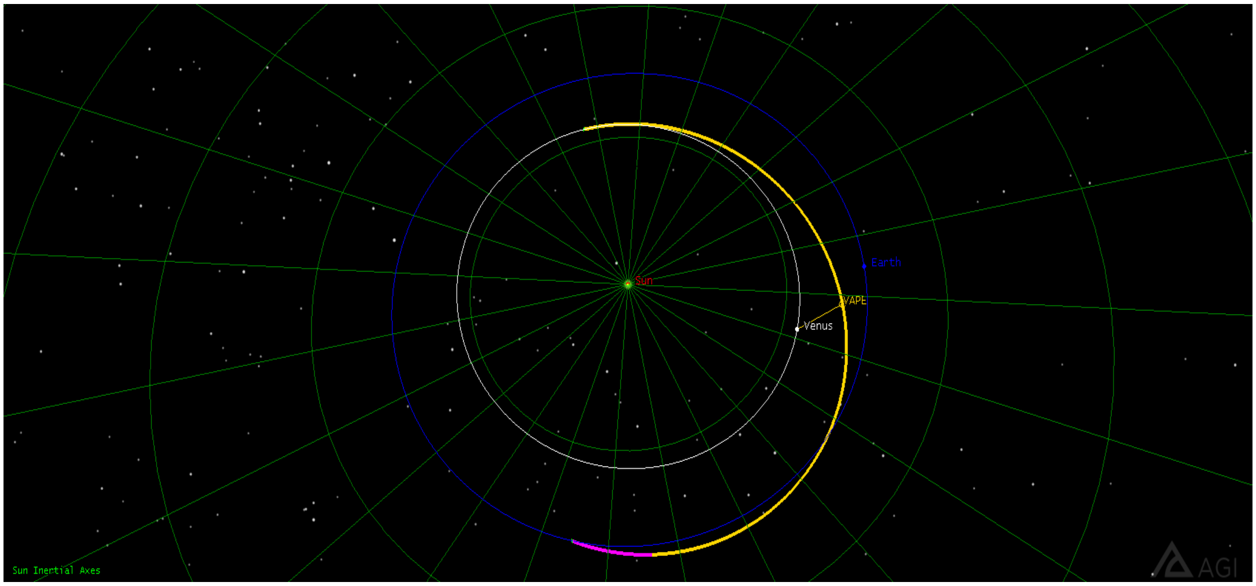
# (Trajectory Design with STK/Astrogator)




## Mission overview

In this mission, we will model a mission to Venus. Starting from the earth, we will:

- Use the target vector outgoing asymptote parameters to specify our outgoing state.
- Use a trajectory correction maneuver to target Venus approach.
- Coast to Venus periapsis
- Perform an impulsive Venus Orbit Insertion (VOI) maneuver.
- Circularize our orbit at 89 degrees.

In order to implement these procedures, we need to use a TCM maneuver in a mission control sequence, used multiple profiles to achieve our desired parameters, used constraints to help us target and created a trajectory that leaves the Earth enters heliocentric space, and then orbits Venus.

For our mission we need to specify an appropriate time for the launch to make it to Venus's orbit. So, the time period for the mission should be ➔ **25 Aug 2029 to 1 May 2030**

# Building the mission control sequences (MCS)

- Setting our satellite (VAPE) by using the propagator as an astrogator, in order to let VAPE making the needed maneuvers for the mission.
- To get to Venus, first we need to adjust our satellite parameters and the location of the launching (Latitude: 27.6648 deg N, Longitude: 81.5158 deg W).
- Taking in consideration our Epoch time which is: **25 Aug 2029**
- Adjust the Ascent type to Cubic motion.
- Adjust the burnout for the launch (time of flight, Azimuth, downrange distance and altitude) and (eccentricity and inclination with respect to Earth as a central body) **Figure (1 and 2)**
- Adjust the Fuel tank parameters so we can get out of earth orbit (tank pressure, tank volume, tank temperature, fuel density, fuel mass and maximum fuel mass), all these factors will help us to support our mission in the beginning **Figure (1 and 2)**

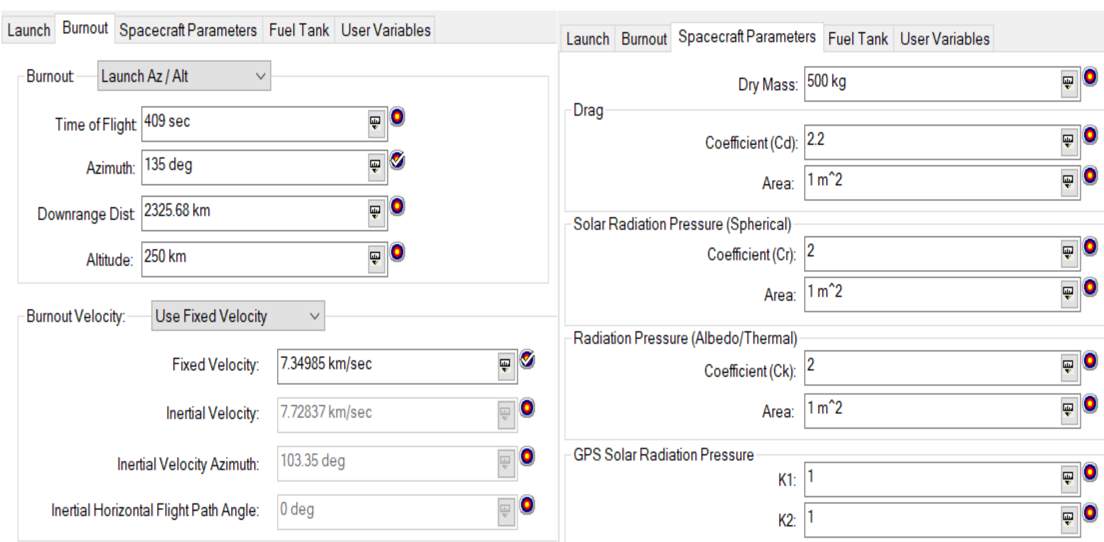



Figure 1,2; showing the values for burnout and Spacecraft Permeameters

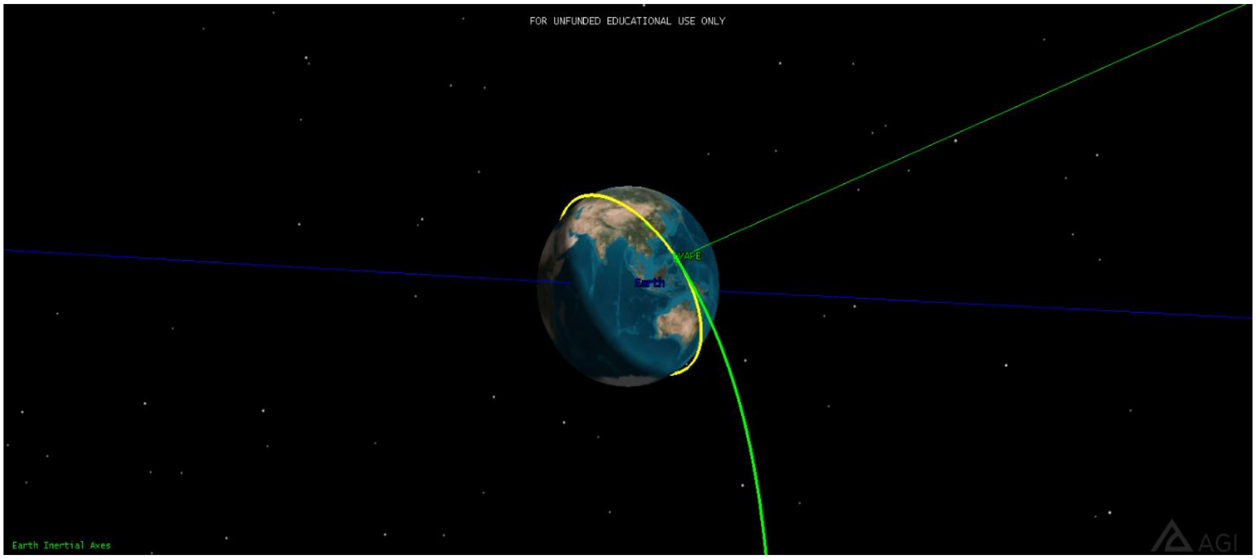



Figure 3; showing the VAPE trajectory

- As we see above, **Figure (3)**, we have the main orbit around earth (yellow) and then do the push to get out of Earth orbit.
- We add the first maneuver (green) for our mission (TVI) with a Delta V magnitude of 3200 m/sec (along velocity vector)
- The maneuver has a specific parameter to do the Hohmann transfer orbit ➔
  1. Target Vector: C3 Energy (central body: Earth)
  2. Target Vector: Outgoing Asymptote Dec (corrdSystem: Earth inertial)
  3. Target Vector: Outgoing Asymptote RA (corrdSystem: Earth inertial)
  4. Maneuver: DeltaV integrated along path.
  5. Our propagator is in the Earth full RFK
- Propagate to TCM1 ➔ (green line)
  1. Our propagator is in the Cislunar
  2. Target Vector: C3 Energy (central body: Earth)
  3. Target Vector: Outgoing Asymptote Dec (corrdSystem: Earth inertial)
  4. Target Vector: Outgoing Asymptote RA (corrdSystem: Earth inertial)
- Making our second Hohmann transfer orbit by using a new propagate (A new Heliocentric) with respect to the sun as a central body (purple line). **Figure (4)**

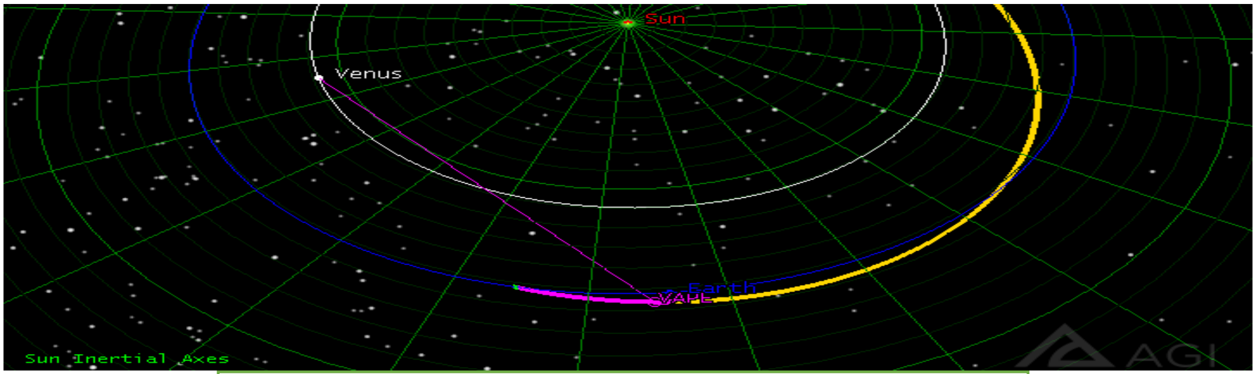



Figure 4; showing the Hohmann transfer orbit

- After this part, the VAPE needs to burn a lot of fuel to transfer from an orbit to another. In order to achieve that, a thrust vector is applied to the satellite (thrust axes with respect to VNC, sun)
- We are using VNC (sun) as the VAPE is in the middle of Earth and Venus. And taking the sun as a main centre body for VAPE.
- DeltaV is needed to do the transfer between orbits (maneuvers)
- We constrain our mission when it reaches Venus, periapsis
- Periapsis is added to the new propagator (Heliocentric) as a stopping condition (central body: Venus) (yellow line)
- This is considered as the most important part of mission to let the VAPE goes along with Venus trajectory and this done by using specific conditions, **Figure 5➔**

    1. B-Plane B and R vector dot product (target body: Venus)
    2. B-Plane B and T vector dot product (target body: Venus)
    3. Adjust the Epoch time to reach the right path on the right time
    4. Adjust the altitude above central body
    5. Adjust the inclination and the declination of incoming aspides

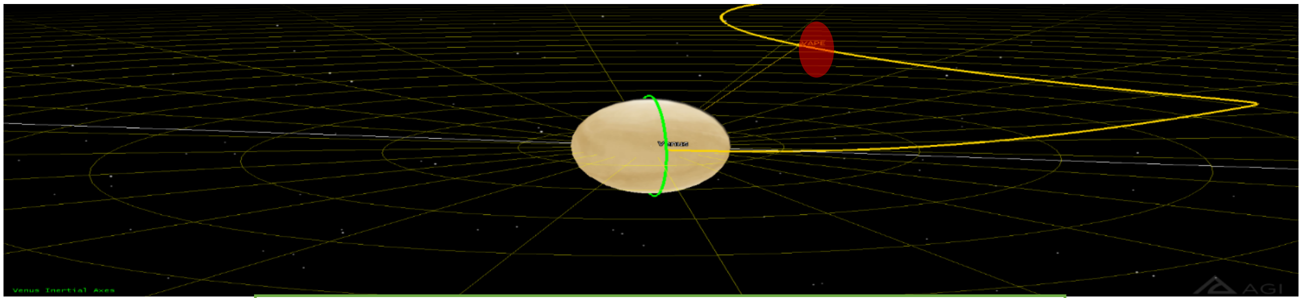


Figure 5; showing the trajectory of VAPE

- In order to achieve all these steps above, we will apply some values to the MCS➔ Get out of earth orbit and get into Venus orbit.

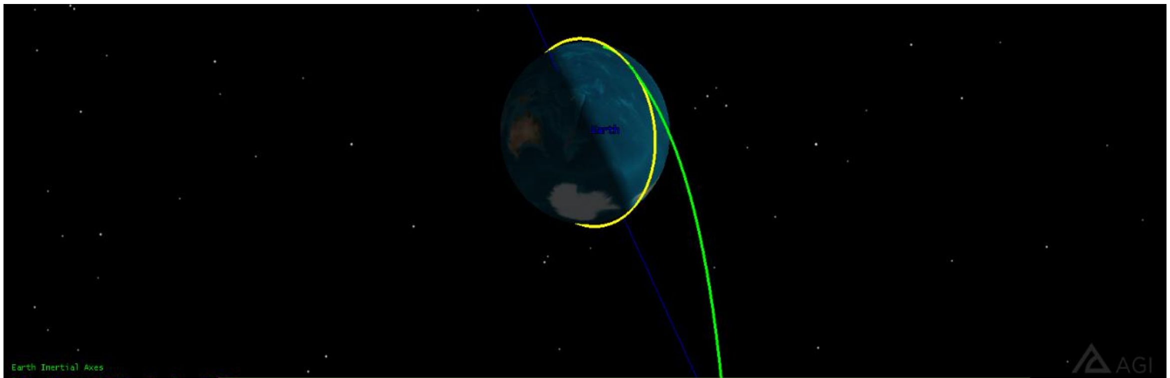



Figure 6; Showing maneuver and propagate

1. Circularize

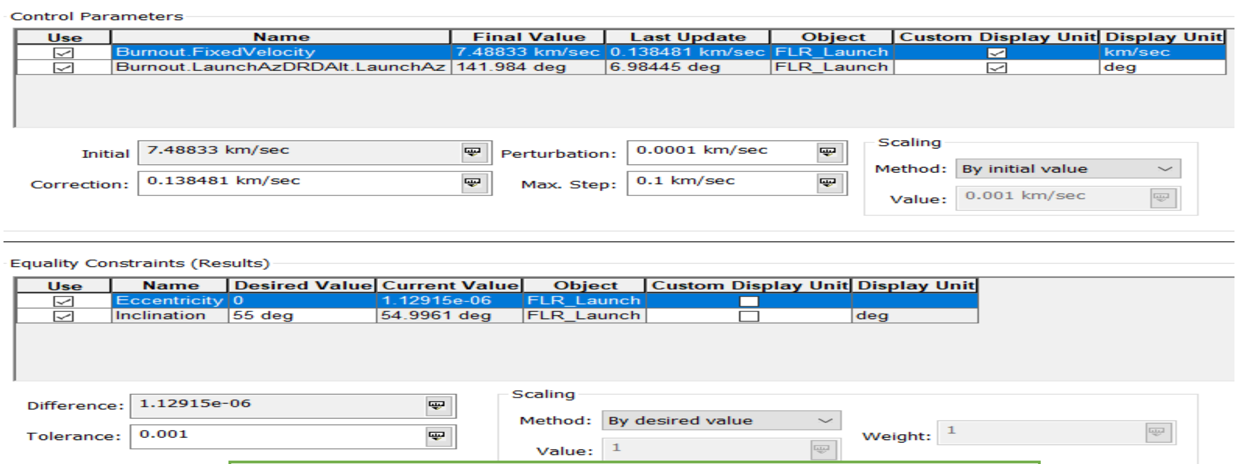



Figure 7; showing the parameters for the orbit around earth

2. Launch Coast Burn

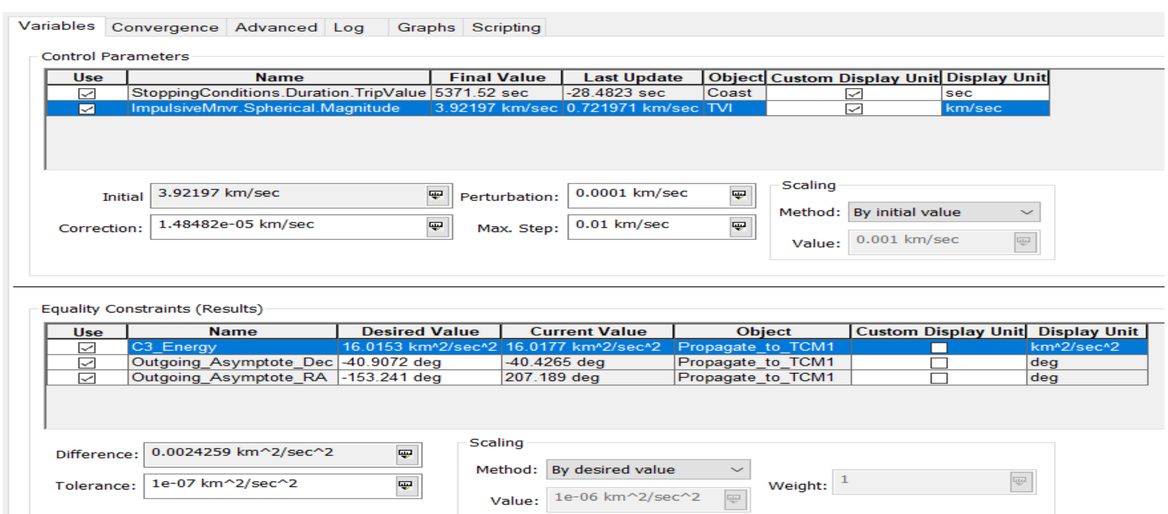



Figure 8; showing the values for burnout and launch.

3. C3 burn

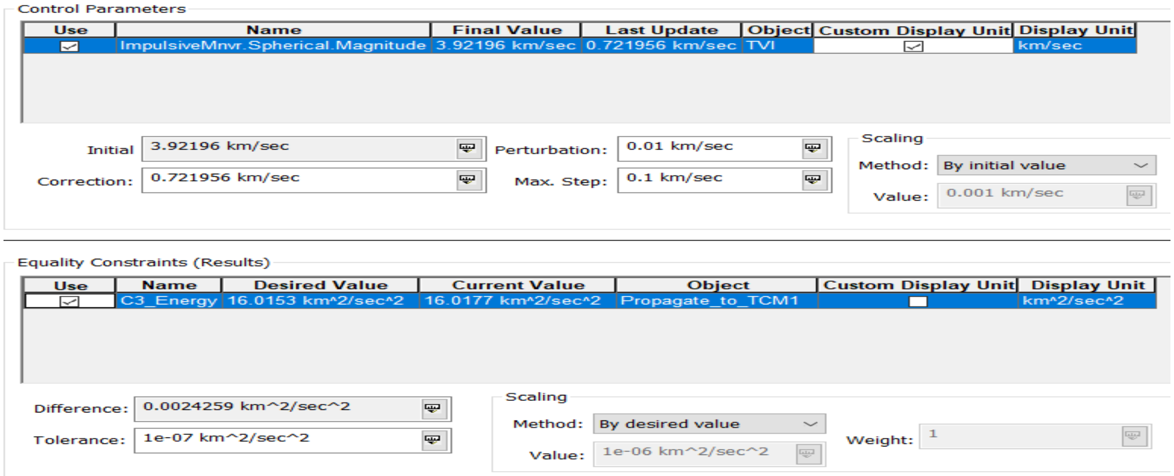



Figure 9; showing the energy to do the push from earth orbit

4. Time

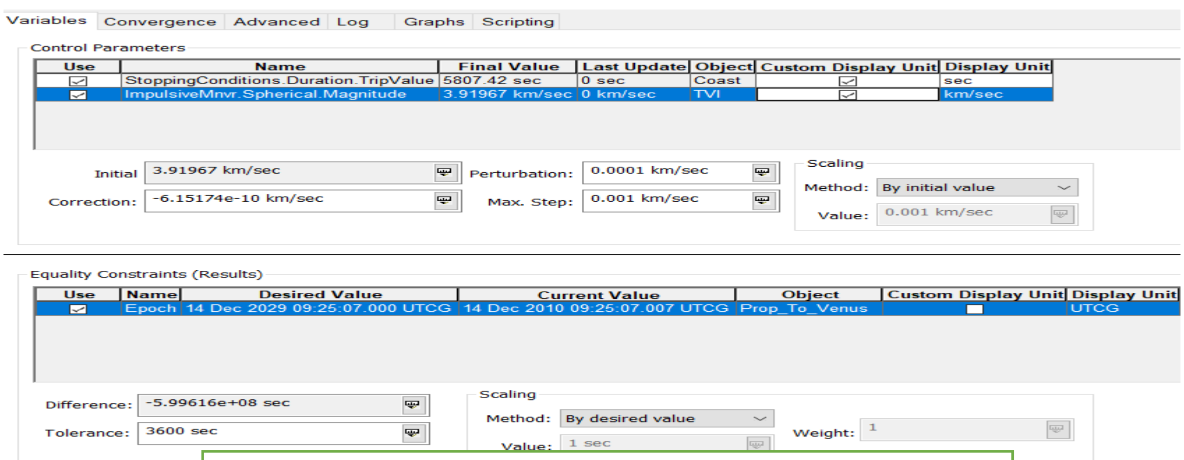
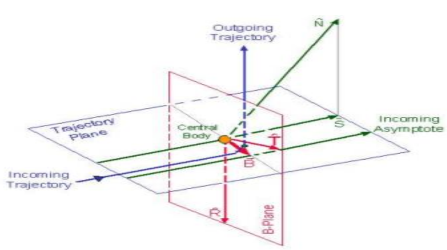
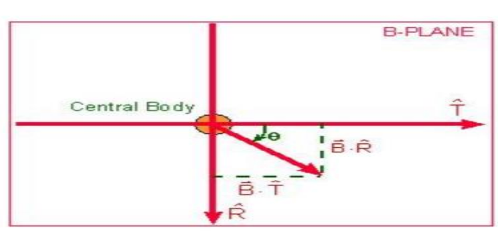



Figure 10; showing the values for time conditions

5. B-Plane: Now we have an impact trajectory, which is close, but we want to get to orbit. The best way to do that is target the B-plane. The B-plane is a planar coordinate system that allows targeting during a gravity assist or for planetary orbit insertion. It can be thought of as a target attached to the assisting body. If you have a trajectory that is close to the encounter planet, the B-plane gives you targets that behave very linearly, which is important with the differential corrector targeting scheme in Astrogator. [1]



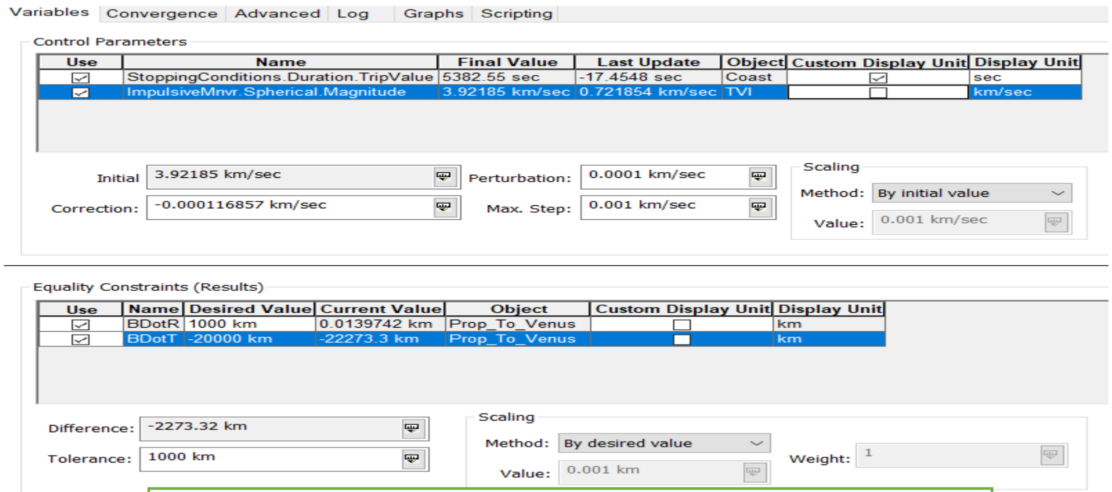



Figure 11, 12; showing the method of B-plane and the values for BDotR and BDotT

6. Altitude

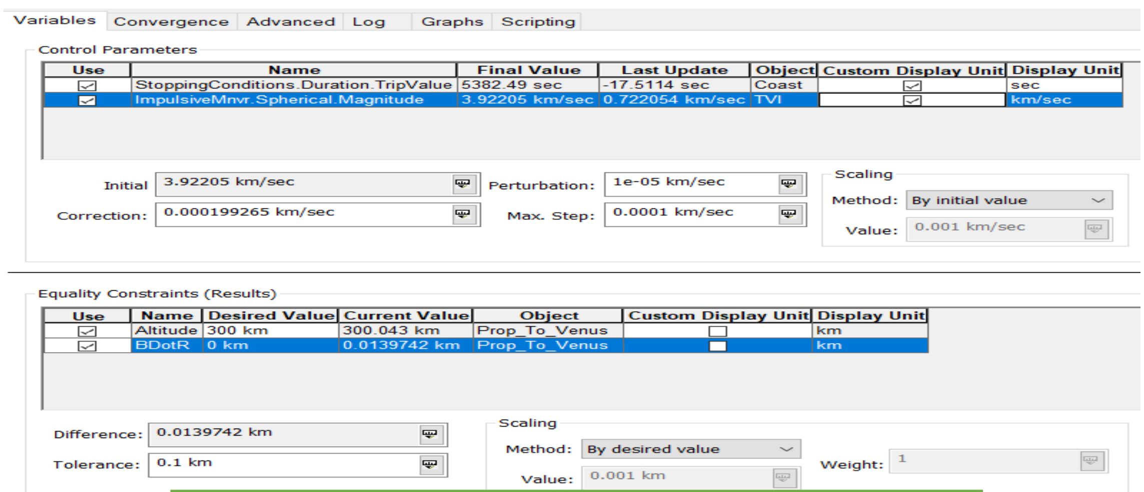


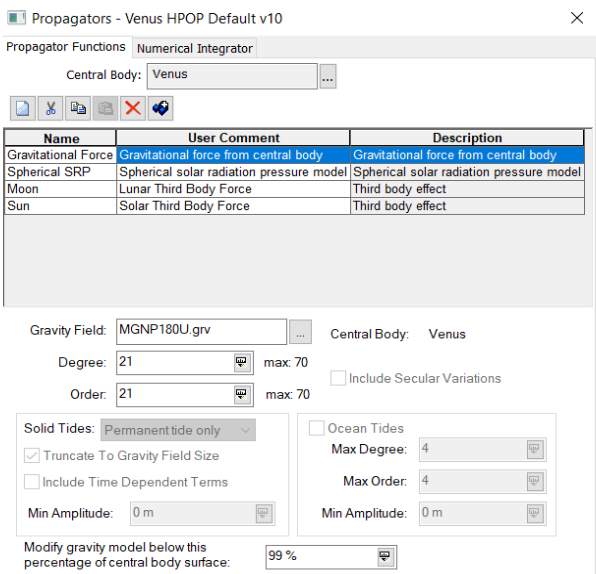

Figure 13; showing the values for the altitude applied

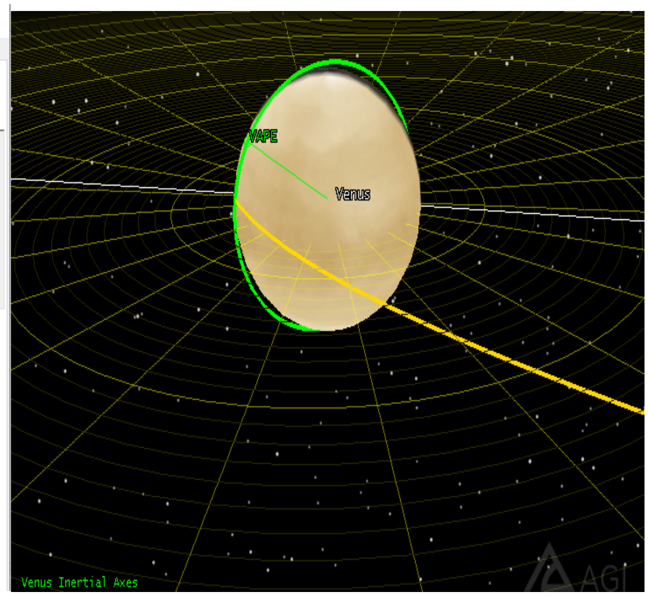
## Get into Venus trajectory and Hit Venus orbit➔

- In this part, we will need to capture the orbit of Venus and that is done by decreasing velocity towards X and Y directions ➔

    1. Thrust Axes, VNC(Venus).
    2. Adjust the eccentricity
    3. Slowdown the C3 energy
    4. Slowdown the DeltaV
    5. Match with Venus orbit period
    6. Adjust the inclination to be 90 degrees
    7. We constrain our mission when it reaches Venus, periapsis

8. Periapsis is added to the new propagator (Venus HPOP) as a stopping condition (central body: Venus) (Green line)





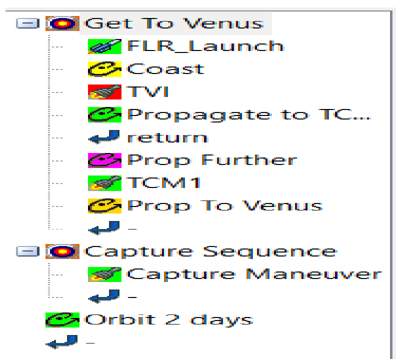




Figure 14, 15,16; showing the final stage, the new propagator and the steps for Vape mission

# From Trade study results ➔

- Do some calculations to prove that polar orbit has an inclination of approxiamlty 90 degree and this we can cover around 90% of Venus atmosphere.

| Orbit | Altitudes | Inclination |
|---|---|---|
| Low inclination orbit | Less than 1000 km | 35 degrees |
| Sun-synchronous orbit | 600 to 800 km | 98 degrees |
| Polar orbit | 200 to 1000 km | 90 degrees |

$$\frac{d\Omega}{dt} = \dot{\Omega} = -\left[\frac{3}{2}\frac{\sqrt{\mu}\,J_2\,R^2}{(1-e^2)^2 a^{\frac{7}{2}}}\right]\cos i = \frac{2\pi}{365.26\times 24\times 3600} = 1.991\times 10^{-7} rad/s$$

$$J_2 = 1.08263x10^{-3},\ e = 0,\ a = 6051.8 + 500km$$

$$\Psi = \left[\frac{3}{2}\frac{\sqrt{\mu}\,J_2\,R^2}{(1-e^2)^2 a^{\frac{7}{2}}}\right] = \frac{3\sqrt{3.986\times 10^5}(1.08263\times 10^{-3})(6051.8)^2}{2(1-0)^2(6051.8+500)^{3.5}} = 8.379x10^{-4}$$

$$\dot{\Omega} = -\Psi\cos i \rightarrow i = \cos^{-1}\left(\frac{-\dot{\Omega}}{\Psi}\right) = \cos^{-1}\left(\frac{-1.991\times 10^{-7}}{8.379x10^{-4}}\right) = 90.01^{o}$$

# MCS Summary report➔

<u>Our results may be different from our slides (as we adjust our inclination and some parameters)</u>

```
State Vector in Coordinate System: Venus Inertial

Parameter Set Type:  Cartesian
         X:    -4239.8700571479794235 km             Vx:        0.6453532485713076 km/sec
         Y:    -4656.1608119049069501 km             Vy:        0.6804734203972366 km/sec
         Z:      830.4079807152747890 km             Vz:        7.1104899362011960 km/sec

Parameter Set Type:  Keplerian
       sma:     6388.6431438031386278 km           RAAN:         227.6593474350365 deg
       ecc:        0.0057602499181513                 w:          7.51209111857262 deg
       inc:         89.84939027707686 deg            TA:     2.898596377980139e-07 deg

Parameter Set Type:  Spherical
 Right Asc:         227.6792078932488 deg     Horiz. FPA:     1.660096877099246e-09 deg
      Decl:         7.512065305463715 deg        Azimuth:        0.1519135462389714 deg
       |R|:      6351.8429626569477477 km            |V|:        7.1720702746227429 km/sec


Other Elliptic Orbit Parameters :
 Ecc. Anom:                         0 deg       Mean Anom:                          0 deg
 Long Peri:         235.1714385536091 deg       Arg. Lat:          7.512091408432258 deg
 True Long:         235.1714388434687 deg       Vert FPA:           89.9999999983399 deg
  Ang. Mom:         45555.86410154356 km^2/sec         p:      6388.4311655627043365 km
        C3:        -50.84938769730888 km^2/sec^2  Energy:        -25.42469384865444 km^2/sec^2
   Vel. RA:         46.51736815742902 deg       Vel. Decl:          82.48640761901046 deg
 Rad. Peri:      6351.8429626569486572 km       Vel. Peri:        7.1720702746227429 km/sec
  Rad. Apo:      6425.4433249493276890 km        Vel. Apo:          7.089917659790863 km/sec
 Mean Mot.:       0.06395240279196272 deg/sec
    Period:          5629.186461861028 sec        Period:          93.81977436435047 min
    Period:          1.563662906072508 hr         Period:        0.06515262108635449 day
               Time Past Periapsis:                   0 sec
          Time Past Ascending Node:          116.1201722387236 sec
   Beta Angle (Orbit plane to Sun):         -59.7816231344369 deg
Mean Sidereal Greenwich Hour Angle:           224.22286401021 deg

Planetodetic Parameters:
  Latitude:         7.512065305463715 deg
 Longitude:        -127.2037901064082 deg
  Altitude:      300.0429626569487027 km
Planetocentric Parameters:
  Latitude:         7.512065305463715 deg
 Longitude:        -127.2037901064082 deg
```

```
Spacecraft Configuration:
        Drag Area:    1 m^2
         SRP Area:    1 m^2
         Dry Mass:    500 kg
        Fuel Mass:    500 kg
       Total Mass:    1000 kg
Area/Mass Ratio:    1e-09 km^2/kg
   Tank Pressure:    5000                    Pa
    Fuel Density:    1000                    kg/m^3
              Cr:    2.000000
              Cd:    2.200000
  Rad Press Area:    1 m^2
Rad Press Coeff:    2.000000

User-selected results:
    Eccentricity =        0.0057602499181513
    C3 Energy =       -50.8493876973088774 km^2/sec^2
    Venus Orbit Period =       5629.1864618610279649 sec
    DeltaV =       12.2796592371535223 km/sec
    Inclination =         89.84939027707686 deg
```

Figure 17; showing the final stage of VAPE (parameters)

| Global statistics | Maneuver Number | Segment | Est./Act. Finite Burn Duration (sec) | DeltaV (m/sec) | Fuel Used (kg) |
|---|---|---|---|---|---|
| | **1** | Get to Venus. TVI | 4332.667 | 3922.053569 | 736.349 |
| | **2** | Get to Venus.TCM1 | 1342.34 | 423.23 | 120.52 |
| | **3** | Capture sequence. Capture maneuver | 5793.425 | 12279.659237 | 984.608 |
| Total Est./Act. Finite Burn Duration (sec) | | | 11468.432 | 16624.94281 | |
| Total DeltaV (m/sec) | | | | 16624.94281 | |
| Total Fuel Used | | | | | 1841.477 |

Table 1; showing the Mission results through 3 maneuvers

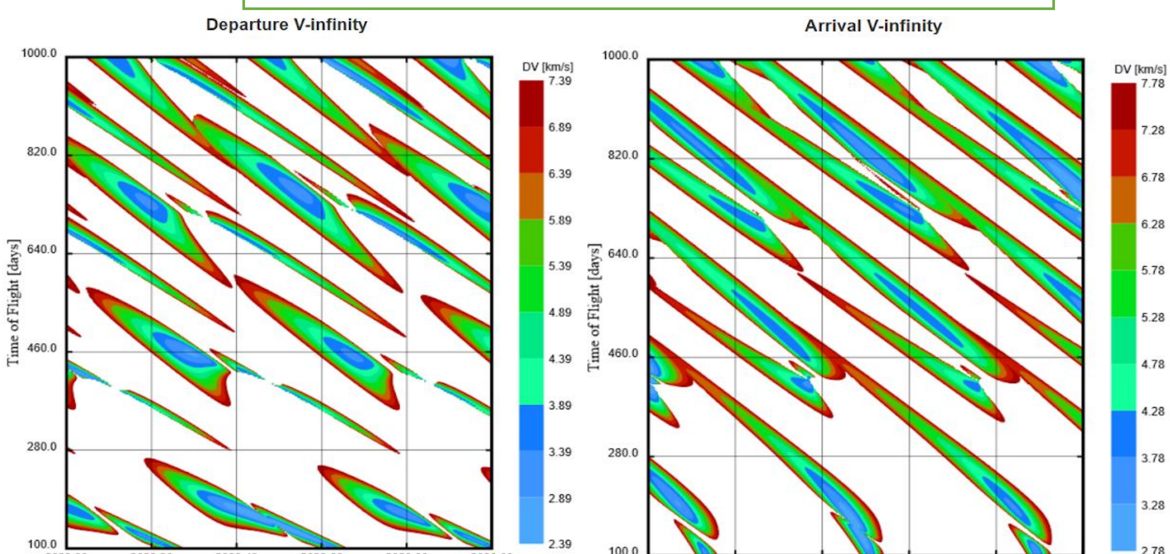



Figure 18; showing the best time for departing and arriving of VAPE

Based on our departure time and arrival time for the mission, we found out that the lowest DeltaV will be suitable for our mission is within the blue regions (low DeltaV and low cost), **Figure 18**.

# References

[1]. B-Plane target. (n.d.). Retrieved from https://see.com/astrogatorsguild/wp-content/Astrogator_Training/Mars_Mission.pdf

# Appendix

***Criteria***

| Criterion | Justification |
|---|---|
| Ground station access time | Crucial to relay the information for analyzing |
| Perturbations | More corrections to gain an accurate data |
| Power generation | Propulsion system for satellite in Venus orbit |
| Global coverage | More areas to cover and more data |

So, we shall apply each of these criteria on each orbit we have and see the most suitable one for our mission objectives based on our mission requirements.

***GROUND STATION ACCESS TIME***

## Low inclination orbit

- Three Ground stations access times; we shall see how long it takes for the data to be transfer going back and forth from the ground stations to the satellite with inclination of 35 deg

```
                                                                          6 Mar 2019 18:00:47
FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-Hartebeesthoek_STDN_HB33-To-Satellite-Satellite2:  Access Summary Report


Hartebeesthoek_STDN_HB33-To-Satellite2
--------------------------------------
                 Access       Start Time (UTCG)           Stop Time (UTCG)       Duration (sec)
                 ------   ------------------------   ------------------------   --------------

Global Statistics
-----------------
Min Duration          1   6 Mar 2019 01:24:36.356    6 Mar 2019 01:37:27.071            770.714
Max Duration          2   6 Mar 2019 02:13:24.423    6 Mar 2019 03:10:28.554           3424.131
Mean Duration                                                                          3128.695
Total Duration                                                                        28158.256
```

```
                                                                          6 Mar 2019 18:02:31
FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-MILA_STDN_MILA-To-Satellite-Satellite2:  Access Summary Report


MILA_STDN_MILA-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2
---------------------------------------------------------------------
                 Access       Start Time (UTCG)           Stop Time (UTCG)       Duration (sec)
                 ------   ------------------------   ------------------------   --------------
                      1   5 Mar 2019 16:55:14.281    5 Mar 2019 17:52:19.586           3425.305
                      2   5 Mar 2019 18:28:15.953    5 Mar 2019 19:25:21.061           3425.108
                      3   5 Mar 2019 20:01:17.621    5 Mar 2019 20:09:44.776            507.155
                      4   6 Mar 2019 09:58:32.788    6 Mar 2019 10:55:35.922           3423.134
                      5   6 Mar 2019 11:31:34.461    6 Mar 2019 12:28:37.401           3422.940
                      6   6 Mar 2019 13:04:36.131    6 Mar 2019 14:01:38.866           3422.736
                      7   6 Mar 2019 14:37:37.792    6 Mar 2019 15:34:40.338           3422.546
                      8   6 Mar 2019 16:10:39.454    6 Mar 2019 16:50:46.413           2406.959

Global Statistics
-----------------
Min Duration          3   5 Mar 2019 20:01:17.621    5 Mar 2019 20:09:44.776            507.155
Max Duration          1   5 Mar 2019 16:55:14.281    5 Mar 2019 17:52:19.586           3425.305
Mean Duration                                                                          2931.985
Total Duration                                                                        23455.883
```

```
                                                                          6 Mar 2019 18:03:50
FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-SGS_Oakhanger_Site_Annex-To-Satellite-Satellite2:  Access Summary Report


SGS_Oakhanger_Site_Annex-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2
-------------------------------------------------------------------------------
                 Access       Start Time (UTCG)           Stop Time (UTCG)       Duration (sec)
                 ------   ------------------------   ------------------------   --------------
                      1   6 Mar 2019 05:20:38.445    6 Mar 2019 06:16:31.467           3353.022
                      2   6 Mar 2019 06:52:29.420    6 Mar 2019 07:49:32.943           3423.523
                      3   6 Mar 2019 08:25:31.086    6 Mar 2019 09:22:34.416           3423.331
                      4   6 Mar 2019 09:58:32.757    6 Mar 2019 10:55:35.887           3423.131
                      5   6 Mar 2019 11:31:34.417    6 Mar 2019 12:28:37.357           3422.940
                      6   6 Mar 2019 13:04:36.086    6 Mar 2019 13:48:56.952           2660.866

Global Statistics
-----------------
Min Duration          6   6 Mar 2019 13:04:36.086    6 Mar 2019 13:48:56.952           2660.866
Max Duration          2   6 Mar 2019 06:52:29.420    6 Mar 2019 07:49:32.943           3423.523
Mean Duration                                                                          3284.469
```

Figure 19; showing the access time between VAPE and the stations

- The access full time duration for D-1 station is 7.8 Hour
- The access full time duration for D-2 station is 0.66 Hour
- The access full time duration for D-3 is 5.47 Hour

## Sun-synchronous orbit

- Three Ground stations access times; we shall see how long it takes for the data to be transfer going back and forth from the ground stations to the satellite with inclination of 98 deg

```
                                                                     6 Mar 2019 18:06:49
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Facility-Hartebeesthoek_STDN_HB33-To-Satellite-Satellite2:  Access Summary Report


Hartebeesthoek_STDN_HB33-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2
-------------------------------------------------------------------------------
                    Access        Start Time (UTCG)           Stop Time (UTCG)        Duration (sec)
                    ------    ------------------------    ------------------------    --------------
                         1    6 Mar 2019 01:24:36.394     6 Mar 2019 01:57:44.050          1987.657
                         2    6 Mar 2019 02:26:57.178     6 Mar 2019 03:30:42.656          3825.479
                         3    6 Mar 2019 03:59:58.031     6 Mar 2019 05:03:41.281          3823.249
                         4    6 Mar 2019 05:32:58.890     6 Mar 2019 06:36:39.915          3821.026
                         5    6 Mar 2019 07:05:59.737     6 Mar 2019 08:09:38.562          3818.825
                         6    6 Mar 2019 08:39:00.590     6 Mar 2019 09:42:37.213          3816.623
                         7    6 Mar 2019 10:12:01.431     6 Mar 2019 11:15:35.869          3814.438
                         8    6 Mar 2019 11:45:02.278     6 Mar 2019 12:48:34.523          3812.245
                         9    6 Mar 2019 13:18:03.113     6 Mar 2019 14:05:46.242          2863.129

Global Statistics
-----------------
Min Duration             1    6 Mar 2019 01:24:36.394     6 Mar 2019 01:57:44.050          1987.657
Max Duration             2    6 Mar 2019 02:26:57.178     6 Mar 2019 03:30:42.656          3825.479
Mean Duration                                                                              3509.186
Total Duration                                                                            31582.671
```

```
                                                                     6 Mar 2019 18:07:56
FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-MILA_STDN_MILA-To-Satellite-Satellite2:  Access Summary Report


MILA_STDN_MILA-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2
---------------------------------------------------------------------
                    Access        Start Time (UTCG)           Stop Time (UTCG)        Duration (sec)
                    ------    ------------------------    ------------------------    --------------
                         1    5 Mar 2019 17:08:51.879     5 Mar 2019 18:12:51.245          3839.366
                         2    5 Mar 2019 18:41:52.762     5 Mar 2019 19:45:49.810          3837.048
                         3    6 Mar 2019 10:12:01.370     6 Mar 2019 11:15:35.744          3814.374
                         4    6 Mar 2019 11:45:02.207     6 Mar 2019 12:48:34.411          3812.204
                         5    6 Mar 2019 13:18:03.050     6 Mar 2019 14:21:33.087          3810.037
                         6    6 Mar 2019 14:51:03.881     6 Mar 2019 15:54:31.774          3807.893
                         7    6 Mar 2019 16:24:04.718     6 Mar 2019 16:50:46.411          1601.693

Global Statistics
-----------------
Min Duration             7    6 Mar 2019 16:24:04.718     6 Mar 2019 16:50:46.411          1601.693
Max Duration             1    5 Mar 2019 17:08:51.879     5 Mar 2019 18:12:51.245          3839.366
Mean Duration                                                                              3503.231
Total Duration                                                                            24522.616
```

```
                                                                     6 Mar 2019 18:08:26
FOR UNFUNDED EDUCATIONAL USE ONLY
Facility-SGS_Oakhanger_Site_Annex-To-Satellite-Satellite2:  Access Summary Report


SGS_Oakhanger_Site_Annex-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2
-------------------------------------------------------------------------------
                    Access        Start Time (UTCG)           Stop Time (UTCG)        Duration (sec)
                    ------    ------------------------    ------------------------    --------------
                         1    6 Mar 2019 05:32:58.802     6 Mar 2019 06:36:39.849          3821.048
                         2    6 Mar 2019 07:05:59.650     6 Mar 2019 08:09:38.489          3818.839
                         3    6 Mar 2019 08:39:00.502     6 Mar 2019 09:42:37.134          3816.632
                         4    6 Mar 2019 10:12:01.343     6 Mar 2019 11:15:35.791          3814.448
                         5    6 Mar 2019 11:45:02.190     6 Mar 2019 12:48:34.449          3812.259
                         6    6 Mar 2019 13:18:03.025     6 Mar 2019 13:48:56.964          1853.939

Global Statistics
-----------------
Min Duration             6    6 Mar 2019 13:18:03.025     6 Mar 2019 13:48:56.964          1853.939
Max Duration             1    6 Mar 2019 05:32:58.802     6 Mar 2019 06:36:39.849          3821.048
Mean Duration                                                                              3489.527
Total Duration                                                                            20937.165
```

Figure 20; showing the access time between VAPE and the stations

- The access full time duration for D-1 station is 8.7 Hour
- The access full time duration for D-2 station is 6.8 Hour
- The access full time duration for D-3 is 5.8 Hour

## Polar orbit

- Three ground stations access times; we shall see how long it takes for the data to be transfer going back and forth from the ground stations to the satellite with inclination of 90 deg

6 Mar 2019 18:10:40

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Facility-Hartebeesthoek_STDN_HB33-To-Satellite-Satellite2:  Access Summary Report

Hartebeesthoek_STDN_HB33-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2

| | Access | Start Time (UTCG) | Stop Time (UTCG) | Duration (sec) |
|---|---|---|---|---|
| | 1 | 6 Mar 2019 01:24:36.386 | 6 Mar 2019 01:54:25.558 | 1789.172 |
| | 2 | 6 Mar 2019 02:23:05.606 | 6 Mar 2019 03:27:24.613 | 3859.007 |
| | 3 | 6 Mar 2019 03:56:07.231 | 6 Mar 2019 05:00:23.686 | 3856.455 |
| | 4 | 6 Mar 2019 05:29:08.841 | 6 Mar 2019 06:33:22.767 | 3853.926 |
| | 5 | 6 Mar 2019 07:02:10.447 | 6 Mar 2019 08:06:21.862 | 3851.415 |
| | 6 | 6 Mar 2019 08:35:12.041 | 6 Mar 2019 09:39:20.959 | 3848.918 |
| | 7 | 6 Mar 2019 10:08:13.630 | 6 Mar 2019 11:12:20.060 | 3846.431 |
| | 8 | 6 Mar 2019 11:41:15.216 | 6 Mar 2019 12:45:19.167 | 3843.951 |
| | 9 | 6 Mar 2019 13:14:16.796 | 6 Mar 2019 14:05:46.207 | 3089.411 |
| **Global Statistics** | | | | |
| Min Duration | 1 | 6 Mar 2019 01:24:36.386 | 6 Mar 2019 01:54:25.558 | 1789.172 |
| Max Duration | 2 | 6 Mar 2019 02:23:05.606 | 6 Mar 2019 03:27:24.613 | 3859.007 |
| Mean Duration | | | | 3537.632 |
| Total Duration | | | | 31838.686 |

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Facility-MILA_STDN_MILA-To-Satellite-Satellite2:  Access Summary Report

MILA_STDN_MILA-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2

| | Access | Start Time (UTCG) | Stop Time (UTCG) | Duration (sec) |
|---|---|---|---|---|
| | 1 | 5 Mar 2019 17:04:55.588 | 5 Mar 2019 18:09:30.448 | 3874.860 |
| | 2 | 5 Mar 2019 18:37:57.252 | 5 Mar 2019 19:42:29.464 | 3872.212 |
| | 3 | 6 Mar 2019 10:08:13.596 | 6 Mar 2019 11:12:19.940 | 3846.344 |
| | 4 | 6 Mar 2019 11:41:15.180 | 6 Mar 2019 12:45:19.054 | 3843.873 |
| | 5 | 6 Mar 2019 13:14:16.759 | 6 Mar 2019 14:18:18.174 | 3841.415 |
| | 6 | 6 Mar 2019 14:47:18.325 | 6 Mar 2019 15:51:17.306 | 3838.981 |
| | 7 | 6 Mar 2019 16:20:19.889 | 6 Mar 2019 16:50:46.411 | 1826.523 |
| **Global Statistics** | | | | |
| Min Duration | 7 | 6 Mar 2019 16:20:19.889 | 6 Mar 2019 16:50:46.411 | 1826.523 |
| Max Duration | 1 | 5 Mar 2019 17:04:55.588 | 5 Mar 2019 18:09:30.448 | 3874.860 |
| Mean Duration | | | | 3563.458 |
| Total Duration | | | | 24944.207 |

6 Mar 2019 18:12:20

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Facility-SGS_Oakhanger_Site_Annex-To-Satellite-Satellite2:  Access Summary Report

SGS_Oakhanger_Site_Annex-To-Satellite2 - Hartebeesthoek_STDN_HB33-To-Satellite2

| | Access | Start Time (UTCG) | Stop Time (UTCG) | Duration (sec) |
|---|---|---|---|---|
| | 1 | 6 Mar 2019 05:29:08.757 | 6 Mar 2019 06:33:22.687 | 3853.930 |
| | 2 | 6 Mar 2019 07:02:10.361 | 6 Mar 2019 08:06:21.770 | 3851.410 |
| | 3 | 6 Mar 2019 08:35:11.964 | 6 Mar 2019 09:39:20.868 | 3848.905 |
| | 4 | 6 Mar 2019 10:08:13.555 | 6 Mar 2019 11:12:19.968 | 3846.413 |
| | 5 | 6 Mar 2019 11:41:15.141 | 6 Mar 2019 12:45:19.079 | 3843.938 |
| | 6 | 6 Mar 2019 13:14:16.717 | 6 Mar 2019 13:48:56.949 | 2080.232 |
| **Global Statistics** | | | | |
| Min Duration | 6 | 6 Mar 2019 13:14:16.717 | 6 Mar 2019 13:48:56.949 | 2080.232 |
| Max Duration | 1 | 6 Mar 2019 05:29:08.757 | 6 Mar 2019 06:33:22.687 | 3853.930 |
| Mean Duration | | | | 3554.138 |
| Total Duration | | | | 21324.828 |

Figure 21; showing the access time between VAPE and the stations

- The access full time duration for D-1 station is 8.8 Hour
- The access full time duration for D-2 station is 6.65 Hour
- The access full time duration for D-2 is 6.1 Hour

Based on the calculations for the three orbits, we found out that the most appropriate orbit that keep sending data with the longest duration is the **polar orbit**. Which means, more data

***Perturbations***

## Low inclination orbit

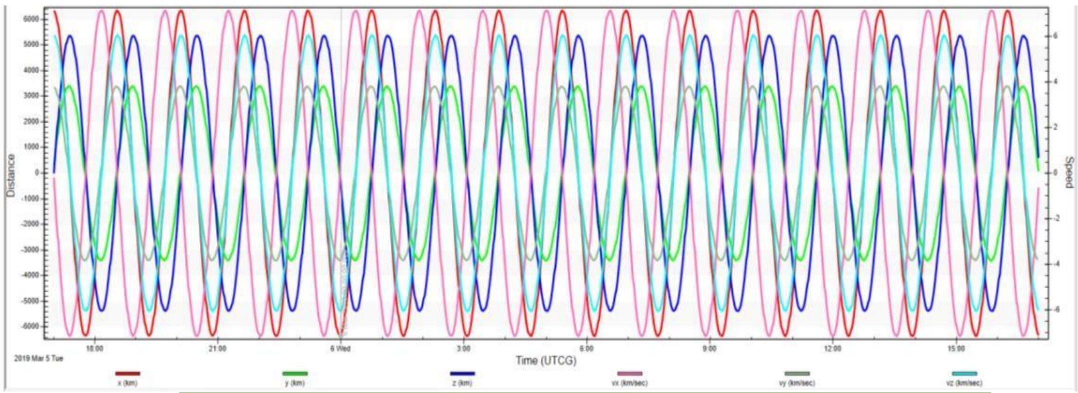


Figure 22; showing the Vape perturbations over Venus

As we see the perturbations with low inclination orbit is not stable and need a lot of correction, especially with y component (displacement) and Vz component (speed)

## Sun-synchronous orbit

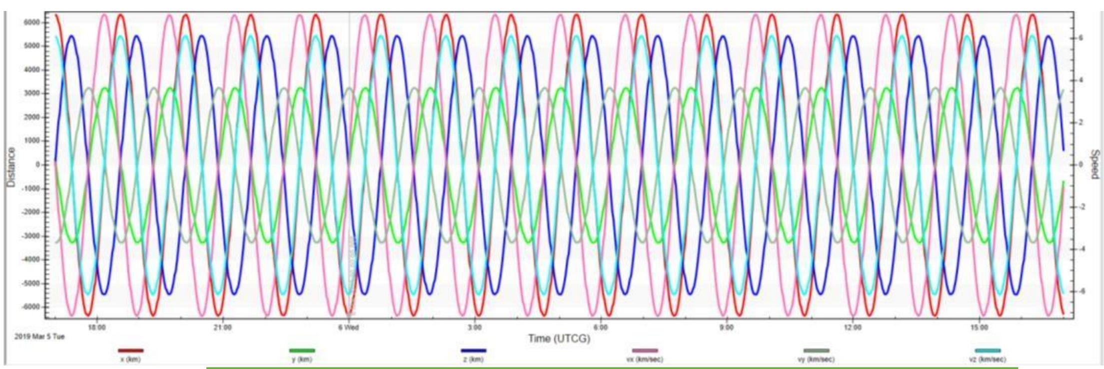


Figure 23; showing the Vape perturbations over Venus

Over here, the rate of error is much less than the previous orbit, but we still have some major perturbations with Vz component (speed) and y component (displacement).

## Polar orbit

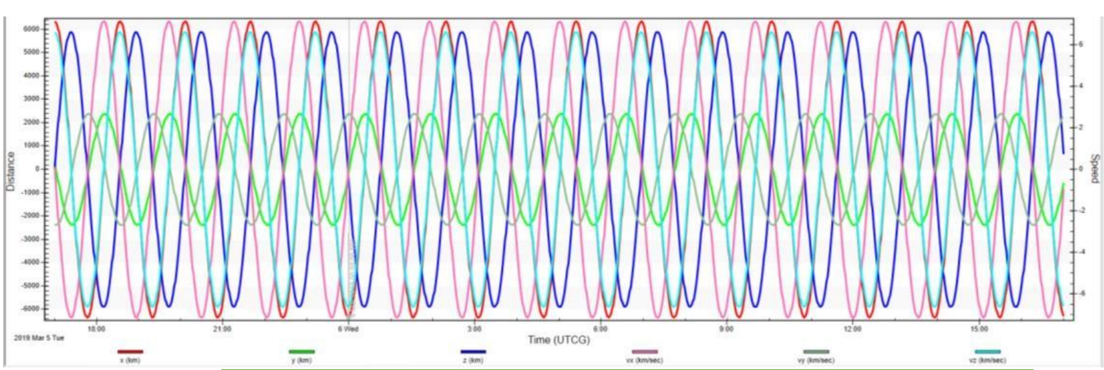


Figure 24; showing the Vape perturbations over Venus

Based on the last two previous orbits, we can see that the **polar orbit** is the most suitable orbit, which needs a little of corrections for Vz component only. That means less observation less cost and spend more time to focus on the main objective of the mission.

***Power generation***□

Satellites can generally receive signals and send them bac to Earth, so to make this possible, a satellite must produce its own power, generating electricity from sunlight falling on solar panels.

## Low inclination orbit □

| Time (UTCG) | Power (W) | Solar Intensity |
|---|---|---|
| 5 Mar 2019 17:00:00.000 | 46.331 | 1.000000 |
| 5 Mar 2019 17:30:00.000 | 46.323 | 1.000000 |
| 5 Mar 2019 18:00:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 18:30:00.000 | 46.288 | 1.000000 |
| 5 Mar 2019 19:00:00.000 | 46.292 | 1.000000 |
| 5 Mar 2019 19:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 20:00:00.000 | 46.272 | 1.000000 |
| 5 Mar 2019 20:30:00.000 | 46.280 | 1.000000 |
| 5 Mar 2019 21:00:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 21:30:00.000 | 46.248 | 1.000000 |
| 5 Mar 2019 22:00:00.000 | 46.245 | 1.000000 |
| 5 Mar 2019 22:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 23:00:00.000 | 46.221 | 1.000000 |
| 5 Mar 2019 23:30:00.000 | 46.217 | 1.000000 |
| 6 Mar 2019 00:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 00:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 01:00:00.000 | 46.189 | 1.000000 |
| 6 Mar 2019 01:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 02:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 02:30:00.000 | 46.166 | 1.000000 |
| 6 Mar 2019 03:00:00.000 | 46.150 | 1.000000 |
| 6 Mar 2019 03:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 04:00:00.000 | 46.134 | 1.000000 |
| 6 Mar 2019 04:30:00.000 | 46.134 | 1.000000 |
| 6 Mar 2019 05:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 05:30:00.000 | 46.079 | 1.000000 |
| 6 Mar 2019 06:00:00.000 | 46.095 | 1.000000 |
| 6 Mar 2019 06:30:00.000 | 0.000 | 0.000000 |

Figure 25; showing the power generation results

As we see here, the power generation (source □ panels) provides low rate power, which would cost us more money to generate more power

## Sun-synchronous orbit□

| Time (UTCG) | Power (W) | Solar Intensity |
|---|---|---|
| 5 Mar 2019 17:00:00.000 | 232.213 | 1.000000 |
| 5 Mar 2019 17:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 18:00:00.000 | 231.796 | 1.000000 |
| 5 Mar 2019 18:30:00.000 | 231.517 | 1.000000 |
| 5 Mar 2019 19:00:00.000 | 231.364 | 1.000000 |
| 5 Mar 2019 19:30:00.000 | 213.138 | 0.922212 |
| 5 Mar 2019 20:00:00.000 | 230.861 | 1.000000 |
| 5 Mar 2019 20:30:00.000 | 230.637 | 1.000000 |
| 5 Mar 2019 21:00:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 21:30:00.000 | 230.212 | 1.000000 |
| 5 Mar 2019 22:00:00.000 | 230.012 | 1.000000 |
| 5 Mar 2019 22:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 23:00:00.000 | 229.556 | 1.000000 |
| 5 Mar 2019 23:30:00.000 | 229.348 | 1.000000 |
| 6 Mar 2019 00:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 00:30:00.000 | 228.872 | 1.000000 |
| 6 Mar 2019 01:00:00.000 | 228.644 | 1.000000 |
| 6 Mar 2019 01:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 02:00:00.000 | 228.188 | 1.000000 |
| 6 Mar 2019 02:30:00.000 | 227.964 | 1.000000 |
| 6 Mar 2019 03:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 03:30:00.000 | 227.543 | 1.000000 |
| 6 Mar 2019 04:00:00.000 | 227.335 | 1.000000 |
| 6 Mar 2019 04:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 05:00:00.000 | 226.879 | 1.000000 |
| 6 Mar 2019 05:30:00.000 | 226.671 | 1.000000 |
| 6 Mar 2019 06:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 06:30:00.000 | 226.203 | 1.000000 |
| 6 Mar 2019 07:00:00.000 | 225.983 | 1.000000 |

Figure 26; showing the power generation results

As we see here, the rate of power generation is high and it should be suitable for our mission, gaining more free power, low cost.

## Polar orbit □

| Time (UTCG) | Power (W) | Solar Intensity |
|---|---|---|
| 5 Mar 2019 17:00:00.000 | 226.219 | 1.000000 |
| 5 Mar 2019 17:30:00.000 | 225.983 | 1.000000 |
| 5 Mar 2019 18:00:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 18:30:00.000 | 225.492 | 1.000000 |
| 5 Mar 2019 19:00:00.000 | 225.291 | 1.000000 |
| 5 Mar 2019 19:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 20:00:00.000 | 224.831 | 1.000000 |
| 5 Mar 2019 20:30:00.000 | 224.591 | 1.000000 |
| 5 Mar 2019 21:00:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 21:30:00.000 | 224.128 | 1.000000 |
| 5 Mar 2019 22:00:00.000 | 223.931 | 1.000000 |
| 5 Mar 2019 22:30:00.000 | 0.000 | 0.000000 |
| 5 Mar 2019 23:00:00.000 | 223.404 | 1.000000 |
| 5 Mar 2019 23:30:00.000 | 223.271 | 1.000000 |
| 6 Mar 2019 00:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 00:30:00.000 | 222.728 | 1.000000 |
| 6 Mar 2019 01:00:00.000 | 222.567 | 1.000000 |
| 6 Mar 2019 01:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 02:00:00.000 | 222.060 | 1.000000 |
| 6 Mar 2019 02:30:00.000 | 221.848 | 1.000000 |
| 6 Mar 2019 03:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 03:30:00.000 | 221.408 | 1.000000 |
| 6 Mar 2019 04:00:00.000 | 221.105 | 1.000000 |
| 6 Mar 2019 04:30:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 05:00:00.000 | 220.720 | 1.000000 |
| 6 Mar 2019 05:30:00.000 | 220.382 | 1.000000 |
| 6 Mar 2019 06:00:00.000 | 0.000 | 0.000000 |
| 6 Mar 2019 06:30:00.000 | 219.997 | 1.000000 |
| 6 Mar 2019 07:00:00.000 | 219.725 | 1.000000 |

Figure 27; showing the power generation results

As we see here, the rate of power generation has similar rate as Sun-synchronous orbit.

- This time for our mission objective, Sun-synchronous orbit is more suitable for power generation as it generates more free power than low inclination orbit.

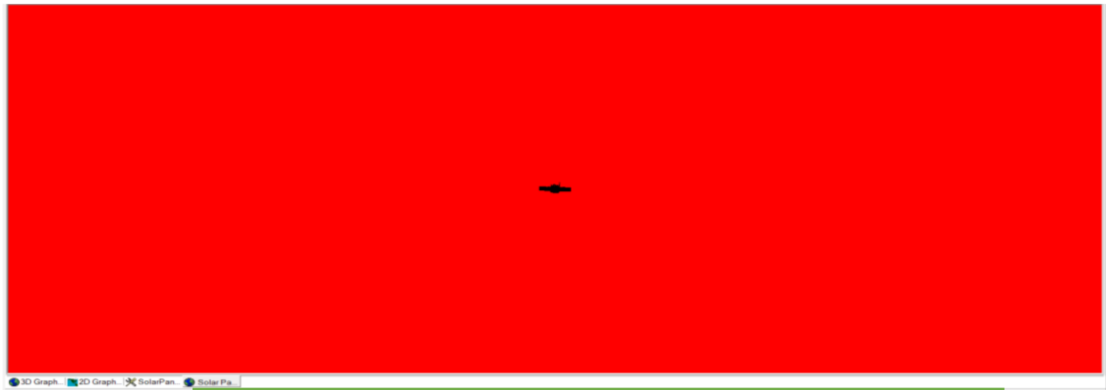

Figure 28; showing the power generation

***Converge access time of the satellite above Venus***

## Low inclination orbit

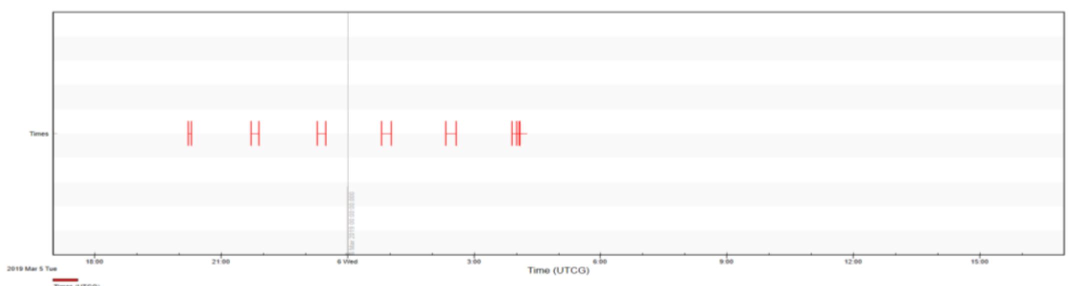


Figure 29; showing the coverage access time

Depends on our simulations on STK, for this orbit, we can see from the figure that coverage time doesn't cover the whole points. Just specific points with specific time.

## Sun-synchronous orbit

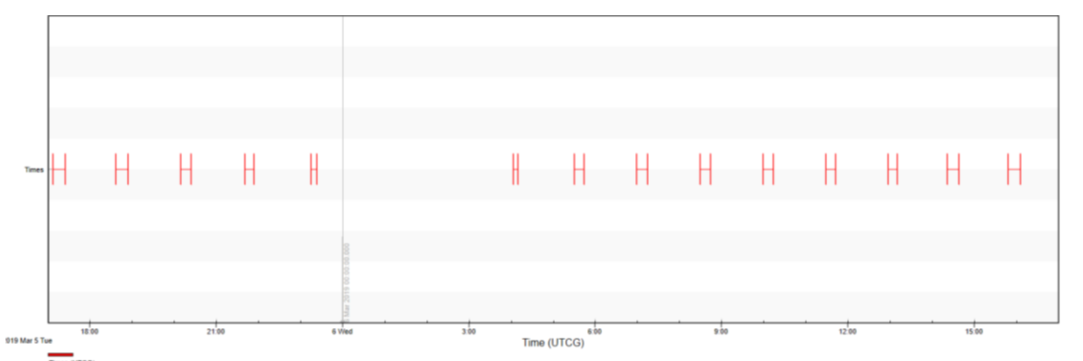


Figure 30; showing the coverage access time

Depends on our simulations on STK, for this orbit, we can see from the figure that coverage time covers more than 60% which is good for our objective.

## Polar orbit

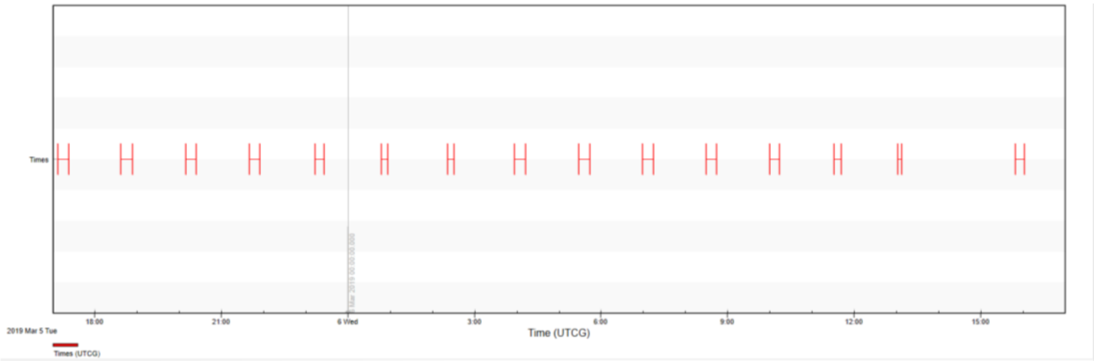


Figure 31; showing the coverage access time

Depends on our simulations on STK, for this orbit, we can see from the figure that coverage time covers almost the whole points. Which consider the best orbit to cover more points, and that means more accurate date. About 90% coverage

- **Polar orbit** coverage access time to Venus orbit is higher than the previous two orbits