Politecnico di Milano

Prova finale: Introduzione all'analisi di missioni spaziali

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Topputo

Elaborato n. C.33

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1. Introduction

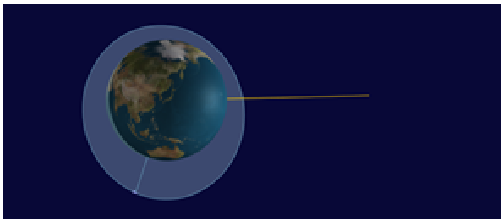
The purpose of this relation is to showcase the possible strategies viable for an orbital transfer.

This orbital transfer is characterised by a starting point located on an initial orbit, and a final point situated on a final orbit; those two orbits are respectively characterised by the orbital parameters *a, e, i, OM, om, theta* and the values $\bar{v}$ and $\bar{r}$.

The options we are going to bring forward are based on the analysis of the most convenient solution based on costs and time required.
Furthermore, we will illustrate alternative strategies to perform the satellite's transfer.

All the calculation and plotting has been done using Matlab software.

2. Initial Orbit Characterisation



2.1

The starting point of the satellite on the initial orbit is characterised by the following values:

$$\bar{r} = \{-3513.9009; -7175.5425; -6550.4418\} \textit{ position vector [km]}$$
$$\bar{v} = \{5.034; -0.1864; -2.905\} \textit{ velocity vector [}km^3/m^2\textit{]}$$

Applying a Matlab Function (car2par), we obtain the perifocal parameters listed below.

a	semi-major axis	9195.8594	km
e	eccentricity	0.1311	-
i	inclination	0.9112	rad
OM	RAAN	0.4265	rad
om	pericenter anomaly	1.2330	rad
theta	true anomaly	2.8395	rad

2.2

Few other useful values that can be easily obtained are:

$$T = 2.43 \text{ [hours]} = 146.20 \text{ [min]}$$
$$E = -\ 21.6727 \text{ [J/kg]}$$

The eccentricity value between 0 and 1 characterises the initial orbit as an ellipse. The altitude of the orbit's pericenter and apocenter are respectively *1618.4 km* and *4031.3 km*. The orbit pericenter's height is below *5000 km* and above *1500 km*, so it can't be classified either as low earth orbit or medium earth orbit.

As an ellipse, the specific mechanical energy (E) is negative.

2.3

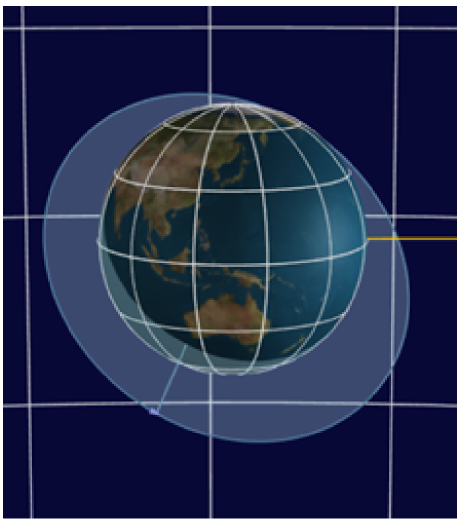


Figure 1: Astrodinamycs 3D Orbit Integration

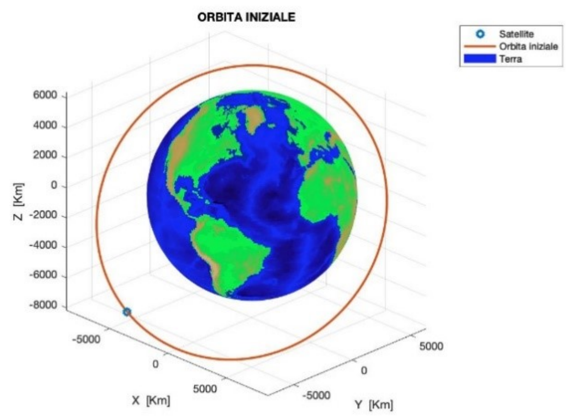
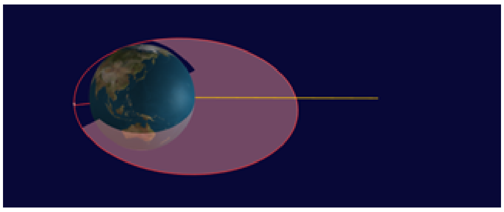


Figure 2: Matlab

3. Final Orbit Characterisation



3.1

The final orbit parameters given are:

a	semi-major axis	13420	km
e	eccenticity	0.3954	-
i	inclination	0.4405	rad
OM	RAAN	1.8610	rad
om	pericenter anomaly	2.9780	rad
theta	true anomaly	0.3339	rad

Applying a MatLab Function (par2car), we obtain the perifocal parameters listed below.

$$\bar{r} = \{3.5353; -7.4222; -0.5956\} \textit{ position vector [km]}$$
$$\bar{v} = \{6.8960; 2.7101; -3.4803\} \textit{ velocity vector [km}^3/m^2\textit{]}$$

3.2

Some additional parameters that can be easily obtained are:

T = 4.29 [hours] = 257.86 [min]
E = - 14.8509 [J/kg]

As the initial orbit, the final one is also an ellipse.

We also notice an increase in eccentricity, and the shape of the orbit is more stretched compared to the initial trajectory.

As an ellipse, the specific mechanical energy is negative but more significant than the initial orbit's one, due to a higher distance from the earth.

The altitude of pericenter and apocenter are respectively 1742.73 km and 1235.52 km. These values of height either make this orbit classifiable as low earth orbit or medium earth orbit.

3.3

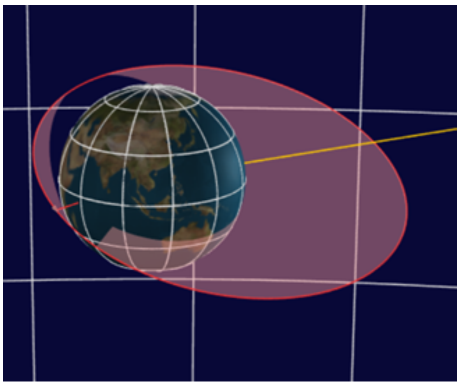


Figure 3: Astrodinamycs 3D Orbit Integration

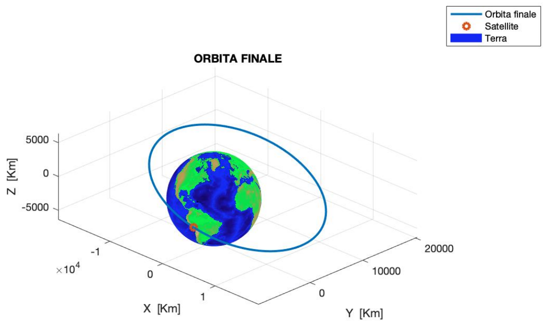


Figure 4: Matlab

4. Transfer trajectory definition and analysis

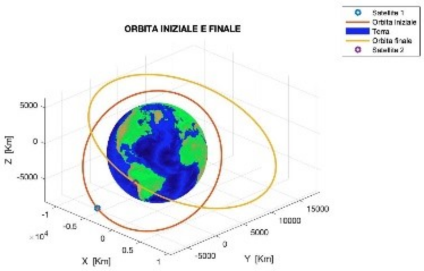


Figure 5: Initial and Final Orbits

4.1 Standard Strategy AP

There are many strategies appliable to achieve the required final position and velocity, starting from the initial orbit given.

The standard strategies are based on three manoeuvres:

- **Change of plane**
- **Change of pericenter's anomaly**
- **Bitangent transfer (pp, aa, pa or ap)**

The strategy exposed (Figure 6) is the most convenient above the standard approaches in terms of time required to complete the orbital transfer.

The first manoeuvre done is a change of orbital plane; this allows us to change the parameters i and OM, making those coincide with the final orbit's one. This manoeuvre is done in the point corresponding to $theta = 4.4938\ rad$. Doing this manoeuvre is to keep in mind that also the pericenter's anomaly value changes.

The second manoeuvre done is a change of pericenter's anomaly (om) to make it coincide with the final ones. This manoeuvre can be done in the two points of intersection between the current orbit and the final one; the chosen one is the nearest to the satellite position at this point in time. $(theta = 4.6246\ rad)$

The third and last manoeuvre of this orbital transfer is a bitangent transfer from the apocenter of the initial orbit, to the pericenter of the final one. This allows us to make the values a and e concide with the final orbit's.

The change of orbital plane is the most onerous above the manoeuvres executed, in the order of 1:5/6.

The global cost of this transfer is *8.3817 km/s*, and the time required to complete the operation is *4.5773 hours*.

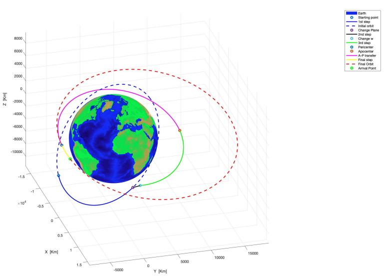


Figure 6: Standard Strategy AP

4.2 Standard Strategy AA

The strategy exposed (Figure 7) is the most convenient above the standard approaches in terms of the cost of the orbital transfer.

The first manoeuvre done is a change of orbital plane; this allows us to change the parameters i and OM, making those coincide with the final orbit ones. This manoeuvre is done in the point corresponding to $theta = 4.4938\ rad$. Doing this manoeuvre has to be kept in mind that also the pericenter's anomaly value changes.

The second manoeuvre done is a change of pericenter's anomaly (om) to make it coincide with the final one. This manoeuvre can be executed in the two points of intersection between the current orbit and an orbit that has the same parameters as the final one, but the pericenter argument rotated of -π; the chosen one is the nearest to the satellite position at this point in time. ($theta = 6.1954\ rad$)

The third and last manoeuvre of this orbital transfer is a bitangent transfer from the apocenter of the initial orbit, to the apocenter of the final one. During this manoeuvre, also the pericenter's anomaly turns into the final one. This allows us to make the values a and e concide with the final orbit's.

The change of orbital plane is the most onerous above the manoeuvres executed, in the order of 1:5.

The global cost of this transfer is *7.4845 km/s*, and the time required to complete the operation is *7.2066 hours*.

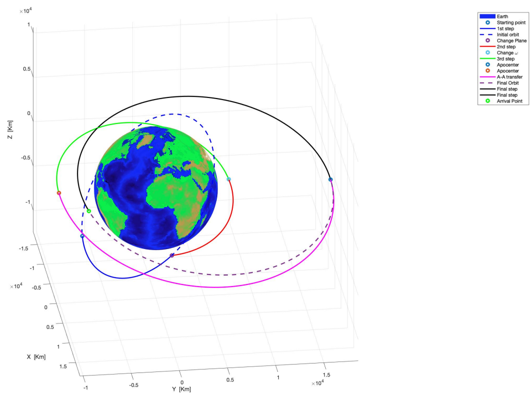


Figure 7: Standard Strategy AA

4.3 Standard Strategies PP and PA

As for the strategies exposed above, the first two manoeuvres done are a change of orbital plane, followed by the shift of pericenter's anomaly.

Then, the bitangent transfer option are:

- From the Pericenter of the initial orbit to the Pericenter of the final orbit (Figure 8)
- From the Pericenter of the initial orbit to the Apocenter of the final one (Figure 9)

Either the alternatives proposed are less convenient than the strategies exposed above, both for the cost and time required.

The cost and time required for the Standard Strategy PP and PA are respectively: *7.6429 km/s* and *6.7078 hours* and *8.3766 km/s* and *8.9041 hours*.

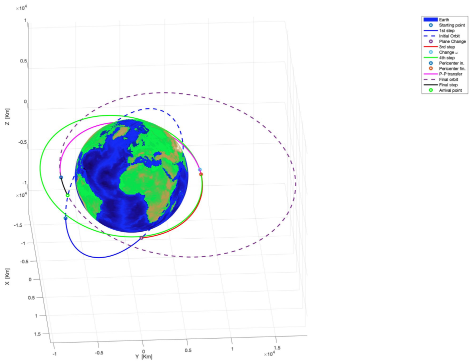


Figure 8: Standard Strategy PP

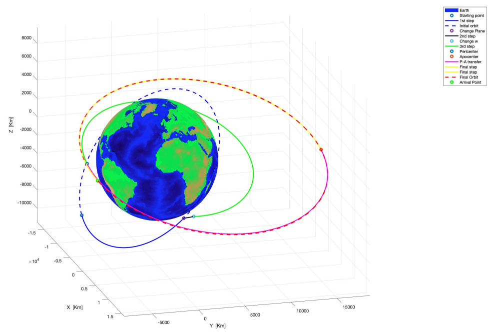


Figure 9: Standard Strategy PA

4.4 Alternative Strategy A

The first Alternative Strategy (Figure 10) exposed actuates three manoeuvres.

At first, a bitangent transfer from the apocenter of the first orbit to the pericenter of the final one allows us to reach the values of a and e required.

Afterwards, a change of orbital plane is completed in the point corrisponding to $theta = 4.4938$ *rad*. After this manoeuvre, the final value of i and OM are reached.

The last manoeuvre is the change of pericenter's anomaly (at $theta = 1.4830$ *rad*), that ultimates the orbital transfer.

The total cost of this orbital transfer is *10.4009 km/h*, and the time required is *6.7773 hours*.

As noticeable, the cost is much higher than the one evidenced in the standard strategies; nevertheless, it requires less time than both Standard Strategy AA and PA to be compleated.

4.5 Alternative Strategy B

This strategy is based on the use of a circular auxiliary orbit. (Figure 11)

The orbital transfer starts with a bitangent transfer from the pericenter of the initial orbit to the apocenter of a transfer orbit, that has the apocenter radius equal to the final orbit's.
Then this transfer orbit is circularised, obtaining a circular orbit with a radius equivalent to the apocenter radius of the final rotation.

So done, a change of orbital plane (at $theta = 4.4938$ *rad*) takes the circular orbit on the final orbit plane.
After this manoeuvre, the value of *om* is imposed to be 0, as well as *theta*.
This is done because the favourable conditions allowed by a circular orbit are lavished.

At last the auxiliary orbit crosses the final one in the apocenter, where the satellite enters his final orbit.

The cost of this orbital transfer is *7.0488 km/s* and requires *9.0882 hours* to be compleated.

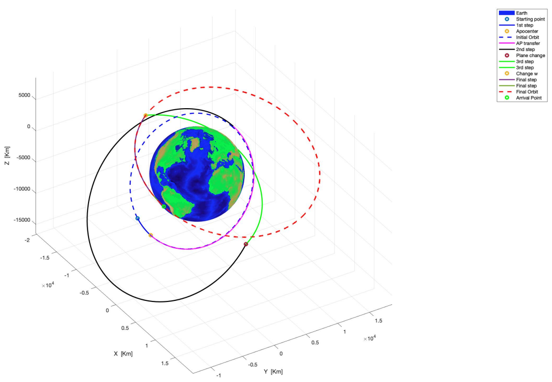


Figure 10: Alternative Strategy A

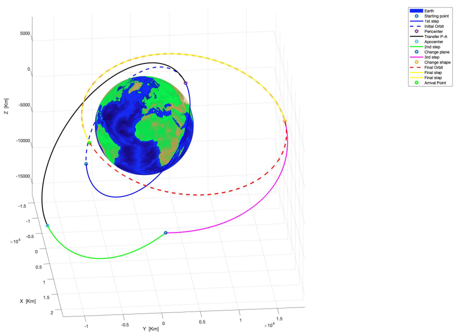


Figure 11: Alternative Strategy B

4.6 Alternative Strategy C

The last alternative strategy exposed (Figure 11) is based on a variation of the standard strategies AA and PP.

As for those, the first two manoeuvres done are a change of plane (at $theta = 4.4938$ rad) and a change of pericenter's anomaly (at $theta = 6.1954$ rad).

The current orbit and the final one intersect each other at $theta = 5.1809$ rad; in this point, an impulse is given to project the satellite on the final rotation.

The global cost of this orbital transfer is 8.8893 km/s and the time required to complete it is 2.4437 *hours*.

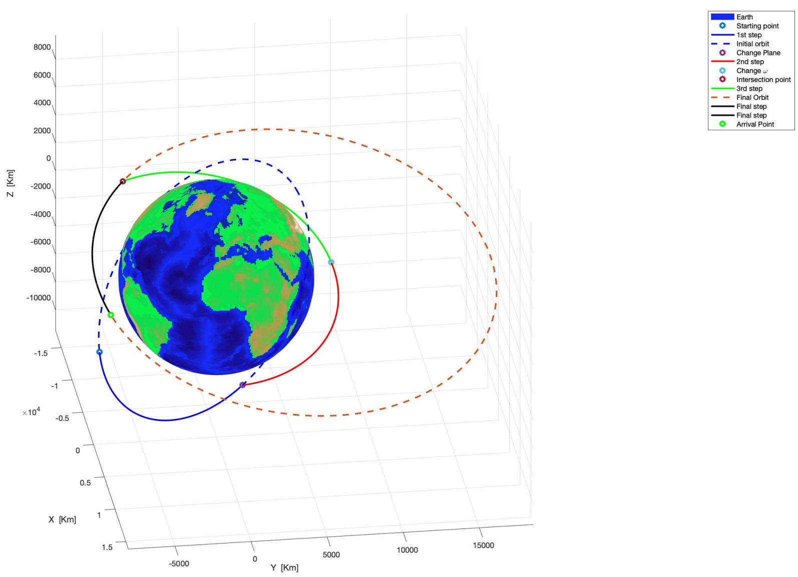


Figure 12: Alternative Strategy C

5. Conclusions

Between all the standard strategies proposed, the AP results to be the least onerous in terms of time required.
This transfer stands out above all the others because it halves the time required by the other standard strategies.

Concerning the costs, the Standard Strategy AA results to be the most convenient because it allows us to gain from the change of pericenter's anomaly manoeuvre compared to the strategies AP and PA.

The other two standard strategies (PP and PA) proposed, represent not incredibly convenient solutions neither in terms of costs or time required to complete the orbital transfer.

Regarding the Standard Strategy PA, it takes double the time required to complete the orbital transfer than the Standard Strategy AP, even if the costs are slightly lower than its.

The Standard Strategy PP is much more onerous than the AA, but it takes a slightly lower amount of time to be completed.

The major issues regarding the standard strategies are the restriction to change the pericenter's anomaly and the fact that the point of orbital plane's change is restricted on the specific initial orbit, this restraint results to be very onerous.

To obviate to these restrictions, we are proposing three alternative strategies.

The Alternative Strategy A doesn't result to be convenient because even if the cost during the manoeuvre of change of orbital plane is lower than the standard strategies, the manoeuvre of change of pericenter's anomaly is much more onerous.
Furthermore, since we are distancing from the final orbit to realise a worthwhile change of orbital plane, the time required to realise the orbital transfer is very high.

The Alternative Strategy B is focused on the circularisation of an auxiliary orbit, to leverage the vantages of a circular orbit, as a means of minimising the cost of the orbital transfer.
This transfer results to be the strategy with a lower cost, despite of the time required that products to be triplicated compared to the one needed to realise the transfer standard AP.

The alternative strategy C, lavish the change of orbital plane and pericenter's anomaly that is initially done in the standard strategies AA and PP.
These manoeuvres allow us to intercept the final orbit without necessitating a bitangent transfer.
This strategy was thought to be an emergency solution in case the transfer requires to be finalised fast.
This orbital transfer requires around 2 hours to be completed, being the most convenient transfer in terms of time needed overall.

In conclusion, we can assume that above all the transfers exposed, the alternative strategy B results to be the least onerous, and the alternative strategy C the one that requires less time to be completed.

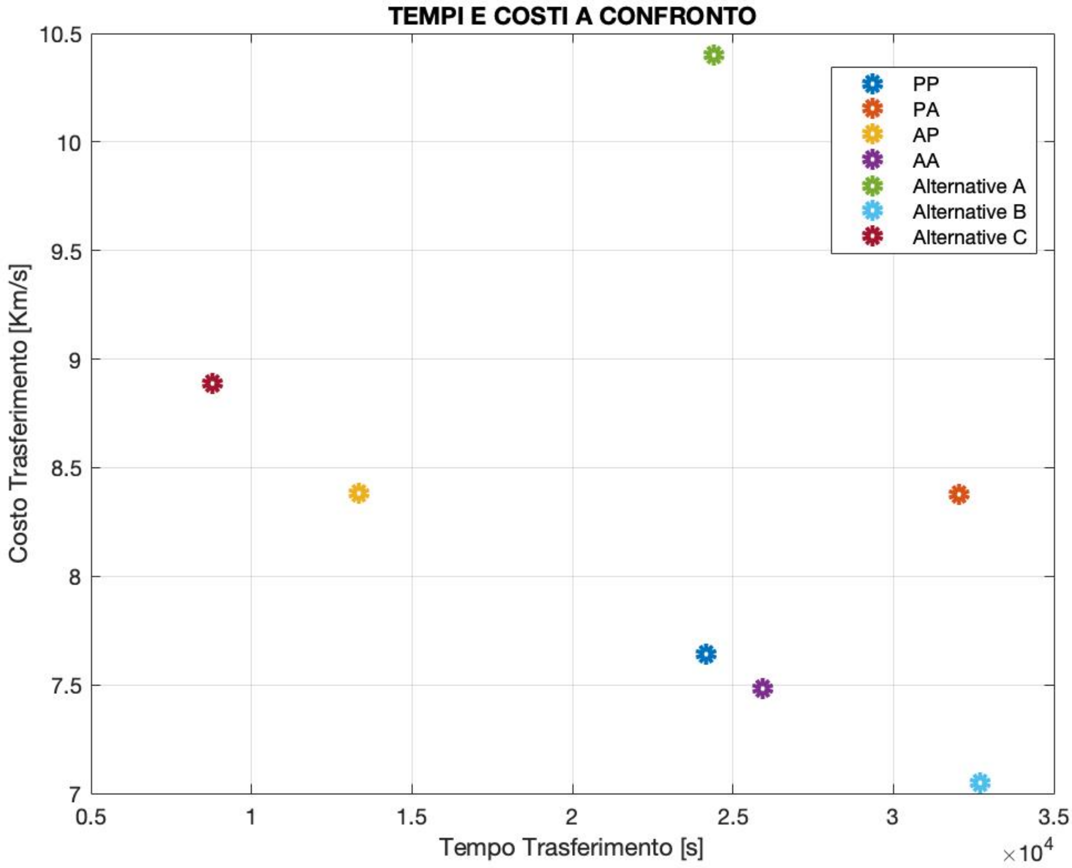


Figure 13: Comparison

6. Appendix

Transfer 1 (Standard Strategy AP)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+2795.2307 *Transfer to the point of: Change of plane*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*5.7707*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+185.3819 *Transfer to the point of: Change of pericenter's anomaly*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.6246*	
Change of Pericenter's Anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.6246*	*1.7359*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.978*	*1.6586*	
+5589.6653 *Transfer to the apocenter*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978*	*1.6586*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.978*	*3.1415*	
+4432.6039 *Bitangent Transfer AP*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978*	*3.1415*	*0.8752*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0*	*(0.0251+0.8499)*
+330.6878 *Transfer to the final point*	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
13333.5696	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*8.3817*

Transfer 2 (Standard Strategy PP)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+2795.2307 *Transfer to the point of: Change of plane*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*5.7707*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+2041.4239 *Transfer to the point of: Change of pericenter's anomaly*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	
Change of Pericenter's Anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	*0.1528 (<0)*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.9780 -pi*	*0.0878*	
+15385.6695 *Transfer to the Pericenter*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.9780 -pi*	*0.0878*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.9780 -pi*	*0*	
+3595.0224 *Bitangent Transfer PP*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.9780 -pi*	*0*	*1.7195*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0*	*(0.4219+1.2976)*
+330.6878 *Transfer to the final point*	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
24148.0343	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*7.6429*

Transfer 3 (Standard Strategy PA)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+2795.2307 Transfer to the point of: Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*5.7707*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+185.3819 Transfer to the point of: Change of pericenter's anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.6245*	
Change of Pericenter's Anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.6245*	*1.7359*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.9780*	*1.6586*	
+13325.5502 Transfer to the Pericenter	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978*	*1.6585*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.978*	*0*	
+7682.1926 Bitangent Transfer PA	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978*	*0*	*0.8700*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	*(0.8507+0.0193)*
+8066.5727 Transfer to the final point	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
32054.9281	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*8.3766*

Transfer 4 (Standard Strategy AA)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+2795.2307 Transfer to the point of: Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*5.7707*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+2041.4239 Transfer to the point of: Change of pericenter's anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	
Change of Pericenter's Anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	*0.1528* *(<0)*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.9780 -pi*	*0.0878*	
+4294.6331 Transfer to the Apocenter	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978 -pi*	*0.0878*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.978 -pi*	*3.1415*	
+8746.1203 Bitangent Transfer AA	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978 -pi*	*3.1415*	*1.5610*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	*(1.2493+0.3117)*
+8066.5727 Transfer to the final point	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
25943.9807	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*7.4845*

Transfer 5 (Alternative Strategy A)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+542.0216 *Transfer to the Apocenter*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*3.1415*	
+4432.6039 *Bitangent Transfer AP*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*3.1415*	*0.8752*
	13420	*0.3954*	*0.9112*	*0.4265*	*1.2330*	*0*	*(0.0251+0.8499)*
+13042.4670 *Transfer to the point of: Change of plane*	*13420*	*0.3954*	*0.9112*	*0.4265*	*1.2330*	*0*	-
	13420	*0.3954*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*13420*	*0.3954*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*4.8517*
	13420	*0.3954*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+4239.8738 *Transfer to the point of: Change of pericenter's anomaly*	*13420*	*0.3954*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	13420	*0.3954*	*0.4405*	*1.861*	*0.0120*	*1.4830*	
Change of Pericenter's Anomaly	*13420*	*0.3954*	*0.4405*	*1.861*	*0.0120*	*1.4830*	*4.6741*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*4.8002*	
+2141.4488 *Transfer to the final point*	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*4.8002*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
24398.6051	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*10.4009*

Transfer 6 (Alternative Strategy B)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+4930.0528 *Transfer to the Pericenter*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*0*	
+7682.1926 *Bitangent Transfer PA to a circular orbit*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*0*	*1.8973*
	18726	*0*	*0.9112*	*0.4265*	*1.2330*	*3.1415*	*(0.8507+1.0455)*
+5488.3656 *Transfer to the point of: Change of plane*	*18726*	*0*	*0.9112*	*0.4265*	*1.2330*	*3.1415*	-
	18726	*0*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of Plane	*18726*	*0*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*4.1263*
	18726	*0*	*0.4405*	*1.861*	*0*	*0*	
+6550.3290 *Transfer to the point of elliptization*	*18726*	*0*	*0.4405*	*1.861*	*0*	*0*	-
	18726	*0*	*0.4405*	*1.861*	*0*	*1.6238* *(3.1415 for the final orbit)*	
Elliptization	*18726*	*0*	*0.4405*	*1.861*	*0*	*1.6238* *(3.1415 for the final orbit)*	*1.0263*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	
+8066.5727 *Transfer to the final point*	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*3.1415*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
32717.5126	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*7.0488*

Transfer 7 (Alternative Strategy C)

t (s)	a (km)	e (-)	i (rad)	Ω (rad)	ω (rad)	θ (rad)	Δv (km/s)
0	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
+2795.2307 *Transfer to the point of: Change of plane*	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*2.8396*	-
	9195.8594	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	
Change of plane	*9195.8594*	*0.1311*	*0.9112*	*0.4265*	*1.2330*	*4.4938*	*5.7707*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	
+2041.4239 *Transfer to the point of: Change of pericenter's anomaly*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*4.4938*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	
Change of Pericenter's Anomaly	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*0.0120*	*6.1954*	*0.1528* *(<0)*
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.9780* *-pi*	*0.0878*	
+2413.6614 *Transfer to the intersection point of the orbits*	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978* *-pi*	*0.0878*	-
	9195.8594	*0.1311*	*0.4405*	*1.861*	*2.978* *-pi*	*2.0393* *(5.1809 on the final orbit)*	
Change of orbit	*9195.8594*	*0.1311*	*0.4405*	*1.861*	*2.978* *-pi*	*2.0393*	*2.9658*
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*5.1809*	
+1547.1068 *Transfer to the final point*	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*5.1809*	-
	13420	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	
8797.4229	*13420*	*0.3954*	*0.4405*	*1.861*	*2.978*	*0.3339*	*8.8893*

7. Images Appendix

In this appendix is reported a broader view of the Images presented above.

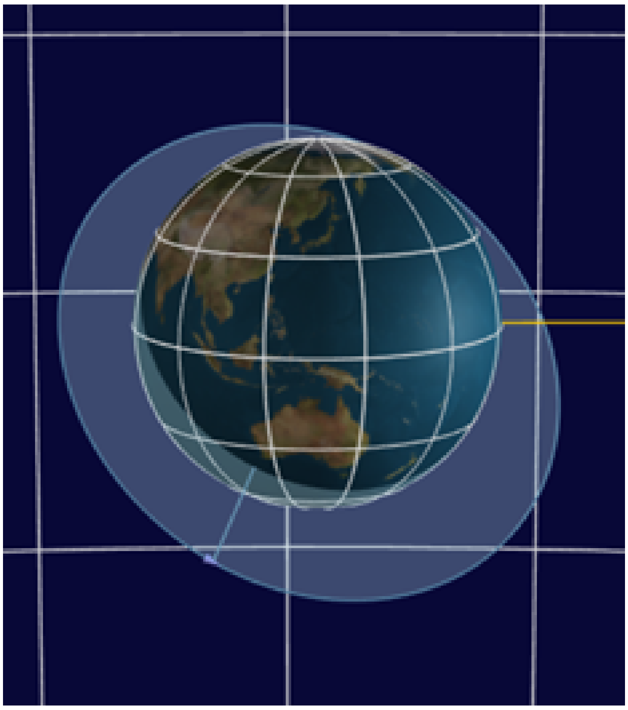


Figure 1

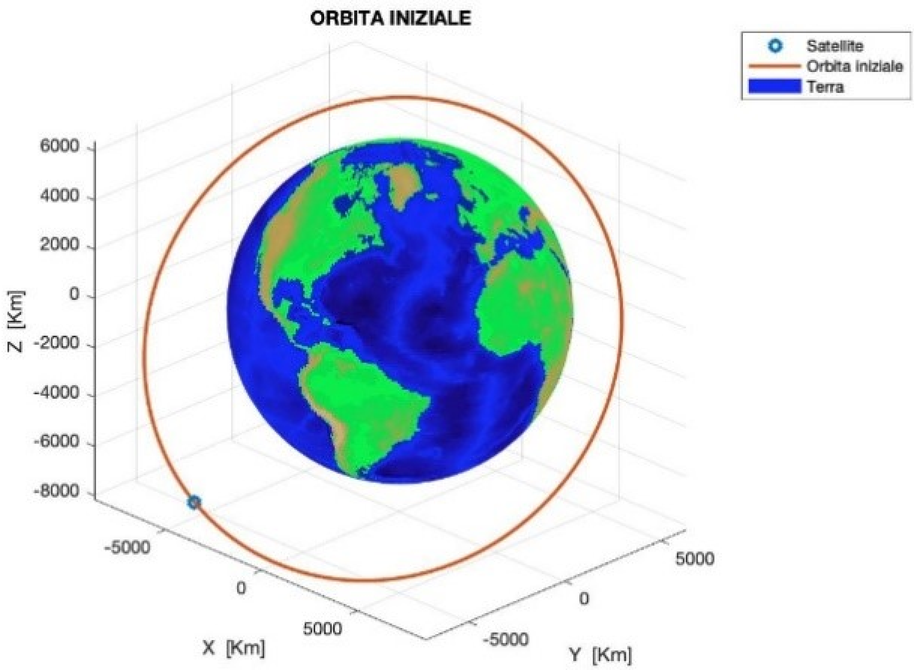


Figure 2

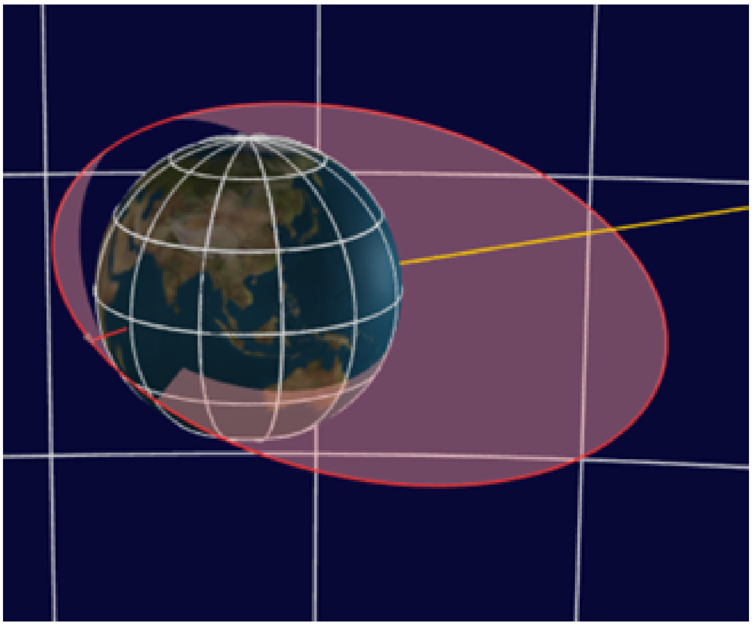


Figure 3

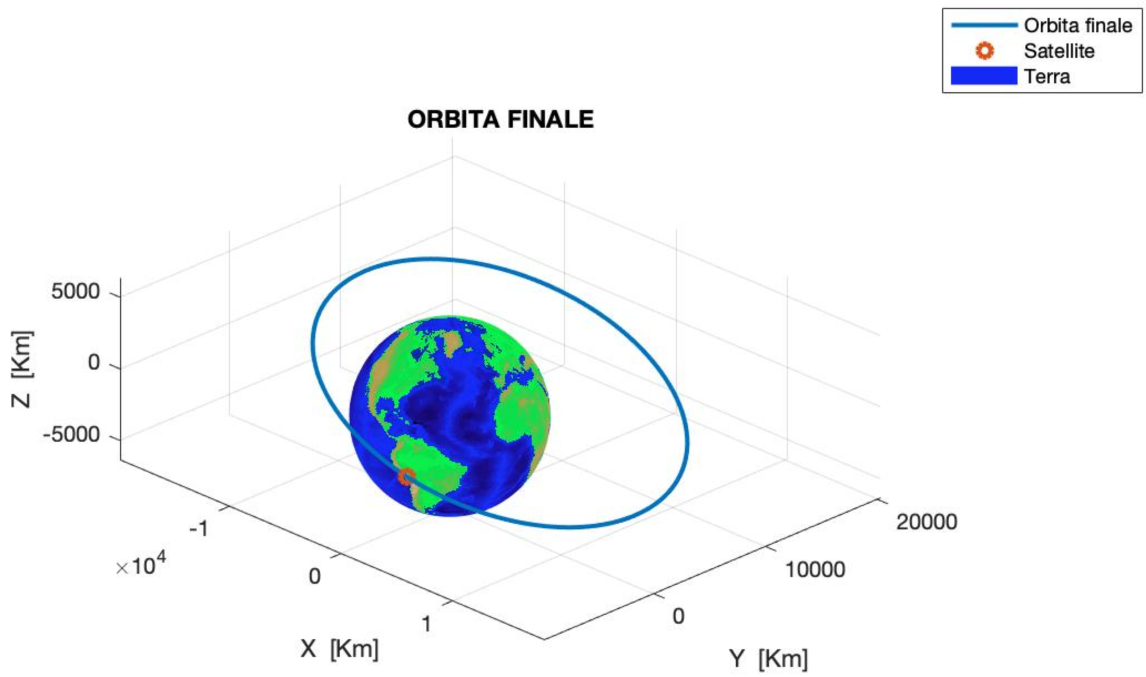


Figure 4

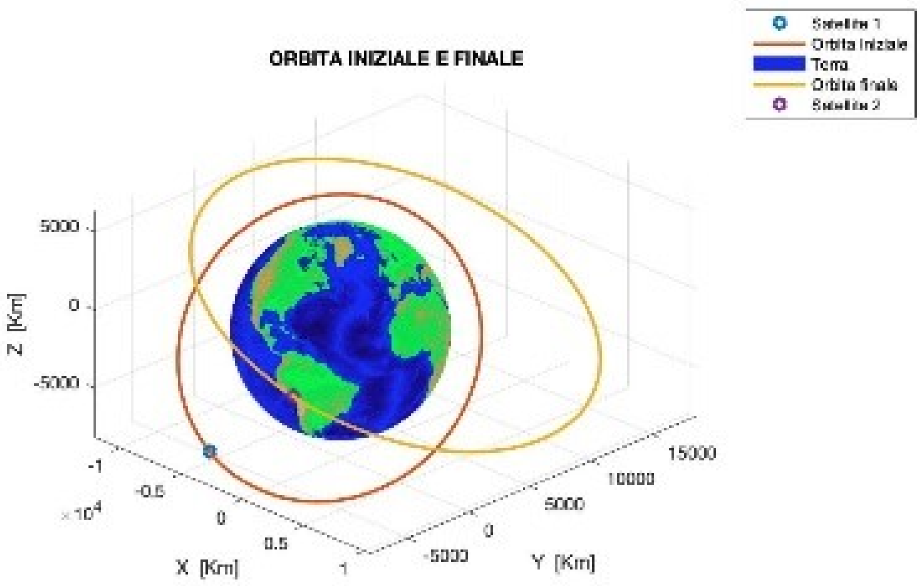


Figure 5

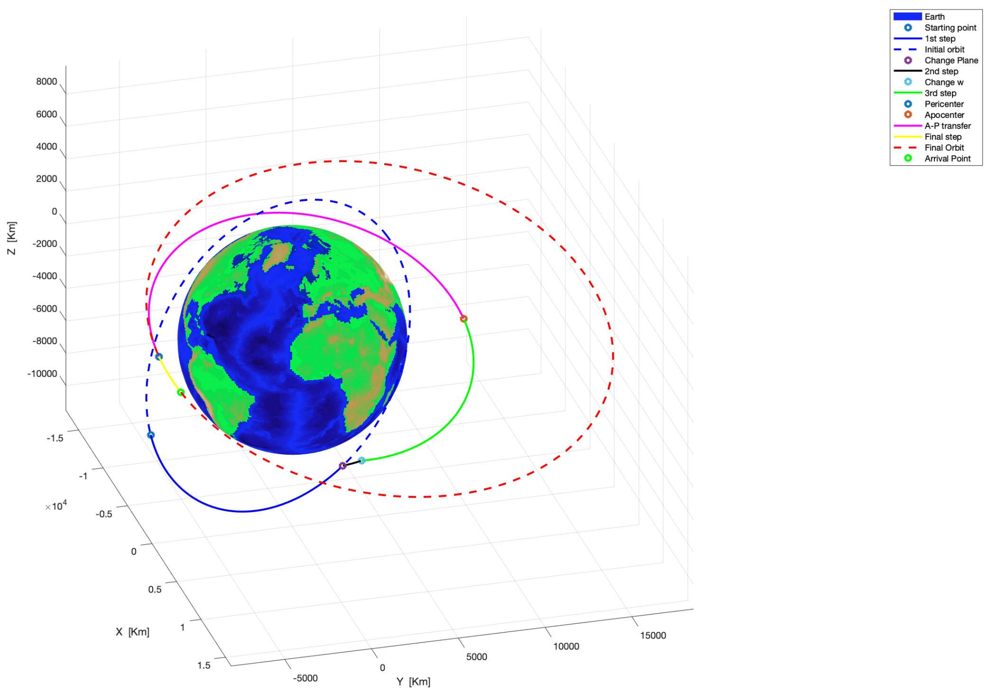


Figure 6

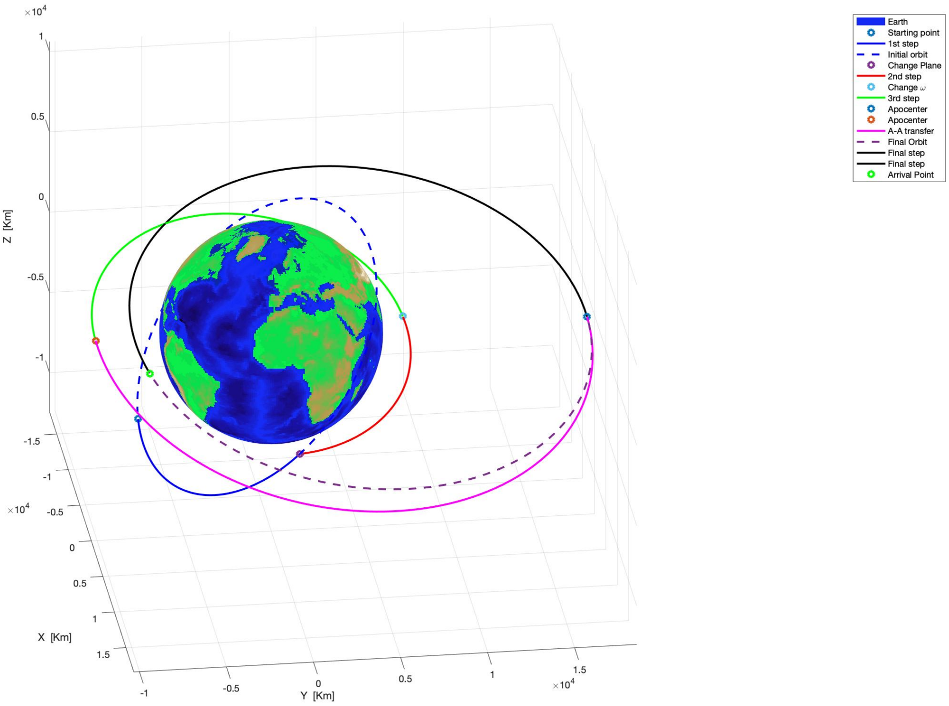


Figure 7

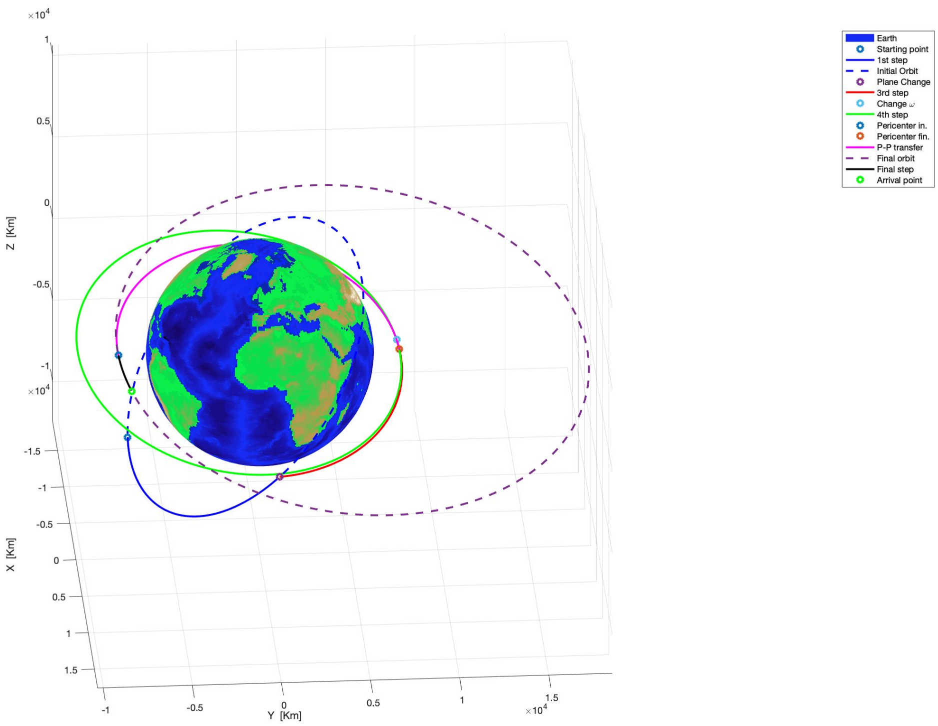


Figure 8

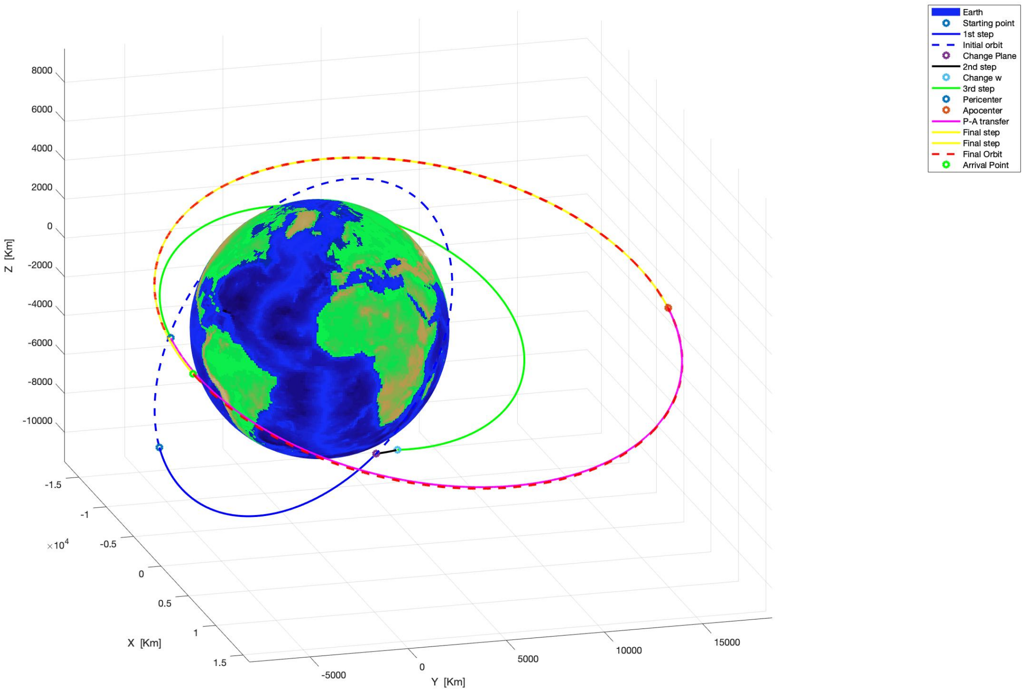


Figure 9

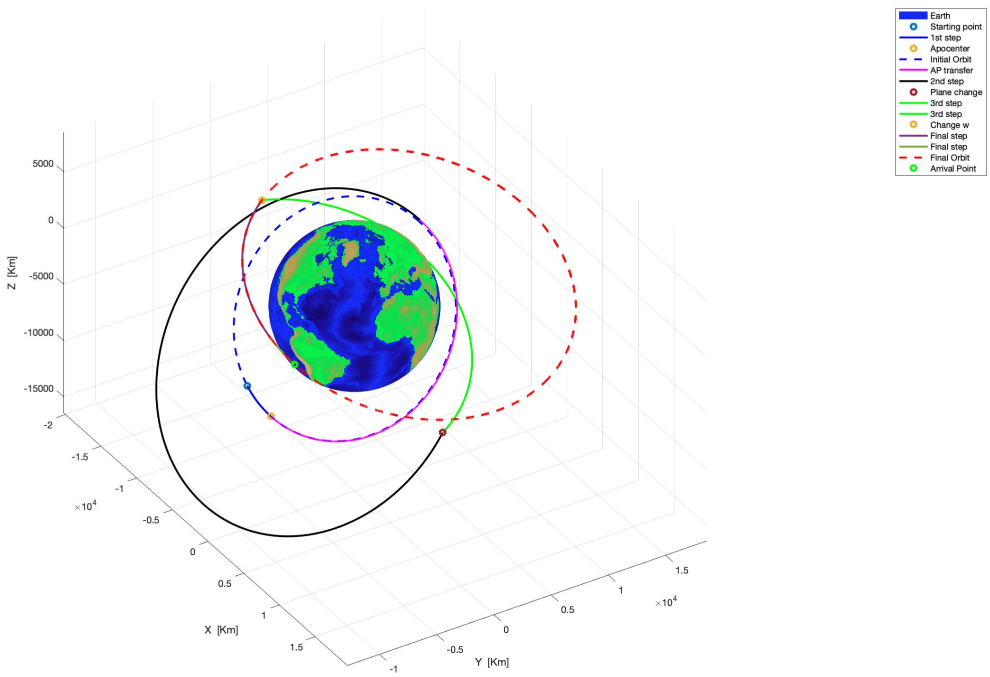


Figure 10

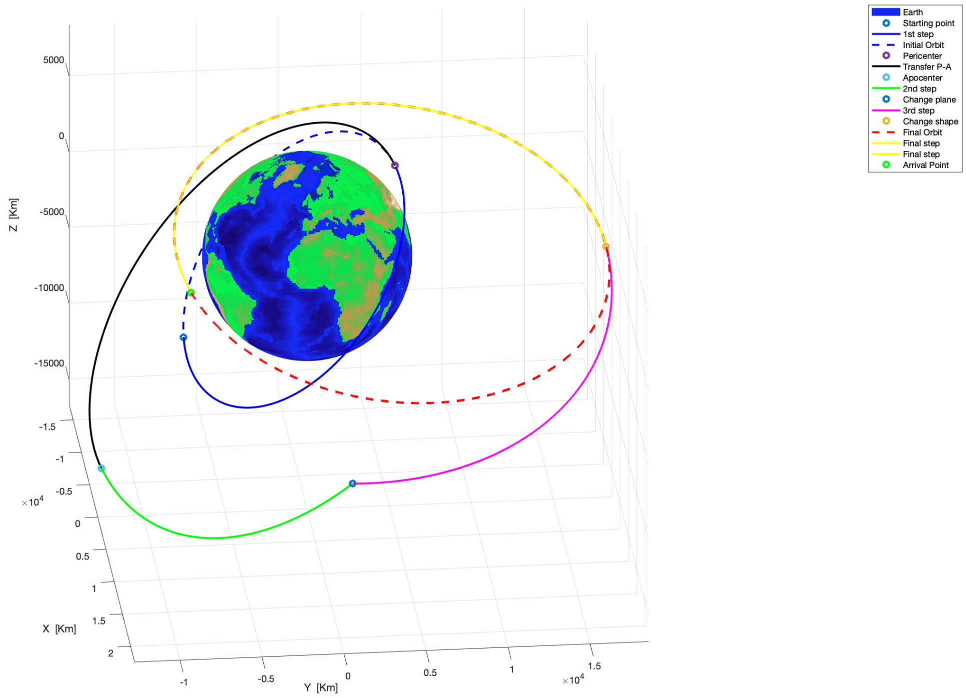


Figure 11

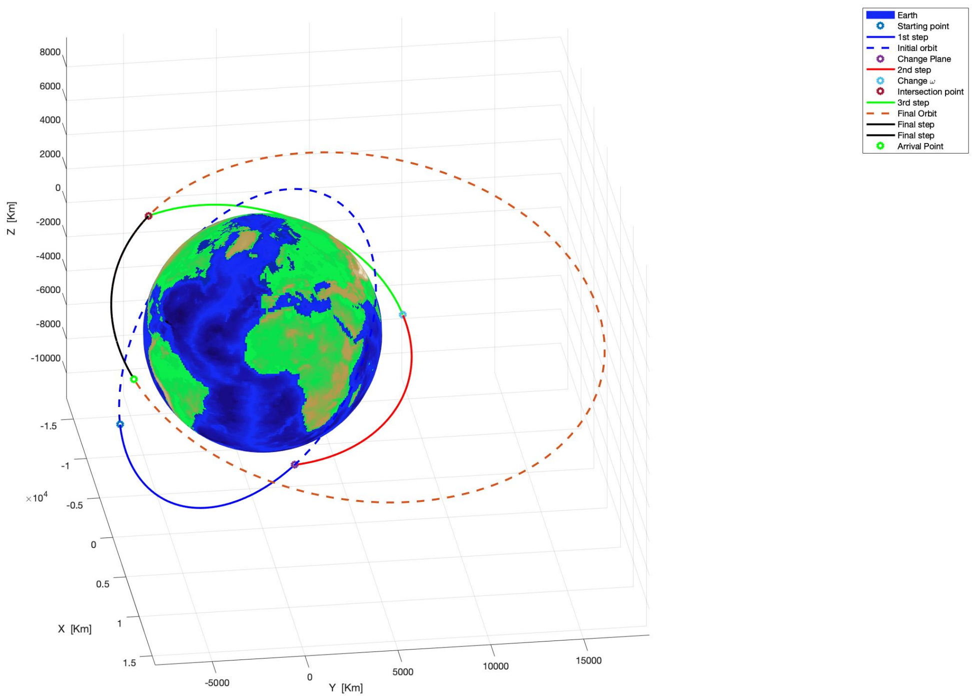


Figure 12