, the positions of the data points must be known. A high precision GPS antenna is mounted on the upper aircraft fuselage. As the LIDAR sensor collects data, the locations of the data are simultaneously recorded by the GPS sensor. After the flight the data are downloaded and processed using specially designed computer software. The end product is an accurate geographically registered longitude, latitude and elevation positions for every point.

These x and y, z data points allow the generation of a digital elevation model on the ground surface. Having collected the data, the next task is how do we interpret the information so received. So, let us look at interpreting LIDAR elevation maps.

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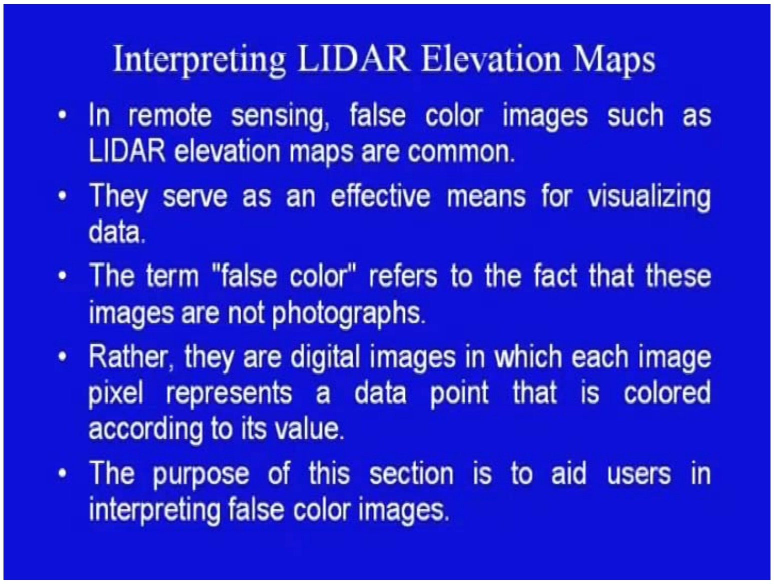


In remote sensing, false color images such as LIDAR elevation maps are common. They serve as an effective mean for visualizing the data. The term false color refers to the fact that these images are not photographs; rather, they are digital images in which each image pixel called represents a data point that is colored according to its value. The purpose of this section is to aid users in the interpretation of false color images.

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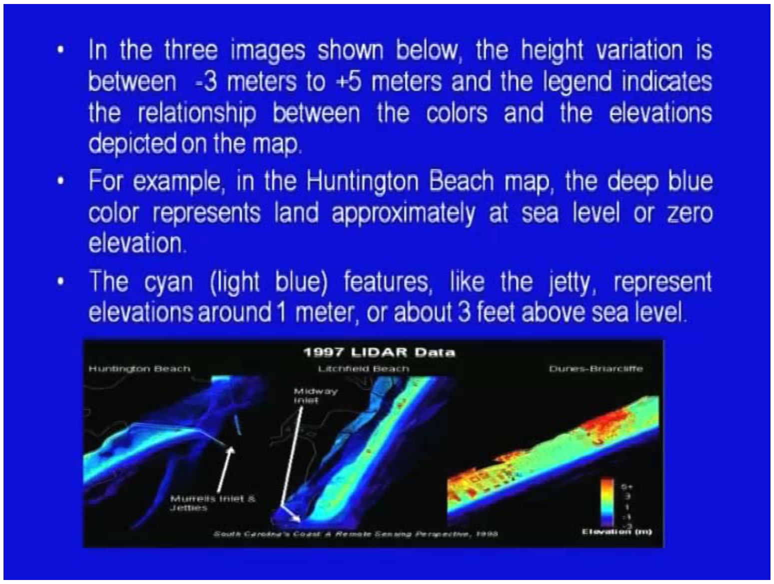


In the 3 images seen below, the height variation is between minus 3 meters to plus 5 meters and the legend indicates the relationship between the colors and the elevation depicted on the map. For example; in the Huntington Beach Beach map, the deep blue color represents land approximately at 0 level or mean sea level. The sign that is the light blue features like the jetties represent elevations around 1 meter above the sea level.

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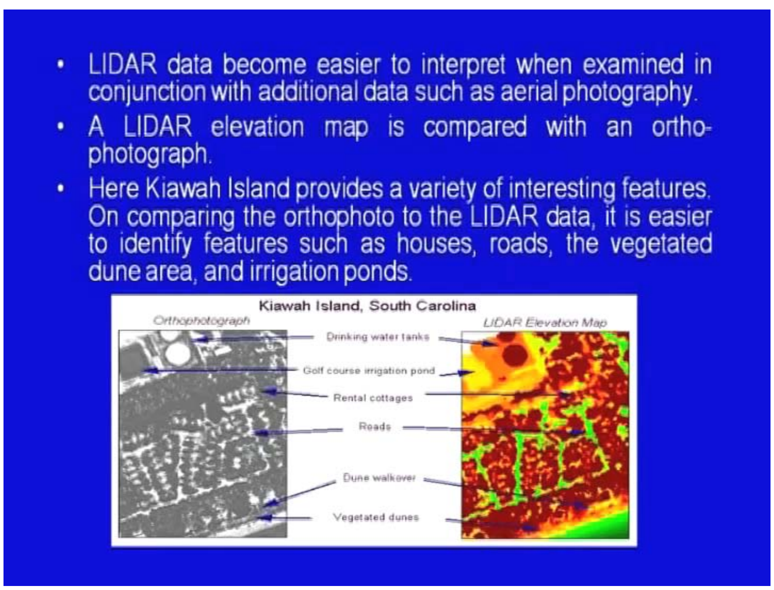


LIDAR data become easily to easier to interpret when examined in conjunction with additional data such as aerial photographs. A LIDAR elevation map is compared with an ortho-photograph. Here, Kiawah Island provides a variety of interesting features. On comparing the ortho-photograph onto the LIDAR data, it is easier to identify features such as houses, roads, the vegetated dune areas and irrigation ponds.

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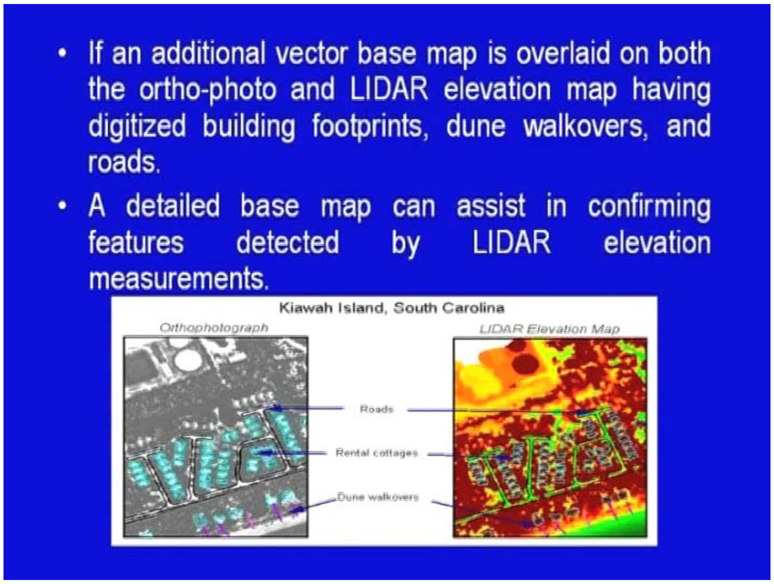


If additional vector base map is overlaid on both the ortho-photo and the LIDAR elevation map having digitized building footprints, dune walkovers and roads, a detailed base map can assist in confirming features detected by LIDAR elevation measurements.

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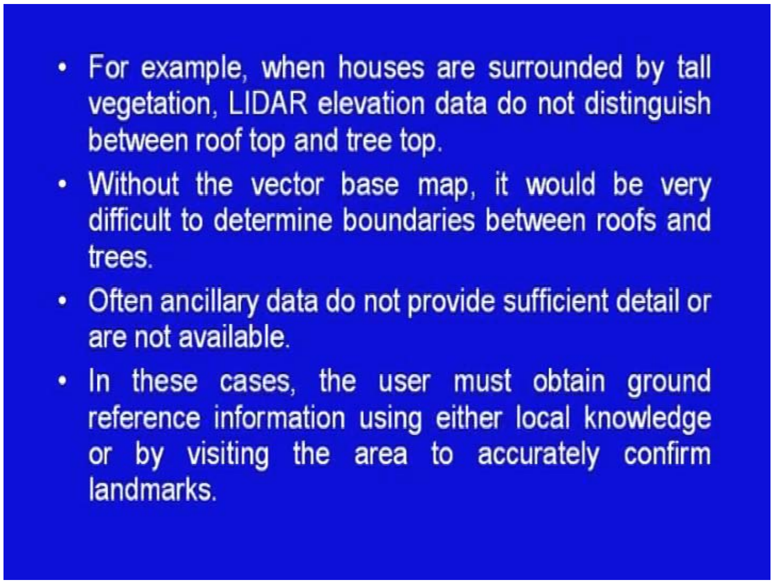

For example; when houses are surrounded by tall vegetation, LIDAR elevation data do not distinguish between roof top and the tree top. Without the vector base map, it would be very difficult to determine the boundaries between roofs and trees. Often, ancillary data do not provide sufficient detail nor it is available. In these cases, the user must obtain ground reference information using either local knowledge or by visiting the area to accurately confirm landmarks.

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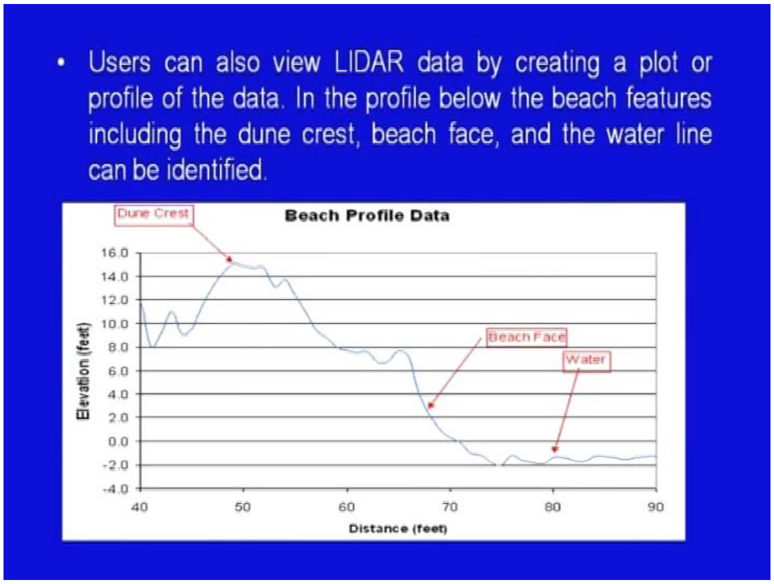


Users can also view LIDAR data by creating a plot of the profile of the data. In this profile below, the beach features including the dune crest, beach face and the water line can be determined.

Now, we come to the next section that is ground based data collection systems. In this, one of the main equipment is ground penetrating radar.

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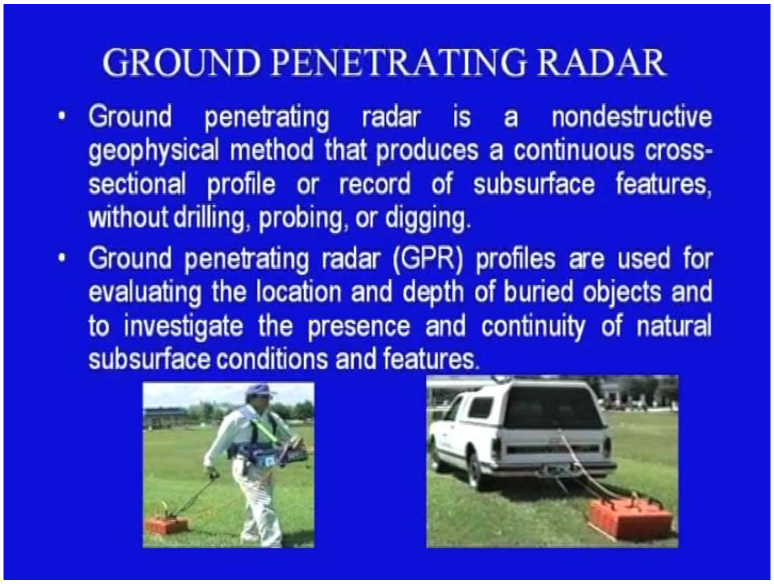


Ground penetrating radar is a nondestructive geophysical method that produces a continuous cross section profile or record of subsurface features without drilling probing or digging. The ground penetrating radar or in short GPR profiles are used for a evaluating the location and depths of buried objects and to investigate the presence and continuity of natural subsurface conditions and features.

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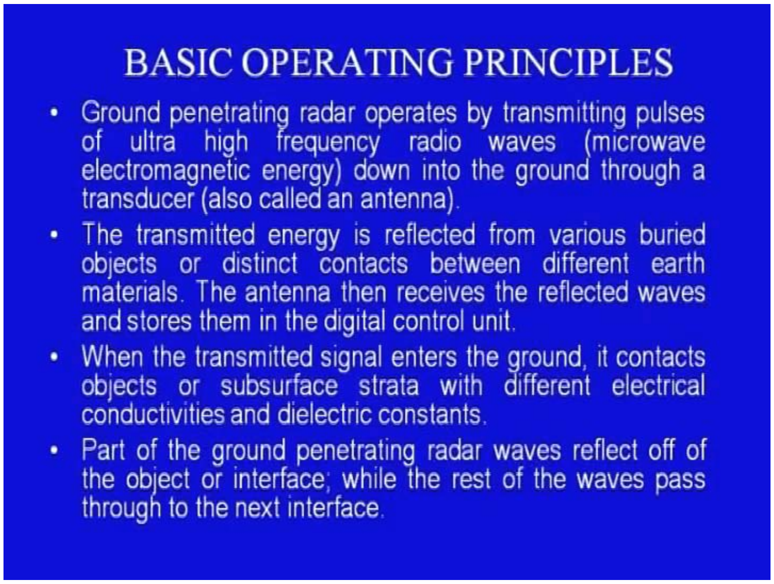


Ground penetrating radar operates by transmitting pulses of high ultra high frequency radio waves that is microwave electromagnetic energy down into the ground through a transducer called an antenna. The transmitted energy is reflected from various buried objects and distinct contacts between different earth materials. The antenna then receives the reflected waves and stores them in the digital control unit.

When the transmitted signal enters the ground, it contacts the object or subsurface strata with different electrical conductivities and dielectric constants. Part of the ground penetrating radar waves reflect off of the subject of the object or interface; while, the rest of the waves pass through the next interface.

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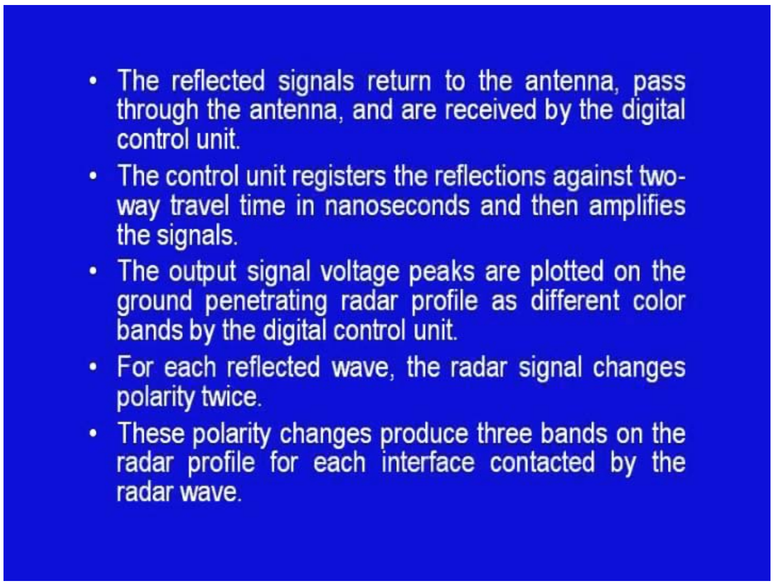


The reflected signals return to the antenna, pass through the antenna and are received by the digital control unit. The control unit registers the reflections against 2 wave time signal in nanoseconds and then amplifies the signals. The output signal voltage peaks are plotted on the ground, penetrating radar profile as band by the digital control unit. For each reflected wave the radar signal changes polarity twice. These polarity change produces 3 bands on the radar profile for each interface contacted by the radar wave.

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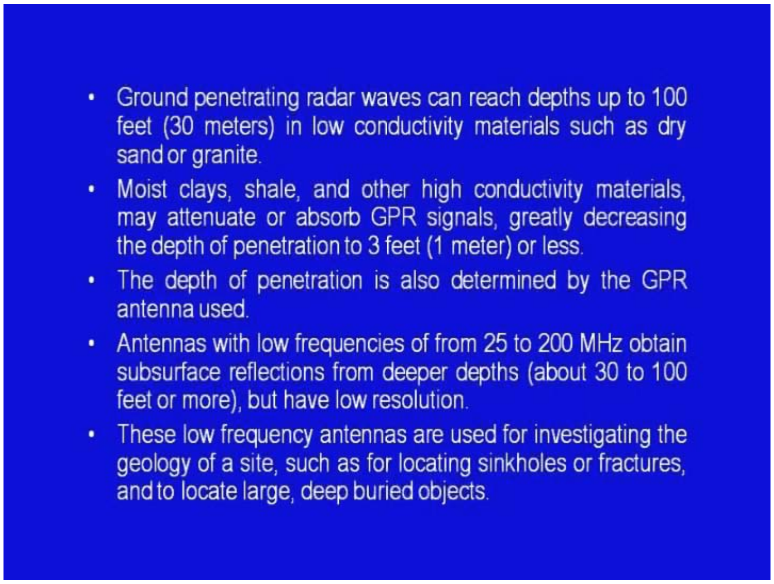


Ground penetrating radar waves can reach up to a depth of 100 feet or 30 meters in low conductivity materials such as dry sand or granite, moist clays shales and other high conductivity materials may accentuate may attenuate or absorb GPR signals greatly decreasing the depth of penetration to 3 feet that is 1 meter or less.

The depth of the penetration is also determined by the GPR antenna used. Antennas with low frequencies ranging from 25 to 200 megahertz obtain subsurface reflections from deeper depth about 30 to 100 feet or more. But have low resolution in terms of information contain. These low frequency antennas are used for investigating the geology of a site such as for locating sinkholes or fractures and to locate large deep buried objects.

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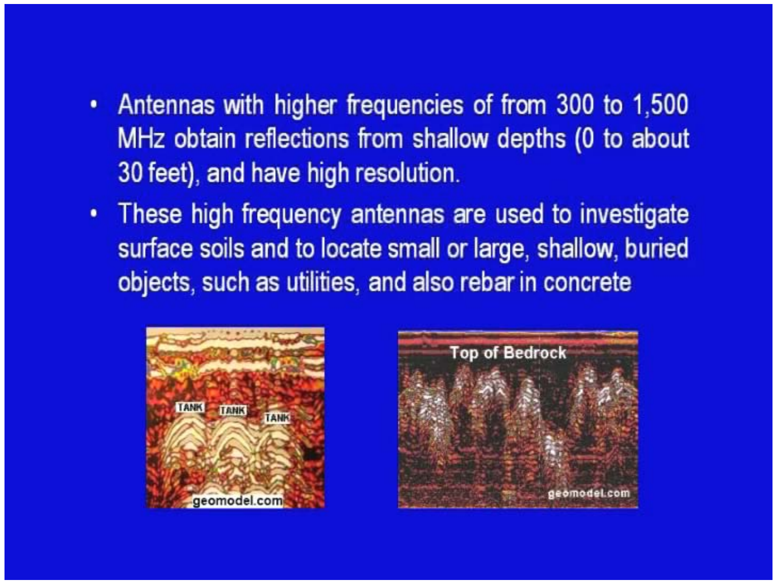


Antennas with higher frequencies ranging from 300 to 1500 megahertz obtain reflection from shallow depths ranging between 0 to 30 feet and have high resolution. These high frequency antennas are used to investigate sub-soils and to locate small or large buried shallow buried objects such as utilities and also rebar in concrete.

In this, one can see on the left hand side we have a high frequency antenna which has been used to obtain the information regarding 3 tanks which are buried below the ground surface; whereas, on the right hand side 1 can see the profile of the GPR using low frequency antennas. The manner in which the soil profile is changing can be very clearly depicted. With this knowledge of different types of input data available, in my next session I would like to discuss the various aspects related to classification of inform.