



Note: This file can not replace watching the video lecture. Because the video lecture contains more explanation through graphical elaboration.

Certified Junior Astronaut Training Course



Satellite Orbits (Part 4)





This lecture will answer the following inquiry:



How can a satellite orbit be designed?

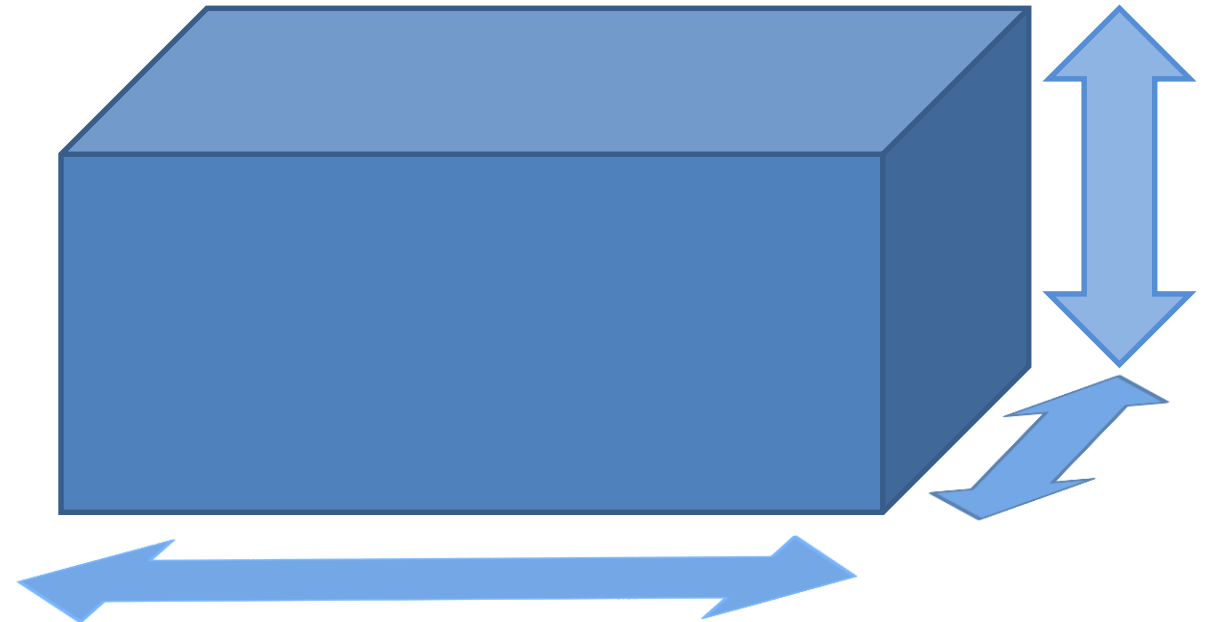




How can a satellite orbit be designed?

In order to imagine the process of orbit design in a simplified way, we should imagine first the following simplified example:

- + If we want to design a cubic box for storing several items, how can we design this box?
- + The design should start by the box description, which is represented in three main elements (Length – Width – and Height). The dimensions should be adequate enough to achieve the desired mission; which is storage.
- + Thus; the box design is simply represented by defining the values of these three main elements that are sufficient to describe the shape of the box.





Cont.. How can a satellite orbit be designed?

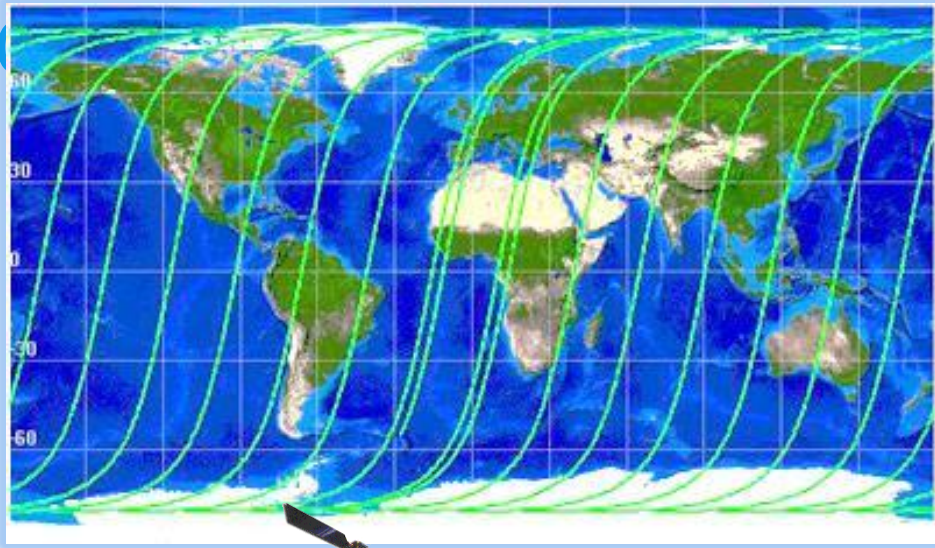
- Similarly; orbit design is defining five elements that are adequate to describe both the shape of the orbit and its orientation in space. These five elements are called Orbital Elements. They will be discussed in details.

Orbital Elements

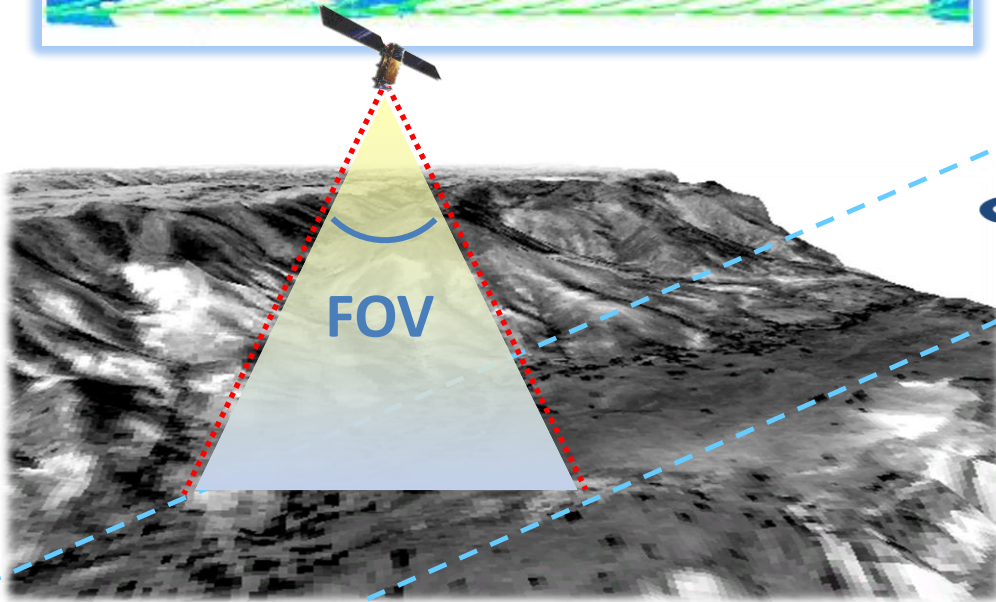
a e i Ω ω



Cont.. How can a satellite orbit be designed?



Swath Width



- ✚ According to the values of these elements that are specified during the orbit design stage and knowing the date and time of launching the satellite into its orbit, we can calculate the satellite track in its orbit on earth during its rotation in order to draw the Ground Tracks. This will enable us to know the coverage areas that the satellite will visit, the count of revisit times per day, and date and time of future visits.
- ✚ We can also calculate the Swath Width by knowing the altitude and Field of View (FOV) of the imaging sensor.



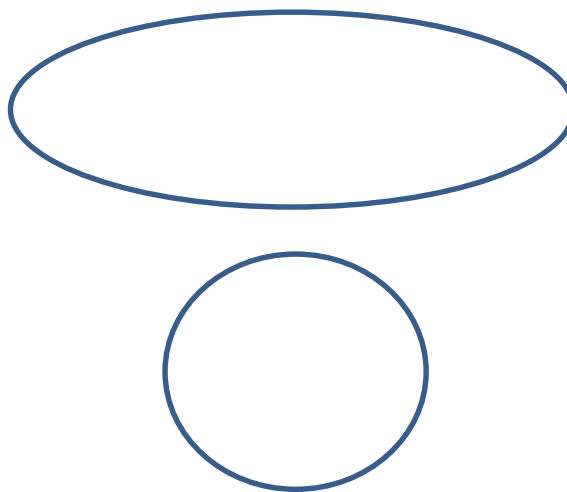
Cont.. How can a satellite orbit be designed?

Orbital Elements

The orbital elements include five symbols: $[a, e, i, \Omega, \omega]$. Two of these symbols are used to describe the Orbit Shape; while the other three symbols are used to describe Orbit Orientation.

a e i Ω ω

Orbit shape



Orbit Orientation

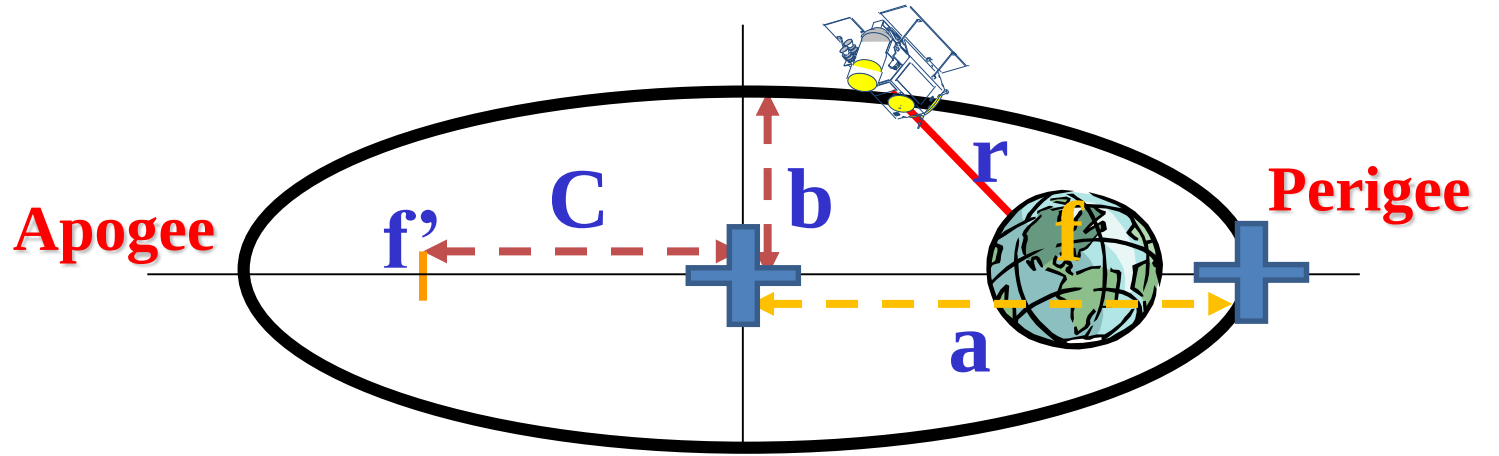




Cont.. How can a satellite orbit be designed?

a, e

- ✚ We use the two values $[a, e]$ to describe the Orbit Shape.
- ✚ The value $[a]$ is called "Semi Major Axis" and represents the width of the orbit which is the distance shown in the drawing located between two points. The first point is located in the middle of the two elliptical shape's centers $[f \text{ \& } f']$. The second point is the Perigee.

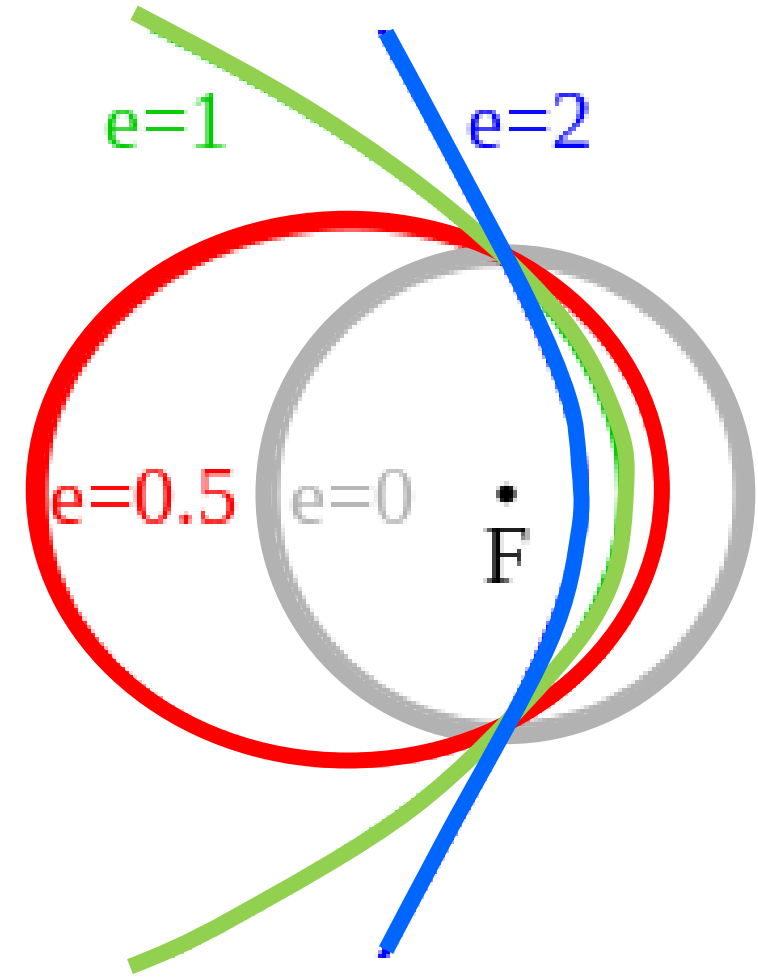


a : Semi major axis b : Semi minor axis
 C : Semi distance between foci
 r : Radius of Satellite



Cont.. How can a satellite orbit be designed?

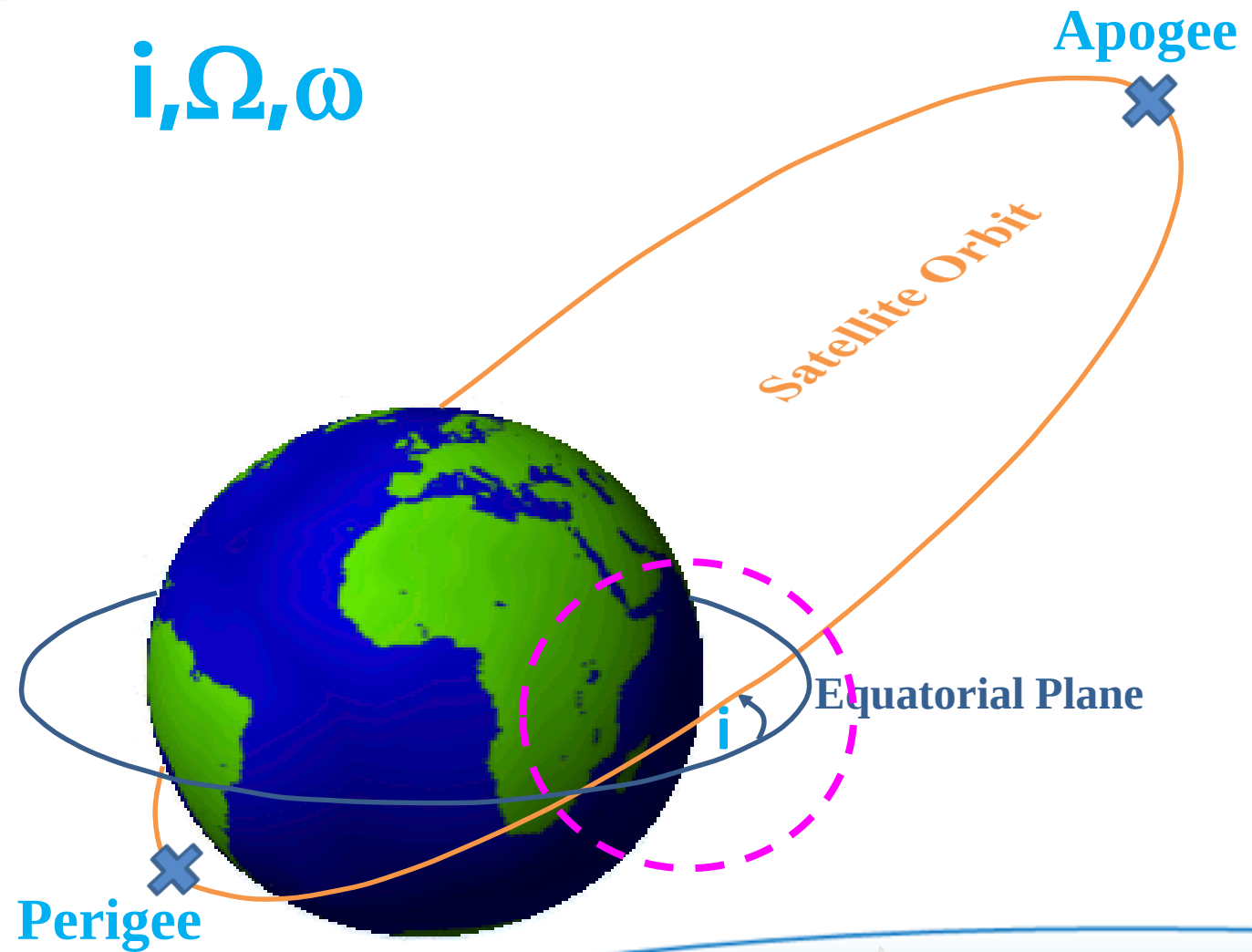
- ✚ The value $[e]$ expresses the range at which the shape of the orbit changes from circular to elliptical shapes. It is called "Eccentricity" which is a value that ranges between zero and 1 for closed orbits. It does not have any measurement unit. When eccentricity is equal to zero like the orbit shown in grey color, this means that the orbit is circular. The nearer to 1, the more elliptical the shape changes such as the orbit shown in red color.
- ✚ If the value of eccentricity is equal to 1, this means that the orbit shape is Parabolic such as the orbit shown in green color. If it exceeds 1, the orbit shape is Hyperbolic such as the orbit shown in blue color. The previous two orbits are examples of the aforementioned open orbits.





Cont.. How can a satellite orbit be designed?

- In order to describe the orbit orientation, the values $[i, \Omega, \omega]$ are used to express three angles that are used to describe orbit orientation.
- With regard to the angle $[i]$:** If the orange orbit represents the satellite orbit and the blue circle represents the equator, angle $[i]$ represents the orbit inclination on the equator. It is called "Orbit Inclination".



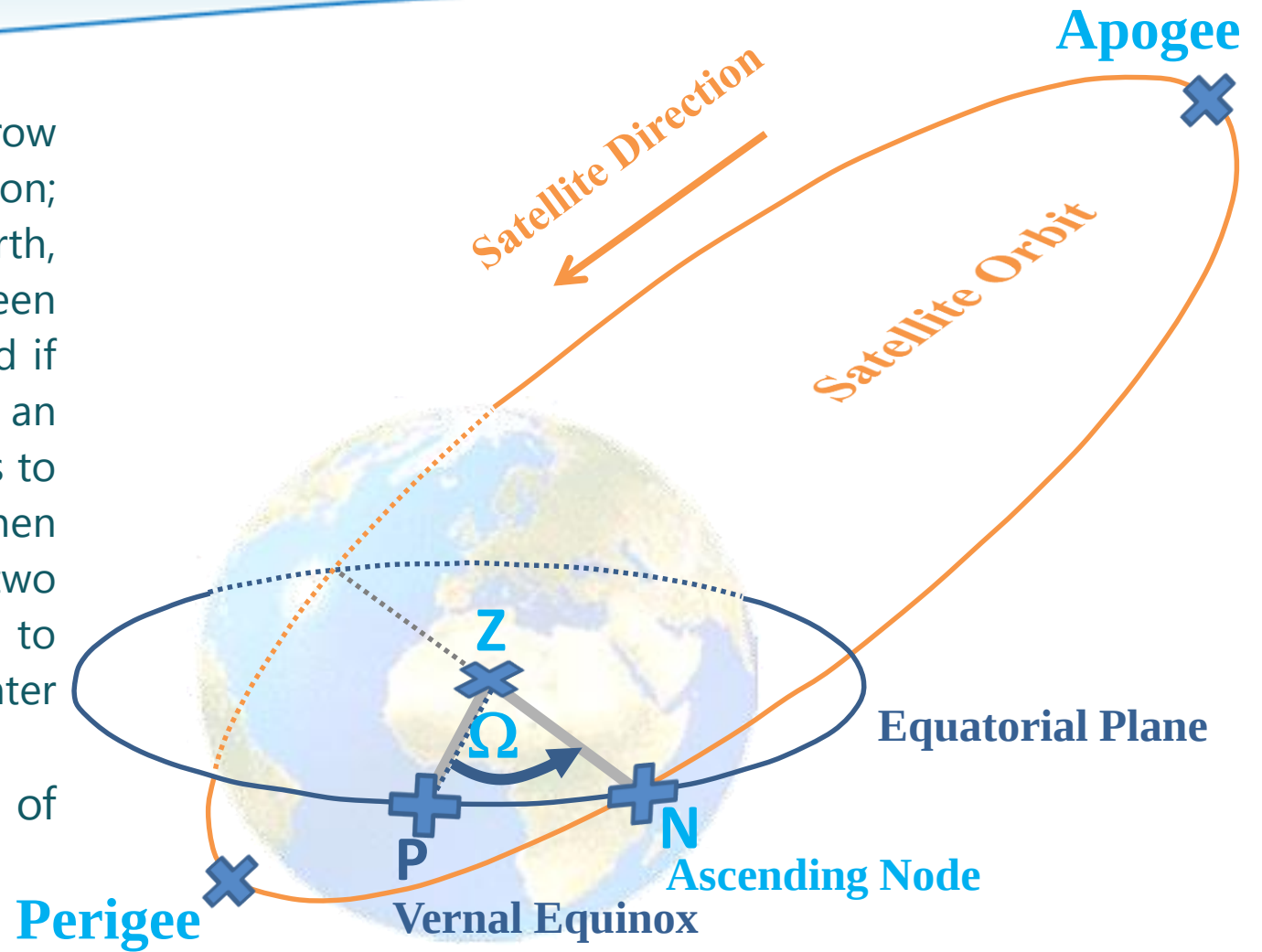
i, Ω, ω



Cont.. How can a satellite orbit be designed?

With regard to the angle $[\Omega]$: If the orange arrow points towards the direction of satellite rotation; while point "Z" represents the center of the earth, and point "N" represents the intersection between the satellite ascending track and the equator, and if point "P" represents the "Vernal Equinox" which is an imaginary reference point in the space that refers to the position of the sun on March 21 every year, then angle " Ω " represents the angle between the two lines: the line connecting the earth center "Z" to point "P" and the line connecting the earth center "Z" to point "N".

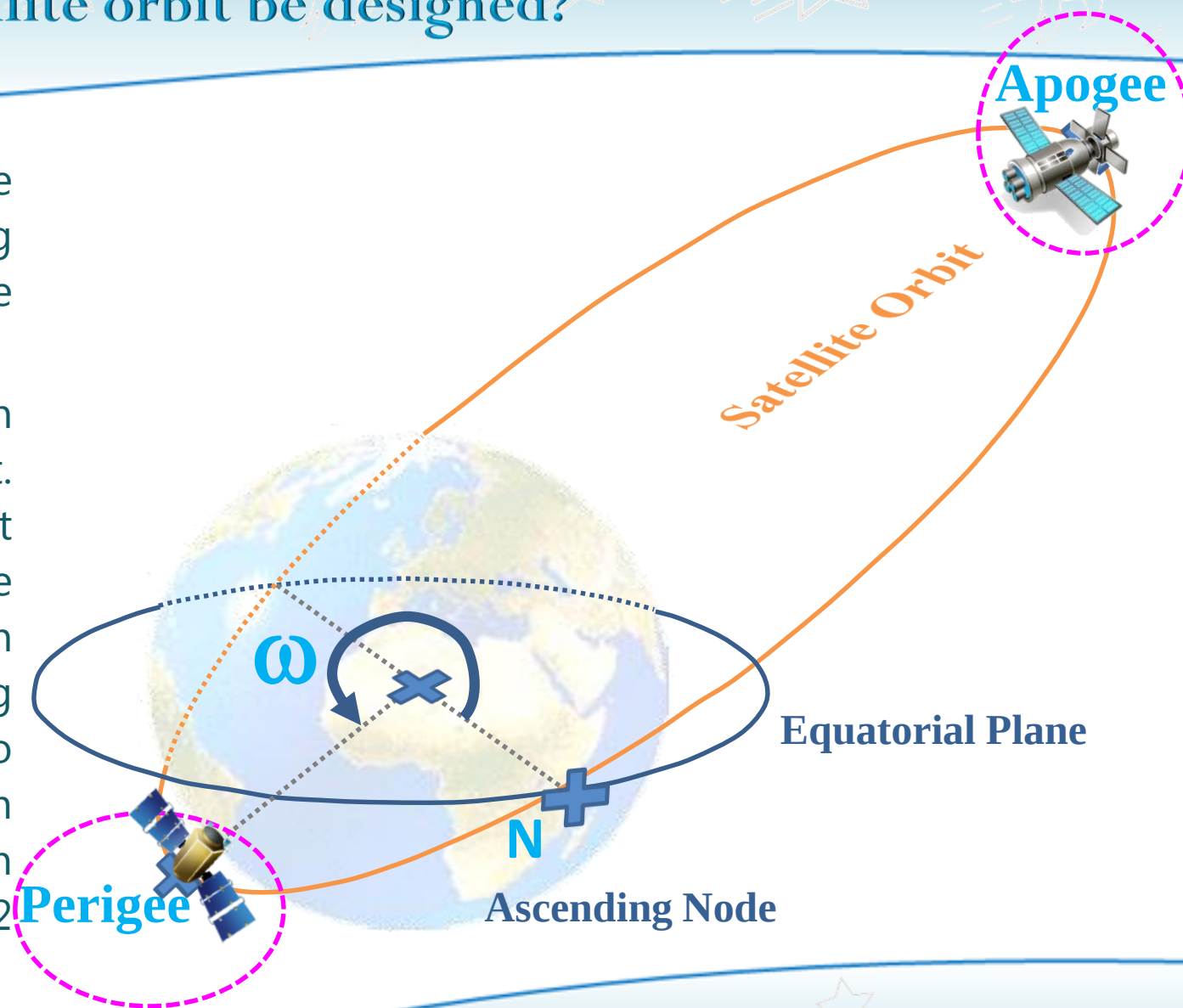
Angle $[\Omega]$ is called "Right Ascension of Ascending Node".





Cont.. How can a satellite orbit be designed?

- With regard to the angle $[\omega]$: It represents the angle between two lines; the line connecting the earth center to the Perigee point and the line connecting the earth center to point "N".
- Changing the value of this angle will result in a change in the location of the Perigee point. Usually, It is positioned above the most important coverage area on the earth surface to be imaged from the nearest distance in order to obtain the highest imaging resolution. On the other hand, with regard to communication satellites covering the North Pole, the Apogee is positioned at a location that makes the satellite covers the Pole for 12 hours / day.
- Angle $[\omega]$ is called "Argument of Perigee".

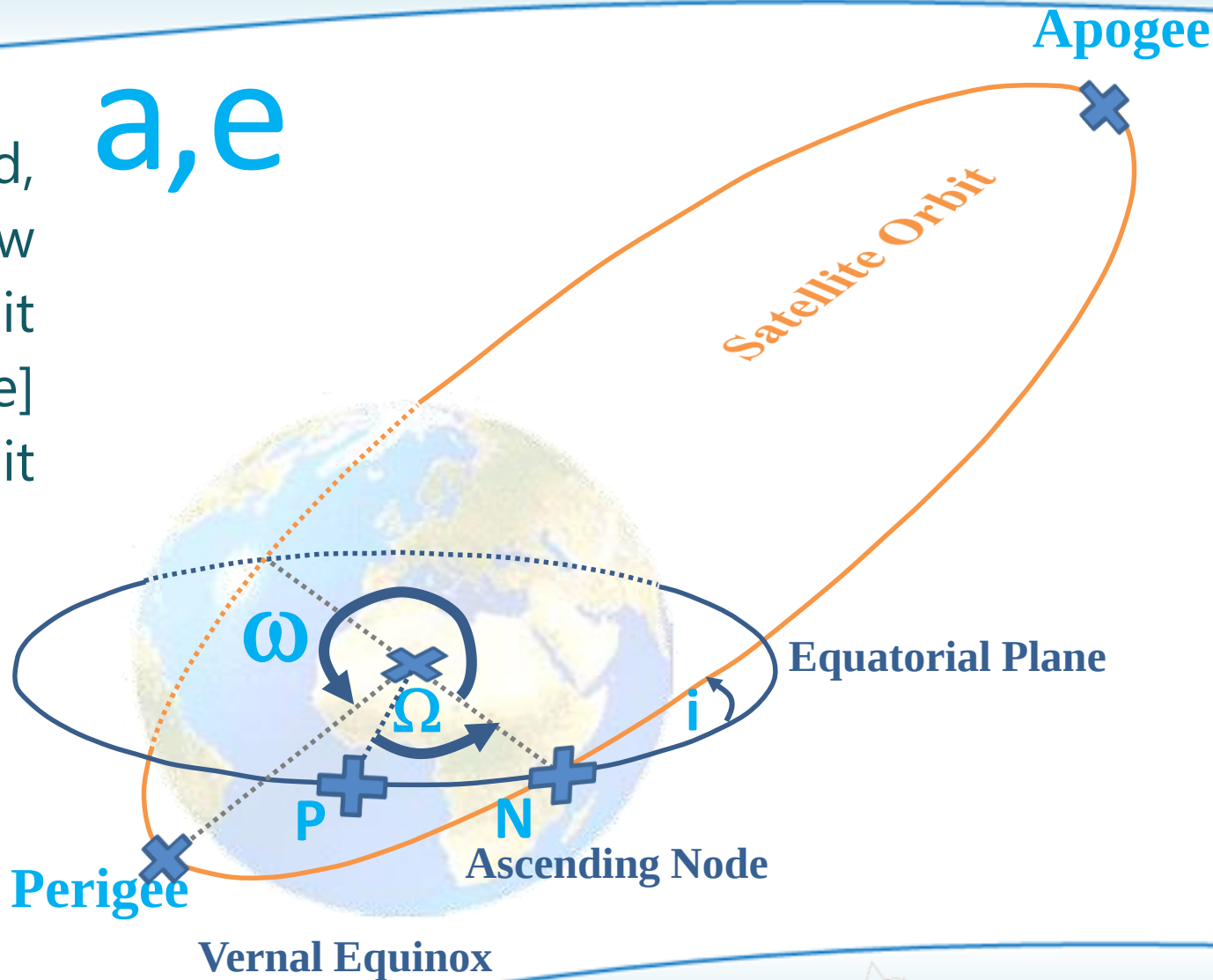




Cont.. How can a satellite orbit be designed?

- According to the aforementioned, the three previous angles show how to describe the orbit orientation; while the values $[a, e]$ show how to describe the orbit shape.

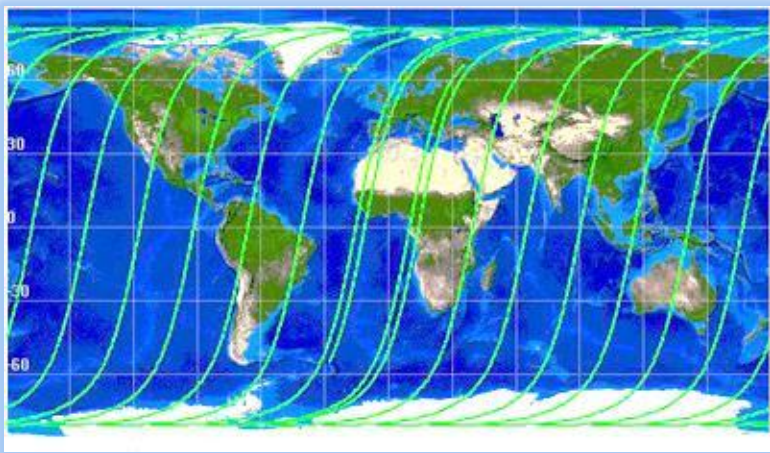
a, e





Cont.. How can a satellite orbit be designed?

- Finally, the orbit design process is represented by defining the precise values of these five orbital elements that satisfy all the requirements of the satellite mission. These requirements can be coverage areas, revisit times, sun illumination conditions and specific orbit altitudes that satisfy the technical requirements of imaging sensors and communication antennas.

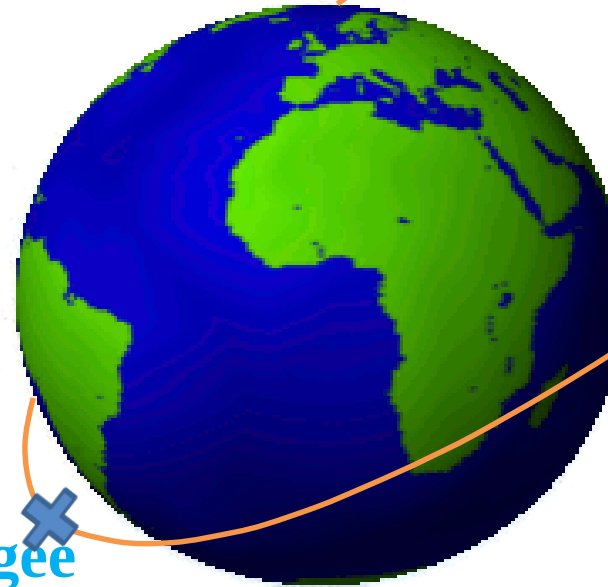


a e i Ω ω

Perigee

Apogee

Satellite Orbit





Thanks for your undivided attention

