**Modern Surveying Techniques**

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**Lecture -8**

**Sensors and Platform**

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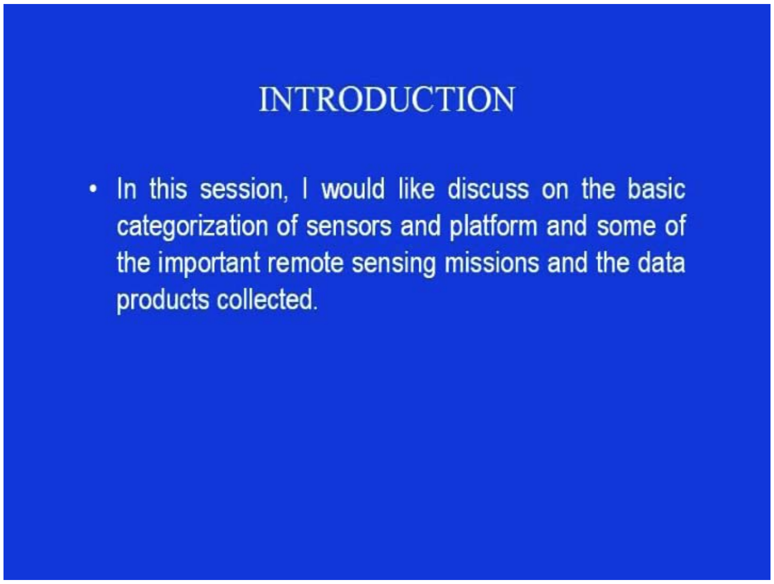


In this session I would like to discuss on the basic categorization of sensors and platforms and some of the important remote sensing missions and the data products collected.

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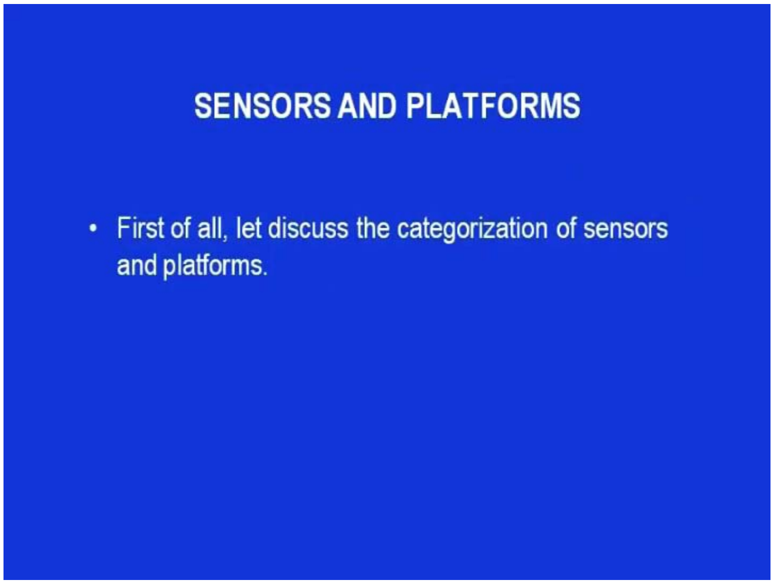


First of all, let us discuss the categorization of sensors and platforms.

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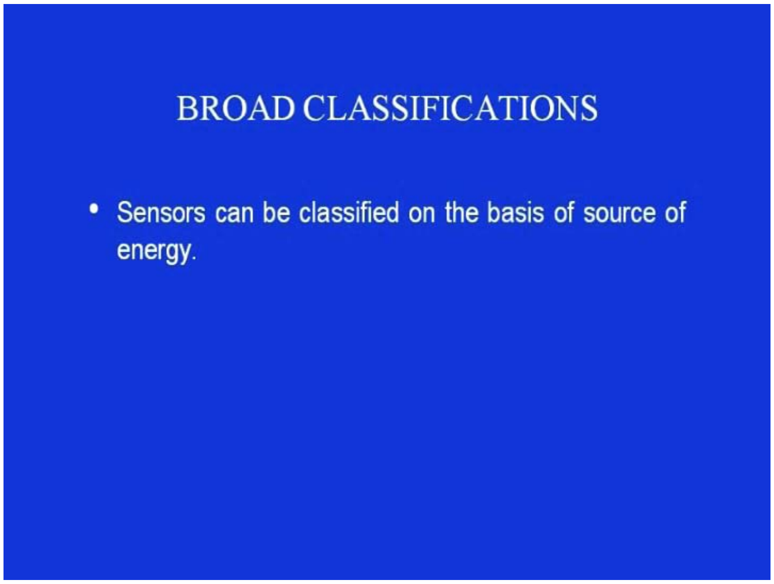


Broad classification: sensors can be classified on the basis of the source of energy.

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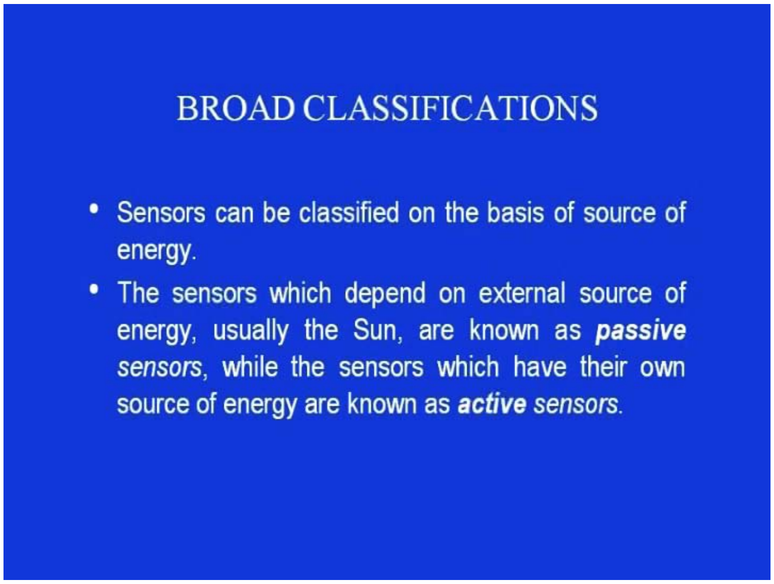


The sensors which depend on the external source of energy, usually the sun are known as passive sensors, while sensors which have their own source of energy are known as active sensors. Let us look at the example of our normal photographic camera.

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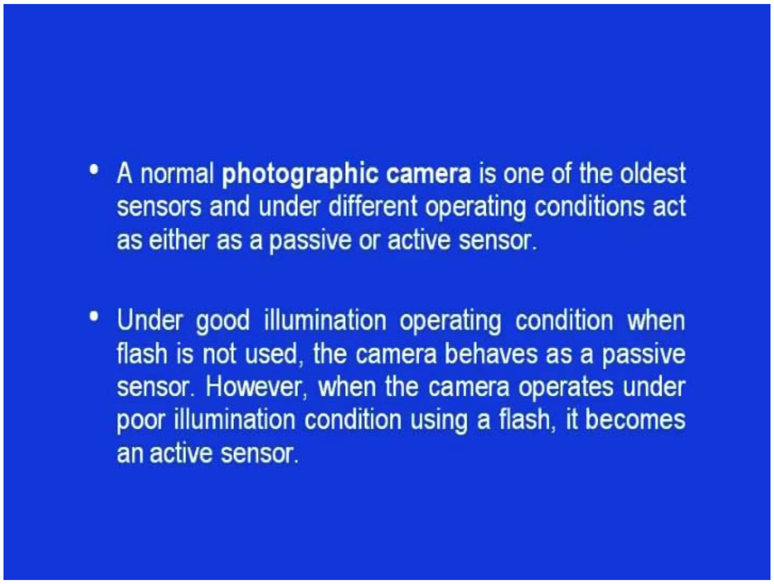


The normal photographic camera is one of the oldest sensors and under different operating conditions act as a passive or active sensor. Under good illumination conditions when the flash is not used, the camera behaves as a passive sensor. However, when the camera operates under poor illumination conditions using a flash, it becomes an active sensor.

So, with this example the user should be able to understand the categorization of the sensors on the basis of energy source. Now, let us look at the categorization of sensor on the basis of its position.

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Sensors placed on ground based platforms are employed for recording detailed information about the surface. The collected information may be used as reference data for subsequent analysis.
Aircrafts or helicopters which are airborne platforms are used to collect images over virtually any part of the earth's surface. Space borne platforms are satellites launched for remote sensing purposes. Under since the satellites provide repetitive coverage of an area under study, satellite's data products have wide application in various fields due to their multi spectral characteristics.

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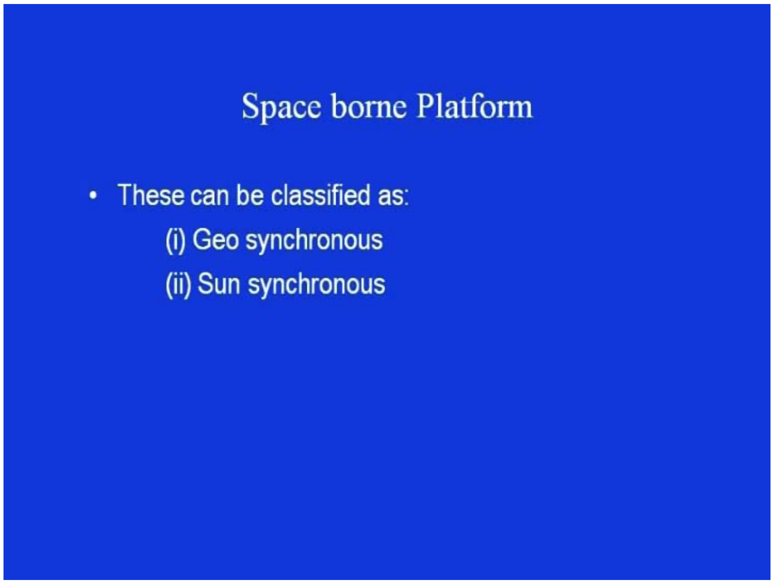


The space borne platform can be classified into 2 categories. First is geo synchronous and the sun second is sun synchronous.

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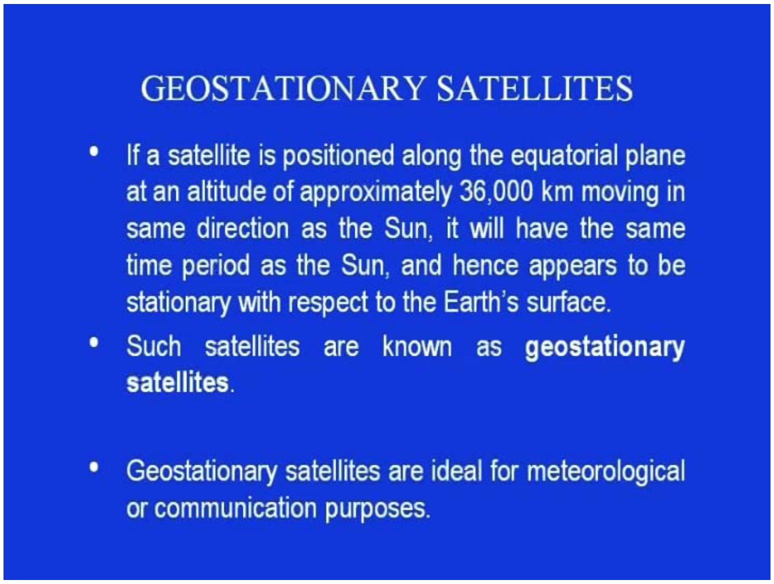


Geo synchronous satellites: if a satellite is positi1d along the equatorial plane of the earth at an altitude of approximately 36000 kilometers moving in the same direction as the sun, it will have the same time period of revolution as the sun and hence the satellite would appear to be stationary with respect to the earth's surface. Such types of satellites or platforms are known as geo synchronous. That is they are synchronized with the motion of the earth. Geo synchronous satellites are ideal for meteorological and communication purposes.

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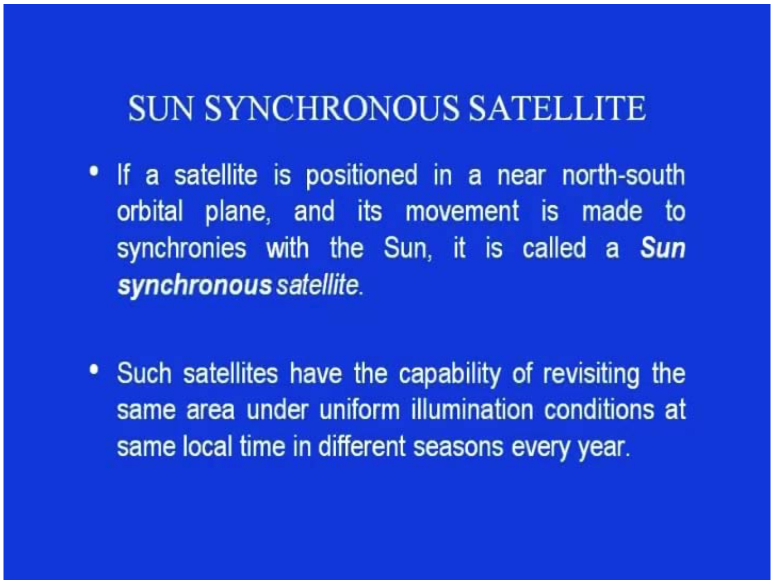


The second category of platform is the sun synchronous satellite. If the satellite is positioned in a near north-south orbital plane and its movement is made to synchronies with the sun, it is called a sun synchronous satellite. Such satellites have the capability of revisiting the same area under uniform illumination conditions at the same local time in different seasons every year.

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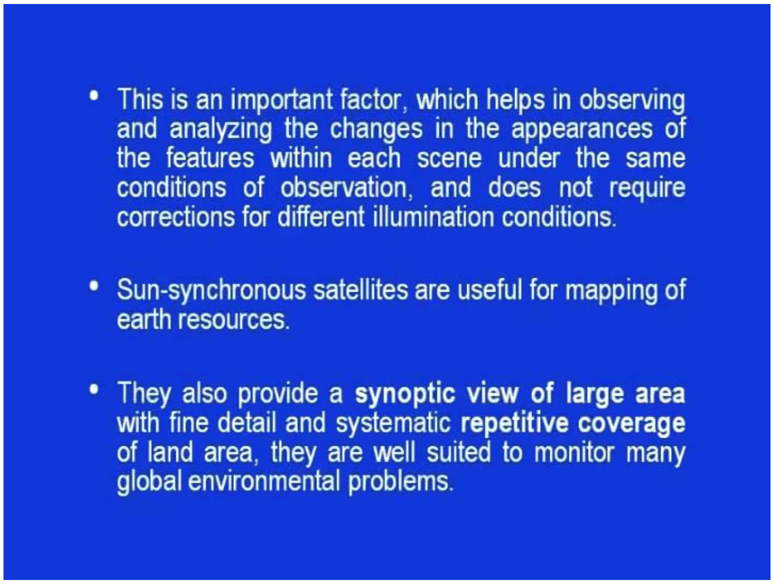


This is an important factor which helps in observing and analyzing the changes in the appearances of the feature with which each scene under the same conditions of observations and does not require correction for different illumination conditions. Sun synchronous satellites are useful for mapping of earth resources. They also provide a synoptic view of large area with fine detail and systematic repetitive coverage of the land area. They are well suited to monitor any global environmental problems.

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Now, let us look at some of the important remote sensing satellite missions. The first mission to be launched was LANDSAT by USA. Then the next one is SPOT which was launched by France and followed by IRS which is an Indian venture.
So, let us look at each of these important remote sensing missions which have been utilized for earth resources mapping.

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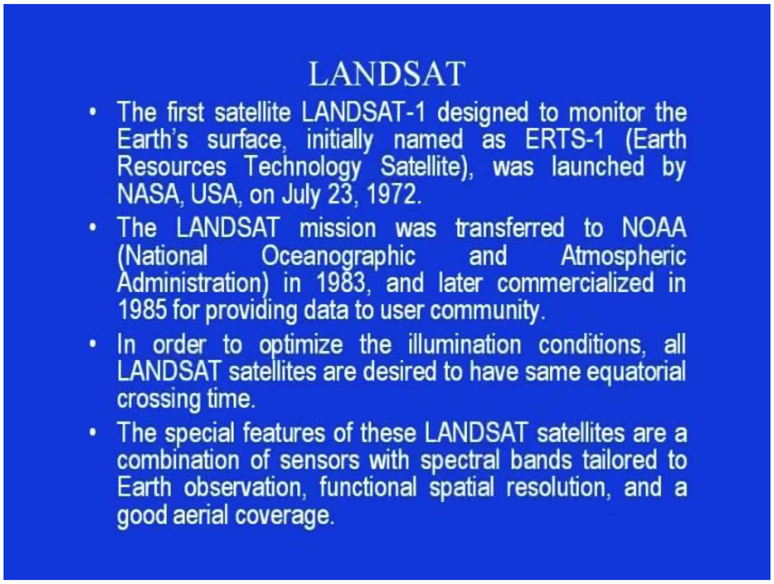

LANDSAT, the first satellite LANDSAT 1 designed to monitor the earth's surface initially named as ERTS 1. That is earth resources technology satellite was launched by NASA, USA on July 23 1972. The LANDSAT mission was transformed to NOAA that is national oceanographic and atmospheric administration in 1983 and later commercialized in 1985 for providing data to user community.

In order to optimize the illumination conditions, all LANDSAT satellites are desired to have the same equatorial crossing time. The special feature of these LANDSAT satellites are a combination of sensors with spectral bands tailored to earth observation, functional spatial resolution and a good aerial coverage. The various types of sensors carried by LAND various LANDSAT missions can be listed as follows.

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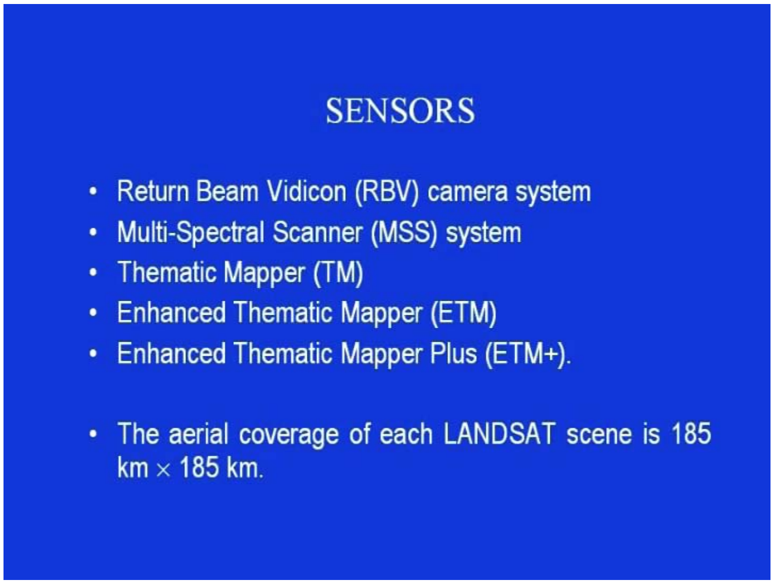


Return beam vidicon or in short RBV camera system, multi-spectral scanner or MSS system, thematic mapper or TM, enhanced thematic mapper or ETM or enhanced thematic mapper plus, ETM plus. The area coverage of each LANDSAT scene is approximately 185 kilometers by 185 kilometers.

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Various LANDSAT missions

| Satellite | Date of launch | Altitude (km) | Orbital inclination | Orbital period (min) | Time of EQ crossing | Repeat cycle (days) | Sensor | Swath Width (km) | Resolution (m) | No. of bands |
|---|---|---|---|---|---|---|---|---|---|---|
| LANDSAT-1 | 23.7.72 | 900 | 91° | 103 | 9:42 A.M. | 18 | MSS<br>RBV | 185<br>185 | 80<br>80 | 4<br>3 |
| LANDSAT-2 | 22.1.75 | 900 | 91° | 103 | 9:42 A.M. | 18 | MSS<br>RBV | 185<br>185 | 80<br>80 | 4<br>3 |
| LANDSAT-3 | 5.3.78 | 900 | 91° | 103 | 9:42 A.M. | 18 | MSS<br>RBV | 185<br>185 | 80<br>120<br>(Thermal band) 40 | 5<br>1 |
| LANDSAT-4 | 16.7.82 | 705 | 98.2° | 99 | 9:45 A.M. | 16 | MSS<br>TM | 185<br>185 | 75<br>30<br>(120 for Band 6) | 4<br>7 |
| LANDSAT-5 | 1.1.84 | 705 | 98.2° | 98.9 | 9:45 A.M. | 16 | MSS<br>TM | 185<br>185 | 75<br>30<br>(120 for Band 6) | 4<br>7 |
| LANDSAT-6 | 5.10.93 | 705 | 98.2° | 98.9 | 10:00A.M<br>- | 16 | PAN<br>TM<br>(ETM) | -<br>185<br>- | 13 x 15<br>30<br>(120 for Band 6) | 1<br>7 |
| LANDSAT-7 | 15.4.99 | 705 | 98.2° | 98 | 10:00 A. M. | 16 | ETM +<br>TM<br>Thermal<br>PAN | -<br>185<br>- | 30 m<br>60 m<br>15 | 6<br>1<br>1 |

This particular table gives us the details of the various LANDSAT missions in terms of the date of launch, the altitude that is the height above the earth's surface where it is revolving, its orbital inclination that is with respect to the equatorial plane measured anticlockwise, the orbital plane inclinations are defined. Further, it also typifies the orbital period that is the time required to complete one complete revolution around the earth's surface in the north south orbital plane.
While it is cross it is traversing from north to south, the satellite collects data and the time of equatorial crossings have been also provided.

Since the satellite and the earth both are revolving, it is possible that we can revisit the same area after the given number of days. So, the repeat cycle for each of the missions have been shown; along with that the sensors which the individual LANDSAT missions have carried. The data has been collected for a specified region; this is what is called as the swath width. For all the LANDSAT mission, this has been kept has constant as 185 kilometers by 185 kilometers.

The resolution with which the data has been collected, has been shown against each of the mission and against each sensor the number of bands in which the data has been collected. So, if we look at LANDSAT 1, this was launched on 23 July 1972 flying at an altitude of 900 kilometers at an orbital inclination of 91 degrees having an orbital period of 103 minutes crossing the equator at 9:42 AM. It revisits area after 18 days and carried 2 sensors which were MSS and RBV having a special resolution of 80 meters. The MSS had 4 spectral bands, while the RBV camera system had 3 bands. The same features are repeated for LANDSAT 2 also. This was launched on 22 of January 1975.

The LANDSAT 3 was launched in the year 1978 on fifth of March, having the same characteristics except that the RBV had a thermal band of 40 meters and the number of MSS bands were enhanced from 4 to 5; while, the RBV was reduced from 3 to 1. The major change in the sensor technology took place with the launching of LANDSAT 4 in 1982 on 16 of July. This particular satellite flew at an altitude of 705 kilometers at an inclination of 98.2 degrees having an orbital period of 99 minutes and crossing the equator at 9:45 AM with a repeat cycle now reduced to 16 days.

This satellite carried a new sensor which is known as the thematic mapper or in short as TM along with the MSS. However, the RBV camera system was now abounded. The MSS had a resolution of 75 meters, whereas, TM has a resolution of 30 meters except for band number 6 where the resolution is 120 meters. The MSS has 4 bands, while TM has 7 bands.

The LANDSAT 5 was launched in 1984 with similar characteristics. The same got enhanced in for LANDSAT 6 which was launched in 1993 wherein, the MSS was discarded and a panchromatic band was introduced with the along with a new sensor which was called as ETM. The coverage of these sensors remained as 185. However, the pixel resolution for PAN was 13 meters by 15 meters, for ETM it was 30 meters and also for ETM it was 30 meters. PAN had only 1 spectral band, whereas, the other two had 7. LANDSAT 7 which was launched in the year 1999 had the same orbital parameters.

However, there was a thermal data which was included which had a spatial resolution of 60 meters and ETM sensor now had 6 bands instead of 1 or 7. Having looked at the various parameters related to the orbit, the coverage area, the sensors, the spectral bands in which they are collecting the information; now, let us look at their specifications of the various sensors which have been onboard.

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Sensors on board various Landsat mission

| Sensor | Band | Spectral range (μm) | Application |
|---|---|---|---|
| RBV | 1 | 0.475 - 0.575 | |
| | 2 | 0.580 - 0.680 | |
| | 3 | 0.090 - 0.830 | |
| | 4 | 0.505 - 0.750 | |
| MSS | 1 | 0.5 - 0.6 | Emphasizes sediment-laden water and delineates areas of shallow water |
| | 2 | 0.6 - 0.7 | Emphasizes cultural details |
| | 3 | 0.7 - 0.8 | Emphasizes vegetation boundary between land & water and land forms |
| | 4 | 0.8 - 1.1 | Penetrates atmospheric haze best, |
| | 5 | 10.4 - 12.6 | Hydrothermal Mapping |

First is RBV that is return bean vidicon which is primarily a camera system consisted of 4 bands and they were operative in the following spectral ranges varying from 0.475 to 0.575. Band 2 was operative between 0.580 to 0.680, band 3 was operative within the range of 0.090 to 0.830 and band 4 was operative in the region of 0.505 to 0.750. The next sensor which was carried by the LANDSAT mission was the MSS. MSS as a matter of fact, had 4 bands at a time. However, the first 3 LANDSAT missions carried MSS 1 to 4. Thereafter, the other missions carried MSS bands 2 to 5.

So, let us look at the spectral range of MSS 1 which is between 0.5 to 0.6 and it can be used for applications related to sediment laid in water and for delineating areas of shallow water. MSS band 2 which is operating within the region of 0.6 to 0.7, it can be used for identifying cultural details. MSS band 3 is operating within the region of 0.7 to 0.8 and it emphasis the vegetation boundaries between land and water and landform systems. Whereas, MSS 4, it is operating between 0.8 to 1.1 and the best part of this particular sensor is that it is able to penetrate through the atmospheric haze. That is the data is not corrupted by atmospheric interactions or scattering as we had discussed earlier.

MSS band 5 is operating between 10.4 to 12.6 mu meters which is in the thermal range and has been utilized for hydrothermal mapping.

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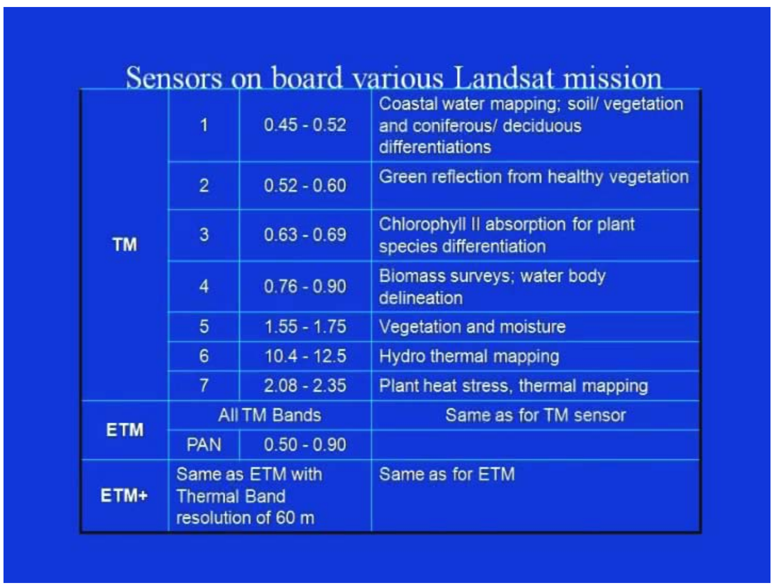

Sensors on board various Landsat mission

| | | | |
|---|---|---|---|
| TM | 1 | 0.45 - 0.52 | Coastal water mapping; soil/ vegetation and coniferous/ deciduous differentiations |
| | 2 | 0.52 - 0.60 | Green reflection from healthy vegetation |
| | 3 | 0.63 - 0.69 | Chlorophyll II absorption for plant species differentiation |
| | 4 | 0.76 - 0.90 | Biomass surveys; water body delineation |
| | 5 | 1.55 - 1.75 | Vegetation and moisture |
| | 6 | 10.4 - 12.5 | Hydro thermal mapping |
| | 7 | 2.08 - 2.35 | Plant heat stress, thermal mapping |
| ETM | All TM Bands | | Same as for TM sensor |
| | PAN | 0.50 - 0.90 | |
| ETM+ | Same as ETM with Thermal Band resolution of 60 m | | Same as for ETM |

Now, let us come to the next sensor that is thematic mapper or in short we call it as TM. TM has 7 bands. Band 1 operates in the region of 0.45 to 0.52 and can be used for coastal water mapping, soil and vegetation, coniferous and deciduous trees differentiations. TM 2 which is operating between 0.52 to 0.60 mu meters is sensitive to green reflections from healthy vegetation. TM 3 which is operating between 0.63 to 0.69 is useful for chlorophyll absorption of plant species differentiation. TM 4 which is operating between 0.76 to 0.9 can be used for biomass surveys water body delineations. TM 5 which is operating between 1.55 to 1.75 can be used for vegetation and moisture mapping. TM 6 which is a thermal band, it is operating between 10.4 to 12.5 and can be used for thermal mapping. TM 7, again this is in the visible region of the infrared portion and it is operating between 02.02 to 2.35 and can be used for plant heat stresses and thermal mapping.

The next development was the enhanced thematic mapper. Well, the enhanced thematic mapper contains all the TM bands and it can be utilized for those applications as discussed earlier for TM. However, it has one additional band and that is the panchromatic band which is operating within the region of 0.50 to 0.90. ETM plus which is the next version of ETM, has the same band specifications as of ETM except that the thermal band resolution has now been improved from 120 meters to 60 meters and the applications are similar to ETM or we can say similar to TM.

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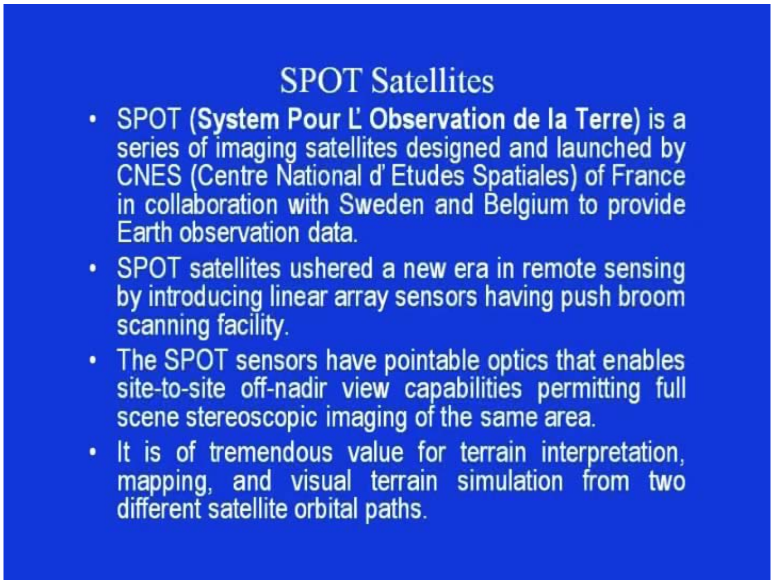


Now, we come to the next satellite system which is the SPOT satellite launched by the French. SPOT, in fact is the acronym of the full form of - System Pour L' Observation de la Terre - is a series of imaging satellites designed and launched by CNES that is Centre National d' Etudes Spatiales of France in collaboration with Sweden and Belgium to provide earth observation data.

SPOT satellite ushered a new era in remote sensing by introducing linear array sensors having push broom scanning facility. The SPOT sensors have pointable optics that enable site-to-site, off-nadir view capabilities permitting full scene stereoscopic image of the same area. It is of tremendous value for terrain, interpolation and mapping and visual terrain simulation from 2 different satellite orbital paths.

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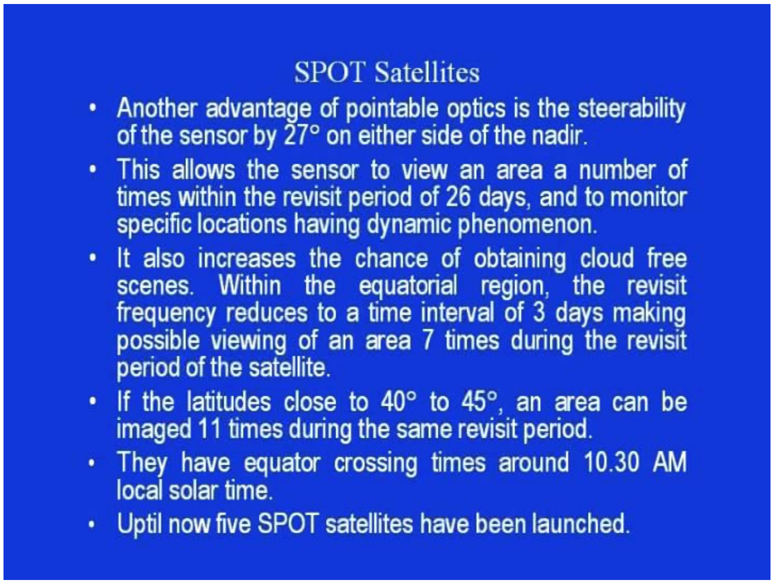


One advantage that SPOT satellites have been able to provide is that the pointable optics which allows steerability of the sensor by 27 degrees on either side of the nadir. This allows the sensor to view an area a number of times within the revisit period of 26 days and to monitor specific locations having dynamic phenomena.

It also increases the chance of obtaining cloud free scenes. It has been found that within the equatorial region, the revisit frequency reduces to a time interval of 3 days making possible viewing of an area 7 times during the revisit period of the satellite. If the satellite is at latitudes close to 40 to 45 degrees and area can be imaged 11 times during the same revisit period. They have an equatorial crossing time of around 10.30 AM, local solar time. Up till now, 5 SPOT satellites have been launched.

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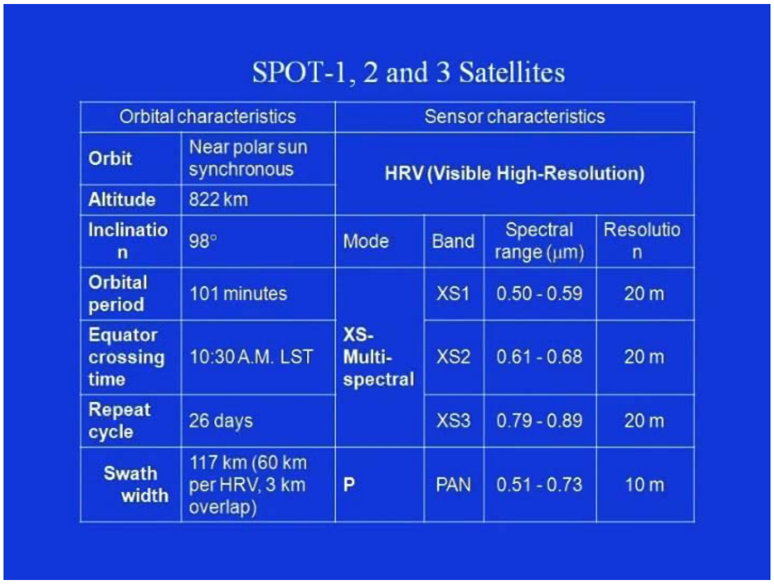
SPOT-1, 2 and 3 Satellites

| Orbital characteristics | | Sensor characteristics | | | |
|---|---|---|---|---|---|
| Orbit | Near polar sun synchronous | HRV (Visible High-Resolution) | | | |
| Altitude | 822 km | | | | |
| Inclination | 98° | Mode | Band | Spectral range (μm) | Resolution |
| Orbital period | 101 minutes | XS-Multi-spectral | XS1 | 0.50 - 0.59 | 20 m |
| Equator crossing time | 10:30 A.M. LST | | XS2 | 0.61 - 0.68 | 20 m |
| Repeat cycle | 26 days | | XS3 | 0.79 - 0.89 | 20 m |
| Swath width | 117 km (60 km per HRV, 3 km overlap) | P | PAN | 0.51 - 0.73 | 10 m |

So now, let us look at the various orbital and sensor characteristics of SPOT 1, 2 and 3 satellites. The SPOT 1, 2 and 3 satellites have a near polar synchronous, sun synchronous orbital. They are flying at an altitude of 822 kilometers at an inclination of 98 degrees having an orbital period of 101 minutes crossing the equator every time at 10:30 AM, local solar time having a revisit period of 26 days with a swath width of 117 kilometers that is 60 kilometer per sensor with a 3 kilometer overlap.

The various sensor characteristics of SPOT 1, 2 and 3 are that it carried a HRV that is visible high resolution sensor. This particular sensor could operate in 2 modes, XS that is multi-spectral and P which is panchromatic. In the XS mode, there are 3 bands in which it would collect the data. XS band 1, the spectral range is 0.5 to 0.59 with a spatial resolution of 20 meters. The band 2 operates within the region of 0.61 to 0.68 again having a spatial resolution of 20 meters, while XS 3 that is the third band operates within the spectral region of 0.79 to 0.89 again with a spatial resolution of 20 meters.

When we compare LANDSAT, we probably find that these hand a higher spatial resolution in comparison to the LANDSAT satellite system. However, the spectral ranges are more or less congruent to the LANDSAT system. The new sensor system which was introduced was the panchromatic mode that is one could get a black and white image and this was collected within the spectral range of 0.51 to 0.73 with still higher resolution of 10 meters.

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SPOT- 4 Orbital and Sensor Characteristics

| Orbital characteristics | | Sensor characteristics | | | |
|---|---|---|---|---|---|
| **Orbit** | Near polar sun synchronous | **HRVIS** | | | |
| **Altitude** | 830 km | | | | |
| **Inclination** | 98° | Mode | Band | Spectral range (µm) | Resolution |
| **Orbital period** | 101 mins | **MIR** | | 0.50 - 0.59 | 20 m |
| **Equator crossing time** | 10:30 A.M. LST | | | 0.61 - 0.68 | 20 m |
| | | | | 20 m | |
| **Repeat cycle** | 26 days | | | 1.98 - 1.75 | 10 m |
| **Swath width** | 117 km (80 km per HRV, 3 km overlap) | **Mono spectral** | **PAN** | 0.61-0.68 | 10 m |

**VEGETATION**

| Band | Spectral range (µm) | Resolution |
|---|---|---|
| **B0** | 0.43 - 0.47 | 1165 m |
| **B2** | 0.61 - 0.68 | 1165 m |
| **B3** | 0.79 - 0.89 | 1165 m |
| **MIR** | 1.58 - 1.75 | 1165 m |

SPOT 4, there were slight modifications to the sensor systems. However, the orbital characteristics remained same. In this particular mission, a new sensor was introduced which was known as HRVIS and this would operate in 2 zones of the electromagnetic spectrum. One was MIR and the other was a mono-spectral band that was the panchromatic.

MIR had 3 spectral ranges of data collection and they were more or less parallel to the one which was identified for SPOT 1, 2 and 3. A new spectral range was introduced and that was within the spectral region of 1.98 to 1.75 mu meters and the spectral spatial resolution was of 10 meters.
The panchromatic data set was collected similar to as of SPOT 1, 2 and 3.

In order to improve the mapping of vegetation which is one of the prime concerns of remote sensing to map vegetation dynamics worldwide, a new sensor called as vegetation was introduced. Vegetation had again, 4 bands of data operating at different regions of the electromagnetic spectrum. Band 0 was operating between 0.43 to 0.47 with a resolution of 1165 meters, band 2 operating between 0.61 to 0.68 with the same spatial resolution of the previous band, band 3 between 0.79 to 0.89, whereas, the MIR was operating between 1.58 to 1.75, the resolutions remaining as 1165 meters.

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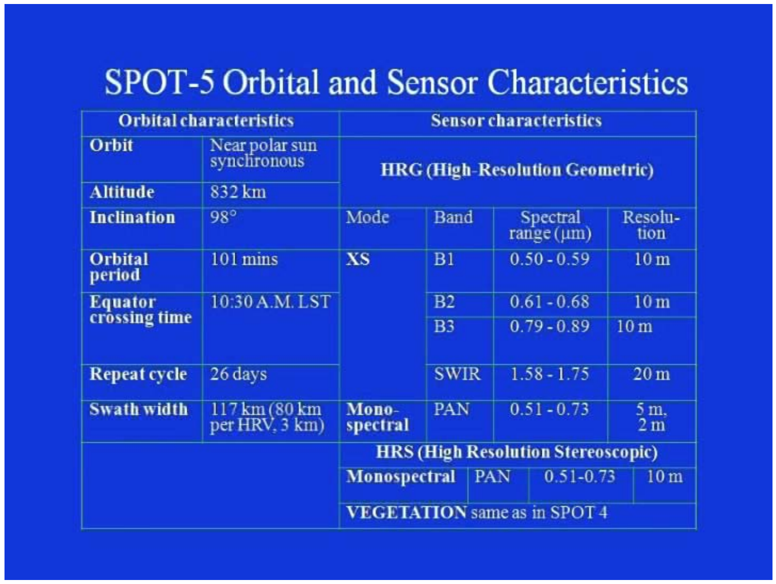

SPOT-5 Orbital and Sensor Characteristics

| Orbital characteristics | | Sensor characteristics | | | |
|---|---|---|---|---|---|
| Orbit | Near polar sun synchronous | HRG (High-Resolution Geometric) | | | |
| Altitude | 832 km | | | | |
| Inclination | 98° | Mode | Band | Spectral range (μm) | Resolu-tion |
| Orbital period | 101 mins | XS | B1 | 0.50 - 0.59 | 10 m |
| Equator crossing time | 10:30 A.M. LST | | B2 | 0.61 - 0.68 | 10 m |
| | | | B3 | 0.79 - 0.89 | 10 m |
| Repeat cycle | 26 days | | SWIR | 1.58 - 1.75 | 20 m |
| Swath width | 117 km (80 km per HRV, 3 km) | Mono-spectral | PAN | 0.51 - 0.73 | 5 m, 2 m |
| | | HRS (High Resolution Stereoscopic) | | | |
| | | Monospectral | PAN | 0.51-0.73 | 10 m |
| | | VEGETATION same as in SPOT 4 | | | |

SPOT 5 satellite, again had the same orbital characteristics. But it had different sensors now. These were much more better than the previous sensors which were available to us and thus this was known as HRG or high resolution geometric sensor. It could again operate in 2 modes that is multi-spectral and panchromatic.

In the multi-spectral there were 3 bands which were common to the previous satellites. However the MIR band was discarded and a new band was introduced that was short wave infrared region operating between 1.58 to 1.75 with a spatial resolution of 20 meters. There were some modifications to the spectral, spatial resolution of the PAN and this was that it could operate within 2 spatial resolutions - 5 meters and 2 meters.

Another sensor which was introduced in SPOT 5 and that was HRS high resolution stereoscopic. This was primarily for stereoscopic application, again having the same spectral characteristics as is for HRG with same spatial resolution of 10 meters and it carried the earlier vegetation sensor of SPOT 4.

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The next satellite mission which I will discuss probably created a revolution in the world of remote sensing. It this is the IRS satellite system launched by India under the umbrella of national resource management system that we call it as NNRMS and coordinated at the national level by the planning commission of NNMRS.

The launch of the first IRS-1A took place on 17 March 1988 which is India's first civil remote sensing satellite marking the beginning of a successful journey in the international space program.

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The 2 LISS that is linear imaging self scanning sensors on board IRS-1A have aided its capabilities in large scale application. Subsequently, the launch of IRS-1B on August 29, 1991 with the same sensors provided better repetitive coverage.

The introduction of PAN and WiFS that is wide field sensor on IRS-1C launched on December 28, 1995 and on IRS-1D in September 1997, further strengthen the scope of remote sensing application in the area of resource mapping and management urban planning forestry studies and disaster monitoring and environmental studies.

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Various IRS mission launched

| Characteristics | IRS IA & IB | IRS IC | IRS ID |
|---|---|---|---|
| Orbit | Near polar | Near polar | |
| | Sun-synchronous | Sun-synchronous | Sun-synchronous |
| Altitude | 914 km | 817 km | 821 km |
| Inclination | 99.028° | 98.69° | 98.62° |
| Orbital period | 103.192 minutes | 101.35 minutes | 100.56 minutes |
| Equatorial crossing time | 1025 hours (local) | 1030 hours (Local) | 1040 hours (Local) |
| Repeat cycle | 26 days | 24 days | 24 days, 5 days for PAN & WiFS |
| Swath width | 148 km (LISS I) | 141 km (LISS III VIS) | 141 km (LISS III VIS) |
| | 74 m (LISS II) | 148 km (LISS III SWIR) | 148 km (LISS III SWIR) |
| | | 70 km (PAN) | 70 km (PAN) |
| | | 810 km (WiFS) | 812 km (WiFS) |

This particular table shows the various IRS mission characteristics in terms of its orbit. Well, all these satellites are near polar sun synchronous satellites. However, IRS-1A and 1B flew at a height of 914 kilometers, whereas, 1C flew at a height of 817 kilometers while, IRS-1D flew at an altitude of 821 kilometers.

The inclination of IRS-1A and 1B was 99.028 degrees, whereas, for IRS-1C, it was 98.69 and for IRS-1D, it was 98.62. The orbital period of IRS-1A and 1B was 103.192 minutes, whereas, for 1C and 1D, it was 101.56 and 100.56 minutes respectively. The equatorial crossing time of IRS-1A and 1B was kept at 19:25 AM in the morning, whereas, for IRS-1C, it was 10:30 and for IRS-1D, it is 10:40 AM.

Well, the repeat cycles for IRS-1A and 1B have been 26 days, whereas, it is 24 days for IRS-1C and D. For PAN and WiFS sensors, this repetitive cycle is 5 days. The swath width that is the area coverage for IRS-1A and 1B based on the sensor configuration which was LISS 1, it is 148 and for LISS 2, it is 74. In case of IR-1C, it is 141 kilometers for LISS 3 in the visible region and 148 in LISS 3 in the SWIR, 70 kilometers for PAN and 810 kilometers for WiFS.

When we look at these specifications for the swath width for IRS- 1D; probably, the only variation is in terms of the WiFS sensor where the area coverage has now got enhanced from 810 to 812, whereas for all other sensors, the coverage has remained same.

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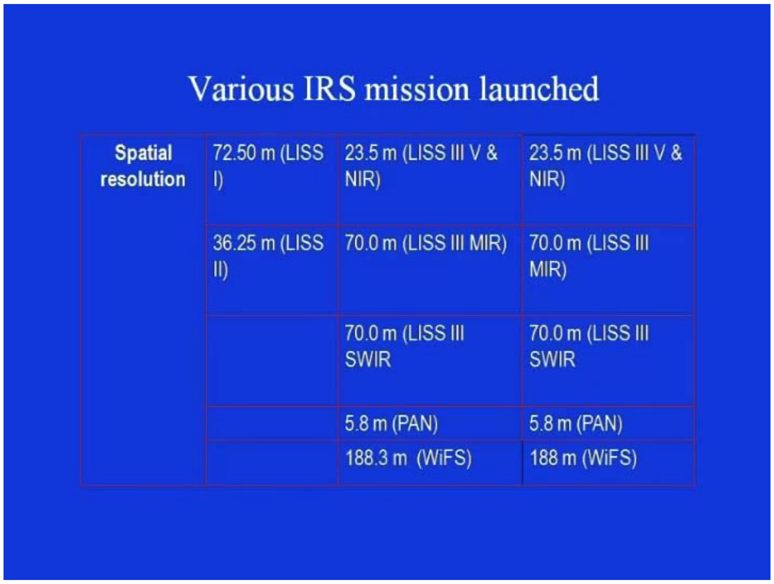


| | | | |
|---|---|---|---|
| **Spatial resolution** | 72.50 m (LISS I) | 23.5 m (LISS III V & NIR) | 23.5 m (LISS III V & NIR) |
| | 36.25 m (LISS II) | 70.0 m (LISS III MIR) | 70.0 m (LISS III MIR) |
| | | 70.0 m (LISS III SWIR | 70.0 m (LISS III SWIR |
| | | 5.8 m (PAN) | 5.8 m (PAN) |
| | | 188.3 m (WiFS) | 188 m (WiFS) |

When we look at the spatial resolution, the IRS-1A and 1D were rather various courses. However, they had 2 forms of spatial resolution. For a sensor configuration of LISS 1, it the spatial resolution was 72.5 meters but for LISS 2, it was 36.25 meters. This got further enhanced or in case of IRS-1C, wherein, it became 23 and half meters for LISS 3 and in the visible region and the infrared region, it was 70 meters for MIR and SWIR, 8.5 meters for the panchromatic, 188.3 meters for WiFS. The specifications remained same for IRS-1D in terms of spatial resolution.

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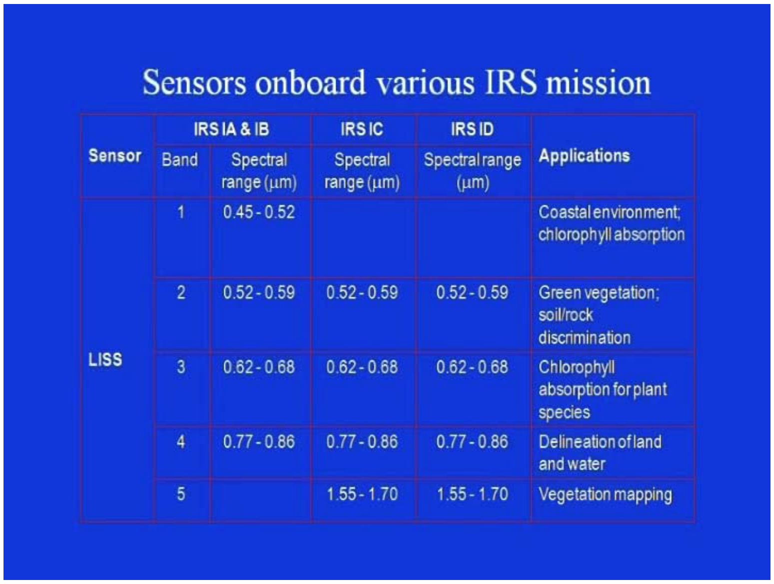
Sensors onboard various IRS mission

| Sensor | IRS IA & IB | | IRS IC | IRS ID | Applications |
|---|---|---|---|---|---|
| | Band | Spectral range (μm) | Spectral range (μm) | Spectral range (μm) | |
| LISS | 1 | 0.45 - 0.52 | | | Coastal environment; chlorophyll absorption |
| | 2 | 0.52 - 0.59 | 0.52 - 0.59 | 0.52 - 0.59 | Green vegetation; soil/rock discrimination |
| | 3 | 0.62 - 0.68 | 0.62 - 0.68 | 0.62 - 0.68 | Chlorophyll absorption for plant species |
| | 4 | 0.77 - 0.86 | 0.77 - 0.86 | 0.77 - 0.86 | Delineation of land and water |
| | 5 | | 1.55 - 1.70 | 1.55 - 1.70 | Vegetation mapping |

When we look at the PAN sensors, these PAN sensors have resolution of varying nature. But the spectral region in which it is collecting data for IRS-1C and 1D, it is between 0.5 to 0.75 and it is useful for resource identification.
WiFS as a matter of fact was introduced in IRS-1C. In the IRS-1C, there were only 2 WiFS band operating in the region of 0.6 2 to 0.68 and 0.077 to 0.86. This was primarily meant for global vegetation mapping.

However, in IRS-1D, the WiFS sensor had the third band in the infrared region that is at 1.55 to 1.75 and this was done in order to enhance the global mapping scenery.

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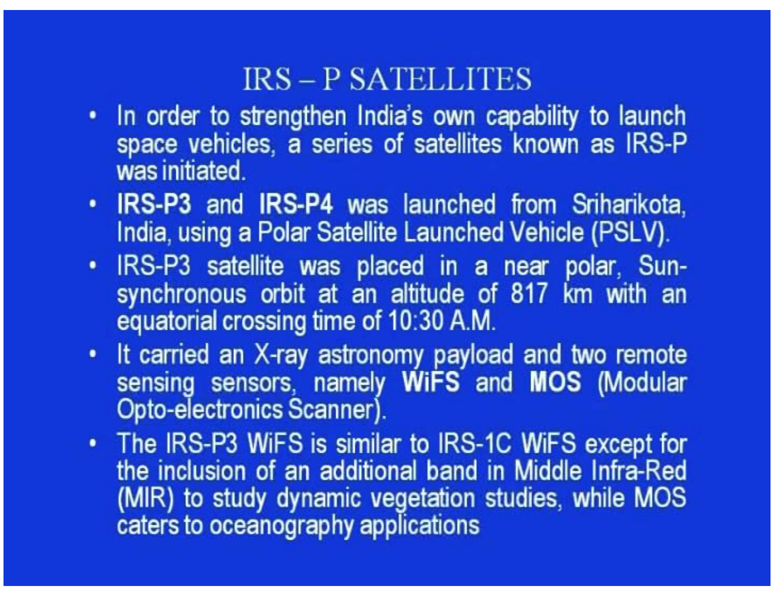

In order to strengthen the India's own capability to launch space vehicles, a series of satellites known as IRS-1P was also initiated. IRS- P3 and P4 was launched from Sriharikota, India using a polar satellite launch vehicle or PSLV.

IRS- P3 satellite was placed in a near polar sun synchronous orbit at an altitude of 817 kilometers with an equatorial crossing time of 10:30 AM. It carried an x-ray astronomy payload and 2 remote sensing sensors namely, WiFS and MOS that is modular opto-electronic scanner.
The IRS- P3 WiFS is similar to IRS -1C WiFS except for the inclusion of an additional band in the middle infrared to study dynamic vegetation studies, while, MOS caters to oceanographic applications.

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Sensor characteristics of IRS-P3

| Characteristics | MOS-A | MOS-B | MOS-C | WiFS |
|---|---|---|---|---|
| Resolution (m) | 1598 × 1395 | 523×523 | 523 × 644 | 188 × 188 (B3 & B4)<br>188 × 246 (B5) |
| Swath (km) | 195 | 200 | 192 | 770 |
| Receptivity (day) | 24 | 24 | 24 | 24 |
| Spectral band (μm) | 0.755-0.768 | 0.408-1.01 | 1.5 - 1.7 | 0.62 - 0.68 (B3)<br>0.77 - 0.68 (B4)<br>1.55 - 1.69 (B5) |

Well, this particular table shows the sensor specifications for IRS- P3 for both the sensors, MOS and WiFS.

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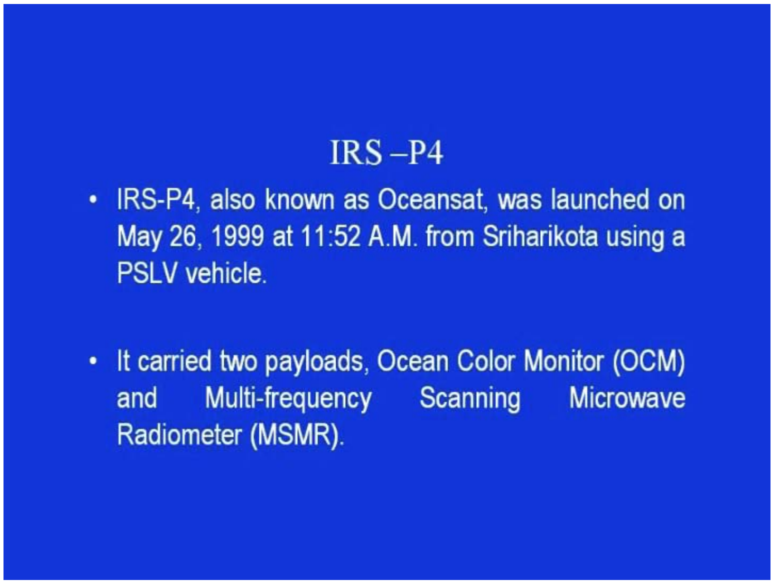


The next series of satellite is the IRS- P4. This is also known as Oceansat as it was launched on May 26, 1999 at 11:52 from Sriharikota using a PSLV launch vehicle. It carried 2 payloads, ocean color monitor and multi-frequency scanning micro radiometer. Well, this was primarily launched so that one could enhance the ocean related studies.

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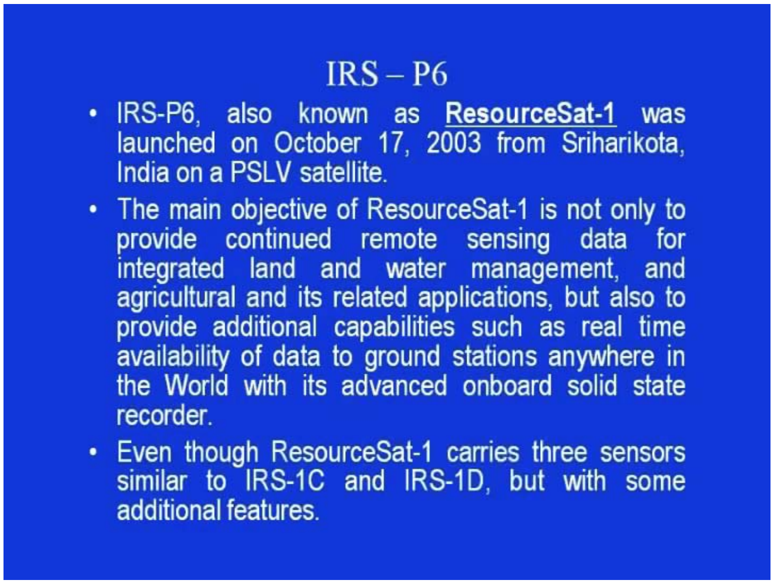


The next satellite which was launched was IRS-P6, also known as ResourceSat-1 and was launched on October 17, 2003, again from Sriharikota using a PSLV launch vehicle. The main objective of ResourceSat is not only to provide continued remote sensing data for integrated land

and water management and agriculture and its related applications, but also to provide additional capabilities such as real time availability of data to ground stations anywhere in the world with its advanced onboard solid state recorder, even though ResourceSat-1 carries 3 sensors similar to IRS-1C and 1D but with some additional features.

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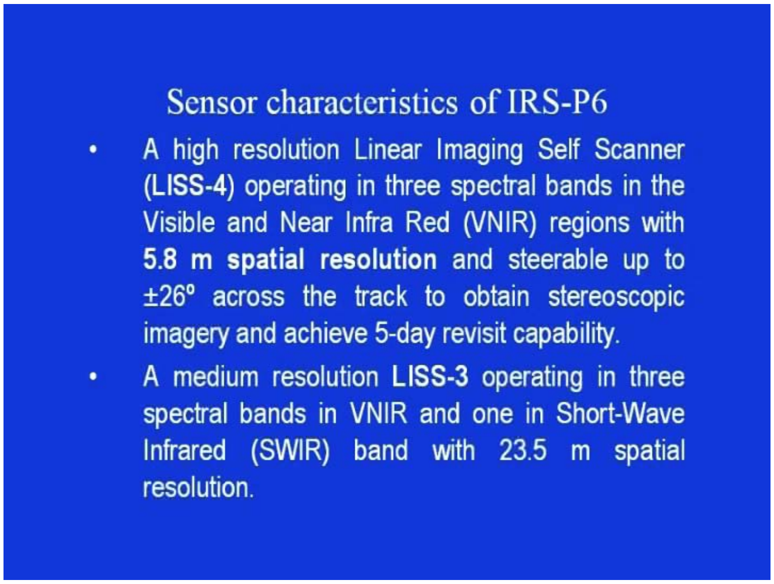


A high resolution linear self scanner, LISS 4 operating in the near in the 3 spectral bands, in the visible and near infrared region with about 5.8 spatial resolution with steerable capabilities of plus minus 26 degrees across the track to obtain stereoscopic imagery and achieve 5 day revisit capability.

The medium resolution, LISS 3 operating in the 3 spectral bands in visible and near infrared region and one in the short wave infrared region with a spatial resolution of 23.5 meters.

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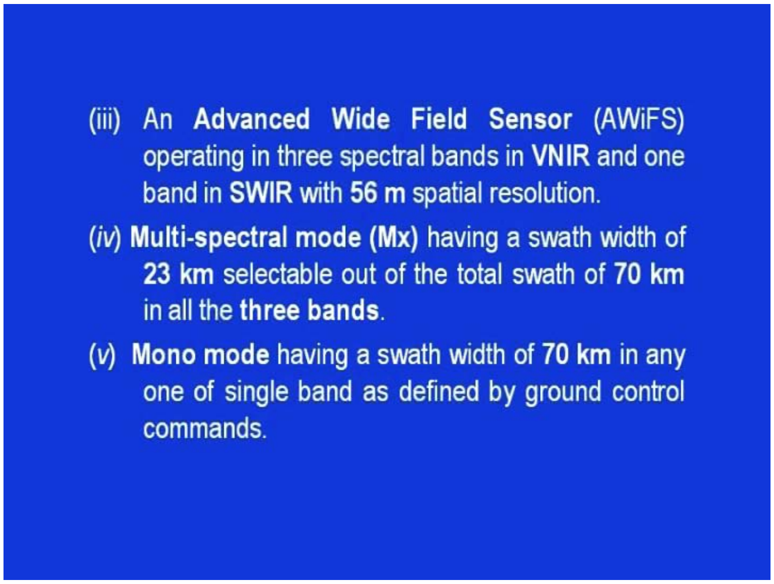


An advanced wide field sensor or AWiFS operating in 3 spectral bands in VNIR and 1 band in SWIR with 56 meter spatial resolution. The multi spectral mode or the as it is known as Mx having a swath width of about 23 kilometers selectable out of a total swath width of 70 kilometers in all the 3 bands is possible. In the mono mode, having a swath width of 70 kilometers in any one of the single bands as defined by ground control commands.

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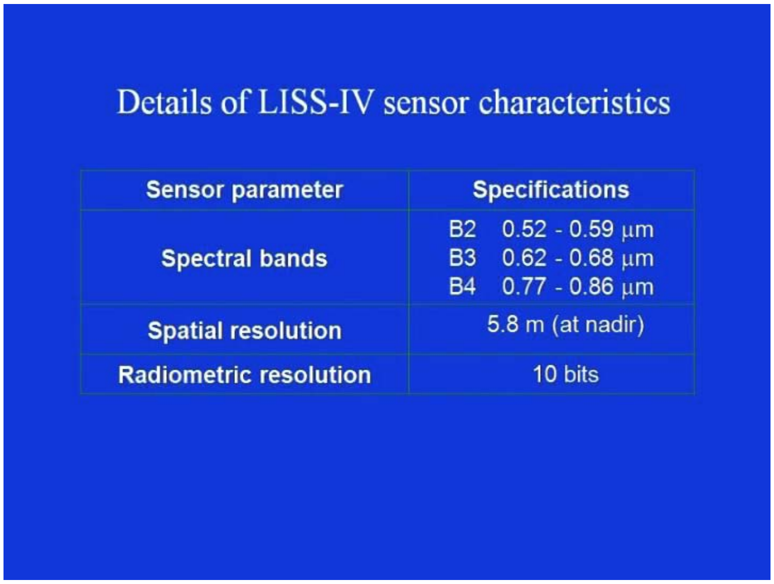


Well, this particular table shows the LISS 4 sensor characteristics. There are 3 bands which are operating in the spectral region of 0.52 to 20.59, 0.62 to 0.68 and 0.77 to 0.86 mu meters having a spatial resolution at nadir of 5.6 meters with a radiometric resolution of 10 bits.

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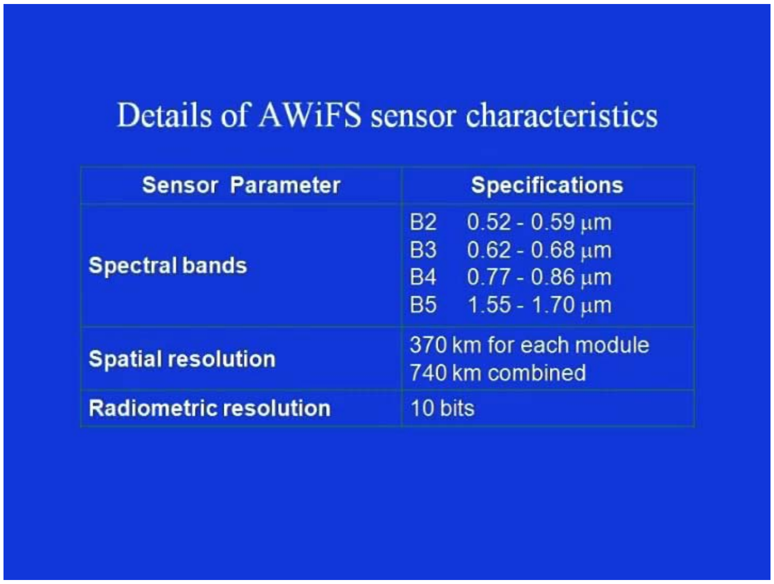
Details of AWiFS sensor characteristics

| Sensor Parameter | Specifications |
| --- | --- |
| Spectral bands | B2 0.52 - 0.59 μm<br>B3 0.62 - 0.68 μm<br>B4 0.77 - 0.86 μm<br>B5 1.55 - 1.70 μm |
| Spatial resolution | 370 km for each module<br>740 km combined |
| Radiometric resolution | 10 bits |

The AWiFS sensor, it consists of 4 bands. The first 3 bands are similar to our LISS sensor, the 5 band which has been introduced is at the middle infrared region that is 1.55 to 1.7 mu meters. The spatial resolution here is course. It is about 370 kilometers for each module and 740 kilometers combined with a radiometric resolution of about 10 bits.

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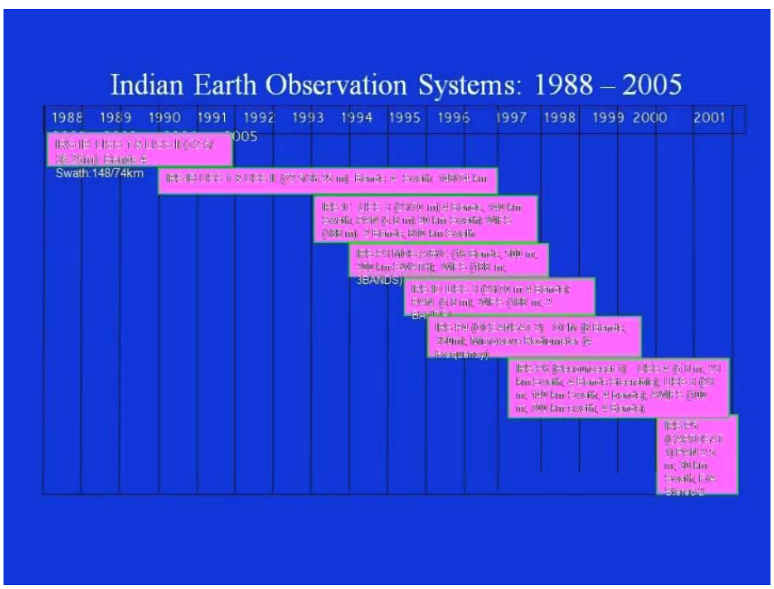


This particular satellite shows the chronological table in which the Indian remote sensing satellites have been launched up till now. Having had a look at the sensors and the missions which are there, operating to collect resources around the earth's surface; it would good that if the user can now be made to understand the utility of each of the electromagnetic spectrum zone, the bands which are operating in different sensors and their application.

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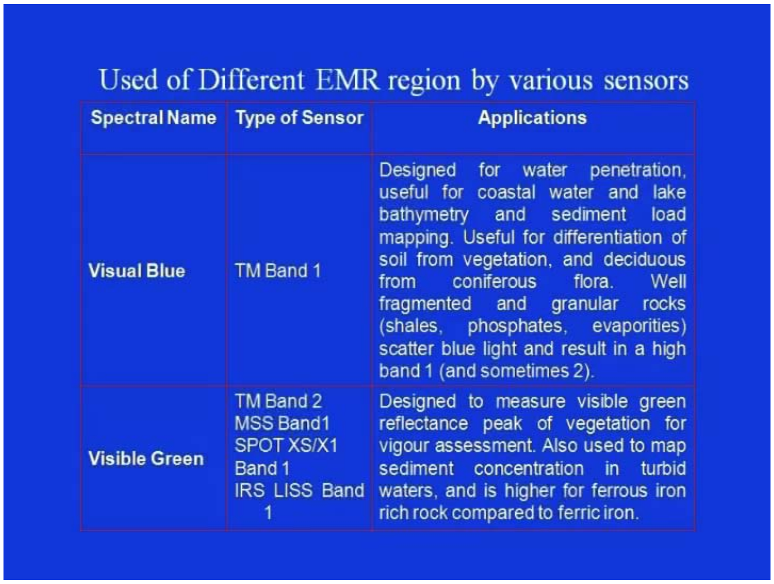

Used of Different EMR region by various sensors

| Spectral Name | Type of Sensor | Applications |
|---|---|---|
| Visual Blue | TM Band 1 | Designed for water penetration, useful for coastal water and lake bathymetry and sediment load mapping. Useful for differentiation of soil from vegetation, and deciduous from coniferous flora. Well fragmented and granular rocks (shales, phosphates, evaporities) scatter blue light and result in a high band 1 (and sometimes 2). |
| Visible Green | TM Band 2<br>MSS Band1<br>SPOT XS/X1 Band 1<br>IRS LISS Band 1 | Designed to measure visible green reflectance peak of vegetation for vigour assessment. Also used to map sediment concentration in turbid waters, and is higher for ferrous iron rich rock compared to ferric iron. |

When we look at the visual blue, only TM band 1 is operating and this is designed for water penetration useful for coastal water and Lake Bathymetry and sediment load mapping. It is useful for differentiation of soil from vegetation and deciduous from coniferous flora. Well fragmented and granular rocks such as shales, phosphates and evaporities scattered blue light and result in a high band 1 and sometimes in band 2.

In the visible green spectral region, we find that the different sensors which are operating are the TM band 2, MSS band 1, SPOT X1, IRS-LISS band 1. Designed to measure visible green reflectance peak of vegetation for vigour measurement, also to use map sediment configurations concentrations in turbid waters and is higher for ferrous iron rich rock compared to ferric iron.

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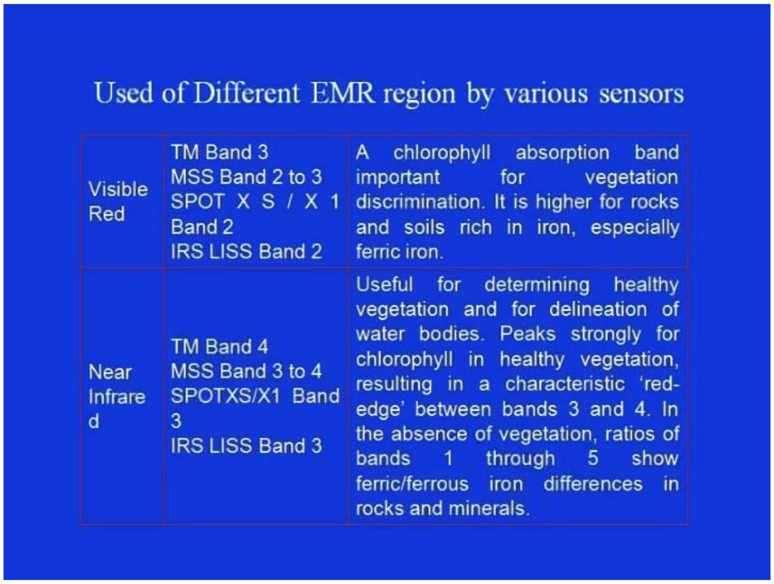


The next spectral region is the visible red and here we find the sensors which are operating are the TM band 3, MSS band 2 and 3, SPOT X and X1 band 2 and IRS-LISS band 2. Well, it can be used for applications for chlorophyll absorption for vegetation discrimination. It is it has a higher response for rocks and soils which are rich in iron, specifically ferric iron.

The next spectral region is the near infrared and TM band 4, MSS band 3 to 4, SPOT X and X1 band 3, LISS IRS-LISS 3 band 3. Well, this is useful for determining healthy vegetation and for delineation of water bodies. It has strong peaks for chlorophyll information in healthy vegetation resulting in a characteristic red edge between bands 3 and 4. In the absence of vegetation ratios of band 1 through band 5 shows ferric ferrous iron differences in rocks and minerals.

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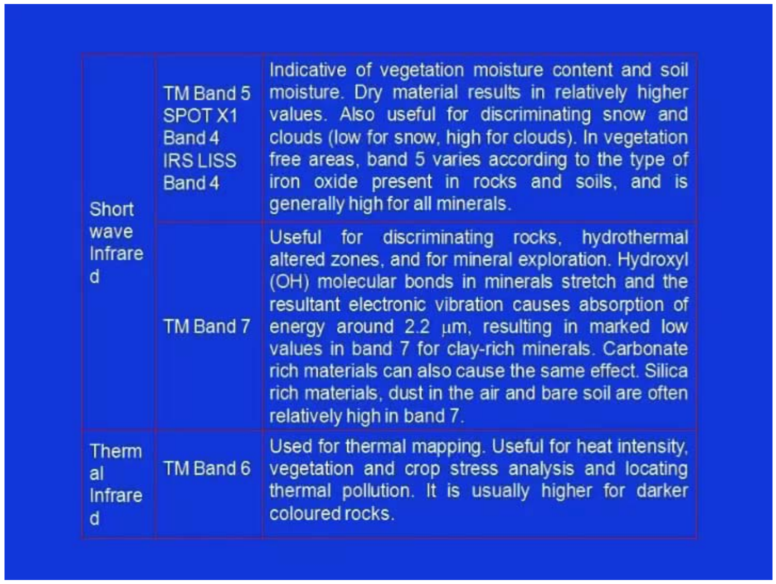

| | | |
|---|---|---|
| Short wave Infrared | TM Band 5 SPOT X1 Band 4 IRS LISS Band 4 | Indicative of vegetation moisture content and soil moisture. Dry material results in relatively higher values. Also useful for discriminating snow and clouds (low for snow, high for clouds). In vegetation free areas, band 5 varies according to the type of iron oxide present in rocks and soils, and is generally high for all minerals. |
| | TM Band 7 | Useful for discriminating rocks, hydrothermal altered zones, and for mineral exploration. Hydroxyl (OH) molecular bonds in minerals stretch and the resultant electronic vibration causes absorption of energy around 2.2 μm, resulting in marked low values in band 7 for clay-rich minerals. Carbonate rich materials can also cause the same effect. Silica rich materials, dust in the air and bare soil are often relatively high in band 7. |
| Thermal Infrared | TM Band 6 | Used for thermal mapping. Useful for heat intensity, vegetation and crop stress analysis and locating thermal pollution. It is usually higher for darker coloured rocks. |

The next spectral region is the short-wave infrared and here we find that there are TM band 5, SPOT X band 4, IRS-LISS band 4 and this is used for indicative of vegetation moisture content and soil moisture. Dry material results in relatively higher values, also useful for discriminating snow and clouds. In vegetation free areas, band 5 varies according to the type of iron oxide present in rock and soils and is generally high for all minerals.

Also, TM band 7 falls in the SWIR region and this is useful for discriminating rocks, hydrothermal altered zones and for mineral exploration. Hydroxyl molecular bonds in minerals stretch and the resultant electronic vibration cause absorption of energy around 2.2 mu meters resulting in a marked low value in band 7 for clay-rich minerals. Carbonate rich materials can also cause the same effect. Silica rich materials dust in the air and bare soil are often relatively higher in band 7.

Then we come to the next spectral zone which is thermal infrared and in this we have the TM band 6. Well, this can be used for thermal mapping, it can be useful for heat intensity vegetation and crop stress analysis and locating thermal pollution. It is usually higher for colored rocks. Now, we come to the next era of sensors where we have high spatial resolution. But probably, we may not have a good spectral resolution. So, let us look at those satellite missions which have are having high spatial resolution.

The first to be discussed is CARTOSAT-1. CARTOSAT-1 is a venture of the Indian space organization.

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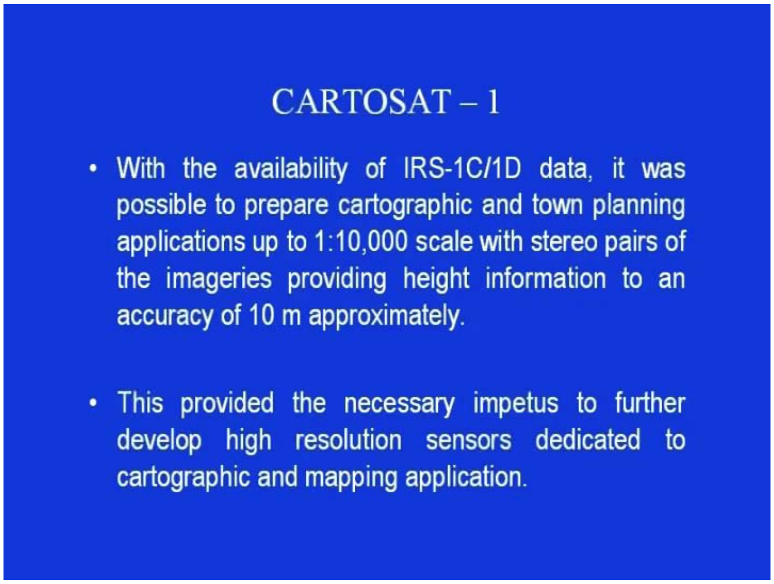


Well, this was initiated because with the availability of IRS-1C and 1D, it was possible to prepare cartographic and town planning applications upto a scale of 10,000 with stereo pairs of imagery providing height information to an accuracy of 10 meters approximately. This provided the necessary impetus to further develop high resolution sensors dedicated to cartographic and mapping applications.

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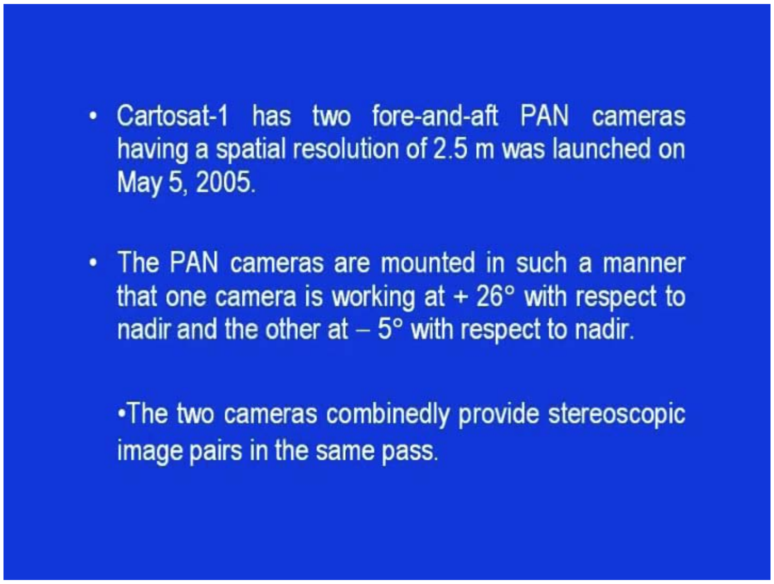


CARTOSAT-1 has 2 fore-and-aft PAN cameras having a spatial resolution of 2.5 meters and was launched on May 5, 2005. The PAN cameras are mounted in such a manner that one camera is working at a positive 23 degrees with respect to the nadir, whereas, the other maybe working at an angular deviation of half a of 5 degrees from the nadir. The 2 cameras combinedly provide stereoscopic image pairs in the same pass.

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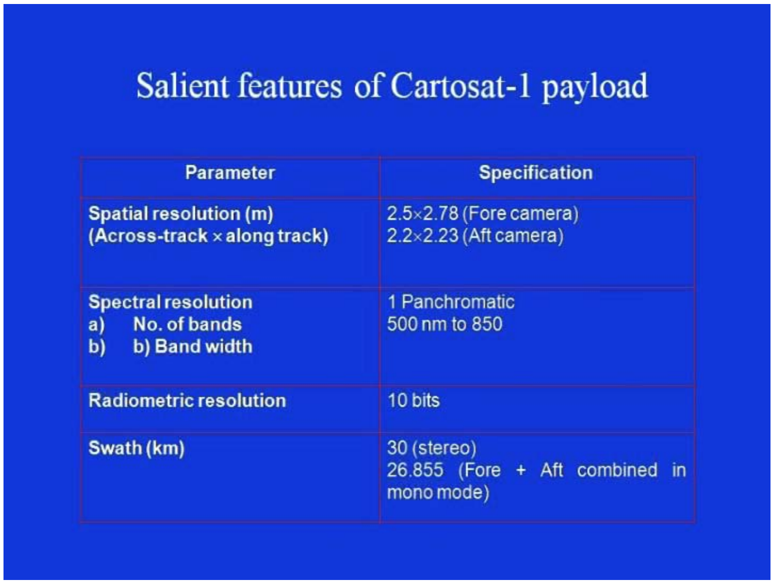

Salient features of Cartosat-1 payload

| Parameter | Specification |
|---|---|
| Spatial resolution (m)<br>(Across-track × along track) | 2.5×2.78 (Fore camera)<br>2.2×2.23 (Aft camera) |
| Spectral resolution<br>a) No. of bands<br>b) b) Band width | 1 Panchromatic<br>500 nm to 850 |
| Radiometric resolution | 10 bits |
| Swath (km) | 30 (stereo)<br>26.855 (Fore + Aft combined in mono mode) |

Some of the salient features of CARTOSAT is that it has varying spatial resolution. The 4 camera has a resolution or pixel size of 2 and a half by 2.78 meters, whereas, the aft camera has an of 2.2 by 2.223.

Well, there is only one band of data which is the panchromatic operating between the regions of 500 to 850 nanometers. The data is collected at with a radiometric resolution of 10 bits. The swath width is 30 kilometers for stereo, while it is 26.855 when the cameras are operating in fore-and-aft mode to collect the data in mono mode.

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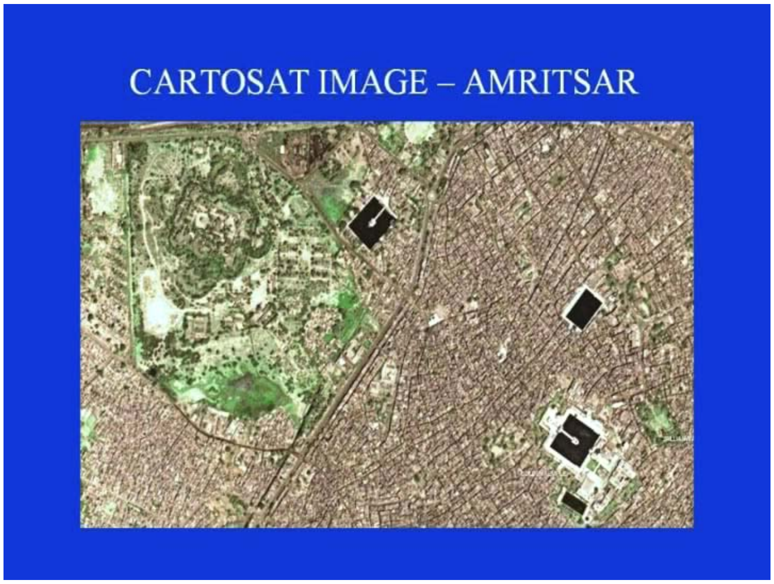


This particular image slide shows the image of Amritsar region. Here the user will be able to appreciate it the detailed manner in which the information has been made available. It is possible to identify each individual house which is there. Some of the salient features which the user may like to know is that on the bottom right corner, one can find the famous Gurudwara or what we call it as the Harmandir Sahib is located.

Close to it on the right hand side, there is a green patch and it has a very important place in the Indian historic independence movement that is the Jallianwala Bagh. Further, if one focuses his attention towards the top center portion, again there is a black patch with a needle like obstruction or a feature coming out; this is the famous Durgiana temple of Amritsar build on the similar patterns as of Harmandir Sahib Gurudwara and one can see the repetitive design which has been adopted in both the cases.

Well, here I would like to emphasize to the user that the detailed manner in which the information is now being made available so that one can do extensive level planning.

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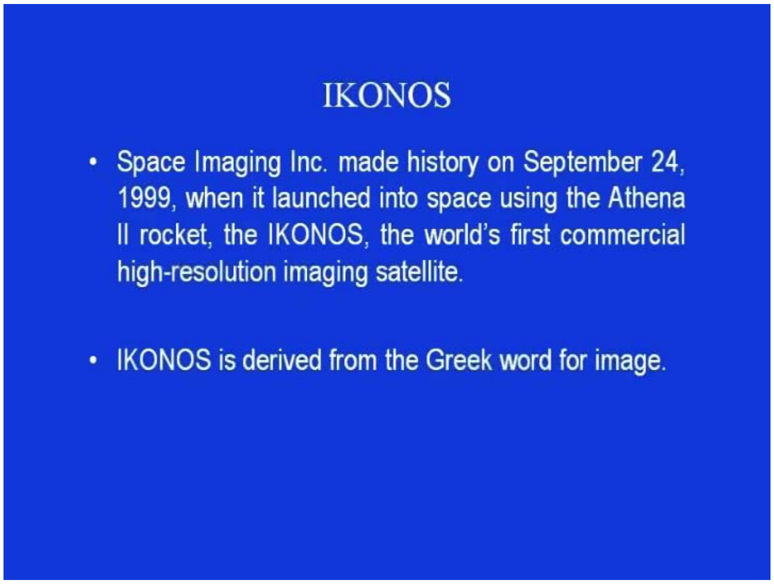


The next high spatial resolution satellite is the IKONOS. Well, IKONOS is the first of its kind having a very high resolution and it created a history when it was launched on September 24, 1990 for acquiring high resolution image collected from the space. Just for interest: IKONOS is a Greek word which means image.

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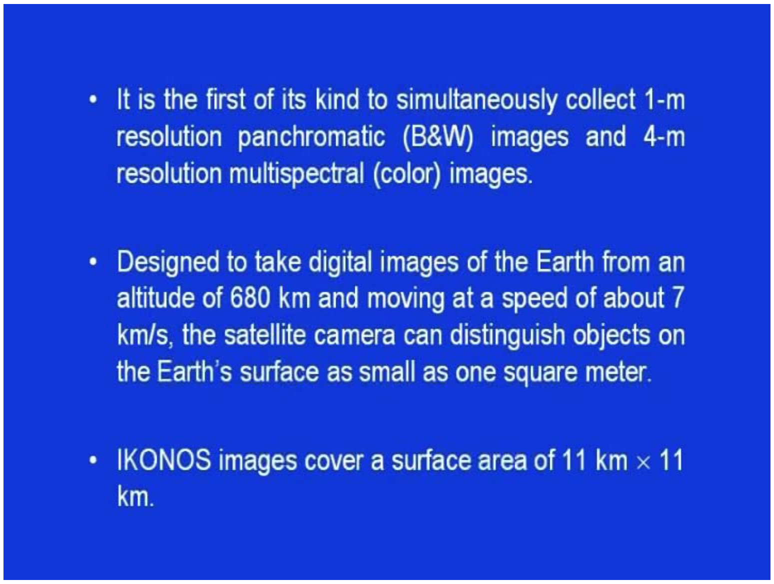


Well, this particular satellite has the capability to collect data in 2 spatial resolutions. It collects data at 1 meter in the panchromatic that is black and white and 4 meter resolution in the multi-spectral mode. It is designed to take digital images of the earth from an altitude of 680 kilometers and it moves at a speed of about 7 kilometers per second so that the camera can distinguish objects on the earth's surface as small as 1 square meter.

However, with the enhanced spatial resolution, IKONOS images cover a surface area of 11 kilometers by 11 kilometers at a time which is far more less than our earth resource satellite such as the LANDSAT or SCOT or the IRS.

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This particular slide shows a very historic monument in USA which is the George Washington museum and here in this particular image, if the user focuses his attention that on the right side there is a huge water body mass and on the left side one can see many linear lines which are nothing but representing the road surface.

If one concentrates, one can see small rectangular wide boxes moving over these black lines and these are nothing but vehicles. Furthermore, one can also see every individual tree which is present in this particular region. Hence, this type of data can provide very accurate and high information for mapping purposes and can be used for a large variety of application other than mapping.

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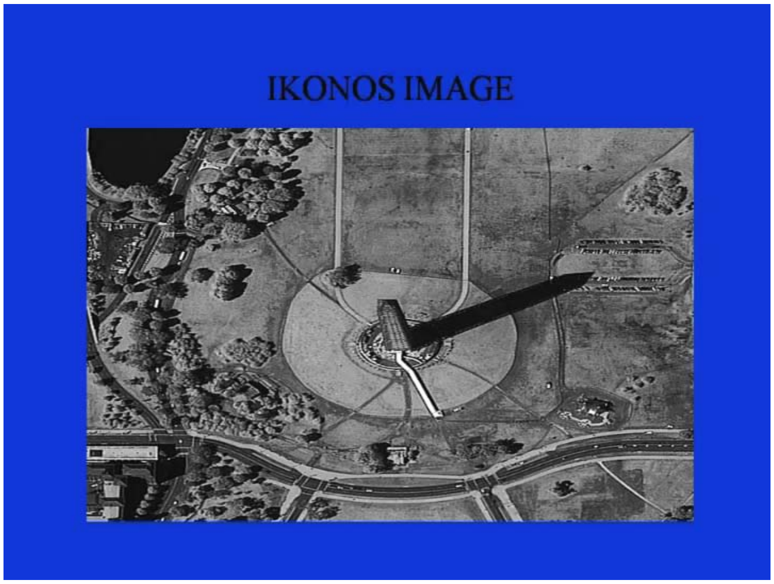


The next slide shows the war memorial for all the soldiers who died during the 2 world wars which were there. The interesting feature to be noted is the shadow which is being casted by the memorial. With the help of this shadow, any user can now identify or determined what is the height of this particular monument; provided, if I know what is the sun's angle at this instant of time. Using simple trigonometrical relationship of tan theta, knowing what is the length of the shadow on the ground and the angle at which the sun rays are coming; it is possible to find out what is the height.

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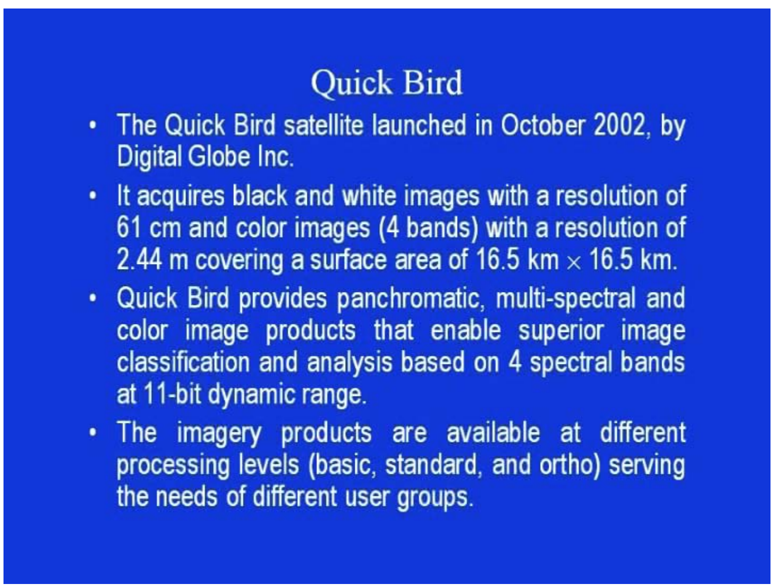

The next high resolution satellite is the quick bird. It further improved the spatial resolution in panchromatic mode from 1 meter of IKONOS to 61 centimeters and in the multi-spectral mode, it operates at 2.44 meter. However, the area coverage of quick bird is about 16.5 kilometers by 16.5 kilometers, slightly larger than IKONOS.

Quick bird provides panchromatic multi-spectral and color image products that enable superior image classification and analysis based on 4 spectral bands in the eleventh bit dynamic range.
That is the radiometric resolution in this data set is far more greater than in the resolution, radiometric resolution of resource satellites which is only 8 bit.

The imagery products are available in different processing levels which can be classified as basic, standard and ortho serving the needs of different user groups.

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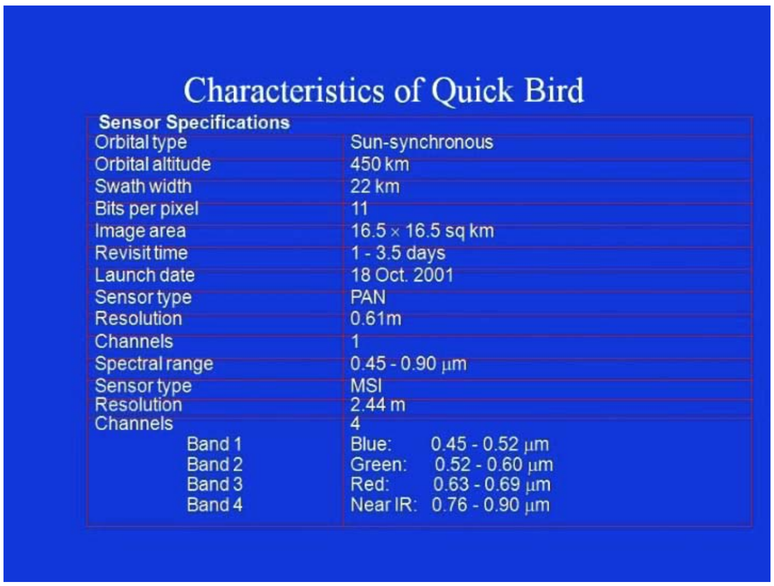


Well, this particular slide shows the characteristics for quick bird. We can see, it is a sun synchronous satellite orbiting at an altitude of 450 kilometers with a swath width of 22 kilometers. Data resolution in terms of radiometric is 11 bits and the image area it for which the data product is available is 16 and a half kilometers by 16 and a half kilometers having a revisit capability varying between 1 to 3 and a half days. It has 4 bands in the multi-spectral, very similar to what has been adopted for LISS-4, TM-4 data sets.

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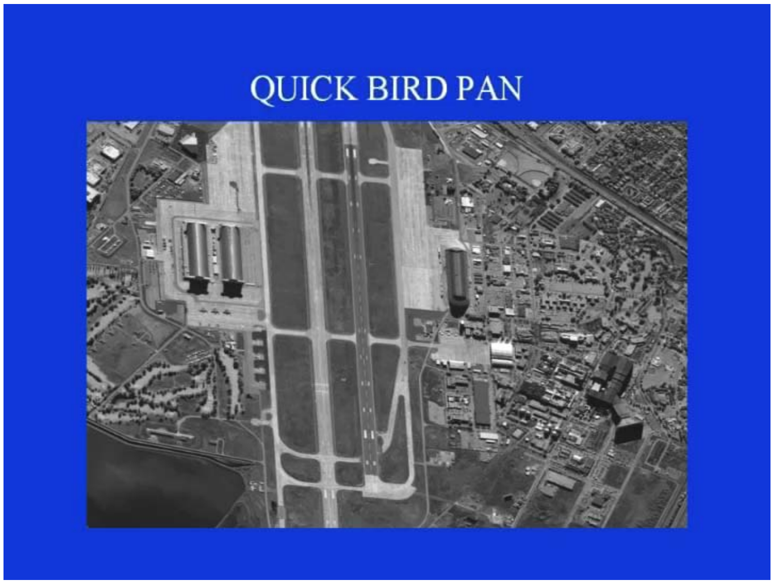


This particular sample shows the quick bird data acquired in the PAN mode that is at 61 centimeter resolution and here, the user can very well see; it is of an airport region and the various markings on the runway can be seen very clearly.

Apart from that one can also see the individual trees, the vehicles parked in the airport terminal areas and other buildings in the close vicinity are very clearly visible.

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The next image is the multi-spectral data set of quick bird and now, one can see the variation of information in color. Specifically, in the lower left portion wherein, the sediment laid in water can be very clearly identified in comparison to the quick bird panchromatic data in the previous slides.

With this I would now like to end my this session wherein, I have focused up to sensors which are having high spatial resolution. In my next session, I would like to focus on the other type of sensors having improved spectral resolution and other sensors which are being used for ground based data collection or for airborne based data collect.

Thank you.