BASIC PRINCIPLE OF SATELLITE METEOROLOGY

1. Meteorological Satellites, Polar Orbiting, Geostationary satellites, Introduction to Satellite Meteorology including Orbital Mechanics.
2. Remote Sensing, principles of Remote Sensing, Application in Meteorology.

What is satellite meteorology?

Satellite Meteorology refers to the study of the earth's atmosphere and oceans using data obtained from remote sensing devices flown onboard satellites orbiting the earth

Meteorology, like every other science, relies on careful and precise measurement of its subject. Meteorologists observe the atmosphere using two basic approaches.

Direct methods, also called in situ for "in place," measure the properties of the air that are in contact with the instrument being used.

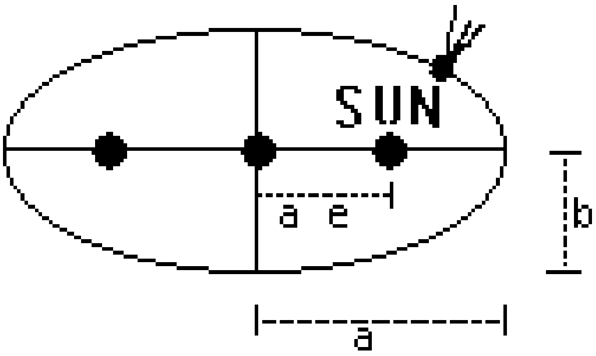
Indirect methods, also referred to as remote sensing, obtain information without coming into physical contact with the region of the atmosphere being measured.

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor - Tycho Brahe - with three statements which described the motion of planets in a sun-centered solar system.

Kepler's laws

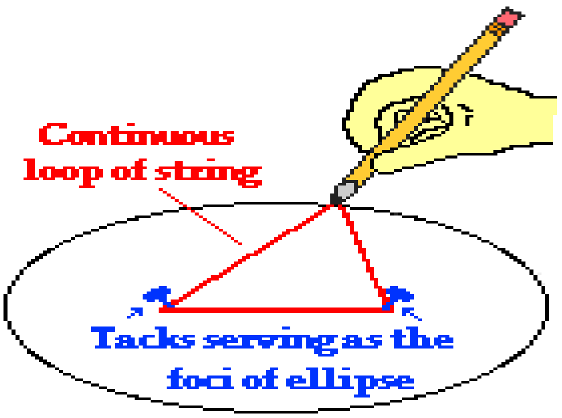
Johannes Kepler (1571-1630)

LAW 1: The orbit of a planet/comet about the Sun is an ellipse with the Sun's center of mass at one focus (The Law of ellipse)

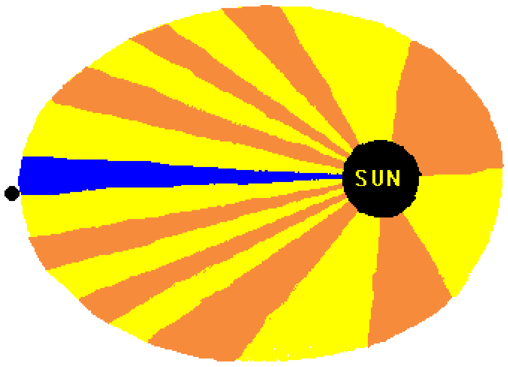


Kepler's first law – (Detailed Explanation)

Sometimes referred to as the law of ellipses - explains that planets are orbiting the sun in a path described as an ellipse. An ellipse can easily be constructed using a pencil, two tacks, a string, a sheet of paper and a piece of cardboard. Tack the sheet of paper to the cardboard using the two tacks. Then tie the string into a loop and wrap the loop around the two tacks. Take your pencil and pull the string until the pencil and two tacks make a triangle (see diagram at the right). Then begin to trace out a path with the pencil, keeping the string wrapped tightly around the tacks. The resulting shape will be an ellipse. An ellipse is a special curve in which the sum of the distances from every point on the curve to two other points is a constant. The two other points (represented here by the tack locations) are known as the foci of the ellipse. The closer together which these points are, the more closely that the ellipse resembles the shape of a circle. In fact, a circle is the special case of an ellipse in which the two foci are at the same location. Kepler's first law is rather simple - all planets orbit the sun in a path which resembles an ellipse, with the sun being located at one of the foci of that ellipse.

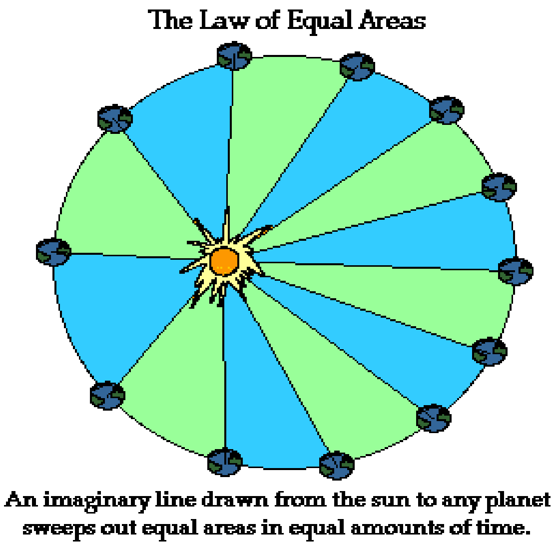


LAW 2: A line joining a planet/comet and the Sun sweeps out equal areas in equal intervals of time (The Law of Equal Areas)



Kepler's second law –(Detailed Explanation)

Sometimes referred to as the law of equal areas - describes the speed at which any given planet will move while orbiting the sun. The speed at which any planet moves through space will be constantly changing. A planet moves fastest when it is closest to the sun and slowest when it is furthest from the sun. Yet, if a line were drawn from the center of the planet to the center of the sun, that line would sweep out the same area in equal periods of time. For instance, if that line were drawn from the earth to the sun, then the area swept out by the line in every month would be the same. This is depicted in the diagram below. As can be noted in the diagram, the areas formed when the earth is closest to the sun can be approximated as a wide but short triangle; whereas the areas formed when the earth is farthest from the sun can be approximated as a narrow but long triangle. These areas (0.5*base*height) are the same size. Since the *base* of these triangles are longer when the earth is furthest from the sun, the earth would have to be moving more slowly in order for this imaginary area to be the same size as when the earth is closest to the sun.



LAW 3: The squares of the periods of the planets are proportional to the cubes of their semimajor axes: (The Law of Harmonies)

$$T_a^2 / T_b^2 = R_a^3 / R_b^3$$

- Square of any planet's orbital period (sidereal) is proportional to cube of its mean distance (semi-major axis) from Sun
- Mathematical statement: $T = kR^{3/2}$, where T = sideral period, and R = semi-major axis
- Example - If a is measured in astronomical units (AU = semi-major axis of Earth's orbit) and sidereal period in years (Earth's sidereal period), then the constant k in mathematical expression for Kepler's third law is equal to 1, and the mathematical relation becomes $T^2 = R^3$

Examples of Kepler's Third Law

Planet	**P (yr)**	**a (AU)**	**T^2**	**R^3**
Mercury	0.24	0.39	0.06	0.06
Venus	0.62	0.72	0.39	0.37
Earth	1.00	1.00	1.00	1.00
Mars	1.88	1.52	3.53	3.51
Jupiter	11.9	5.20	142	141
Saturn	29.5	9.54	870	868

Kepler's third law –(Detailed Explanation)

Sometimes referred to as the law of harmonies - compares the orbital period and radius of orbit of a planet to those of other planets. Unlike the first and second laws, which describe the motion characteristics of a single planet, the third law makes a comparison between the motion characteristics of different planets. The comparison being made is that the ratio of the squares of the periods to the cubes of their average distances from the sun is the same for every one of the planets. As an illustration, consider the orbital period and average distance from sun (orbital radius) for earth and mars as given in the table below.

Planet	Period(s)	AverageDist. (m)	$T^2/R^3 (s^2/m^3)$
Earth	3.156×10^7s	1.4957×10^{11}	2.977×10^{-19}
Mars	5.93×10^7s	2.278×10^{11}	2.975×10^{-19}

Observe that the T^2/R^3 ratio is the same for earth as it is for mars. In fact, if the same T^2/R^3 ratio is computed for the other planets, it will be found that thisratio shows approximate agreement with the same value for both earth and mars (see table below). Amazingly, every planet has the same T^2/R^3 ratio.

Planet	Period (yr)	Ave. Dist. (au)	T^2/R^3 (yr^2/au^3)
Mercury	**.241**	**.39**	**0.98**
Venus	**.615**	**.72**	**1.01**
Earth	**1.00**	**1.00**	**1.00**
Mars	**1.88**	**1.52**	**1.01**
Jupiter	**11.8**	**5.20**	**0.99**
Saturn	**29.5**	**9.54**	**1.00**
Uranus	**84.0**	**19.18**	**1.00**
Neptune	**165**	**30.06**	**1.00**
Pluto	**248**	**39.44**	**1.00**

NOTE: The average distance value is given in astronomical units where 1 a.u. is equal to the distance from the earth to the sun - 1.4957×10^{11} m. The orbital period is given in units of earth-years where 1 earth year is the time required for the earth to orbit the sun - 3.156×10^7 seconds.

Kepler's third law provides an accurate description of the period and distance for a planet's orbits about the sun. Additionally, the same law which describes the T^2/R^3 ratio for the planets' orbits about the sun also accurately describes the T^2/R^3 ratio for any satellite (whether a moon or a man-made satellite) about any planet. There is something much deeper to be found in this T^2/R^3 ratio - something which must relate to basic fundamental principles of motion.

<u>Orbital Parameters or Elements:</u>

Some geometric terms and Orbital elements are the parameters required to uniquely identify a specific orbit. In celestial mechanics these elements are generally considered in classical two-body systems, where a Kepler orbit is used (derived from Newton's laws of motion and Newton's law of universal gravitation).

A real orbit (and its elements) changes over time due to gravitational perturbations by other objects and the effects of relativity. A Keplerian orbit is merely an idealized, mathematical approximation at a particular time.

<u>Elements that defines shape and size of an ellipse:</u>

<u>Eccentricity (</u>ε) is a parameter that determines the amount by which its orbit around another body deviates from a perfect circle. A value of 0 is a circular orbit, values between 0 and 1 form an elliptical orbit, 1 is a parabolic escape orbit, and greater than 1 is a hyperbola. Basically it defined the shape of the ellipse, describing how much it is elongated compared to a circle.

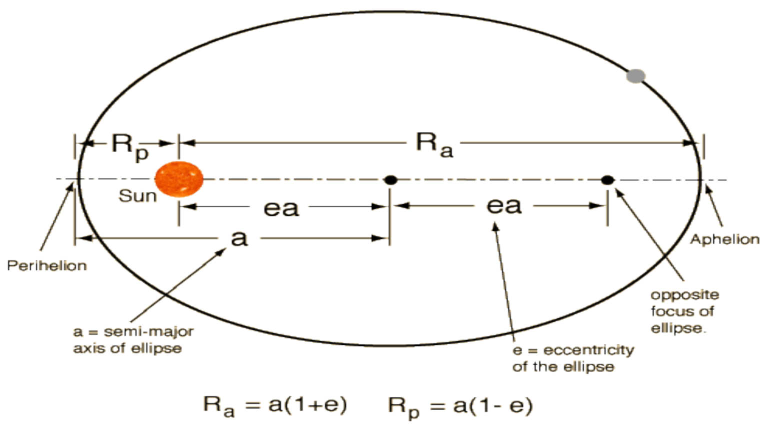
The eccentricity may take the following values:

- circular orbit: $e = 0$
- elliptic orbit: $0 < e < 1$
- parabolic trajectory: $e = 1$
- hyperbolic trajectory: $e > 1$

<u>Semi major axis (</u>a) - The sum of the periapsis and apoapsis distances divided by two. For circular orbits the semi major axis is the distance between the centers of the bodies, not the distance of the bodies to the center.

Perigee - point on the orbit where the satellite is closest to Earth

Apogee - point on the orbit where the satellite is furthest from Earth



Line of apsides – the line joining the perigee and apogee through the center of the earth

Ascending Node – the point where the orbit crosses the equatorial plane going from south to north.

Descending Node – the point where the orbit crosses the equatorial plane going from north to south.

Line of Nodes – the line joining the ascending and descending nodes through the center of the earth

Orbital Elements: In order to specify a satellite orbit or to determine the location of a satellite in space, a set of parameters are needed called orbital elements, defined as follows(using the Ω-δ system):

(1) **Semimajor axis (a)**

(2) **Eccentricity (ε)**

(3) **Inclination angle (i)**: is the angle between the equatorial plane and the orbital plane,i = 0° if these planes coincide and if the satellite revolves in the same direction as Earth's rotation

i =180° if these planes coincide but the satellite revolves in the opposite direction to Earth's rotation

i< 90° is called a **prograde orbit**

i> 90° is called a **retrograde orbit**

(4) **Right ascension of the ascending node (Ω):** Nodes are the points where an orbit crosses a plane, such as a satellite crossing the Earth's equatorial plane. If the satellite crosses the plane going from south to north, the node is the ascending node; Ω is the right ascension of this point. In practice, it is the right ascension of the intersection of the orbital plane with the equatorial plane. if the satellite moving from north to south, it is the descending node. The longitude of the ascending node is the node's celestial longitude. Celestial longitude is analogous to longitude on Earth and is measured in degrees counter-clockwise from zero with zero longitude being in the direction of the vernal equinox

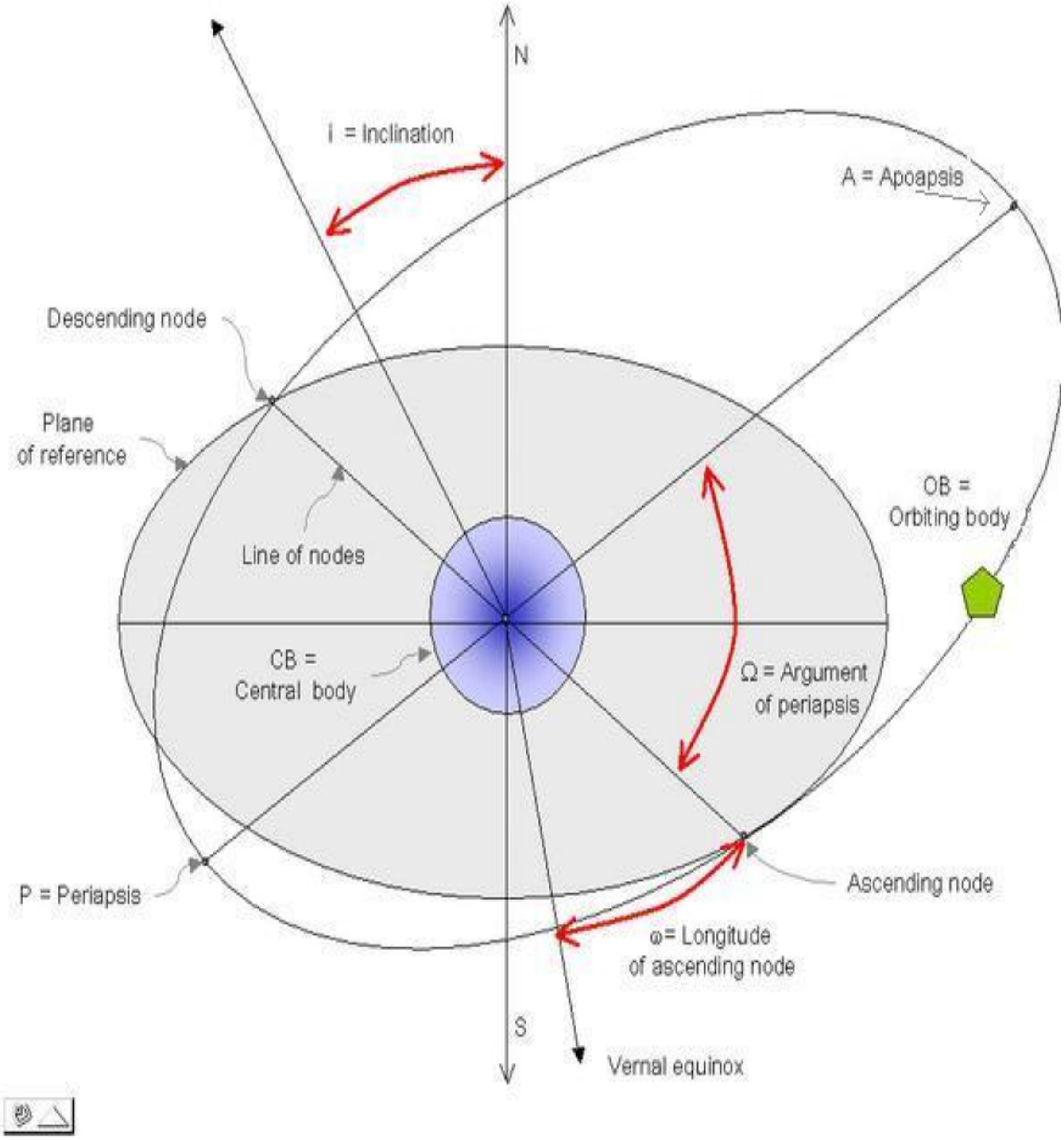
(5) **Argument of perigee (ω):** is the angle between the ascending node and perigee, measured in the orbital plane.

(6) **Epoch time (t):** is the time at which the orbital elements are observed, needed because some of these elements are time-dependent. Sometimes tp (time of perigee passage) is used.

(7) **Mean anomaly (M):** defines the position of the orbiting body along the ellipse at a specific time(the "epoch").

a and ε are the "shape" elements - they define the size and shape of the orbit, i, Ω, and ω are the "orientation" elements - they position the orbit in the Ω-δ system

Orbital elements Ω, ω, t, and M depend on time, and are often subscripted with "o" to indicate their value at the epoch time.

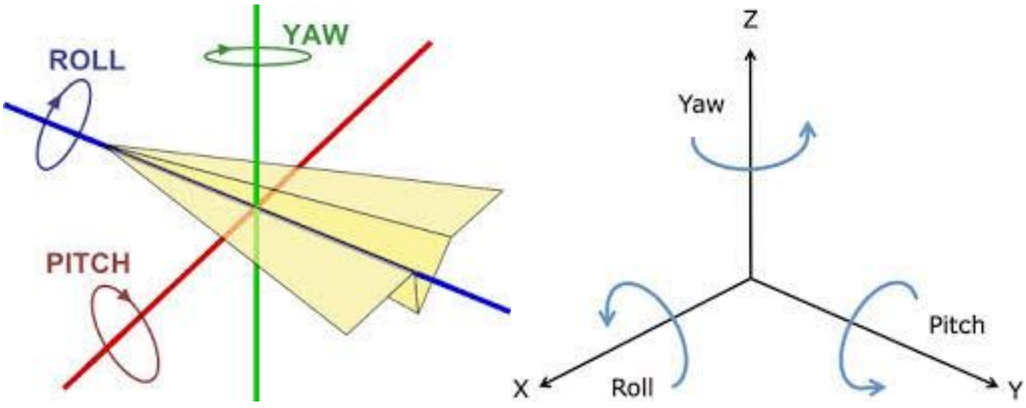


Satellite Attitude:The term satellite attitude refers to the orientation of the satellite spin vector in space. In non-spinning satellite the attitude are defined in terms of the deviation from the nominal orientation of its Roll,Pitch and Yaw.

Roll-it is the orientation of the space craft around the direction of its forward movement.

Yaw-rotation of spacecraft around the axis looking at the nadir.

Pitch-rotation of the spacecraft around axis normal to roll and yaw axis.



In the case meteorological satellites, the antennas must always remain in ground contact for communications and data transfer and its imaging sensors must always view the Earth.Satellite attitude therefore demands to be carefully controlled and the two ways of doing it are through spin stabilization and 3-axis stabilization.

SPIN STABILIZIED SATELLITE:A spin stabilized satellite rotates around its own vertical axis spinning like a top and resisting external perturbation forces. Here the orientation of the satellite spin vector in space defines its attitude. Spin stabilized satellite equipped with thrusters which can be fired occasionally to bring about desired changes in the spin rate and to restore the spin vector orientation. The disadvantage in spinning satellites is that they cannot have large solar arrays and required to be supported by the battery power. Another inconvenience factor is that instruments or antennas are required to de-spin so that the antenna and radiometers maintained their desired orientation relative to the earth.

THREE AXIS-STABILIZIED SATELLITE: The attitude of non-spinning satellites is controlled by minimizing the roll, pitch and yaw. This is called 3-axis stabilization and it is achieved through the deployment of electrically powered spinning wheels called Momentum Wheels. If the satellite is found to be deviating from its desired attitude, the appropriate wheels are speeded up or slow down to restore the correct attitude.

An advantage of 3-axis stabilization is that radiometers and antennas can always be made to point at the desired targets without having to perform de-spin maneuvers.

In three-axis stabilized geostationary meteorological satellites, the scanning radiometers have to alternate their scan between east-west and west-east directions until the earth’s disc gets fully scanned.

Meteorological Satellite Orbits

Brief History of Satellite Meteorology:

Until the invention of the hot-air balloons in 1972, the only way humans could get a bird's eye view of the earth was to climb a tree or hike to the top of the mountain. When the camera was developed in the mid-1800's people began to take aerial photographs from hot-air balloons.

Then in 1950's when scientists readied to launch satellites that would orbit the earth and enable continuous remote sensing of our atmosphere, lithosphere, biosphere and hydrosphere.

Today, satellites record natural disasters such as fire, earthquakes, and volcanoes on a routine basis, along with monitoring the oceans, weather and just about everything else that goes on between the earth's surface and the top of the exosphere.

In the short span of four decades, humans have launched thousands of satellites. According to NASA, there are currently over 2500 satellites orbiting earth.

Meteorological satellites requirements:

a) To serve as an observing platform with appropriate sensors on board and transmitting the information (imaging & sounding) to the stations located on the earth's surface.

b) To serve as a collector of meteorological data from unmanned land/ocean based instruments - Data collection platforms.

c) To serve as a communication satellite for rapid exchange of meteorological data among centers and for rapid dissemination of weather forecasts, warnings etc. to user agencies.

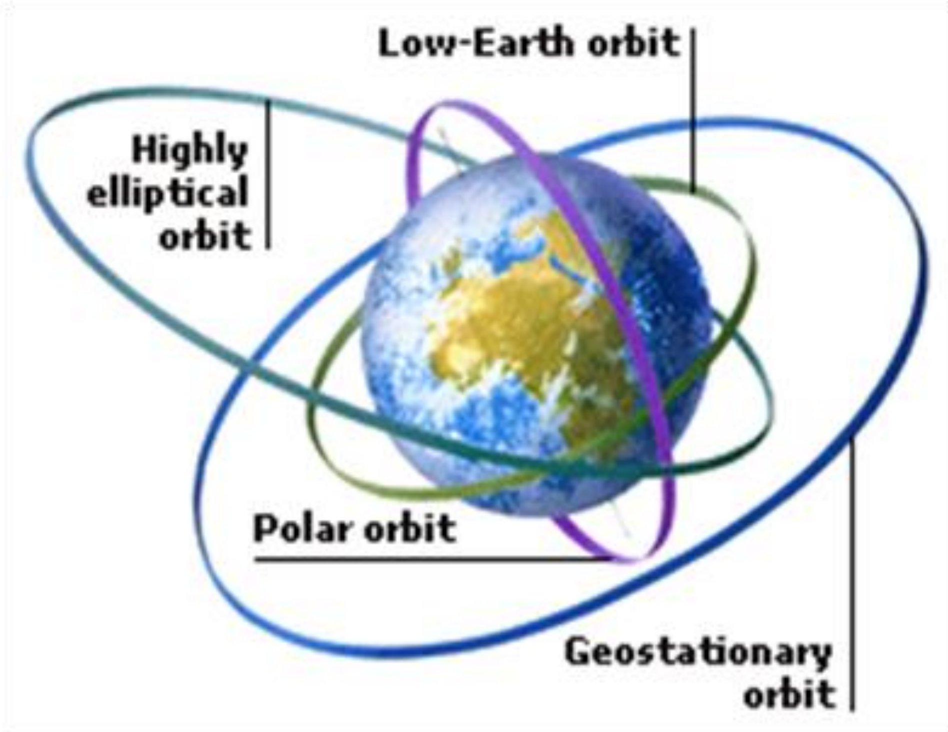
Satellites on the basis of Orbits:

A satellite is an object that orbits a larger object, such as a planet. The earth's moon is an example of a natural satellite; weather satellites are the result of human ingenuity.

Types of satellite Orbit

An orbit for a satellite is chosen based on the mission of that particular satellite. For instance, the lower the altitude of a satellite, the better the resolution an onboard camera can have and the shorter the time it takes to travel around the earth (period). On the other hand, the farther out a satellite is, the more of the earth's surface it can observe at one time. Also, the farther the orbit is tilted away from the equator, the more of the earth's surface a satellite will observe over the course of an orbit. These parameters (which will be described in more detail later in the chapter) drive the four basic orbit types: low Earth orbit (LEO), medium Earth orbit (MEO), geosynchronous Earth orbit

(GEO), and highly elliptical orbit (HEO). Table 6-1 lists the various orbit types and the missions associated with each one.



LOW EARTH ORBIT SATELLITES

LEO satellites orbit the earth at an altitude lies between 60 to 1,600 km by the laws of orbits, corresponding to periods of about 100 minutes to go around the earth. At these altitudes, onboard sensors have the best resolution, communication systems require the least power to talk to the earth, and rockets require the least energy to get them to orbit. LEO satellites can be divided into three general categories: polar sun-synchronous, polar non–sun-synchronous, and inclined nonpolar.

The term inclined nonpolar orbit refers to all LEO satellites that are not in near-polar orbits.1 The inclination of the orbit is equal to the maximum latitude the satellite will pass over. Thus, this type of orbit is used when global coverage of the earth is not needed. The chosen inclination is ordinarily the latitude of the launch site to maximize the amount of energy gained from the rotation of the earth. The International Space Station and space shuttle fall into this orbit category.

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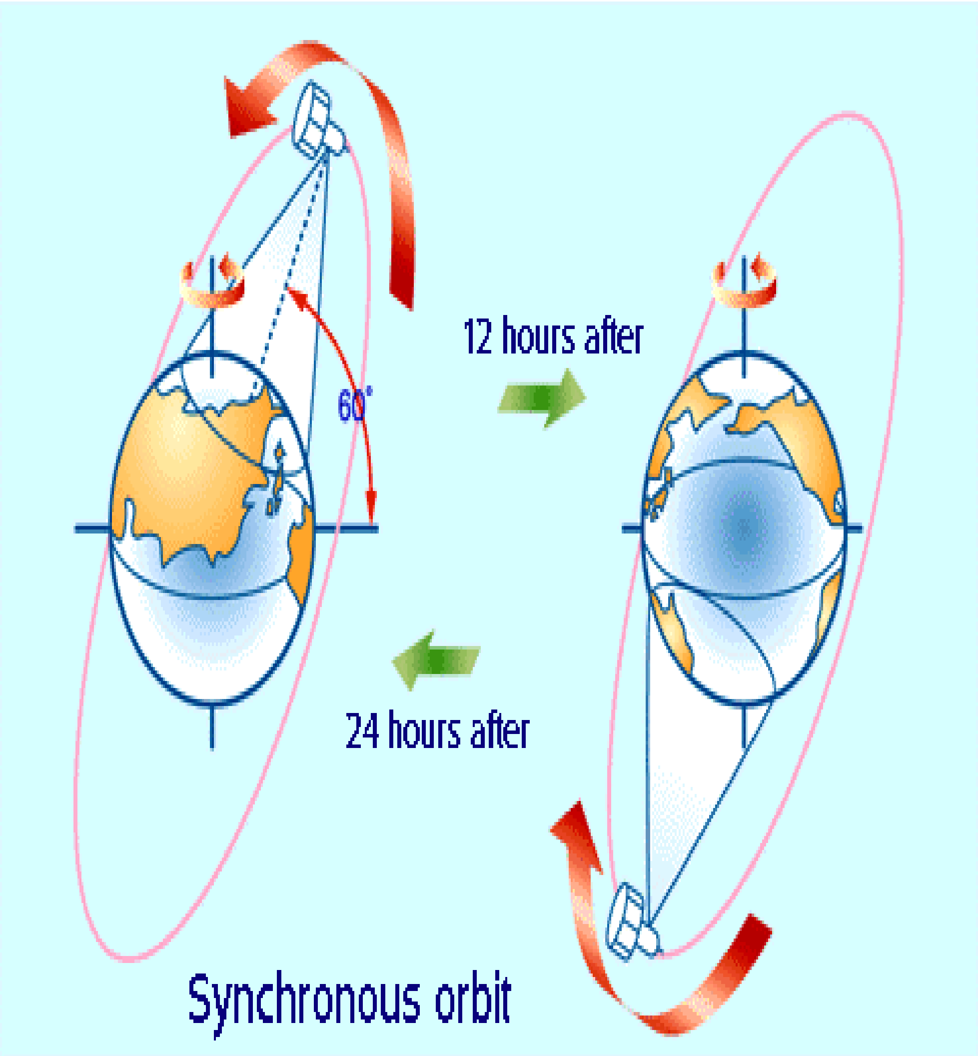
Polar Sun Synchronous:

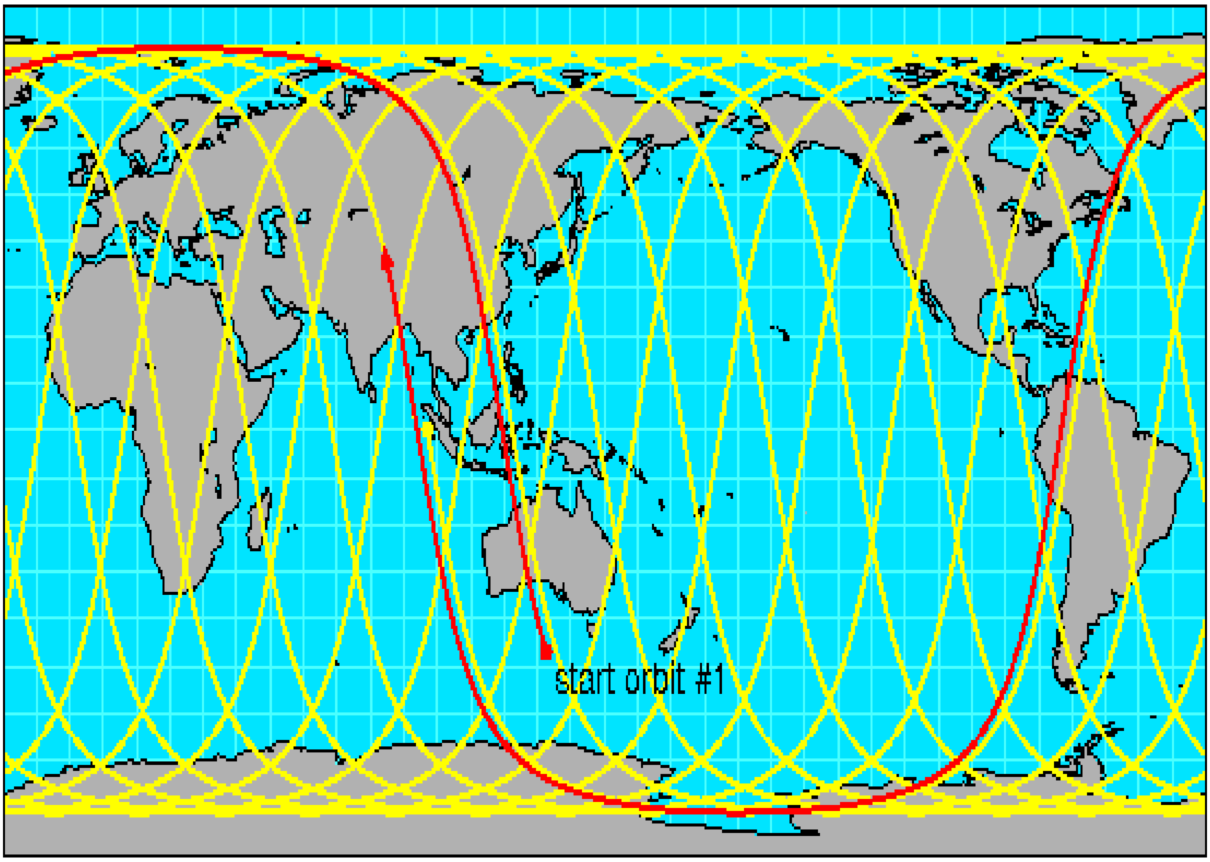
If the designers want the orbit to pass over a specific point on the earth at a specific time each day, a **polar sun synchronous** orbit is needed. In this type of orbit, a specific altitude and inclination are picked such that the natural orbit precision exactly matches the rate that the earth orbits the sun [(360° per year)/ (365.25 days per year) = .986° per day].

Sun-synchronous polar orbiting satellites pass over any given latitude at almost the same local time during each orbital pass. Thus they image their swaths at about the same local time during each pass, so that lighting remains roughly uniform. Of course the clouds change with each orbit, but their broad patterns and positions remain mostly unchanged in the short orbital periods involved.

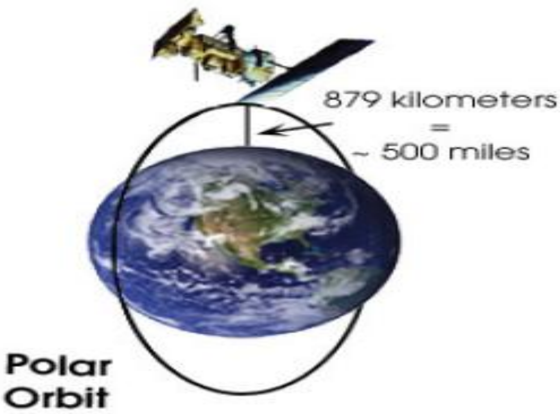
From this method, we can make a daily mosaic from the swaths, which is a good general summary of global weather patterns for that period. This same orbital configuration applies to Landsat, SPOT, and some of the other land observers.



These satellites collect data in a swath beneath them as the earth rotates on its axis.In this way, a polar orbiting satellite can "see" the entire planet twice in a 24 hour period. The basic operational mode deploys two polar orbiting satellites continuously, one passing north to south (descending) and the other passing south to north (ascending), circling the earth every 12 hours.



Polar Non–Sun-synchronous: A **polar non–sun-synchronous** orbit is like the previous orbit except that the inclination is nearly polar. This type of orbit is used to maximize the coverage of the earth—every latitude will ultimately be passed over, and because of the fast period, a large part of the earth's surface will be seen each day. All the earth's surface will ultimately be overflown. This type of orbit is commonly used for constellations of communication satellites. One phenomenon affecting a polar, non–sun-synchronous orbit is that, because the earth is not a perfect sphere, the orbit will drift (or precess) over time.

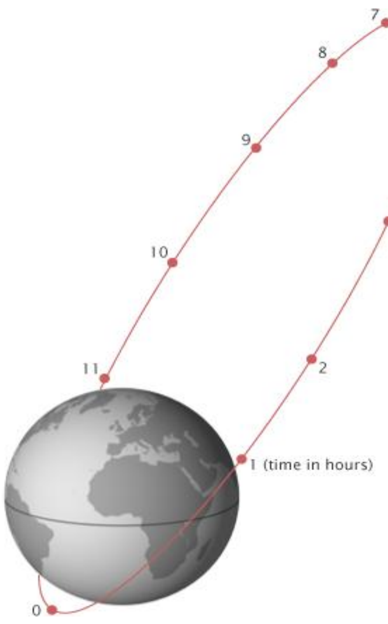


INCLINED NONPOLAR: The term inclined nonpolar orbit refers to all LEO satellites that are not in near-polar orbits. The inclination of the orbit is equal to the maximum latitude the satellite will pass over. Thus, this type of orbit is used when global coverage of the earth is not needed

MEDIUM EARTH ORBIT SATELLITES:

MEO satellites orbit the earth at an altitude between approximately 1,000 and 12,000 statute miles (1,600 to 19,300 km), corresponding to periods between 100 minutes and 12 hours. Medium Earth orbits are used to provide longer dwell times over a given region and a larger coverage area of the earth as compared to LEO satellites. In addition, the higher altitude above the earth reduces the effects of atmospheric drag to effectively zero. MEO satellite missions include navigation systems. An example of an MEO satellite, a semi synchronous satellite ground track, can be seen in this orbit, with an orbital period (the time it takes to make one complete orbit around the earth) of approximately 12 hours, repeats twice a day. Since the earth turns halfway on its axis during each complete orbit, the points where the sinusoidal ground tracks cross the equator coincide pass after pass, and the ground tracks repeat each day as shown. This predictability is very helpful for ground stations monitoring the satellite.

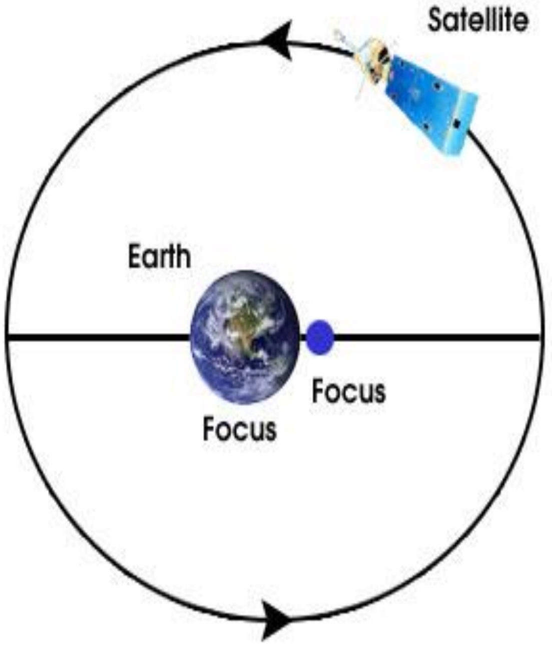
Highly Elliptical Orbit Satellites: All the orbits discussed thus far have been circular. However, orbits can also take on an elliptical shape. HEO satellites are the most common noncircular orbits, and they orbit the earth at altitudes which vary between approximately (1,060 and 38,624 km) in a single period. Satellites travel faster the closer they are to the earth, so HEO orbits enable long dwell times as well as large fields of view when at their farthest points from the earth (apogee). They are primarily used for communications, scientific research, and intelligence, surveillance and reconnaissance (ISR) missions when GEO orbits are inaccessible. The most popular highly elliptical orbit is the "Molniya" orbit, named after the Russian word for lightning to describe the speed at which a satellite in this particular orbit travels through its closest point of approach (perigee).



GEOSYNCHRONOUS EARTH ORBIT SATELLITE

GEO satellites orbit the earth at an altitude of 22,236 statute miles (35,786 km). At this altitude, a satellite in a circular orbit and zero inclination will have an orbital period equal to the earth's rotational period (approximately 24 hours). This allows a satellite to remain relatively fixed over a particular point on the earth's surface. At an altitude of 22,236 miles, one geosynchronous satellite has a commanding field of view of almost one-third of the earth's surface from approximately 75° south latitude to approximately 75° north latitude.

Therefore, geosynchronous orbits are desirable for communications and early warning systems. However, this altitude and inclination are the most difficult to achieve, especially for nations without an equatorial launch site. The terms geosynchronous and geostationary have been used interchangeably, but there is a distinct difference between the two. Geosynchronous refers to a satellite with a 24-hour period, regardless of inclination. Geostationary refers to a satellite with a 24-hour period, in a near-circular orbit, with an inclination of approximately zero. It appears to hover over a spot on the equator. All geostationary orbits must be geosynchronous, but not all geosynchronous orbits are necessarily geostationary.



An example of a non-geostationary satellite would be the Syncom 2, launched in 1963 into a geosynchronous orbit with a 33° inclination Now take the same orbit and give it an inclination of 30°. The period and orbit shape remain the same. The ground trace will retrace itself with every orbit, in this case in a figure-eight pattern. The ground trace will also vary between 30° north and 30° south latitude due to its 30° inclination. In another example, if the geostationary satellite has an eccentricity near zero and an inclination of 60°, the ground trace would follow a similar, larger figure-eight path between 60° north and 60° south latitude.

Orbit types:

Orbit Type	Mission	Altitude	Period	Tilt	Shape
LEO					
Polar sun-synchronous	Remote sensing/weather	150–900 km	98–104min	98°	circular
Inclined nonpolar	International Space Station	~ 340 km	~91 min	~51.6°	circular
Polar non–sun-synchronous	Earth observing,scientific	~450–600 km	~90–101min	~80–94°	circular
MEO					
Semi synchronous	Navigation, communications, space environment	~20,100 km	~12 hours	~55°	circular
GEO					
Geosynchronous Geostationary	Communication, early warning, nuclear detection, weather	~35,786 km	~24 hours (23h 56m 04s)	~0°	circular
HEO					
Molniya	Communications Varies from	~495 km to ~39,587 km	~12 hours (11h 58m)	63.4° long	ellipse

Remote sensing

An Introduction

Remote Sensing is the science and art of acquiring information (spectral, spatial, temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilised. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter. EMR is considered to span the spectrum of wavelengths from 10-10 mm to cosmic rays up to 1010 mm, the broadcast wavelengths, which extend from 0.30-15mm.

Types of remote sensing

1. **In respect to the type of Energy Resources:**

    - **Passive Remote Sensing**: Makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural sources.

- **Active remote Sensing**: Makes use of sensors that detect reflected responses from objects that are irradiated from artificially-generated energy sources, such as radar.

2. **In respect to Wavelength Regions:**

   Remote Sensing is classified into three types in respect to the wavelength regions
   - Visible and Reflective Infrared Remote Sensing.
   - Thermal Infrared Remote Sensing.
   - Microwave Remote Sensing.

Major Components of Remote Sensing Technology:

The following are major components of Remote sensing System:

1. Energy Source
2. Passive System: sun, irradiance from earth's materials;
3. Active System: irradiance from artificially generated energy sources such as radar.
4. Platforms :(Vehicle to carry the sensor) (truck, aircraft, space shuttle, satellite, etc.)
5. Sensors :(Device to detect electro-magnetic radiation) (camera, scanner, etc.)
6. Detectors: (Handling signal data) (photographic, digital, etc.)
7. Processing :(Handling Signal data) (photographic, digital etc.)
8. Institutionalization: (Organization for execution at all stages of remote-sensing technology: international and national organizations, centers, universities, etc.).

Platforms

The vehicles or carriers for remote sensors are called the platforms. Typical platforms are satellites and aircraft, but they can also include radio-controlled aeroplanes, balloons kits for low altitude remote sensing, as well as ladder trucks or 'cherry pickers' for ground investigations. The key factor for the selection of a platform is the altitude that determines the ground resolution and which is also dependent on the instantaneous field of view (IFOV) of the sensor on board the platform.

Bands Used in Remote Sensing

Emission of EMR (Electro-Magnetic Radiation) from gases is due to atoms and molecules in the gas. Atoms consist of a positively charged nucleus surrounded by orbiting electrons, which have discrete energy states. Transition of electrons from one energy state to the other leads to emission of radiation at discrete wavelengths. The resulting spectrum is called line spectrum. Molecules possess rotational and vibrational energy states. Transition between which leads to emission of radiation in a band spectrum. The wavelengths, which are emitted by atoms/molecules, are also the ones, which are absorbed by them. Emission from solids and liquids occurs when they are heated and results in a continuous spectrum. This is called thermal emission and it is an important source of EMR from the viewpoint of remote sensing.

The **Electro-Magnetic Radiation** (EMR), which is reflected or emitted from an object, is the usual source of Remote Sensing data. However, any medium, such as gravity or magnetic fields, can be used in remote sensing.

Remote Sensing Technology makes use of the wide range Electro-Magnetic Spectrum (EMS) from a very short wave "Gamma Ray" to a very long 'Radio Wave'.

Wavelength regions of electro-magnetic radiation have different names ranging from Gamma ray, X-ray, Ultraviolet (UV), visible light, Infrared (IR) to Radio Wave, in order from the shorter wavelengths. The optical wavelength region, an important region for remote sensing applications, is further subdivided as follows:

Name	**Wavelength (mm)**
Optical wavelength	0.30-15.0
Reflective	0.38-3.00
1. Visible	0.38-0.72
2. Near IR	0.72-1.30
3. Middle IR	1.30-3.00
Far IR (Thermal, Emissive)	7.00-15.0

Microwave region (1mm to 1m) is another portion of EM spectrum that is frequently used to gather valuable remote sensing information.

SENSORS:

PASSIVE SENSORS- Detect the reflected or emitted electromagnetic radiation from natural sources.

ACTIVE SENSORS - Detect reflected responses from objects that are irradiated from artificially-generated energy sources such as radar.

Resolution

In general resolution is defined as the ability of an entire remote-sensing system, including lens antennae, display, exposure, processing, and other factors, to render a sharply defined image. Resolution of a remote-sensing is of different types.

1. Spectral Resolution: of a remote sensing instrument (sensor) is determined by the band-widths of the Electro-magnetic radiation of the channels used. High spectral resolution, thus, is achieved by narrow bandwidths width, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad bandwidth.
2. Radiometric Resolution: is determined by the number of discrete levels into which signals may be divided.
3. Spatial Resolution: in terms of the geometric properties of the imaging system, is usually described as the instantaneous field of view (IFOV). The IFOV is defined as the maximum angle of view in which a sensor can effectively detect electro-magnetic energy.
4. Temporal Resolution: is related to the repetitive coverage of the ground by the remote-sensing system.

APPLICATIONS IN METEOROLOGY

Remote sensing in visible, Infra Red and microwave regions has proved to be very useful in weather analysis and forecasting. Some of its applications are listed below:

1. Satellite imageries are used by the forecasters asfirst hand information along with synoptic chart analysis while issuing the forecast. Continuous recording and transmission of data is possible.

2.Atmospheric sounding, clouds precipitation, convergence and divergence in the atmosphere, thunderstorm formation,various convective activities, CMV's etc. can be derived / forecasted with the help of satellite pictures and their analysis.

3. Cyclone formation, its intensity and movement (Track) can be monitored and predicted.

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