

Orbit Definition

TMG can model three types of orbits: Beta Angle, Geostationary and Classical. For Earth, three special classical orbits are already partially defined: Sun-synchronous, Shuttle and Molniya.

Alternatively, you can specify constant or time-varying sun and planet vectors together with spacecraft altitude, thereby defining spacecraft position or movement.

For each orbit type, TMG offers several options to help define the orbit parameters in the most practical way for you. The orbit parameters and the options to select them are explained below.

Reference Vector

You can use different reference axes to define the parameters of an orbit.

Vernal (March) Equinox Vector

This vector points at the zodiac constellation Aries and it is found by drawing a line from the Earth through the Sun on the first day of spring, March 21. On this day, the Sun appears to cross the equator from south to north and the length of daylight equals the length of night. Therefore, the Vernal Equinox vector lies on the equatorial plane. Since the Aries constellation is very far from our solar system, this vector is considered to have the same orientation for all planets at all times.

Typically, the Vernal Equinox axis is referenced as the starting position for right ascension angles, measured eastwards on the equatorial plane. For example, the Sun Right Ascension is the angle measured eastwards from the Vernal Equinox vector to the projection of the Sun Vector on the equatorial plane.

Sun Vector

This is the vector pointing from the planet to the sun. The Sun Vector is located with the solar declination and right ascension. The sun declination is the angle between the sun vector and the equatorial plane.

For Earth, the sun declination and right ascension are known for each day. They are calculated from the specified Sun Position on the Planet & Sun Characteristics form. The sun declination varies between $+23.45^\circ$ and -23.45° depending on the day of the year.

For other planets, you provide the sun right ascension and declination on the Planet & Sun Characteristics form.

Local Noon and Local Midnight

Local Noon is the projection of the Sun Vector on the equatorial plane. It points as closely towards the sun as possible while remaining in the equatorial plane. Angles measured from Local Noon are measured on the equatorial plane, they are positive if, viewing the equatorial plane from the North pole, they are measured in the counterclockwise direction.

Local Midnight is the projection of the Sun Vector on the equatorial plane but it points in the opposite direction of the sun. Angles measured from Local Midnight are measured on the equatorial plane.

Specific Time References

For Earth, you can also use time and dates as reference to define the location of specific orbit parameters:

- GMT Date: the date and time at Greenwich. With this information, TMG computes the position of the Local Noon and the Right Ascension.
- Local Time: the local time at a specific location. With this information TMG can calculate the angle from the Local Noon to the specific location.

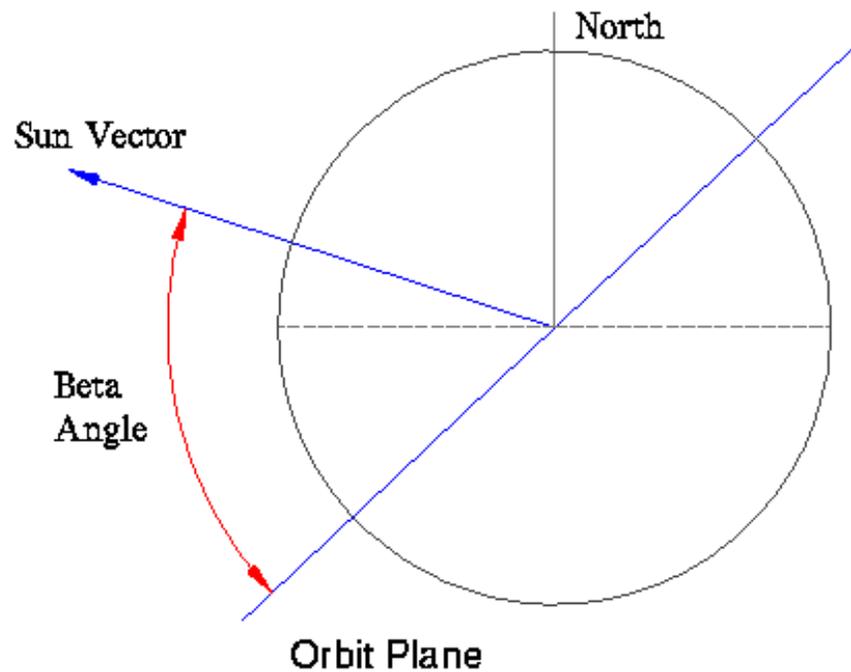
Internally, TMG uses an inertial reference coordinate system to define the orbit and the Sun's position. The origin of the inertial reference coordinate system (CS) is the center of the orbited planet and the Vernal Equinox direction is the principal direction (X axis). The direction from the planet center to the North Pole is the Z axis, which is normal to the equatorial plane. The third (Y) axis comes from the right hand rule.

Beta Angle Orbit Type

The beta angle for an orbit is the minimum angle between the orbit plane and the solar vector. It can be computed given the orbit inclination RI (angle between the orbit plane and the equatorial plane), solar declination D (angle between the solar vector and equatorial plane) and ascending node angle RA:

$$\beta = \sin^{-1} (\cos D \sin RI \sin RA + \sin D \cos RI)$$

To completely define the orbit for TMG thermal analysis, you must also specify the orbit altitude.



Beta Angle Definition

The Beta Angle does not define a unique orbit plane, but for a given Beta Angle and a given altitude, all Beta Angle orbits have the same exposure to the sun. The TMG Orbit Visualizer displays a Beta Angle orbit that has its Right Ascending Node located 90° eastward from Local Noon if the Beta Angle is positive and 270° eastward from Local Noon otherwise. (The term *Right Ascending Node* is defined below with the Classical orbit parameters.)

If you need to display a different orbit plane, use the Classical orbit definition.

Geostationary Orbit Type

In nearly every case, you do not need to specify parameters for a geostationary orbit, since a unique geostationary orbit exists for each planet.

For Earth, this orbit has a period of 24hrs.

However, if you are specifying a geostationary Earth orbit and you are using GMT date to define the Sun Position, you need to define the Sub-Satellite Longitude for this GMT date. This allows the TMG Visualizer to locate the satellite correctly in relation to the Earth. The Sub-Satellite Longitude is the longitude of the projection of the satellite on the Earth surface.

Classical Orbit Types

You need six parameters to describe the classical orbit shape and orientation and the satellite position.

Two parameters define the orbit shape. Select them from the four available options:

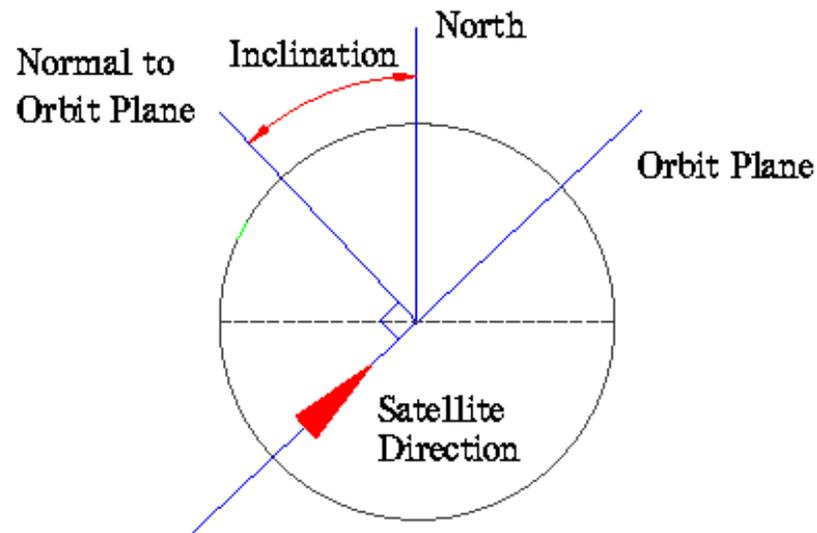
- maximum or minimum radius (must be greater than planet radius)
- eccentricity (eccentricity of 0 corresponds to a circular orbit)
- period
- minimum or maximum altitude

The other four required parameters are all angles. The first three are angles that position the orbit in relation to the planet and the last one is an angle that positions the satellite on the orbit path:

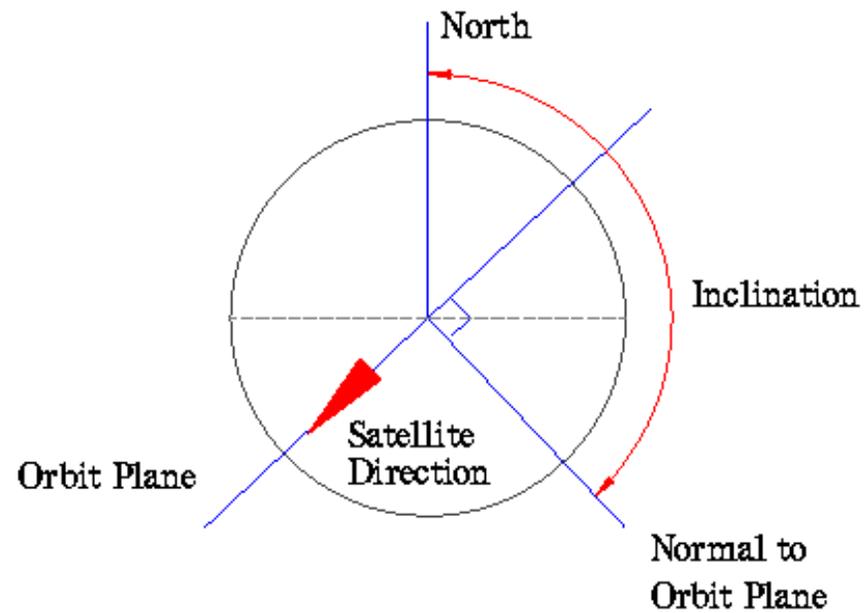
- orbit inclination
- position of ascending node
- argument of Perigee
- start angle

Orbit Inclination

The orbit inclination is the angle between two vectors: the North pole vector (Z axis of the inertial reference CS) and the normal to the orbit plane vector. This angle describes the tilt of the orbit plane with respect to the equator of the planet. From the right hand rule, the Orbit Plane Normal points to the Northern hemisphere for a counterclockwise satellite rotation and points to the Southern hemisphere for a clockwise satellite rotation as shown:



Inclination for Counterclockwise Rotation



Inclination for Clockwise Rotation

Position of Ascending Node

The Ascending Node is the point on the equatorial plane where the satellite passes from the Southern hemisphere to the Northern hemisphere. By contrast the Descending Node is where the satellite passes from the Northern hemisphere to the Southern hemisphere.

TMG follows the convention of measuring the angle of the Ascending Node in the eastward direction from its reference. This angle is between 0° and 360° .

For Earth, three options exist to define the Ascending Node:

- Local time at Ascending Node
- Local Noon to Ascending node angle
- Right Ascension of Ascending Node

For other planets, only the two last options are available.

For orbits that lie on the equatorial plane (orbit inclination of 0° or 180°), you can define an Ascending Node. The default is at Local Noon.

Argument of Perigee

The Perigee is the orbit point closest to the planet.

The Argument of Perigee is the angle between the Ascending Node and the Perigee on the orbit plane. By convention, this angle is measured in the direction of satellite rotation.

Start Angle

The Start Angle specifies the location of the satellite at the beginning of the analysis. It is measured from the specified Reference Position to the satellite location in the direction of satellite rotation. You can reference the Start Angle from the:

- Ascending Node
- Descending Node
- Local Noon
- Local Midnight
- Perigee
- Apogee (orbit point farthest from the planet)

Special Classical Orbits

For Earth, three special classical orbits are defined for you with default parameter values as described below:

Orbit Type	Orbit Size	Eccentricity	Inclination
Sun-Synchronous	Altitude Min: 900km	0	95
Shuttle	Altitude Min: 200 n. miles	0	51.6
Molniya	Radius Max: 45170 km	0.7	63.4

Sun & Planet Vectors

Instead of specifying a complete orbit definition, you can use *Sun & Planet Vectors* to define one or more positions of the spacecraft during the course of the simulation by specifying the sun and planet vectors as well as the altitude or radius of the spacecraft position. TMG calculates orbital effects at each position without calculating an orbit.

You can provide the planet and the sun vectors for either a constant position, which means the spacecraft does not change its relative position during the simulation or provide the time tables of the vectors, which means a series of spacecraft positions are modeled.

You must use the model Global Coordinate System to define the Planet Vector and the Solar Vector. The Planet Vector is from the satellite global coordinate system origin to the planet center. Since the sun is very far, the Solar Vector is not defined from the origin of the satellite, but is rather parallel to the Sun Vector (the vector from the planet center to the sun).

Importing and Exporting Vector Data

You can also import or export vector data as an ASCII file.

To export the file, simply make note of the optional settings (Altitude vs Radius, and Units), pick the *Export to File* button and name the file and the data block. Any Cartesian values will be converted to Theta and Phi (plus a magnitude value for reversion to Cartesian) and written to the ASCII file name specified.

Import a file that was previously exported from the *Sun and Planet Vector Data* form as follows:

1. Use an empty *Sun and Planet Vector Data* form (Pick *Delete All* if you are replacing existing values).
2. Set the *Units* and the *Altitude/Radius* options to correspond to the settings in effect at export.
3. Pick *Import from File* and select the file and the data block.

If you need to import vector data from another application, Sun and planet vectors must be expressed in terms of Theta and Phi. Use the following data block format for the ASCII file:

- Block name must be alphabetic and must start in the first column.
- Each line consists of an analysis time value and the corresponding vector and altitude/radius values
- Values are separated by white space
- Values are in the following sequence:

```
Time SolVectMag Theta(1) Phi(1) PlanetVectMag Theta(2) Phi(2) AltOrRad
```

where:

Time	is the analysis time in seconds
SolVectMag	is the conversion factor resulting from previous conversion from Cartesian CS (use 1 for data originating in Spherical CS)
Theta(1) and Phi(1)	are the solar Theta and Phi values
PlanetVectMag	is the conversion factor resulting from previous conversion from Cartesian CS (use 1 for data originating in Spherical CS)
Theta(2) and Phi(2)	are the planet Theta and Phi values
AltOrRad	will be interpreted as the orbit Altitude or Radius, depending on the settings on the form at import.
Note: If you want to omit Planet Vector data (i.e. if <i>Account for Planet Eclipse</i> is toggled OFF on the <i>Sun and Planet Vectors</i> form), omit the last four values of each line.	

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