

Slide 1 – Title Slide

Hello and welcome to Week 10, part 1 of EGM310: Satellites and Sensors. In this lesson, we will learn about artificial satellites and different orbits, as well as start to talk about how satellite sensors actually record information.

Slide 2 – Week 10 Outline

In the rest of the lessons this week, we'll talk about different kinds of sensors, as well as the different kinds of distortion that can be present in the data they acquire. We'll also talk about different satellite missions and how we can access satellite data, and finish the week by introducing digital images – how we typically work with satellite images on a computer.

Slide 3 – What is a satellite?

A satellite is any smaller object that orbits a larger object in space. Satellites occur naturally – for example, the Moon is a natural satellite of Earth. Jupiter has 79 different satellites orbiting it – the largest of these, Ganymede, is the 9th largest object in the solar system – larger even than the planet Mercury. Satellites can also be artificial, and these are what we will talk about today. Earth has an estimated 5000 artificial satellites in orbit right now, only about 1900 of which are still operational. Artificial satellites serve as platforms for sensors or equipment, serving many different purposes – oftentimes multiple purposes. Satellites can be used for communication, to relay radio signals, television, or even internet. They can be used for weather observation and forecasting, such as the GOES, Suomi, or Meteosat satellites. They can also be what are called Earth-observing or Earth-observation satellites, which acquire images of the Earth. As you might guess, these are perhaps the most useful for what we'll talk about in this course – namely, to study the Earth and its systems. Satellites can also have military or intelligence purposes, as many of the first artificial satellites were used; they can also be used for Astronomy, such as the Hubble Space Telescope. We also use satellites for navigation, with the Global Positioning System from the United States, GLONASS from the Russian Federation, and Galileo from the European Union being 3 prominent examples.

Slide 4 – Orbits

When we talk about an object's orbit, we're referring to the path or trajectory that it moves along. There are several different “parts” of an orbit that determine how a satellite moves. Objects move in elliptical orbits – that is, their orbits are ellipses. As a brief recap, an ellipse is a curve surrounding two points, called focal points or foci, such that the sum of the distance between any point on the curve and each focal point – here denoted d_1 and d_2 - is a constant value, denoted here as C . The two axes that define the ellipse are known as the major and minor axes – the major axis being the larger of the two. The semimajor axis is then half of the length of major, or longest, axis. For a satellite orbiting the Earth, we can also define its altitude, which is the average height it keeps above the surface of the Earth. The eccentricity of an orbit describes how “squished” the orbit is – how much it deviates from

being a circle. The inclination of the orbit is defined as the angle between the satellite's orbit and the Equator. So, an orbit with an inclination of 0 degrees will be directly above the equator, while an orbit with an inclination of 90 degrees will cross right over the Earth's poles. Above 90 degrees of inclination, we have what are known as *retrograde* orbits, meaning that the satellite is moving in the opposite direction of Earth's spin – so a satellite orbit of 180 degrees will orbit above the Equator, but it will move in the direction opposite of the Earth's rotation. Finally, the period of the orbit is how long it takes for the satellite to complete the orbit, and it's determined by the semi-major axis of the orbit and the mass of the object the satellite is orbiting. For the type of remote sensing we'll discuss in this module, we can think of satellites as belonging to two main classes. The first, polar orbits, are sometimes also called Low-Earth orbit, or LEO – they typically have an altitude between 400 and 900 km, though some definitions can go all the way out to 2000 km, which means they have an orbital period of around 60-120 minutes. These orbits are inclined in away that they pass near the Earth's poles – hence the name polar. Geostationary orbits, on the other hand, have an orbit altitude of nearly 36,000 km – so they're much further away from the Earth's surface, which means their orbital period is much longer than low-earth orbits. For artificial satellites, the choice of orbit mostly depends on the application – something we'll discuss more in the coming slides.

Slide 5 – Geostationary orbits

In the next two slides, we'll discuss two special types of orbits that are widely-used for remote sensing. The first of these is called a geostationary orbit, which is a special type of geosynchronous orbit. Geostationary orbits have an orbital period that exactly matches Earth's rotation, which is 23 hours, 56 minutes, and 4 seconds. Ish. They also have an orbital inclination of 0 degrees, which means that from the ground, they appear fixed in the sky, as you can hopefully see in the animation here to the right. Because they don't appear to move to an observer on the ground – in other words, they are stationary – they're great for weather satellites, communication satellites, and navigational satellites.

Slide 6 – Sun-synchronous orbits

The second special class of orbit that we'll discuss is what's called a sun-synchronous orbit. This is a special class of polar orbit – meaning it's inclined in such a way that it comes close to the Earth's poles. This kind of orbit precesses a complete revolution each year. What this means is that the orbital plane shifts about one degree to the East each day, so that after a whole year, the orbital plane has made one full rotation around the Earth, matching the movement of the Earth around the sun. As a result, the satellite crosses the Equator at the same local time on each pass. Because the satellite passes over each point at nearly the same local time, and each scene will have mostly consistent lighting, at least outside of extreme latitudes. The inclination of most of these orbits is also typically more than 90 degrees, which means the satellite is in a retrograde orbit – it's moving in the opposite direction of the Earth's rotation, as you can see here on the animation. Because of the consistent illumination and repeat visit time, these kinds of orbits are great for imaging – the kind of thing that we're interested in studying – and also for spying and intelligence purposes.

Slide 7 – Resolution

Before we keep going, we need to lay out a few different definitions of resolution to help keep us straight, as they can be easy to get confused. The first definition is the spatial resolution of a satellite sensor, which tells us how small an object on the ground can be to still be identified as a distinct object. Note that this is not the same thing as pixel size – we can re-sample an image to finer and finer pixel sizes, but this doesn't mean actually mean that we can identify smaller and smaller objects – not even if we keep saying “enhance” as we do so. The second kind of resolution that we want to think about is a sensor's spectral resolution, which tells us how small of a spectral separation we can measure. This depends on the number of bands, where they are along the electromagnetic spectrum, and how narrow they are. Next, we have temporal resolution - how often we get a repeat observation, meaning how often the satellite comes back to the same viewing angle. This determines how well we can detect changes over time. Radiometric resolution refers to how sensitive the sensor is to subtle differences in brightness. If you think about the lesson on digital images from last week, a sensor that uses 8 bits (256 possible values) to distinguish between the brightest and darkest values it sees has a much lower radiometric resolution than a sensor that uses 12 bits (4096 possible values).

Slide 8 – Some definitions

Next, we have some more definitions that we need to lay out before moving forward. A satellite's swath refers to the area imaged, or “seen” during an orbit. How large the swath is depends on both the satellite altitude as well as the sensor itself, and is related to the field of view and viewing angle of the satellite, that is, how wide an angle the satellite “sees” - a narrow field of view means a narrow swath, and vice-versa. A satellite's ground track is the path directly underneath the satellite or sensor. Another important angle definition is nadir – this is the angle pointing directly down from the sensor – the sensor sees them from directly overhead. Related to this, we can refer to off-nadir points, which are points that the sensor sees at an angle.

Slide 9 – Summary

In this lesson, we've discussed satellite orbits and some different concepts related to satellite sensors. We discussed how artificial satellites serve as a platform for sensors and other equipment, which can be used for any number of applications. We talked about how a satellite's orbit determines how much, how often, and when a sensor observes Earth's surface. Finally, we discussed different definitions of resolution, and how each of these different kinds of resolution help us determine what we can actually see in a satellite image.

Slide 10 – Additional Resources

Once again, you can read more about the concepts we've covered in this lesson in the textbooks, Chapter 5 of Lillesand, Kiefer & Chipman; and Chapter 6 of Campbell & Wynne. You can also read more in the online Remote Sensing Tutorials from Natural Resources Canada. I've included links for several different videos, including a series on Kepler's three laws of planetary motion, another on

classical orbital elements, and a video on orbit types that goes into a bit more detail about different orbit types we didn't cover today. That's all for this lesson – I hope you found it interesting, and if you have any questions, please don't hesitate to e-mail me or post in the discussion forum on blackboard. Bye!