Remote Sensing: Principles and Applications
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Lecture-53
Platforms for Remote Sensing Observations-Part-4

Hello everyone, welcome to the next lecture in the topic platforms for remote sensing observations. In the last lecture, we discussed about geosynchronous orbits and as a special case geostationary orbits. The main purpose of why satellites are launched in geostationary orbits and we also discussed about Lagrange points. So, if a satellite is placed in geostationary orbit, it will be observing the same point on earth again and again. So, it will cover a certain region of the globe.

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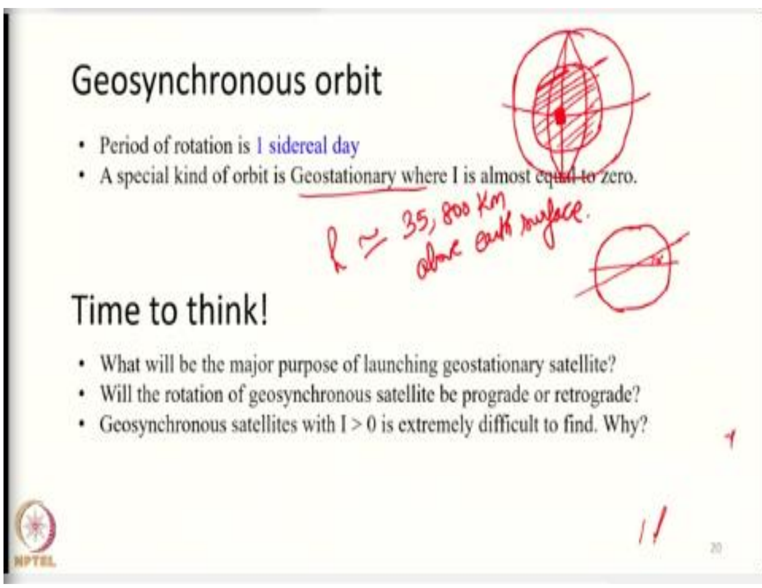

As given in the slide, it will say this particular red circle here is an example for the coverage of geostationary satellite. It may cover a much larger region, but for most of the useful applications it will be contained within this particular zone. So, if a satellite is placed in geostationary orbit, it will not provide global coverage, it will be seeing only a certain part of the globe, but it will provide continuous coverage over that particular part of the globe. Also, we got introduced to concept of Lagrange points which are the special points that come into effect, because of the combined gravity of two objects which are in motion related to each other, it is a two body problem which is moving in tandem.

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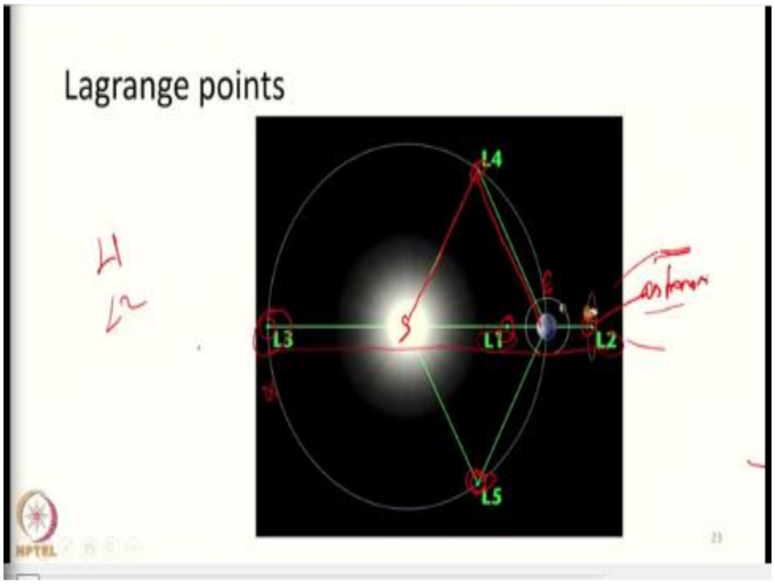

So, between sun and earth we can fix, 5 Lagrange points L1 to L5 where L1, L2, L3 are in the line joining sun and earth and L4 and L5 will be found as one of the corners or the vertex of equatorial triangle, joining sun earth and that particular point. Sun earth and L4, sun earth and L5 something of that sort. So, for remote sensing application the point L1 is used.

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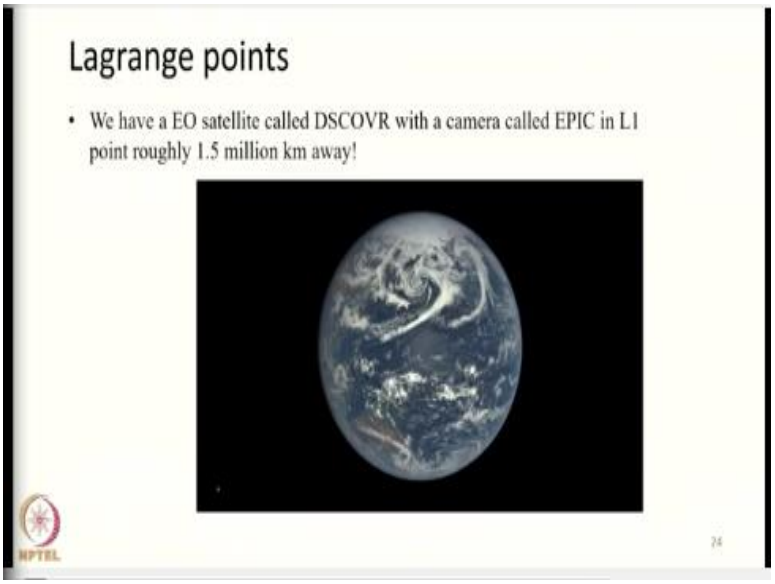

There is a satellite called discover with a camera called EPIC, in the L1 point roughly 1.5 million kilometers away. Here is again a small video by NASA. **(Video Starts: 02:22)**

So, this is how that particular EPIC camera sees the earth. So, when moon crossed over the earth the EPIC camera captured it. So, this is three cyclones same time in Pacific ocean captured by this camera, the north pole, here this north pole, this is south pole this is smog travelling, moon shadow. So, these are like another moon crossing. So, basically, this is kind of an example to tell the application of observations from L1 point. **(Video Ends: 03:12)**

The satellite is actually placed in L1 point mainly for climate applications in order to observe the earth as a whole. So, it may appear very close to the concept of geostationary orbit or geosynchronous orbit, but there are huge differences between them. So, if some satellite is placed in L1 lagrange point, the time period is not synchronized. This satellite will be here only, earth is rotating around itself. So, earth will be rotating at a different speed and satellite will be moving along with the sun and earth as a whole. Like sun earth system the L1 point will be fixed because of the combined motion between them. So, the speed of revolution of satellite will not be synchronized with earth, earth will be rotating at a different speed the satellite will be moving around in a different speed due to the combined effect of sun and earth.

So, if a satellite is placed in L1 point, it can observe the entire globe based on earth’s rotation, as the earth rotates the camera appears to be stationary with related to earth. But at the same time due to earth’s rotation, it will be imaging different, different portions of the earth; it can see north pole and south pole and all. Because let us say during summer what will happen? earth is tilted at 23 and a half degrees, so the camera will be here, let us say sun is here, camera will be between earth and the sun. So when earth is tilted during northern hemisphere summer, the camera will be observing the north pole. During southern hemisphere summer, earth will be tilted like this, north will be pointing away from the sun, so the camera will be seeing the south pole. So, normally if a camera is placed in L1 orbit it can observe different parts of the globe as the speeds are non synchronized.

This is not like a synchronous orbit and all, earth is rotating in a different speed, satellite is moving around with a different speed. Whereas a geostationary orbit everything is synchronized, earth's speed and this thing. And also since earth is tilted, when you see from outer space, when you move away from the earth and observe it, we can see the earth's tilt. Similarly, satellite also will be placed along the equator and it will also have the 23 and a half degree tilt, if you see this from outer space, normally that will happen.

So, these are some small differences between L1 orbit and the geostationary orbit, do not confuse them, they are completely different class of orbits with completely different purposes. If a satellite is placed Lagrange point, it will produce extremely coarse resolution images, because the distance between earth and sun is 15 lakh kilometers, a huge distance. So, the spatial resolution will be extremely coarse, useful for climate monitoring, climate applications. But, I just wanted to let you know there is satellite from such long distances in a particular point L1 which is used for earth observation.

So, the next class of orbit which we are going to see is polar or near polar orbit. So, this is one of the most widely used orbit for remote sensing purposes.

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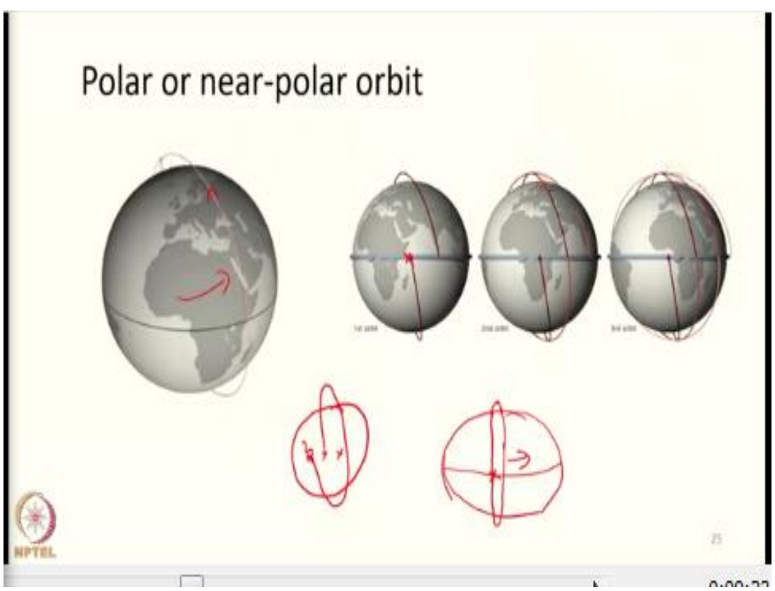

That is depicted here in this particular slide, you can see earth is rotating underneath it satellite is moving in its orbital plane and it will appear as if moving from north to south, say this is how basically to rotate. Let us say the satellite is starting from here. So, as a satellite completes one rotation and comes here earth would have moved and now the satellite will be landing in at a new location. This is starting point by the time it comes and finishes it may be coming at a point to the west of it, this is second orbit. Satellite will be moving in an orbit, earth will be rotating underneath it, if the satellite moves exactly over pole 90 degree north and 90 degree south, we call this polar orbit.

But normally for remote sensing applications satellite will not be placed exactly over poles not 90 degrees, it will be placed with slightly higher inclination 98 degrees 99 degrees and so on. If a satellite is placed in near polar orbit what will happen is, the satellite orbit itself will not be fixed in space. That is just look at this animation in the previous slide, here you can see the orbit as if it is appearing fixed in space and earth is moving.

Normally we will think it will happen, say geostationary orbits are all fixed orbits, it will be fixed, earth will be moving around it that is all. But if a satellite is placed in any angle other than like 0 degree inclination that is away from the equator the orbit will undergo precession. What exactly procession is?

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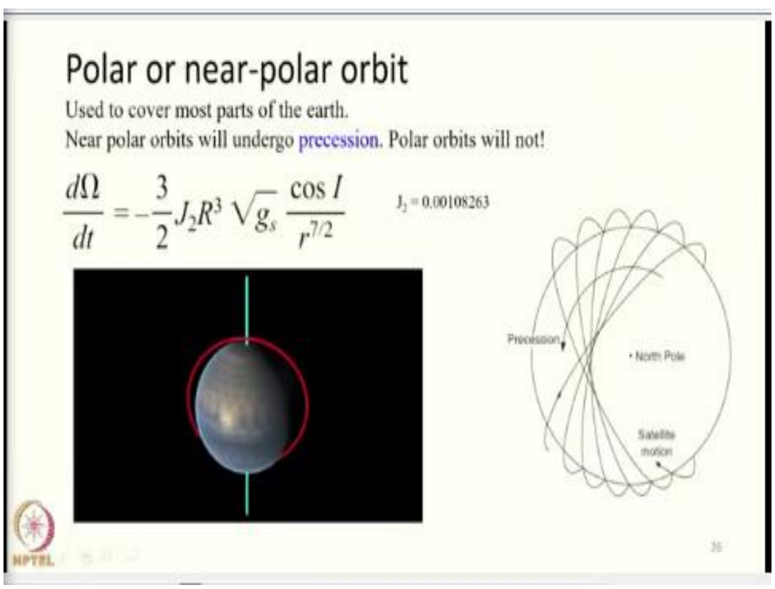

Similar to earth rotating around itself, the orbit also will move around itself. **(Video Starts: 09:33)** So, that is you can see from this particular video this is highly exaggerated animation what is being shown here, but this is just to tell you the effect of orbital precession. That is, as the earth rotates around itself the orbit will also be keep on rotating. Say here you can observe, orbit itself will be rotating around itself, this is known as precession.

Orbit center also will be aligned with earth center. But what will happen is, the orbit also will spin independently, if the inclination is above 0 degrees**. (Video Ends: 10:21)**. So, normally satellite will be placed with the inclination greater than 90 degrees**,** near polar orbits 98 degrees 99 degrees and so on. Such orbits will undergo this precession that is the orbital plane itself will rotate. This is because of earth's asymmetry. Earth is not a perfect sphere, it is slightly flattened at poles bulging at the equator. Due to this, if a satellite is moving in an inclined orbit, it will feel that asymmetrical nature of earth's mass distribution and the orbit will undergo precession, it will rotate around itself.

So, this is actually we may think it is bad, the orbit is not fixed, the orbit itself is rotating around itself in a plane. But this orbital precession is useful for remote sensing purposes, we will see it how? But before seeing that just one thing I would like to tell you. If the inclination is anything other than 0 degrees or 90 degrees orbit will undergo precession. If an orbit is placed exactly over poles 90 degree north and 90 degree south the orbit will not undergo precession, orbit will remain fixed in initial space. If you go outside of earth, the orbit will appear as if it is fixed around the earth**,** it will not appear to undergo any sort of rotation. But if any other inclination is there, say 92 degrees, 93 degrees, 88 degrees whatever orbit will undergo precession.

The orbit is precessing and I told you it is useful in remote sensing, how? It is useful in remote sensing in order to achieve what is known as a near polar sun synchronous orbit. We already seen geosynchronous orbit, the orbital rotation is synchronized with earth rotation. Similarly, for remote sensing applications, we also have orbits which are classified as sun synchronous orbits. What exactly sun synchronous orbits are, why it is needed? We will see. Let us say there is some orbit, this is the orbital plane we are seeing from the top. So, this is the orbital plane, this is earth, this is sun during different, different time period in the year, the earth will be keeps on rotating around the sun**.**

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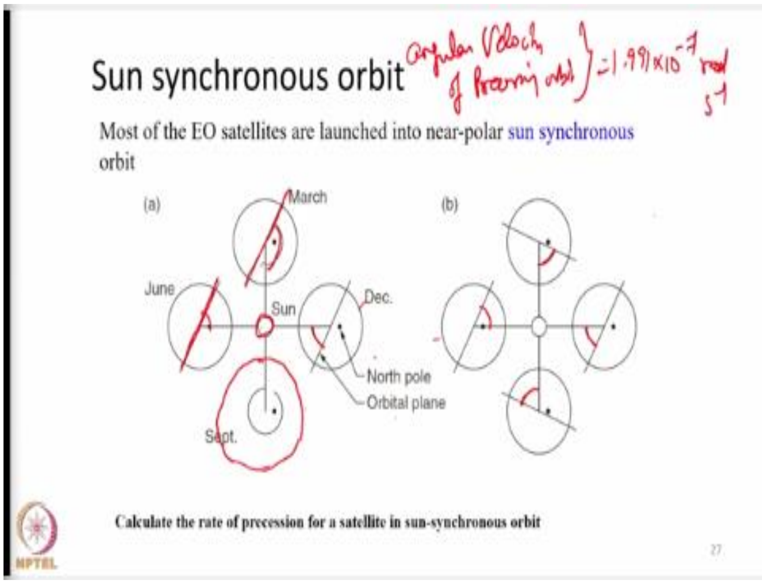

If the orbit is not undergoing any precession, if it is fixed, the angle between the sun or the line joining the sun center, earth center in the orbit will be keep on varying. Let us say the orbit is permanently fixed, earth is rotating like this, orbit is fixed means earth will be rotating independently, nothing would have happened.

If the orbit is not undergoing any precession, due to earth's rotation around the sun, the angle between the line joining the sun, earth and the orbital plane will be keep on varying during different times of year. This will change the illumination conditions, what will happen is during one time sun will be over head at a place during morning, and one time sun will be over head at a place during evening, solar illumination conditions will change drastically. But for in optical remote sensing we learnt that the reflectance or same object will look completely different if the illumination changes which is the BRDF effect. This will be a huge problem, if the sun's illumination is continuously changing, if the imaging happens during different, different days.

Let us say I am going to acquire some images over Mumbai city, today I am acquiring image at say 10 AM, tomorrow I am acquiring an image say afternoon 2 PM. After the time acquiring an image at evening 6 PM and so on, so what exactly will happen? I am changing the illumination conditions as the time of observation changes, the solar illumination will change. The strength of illumination, the angle at which the sun shines everything will change; this will severely affect our remote sensing observations. So, we will normally try to achieve uniform illumination conditions.

For that particular thing sun synchronous orbits will help. So, if a satellite is placed in sun synchronous orbit, then the angle between the line joining the sun and the earth and the orbital plane will always be equal whatever be the season. So, the sun will be illuminating the earth surface from a constant angle, there will be seasonal variation like the amount of solar radiation coming in will vary, but at least the illumination conditions will be more or less fixed.

Because the orbit is precessing we are using that particular orbital precession to our advantage, it is a natural phenomena. The orbital plane rotating around itself is a natural phenomenon; we are using it for our own benefit that is one thing. And also if a satellite is placed in sun synchronous orbit, then the satellite will be moving or observing the same spot on the earth at the same given mean local solar time or mean solar time, in short.

What is mean solar time? That means, let us say if you look at catalogues or brochures of different, different satellites, say Landsat, MODIS and all they will mention what is known as a equatorial overpass time. What that signifies is, it will mention at what time the satellite will cross the equator. They will also give whether it is ascending mode or descending mode, let us say a satellite has been mentioned 10 AM equatorial overpass time in ascending mode, what does it represent? So, along the equator 0 degree axis, there will be a lot of places**,** whatever be the place, whenever the satellite crosses the equator from north to south, in ascending mode I told you from north to south the time will be 10 AM at that particular location at which the satellite is overhead.

Let us say Ethiopia or somewhere closer to equator. So, the time will always be 10 AM whenever the satellite crosses that particular location, same thing will happen even to other places. So, here what we are doing? We are making sure the sun is having almost constant illumination conditions and the satellite will image those locations at a constant time in order to ensure almost uniform illumination conditions and to achieve taking images at different, different times of day. So, this is known as sun synchronous orbit. So, a sun synchronous orbit is one in which the angle between the orbital plane and the line joining the earth and the sun, it will be kept constant. That is we will make sure we will put a satellite in such an orbit that the orbit undergoes precession, the orbit itself will rotate and the rotation speed will be adjusted, so that it will match this seasonal effect to some extent, this is sun synchronous.

And also the time of observation over a given location on the earth will be equal, this is the advantage of launching satellites in sun synchronous orbit. So, most of the remote sensing satellites are placed in near polar sun synchronous orbits. I am repeatedly telling near polar, because I told you before if a satellite is placed exactly over poles with inclination equal to 90 degrees it will not undergo precession.

Such orbits will never be sun synchronous, orbit will be fixed in inertial space. If you see from the outer space the orbit will never undergo rotation. If inclination is more than 90, typically it will be between 90 to 100 degrees, 98 degrees, 99 degrees and so on, the orbit will undergo a precession and the altitude will be matched in order to achieve this sun synchronous nature. So, as a small example we will calculate the rate of precession of a satellite orbit, if it is in sun synchronous orbit.

That is at what speed the orbit will rotate around itself. Earth is spinning, the orbit also will spin, that is the precession; at what speed it will rotate, we will calculate its angular velocity. It is very simple to imagine, no need to derive anything, just I will orally tell you. If an orbit has to be sun synchronous, what it has to do? It has to match the speed of earth's revolution that is the speed at which the orbit rotates around itself, the precession should match the speed of earth's revolution around the sun.

That is let us say sun is here, it is going to move in an orbit around the sun, the orbit also will rotate and that rotation should match this revolution speed. So, in one full year only the orbit should complete one full circle. I am not talking about satellite speed, satellite anyways moving in the orbit but I am talking with the speed in which the orbit itself will rotate, the plane itself will rotate. So, in one full year, that plane will complete one full cycle around itself, then that particular plane will be sun synchronous. So, typically we can work out the angular velocity with which such orbit rotates will be 1.991.

The angular velocity of the orbital precession will be 1.991×10^{-7} radian/second, extremely small value. If an orbit rotates around itself with this angular velocity, in one full year it will complete one full circle around itself, then it will achieve the sun synchronous nature. So, if a satellite is launched in that particular orbit, it will cover one full circle around itself and the satellite placed in such an orbit will maintain more or less uniform solar illumination conditions. And also it will overpass a given location of earth at a same mean solar time.

This is the advantage of placing a satellite in sun synchronous orbit. Most of the remote sensing satellites Landsat, MODIS, SMAP everything are placed in near polar sun synchronous orbits. Also there are calculations, we can make to show for typical orbital height around 700 to 800 kilometers range normally at which we put the satellites.

The inclination angle should be between, 90 to 100 degrees. Landsat satellites has inclination of around 98, 99 degrees, there is a satellite called ISAT 2 with inclination around 91 degrees. So, the inclination angle will always be more than 90, it will not be exactly over poles, they will be slightly away from the poles, then only it will undergo precision, then only it will be made sun synchronous. And also the direction in which the satellite moves will be in retrograde. That is let us say earth is rotating from west to east the satellite will appear as if it is moving from east to west. So, the net effect of motion in the east, west direction will be opposite to that of earth. The satellite is moving from north to south only, but there will be a slight component in the east, west direction also. And that component will be opposite to that of earth's motion, earth will be moving like this, satellite will be moving like this. So for satellite to be in sun synchronous orbit, the orbit will be retrograde, inclination will be greater than 0.

So, as a summary, in this lecture we got introduced to polar orbit or near polar orbit. Also we started discussing about the sun synchronous orbit and why we need sun synchronous orbit. We will discuss these concepts further in the next lecture.

Thank you very much.