# Geosynchronous Orbit

## Description

A geosynchronous orbit is a high Earth orbit that allows satellites to match Earth's rotation. Located at 22,236 miles (35,786 kilometers) above Earth's equator, this position is ideal for monitoring weather, communications and surveillance. The International Telecommunication Union (ITU) assigns slots for geosynchronous orbit and settles disputes between countries about slots. For disposal, it is considered good practice to move satellites at or near end-of-life into a "graveyard" orbit above geosynchronous orbit before they run out of fuel so to open the slot for follow-on systems [1].

A geosynchronous orbit (GEO) is a prograde, low inclination orbit about Earth having a period of 23 hours 56 minutes 4 seconds. A spacecraft in geosynchronous orbit appears to remain above Earth at a constant longitude, although it may seem to wander north and south. The spacecraft returns to the same point in the sky at the same time each day [2].

Geosynchronous orbits (GEO) are circular orbits around the Earth having a period of 24 hours. A geosynchronous orbit with an inclination of zero degrees is called a *geostationary orbit*. A spacecraft in a geostationary orbit appears to hang motionless above one position on the Earth's equator. For this reason, they are ideal for some types of communication and meteorological satellites. A spacecraft in an inclined geosynchronous orbit will appear to follow a regular figure-8 pattern in the sky once every orbit. To attain geosynchronous orbit, a spacecraft is first launched into an elliptical orbit with an apogee of 35,786 km (22,236 miles) called a geosynchronous transfer orbit (GTO). The orbit is then circularized by firing the spacecraft's engine at apogee [3].

## Advantages of GEO

Due to the height of satellites in geosynchronous earth orbit a significant geographical area can be covered by a single satellite. More specifically, only three satellites are required to provide coverage for the entire earth with the exception of the north and south polar regions. Satellites in GEO remain in a fixed position enabling 24/7 access from ground stations eliminating the need for inter-satellite handovers. Lastly, satellites in geosynchronous earth orbit eliminate the need to compensate for doppler shifts due to satellite being stationary relative to the earth.

## Disadvantages of GEO

Due to the height of satellites relative to ground stations, there is considerable latency of approximately 240 milli-seconds (round-trip) due to the radial distance of the satellite from earth ground stations. Therefore, despite the increased coverage with less satellites, these satellites are not ideal for time-critical operations such as real-time voice, image, and video communication systems. Furthermore, the increased distance also results in the need of more complex and costly electronics such as low-noise amplifiers and signal processing equipment on the payload as well as the ground stations. Lastly, due to the fixed position of satellites in geosynchronous earth orbit and the curvature of the earth, communications of \pm 70 degrees latitude is not possible.

# Geostationary Orbit

## Description

To achieve a geostationary orbit, a geosynchronous orbit is chosen with an eccentricity of zero, and an inclination of either zero, right on the equator, or else low enough that the spacecraft can use propulsive means to constrain the spacecraft's apparent position, so it hangs seemingly motionless above a point on Earth. (Any such maneuvering on orbit, or making other adjustments to maintain its orbit, is a process called **station keeping**.) The orbit can then be called geostationary. This orbit is ideal for certain kinds of communication satellites and meteorological satellites. The idea of a geosynchronous orbit for communications spacecraft was first popularized by science fiction author Sir Arthur C. Clarke in 1945, so it is sometimes called the Clarke orbit [2].

# Geosynchronous Transfer Orbit

## Description

To attain geosynchronous (and geostationary) Earth orbits, a spacecraft is first launched into an elliptical orbit with an apoapsis altitude about 37,000 km. This is called a **Geosynchronous Transfer Orbit** (GTO). The spacecraft then circularizes the orbit by turning parallel to the equator at apoapsis and firing its rocket engine. That engine is usually called an **apogee motor**. It is common to compare various [launch vehicles' capabilities](https://solarsystem.nasa.gov/basics/chapter14-1) according to the amount of mass they can lift to GTO [2].

# Polar Orbits

## Description

Polar orbits are 90-degree inclination orbits, useful for spacecraft that carry out mapping or surveillance operations. Since the orbital plane is nominally fixed in inertial space, the planet rotates below a polar orbit, allowing the spacecraft low-altitude access to virtually every point on the surface. To achieve a polar orbit at Earth requires more energy, thus more propellant, than does a direct orbit of low inclination. To achieve the latter, launch is normally accomplished near the equator, where the rotational speed of the surface contributes a significant part of the final speed required for orbit. A polar orbit will not be able to take advantage of the "free ride" provided by Earth's rotation, and thus the launch vehicle must provide all the energy for attaining orbital speed [2].

# Walking Orbits

## Description

Planets are not perfectly spherical, and they do not have evenly distributed surface mass. Also, they do not exist in a gravity "vacuum." Other bodies such as the sun, or natural satellites, contribute their gravitational influences on a spacecraft in orbit about a planet. It is possible to choose the parameters of a spacecraft's orbit to take advantage of some or all these gravitational influences to induce precession, which causes a useful motion of the orbital plane. The result is called a walking orbit or a precessing orbit, since the orbital plane moves slowly with respect to fixed inertial space [2].

# Sun-synchronous Orbits

## Description

A walking orbit whose parameters are chosen such that the orbital plane precesses with nearly the same period as the planet's solar orbit period is called a sun synchronous orbit. In such an orbit, the spacecraft crosses periapsis at about the same local time every orbit. This can be useful if instruments on board depend on a certain angle of solar illumination on the surface. Mars Global Surveyor's orbit is a 2-pm Mars Local Time sun-synchronous orbit, chosen to permit well-placed shadows for best viewing. It may not be possible to rely on use of the gravity field alone to exactly maintain a desired synchronous timing, and occasional propulsive maneuvers may be necessary to adjust the orbit [2].

# Orbital Elements

To completely describe an orbit mathematically, six quantities must be calculated. These quantities are called orbital elements, or Keplerian elements, after Johannes Kepler (1571-1630).

## Semi-major Axis

The value representing one-half of the major axis and the satellites mean distance from the Earth

## Eccentricity

The quantitative value describing deviation of a curve or orbit from circularity (i.e., a value of zero indicates a circle)

## Inclination

The angular distance of the orbital plane from the plane of the planet’s equator (or from the ecliptic plane in heliocentric orbits)

## Argument of Periapsis

The angular distance of the periapsis (shortest distance between satellite and Earth) from the ascending node

## Time of Periapsis Passage

The time in which a satellite moves through its point of periapsis (shortest distance between satellite and Earth)

## Celestial Longitude of Ascending Node

The nodes celestial longitude: celestial longitude is analogous to longitude on Earth and is measured in degrees counterclockwise from zero with zero longitude being in the direction of the vernal equinox

# Atmospheric Windows

Below 30 MHz, the ionosphere, at altitudes from around 100 to 500 km, absorbs and reflects signals. Above 30 GHz, the lower atmosphere or troposphere, below 10 km, absorbs radio signals due to oxygen and water vapor. Even between 20 and 30 GHz, there are some absorption bands that must be avoided [3].