Assignment 1: Express Mission to rendezvous with the asteroid 1989UQ

February 22, 2017

Group ID: 32

Alessandro Turano 810804

Giovanni Valinate 841391

Giuseppe Viola 874643

Part I

Aim of the mission

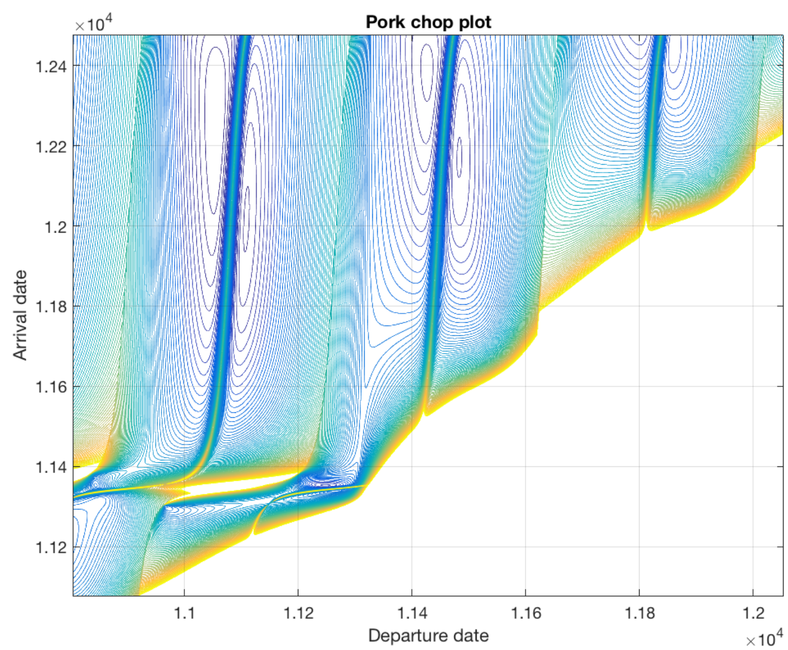
The aim of this mission is to perform a transfer between two celestial bodies of the Solar System.
The select departure planet is The Earth, the arrival asteroid is 1989UQ.
The time window selected for the mission is the following:

	From	To
DEPARTURE from The Earth	2029/08/01	2033/01/01
ARRIVAL on 1989UQ	2030/05/01	2034/03/01

Part II

Porkchop plot of the mission

The Pork Chop diagram shows the $\triangle v$ function of departure and arrival dates. In this graph the minimum $\triangle v_{tot}$ can be chosen and in this way, also the Departure and Arrival dates.



The result is obtained with a double “for” loop that takes in account all the possible dates of departure and all the possible dates of arrival.
For each combination of these dates (with a control that deny the overlap of dates) the Lambert function calculates the orbital parameters, initial and final velocity of the transfer trajectory known the position of the two celestial body in the given dates and the time of flight.

After that, the $\triangle v$ of the mission is calculated. To do that, the spacecraft is considered to depart from the Earth (centrifuge force is not considered, so it is like the spacecraft is departing from the Poles) and to arrive on a circular parking orbit around the asteroid (with a radius 10 times the asteroid's radius).
The Lambert function gives the outcoming velocity of the spacecraft from the SOI of the Earth and the final velocity while reaching the SOI of the asteroid, these two velocities are referred with repect to the sun.

The outcoming velocity is referred with respect to the Earth subtracting the velocity of the Earth itself, and from the equation of energy we can calculate the pericenter velocity of the escaping hyperbola, starting from the surface of the Earth.
The same strategy is adopted to calculate the velocity at the pericenter of the asteroid's hyperbola (at the same distance of the asteroid's circular parking orbit).

The total $\triangle v$ is the sum of the initial $\triangle v$ given by the pericenter velocity of the hyperbola (the velocity to escape from Earth to enter the lambert transfer ellipse) and the final $\triangle v$ that is the differnce between the pericenter velocity of the asteroid's hyperbola and the velocity of the circular parking orbit.

Part III

Minimum $\triangle v$ for the mission

The total $\triangle v$ can be calculated in this way:

$\triangle v_{tot} = \triangle v_1 + \triangle v_2 = 19.0277\, {}^{km}/_{s}$

Where:

$\triangle v_1$ is the $\triangle v$ to be given to depart from the Earth.
$\triangle v_2$ is the $\triangle v$ to be given to rendezvous with the asteroid 1989UQ.

This $\triangle v$ is obtained departing from Earth on the $9^{th}\, April\, 2030$ and arriving at the rendezvous with the asteroid on the $5^{th}\, August\, 2033$.

Part IV

Minimum $\triangle v_{c3}$ for the mission, given the C3 limit on the launcher

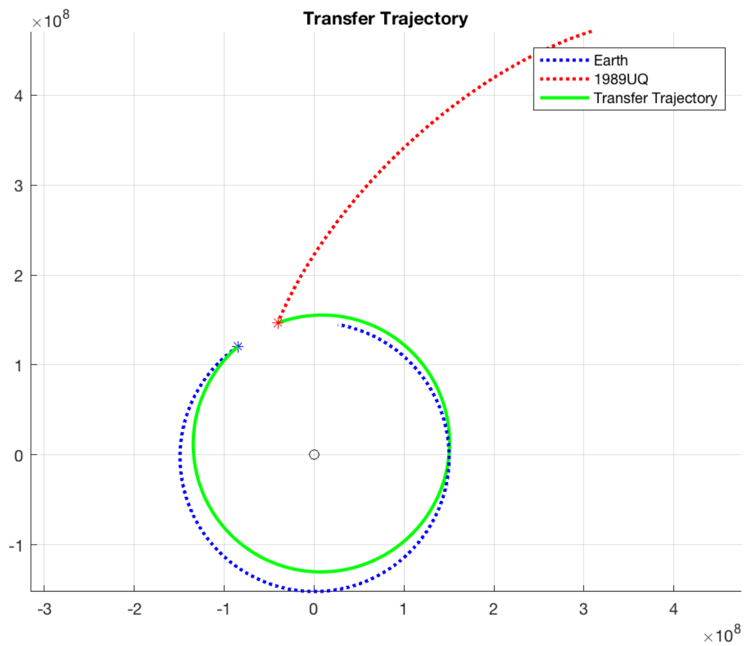
The ΔV found putting a limit on the maximum escape velocity of the launcher is of course higher than the previous one and it is:
$\triangle v_{c3} = 39.9026\, {}^{km}/_{s}$

This time the $\triangle v_{c3}$ is obtained departing from Earth on the $25^{th}\, January\, 2030$ and arriving at the rendezvous with the asteroid on the $12^{th}\, December\, 2030$.

Part V

Plot of the minimum $\triangle v_{c3}$ trajectory

The optimal solution is shown in the following figure.
It shows the heliocentric trajectory of our transfer and the orbits of the two celestial bodies.

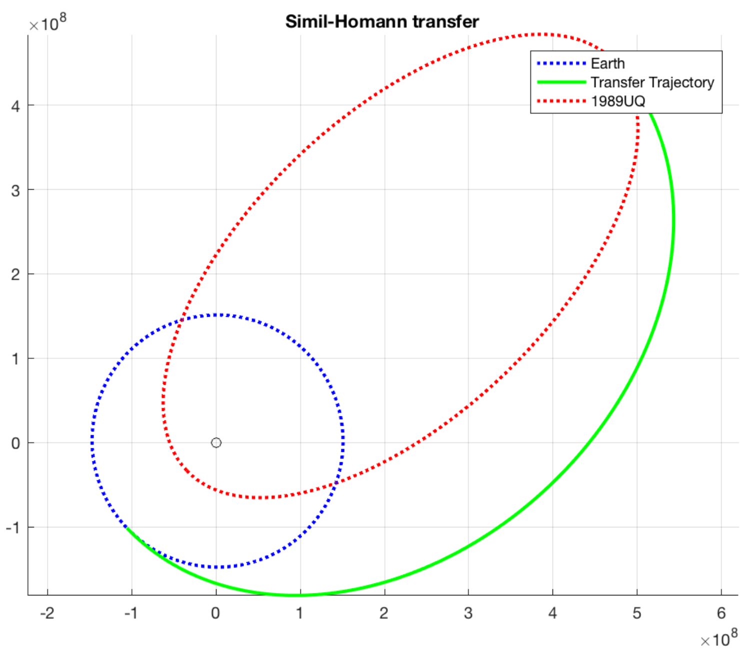


Part VI
Simil-Homann transfer

The assumption coplanar orbits has been made assuming:

- $i_1 = i_2$
- $\Omega_1 = \Omega_2$
- $\omega_1 = \omega_2$

This is the figure showing the Homann transfer with the orbits of the two celestial bodies.



The minimum $\triangle v$ for the mission required in this case is:

$\triangle v_h = 17.1554 \, {}^{km}/_{s}$

The $\triangle v$ of the Homann transfer is a little bit smaller than the one found with the Lambert problem, that's because of the assumption made to simplify the problem (same plane and no rendez-vous).
In fact this Homan transfer is done only to have a qualitative result to compare to the Lambert one.

Assignment 2: Flyby Explorer Mission

February 21, 2017

Group ID: 32

Alessandro Turano 810804

Giovanni Valinate 841391

Giuseppe Viola 874643

Part I

Aim of the mission

The aim of Flyby explorer mission is to perform a transfer between two planets and flyby of a third planet of the Solar System.
The select departure planet is Jupiter, the arrival planet is Mercury, after a flyby of the Earth.
The time window selected for the mission is the following:

	From	To
DEPARTURE from Jupiter	2020/01/01	2021/12/31
GRAVITY ASSIST on Earth	2020/01/01	2024/12/31
ARRIVAL on Mercury	2023/01/01	2024/12/31

These dates have been chosen to satisfy the requirements of the mission (departure date within 2021 and arrival date within 2024 because this mission is an extension of a previous mission).
The time window for Gravity Assist manoeuver has been chosen between the first date of departure and the last date of arrival to simplify the description.
In future, to make the calculation easier, hypothesis of the minimum time to reach the Earth from Jupiter and the minimum time to reach Mercury from the Earth can be done and can be subtracted from the starting date and from the final date of Gravity Assist time window.

Part II
Assumptions

Using a linked conics approach, the trajectory, the time and the$\triangle v$ needed have been computed.
The assumption made for the calculation are:

From a Sun observer:

- Planet's SOI is infinitesimal
- Instantaneous change in trajectory
- Unique attractor is considered

Because of the last hypothesis multiple Lambert's arc have been used to perform the transfer.

From a Planetary observer:

- Planet's SOI is infinite

In this way the problem has been reduced in three part:

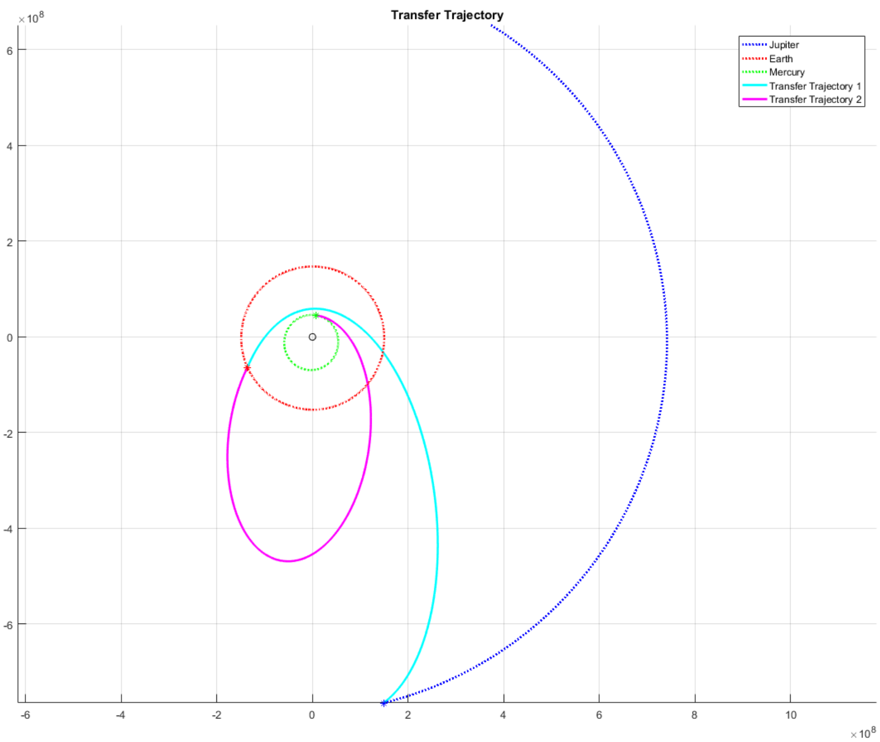
- First Lambert's arc: from Jupiter to Earth
- Gravity assist on Earth (Powered)
- Second Lambert's arc: from Earth to Mercury

Part III
Results

The result of the optimization of the trajectory in terms of minimum $\triangle v$ are the following:

Start	Gravity Assist	Arrival
2020/03/01	2022/04/15	2024/06/14

The optimal solution is shown in the following two figures, the first one shows the heliocentric trajectory, and the second one shows the incoming and outgoing hyperbola legs during flyby.

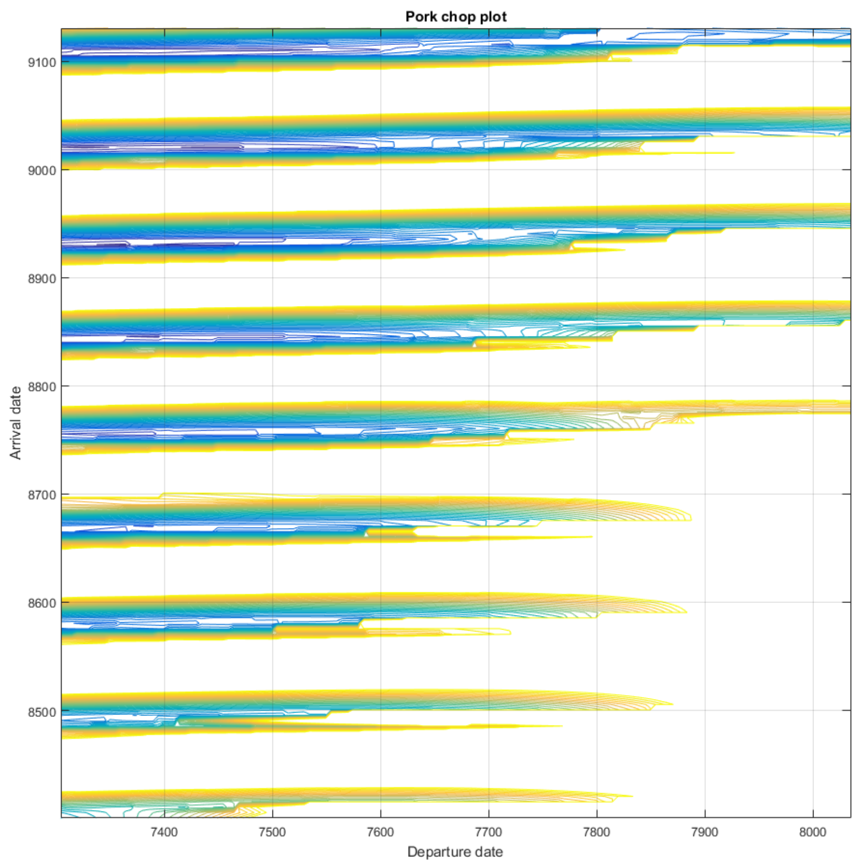


The $\triangle v$ required for each part and the total $\triangle v$ are listed in the tables below:

Initial kick	Gravity Assist (Powered)	Mercury rendezvous
$\triangle v_1 = 7.3131\, {}^{km}/_{s}$	$\triangle v_2 = 0.1368\, {}^{km}/_{s}$	$\triangle v_3 = 13.3224\, {}^{km}/_{s}$

$\triangle v_{tot}$
$20.78\, {}^{km}/_{s}$

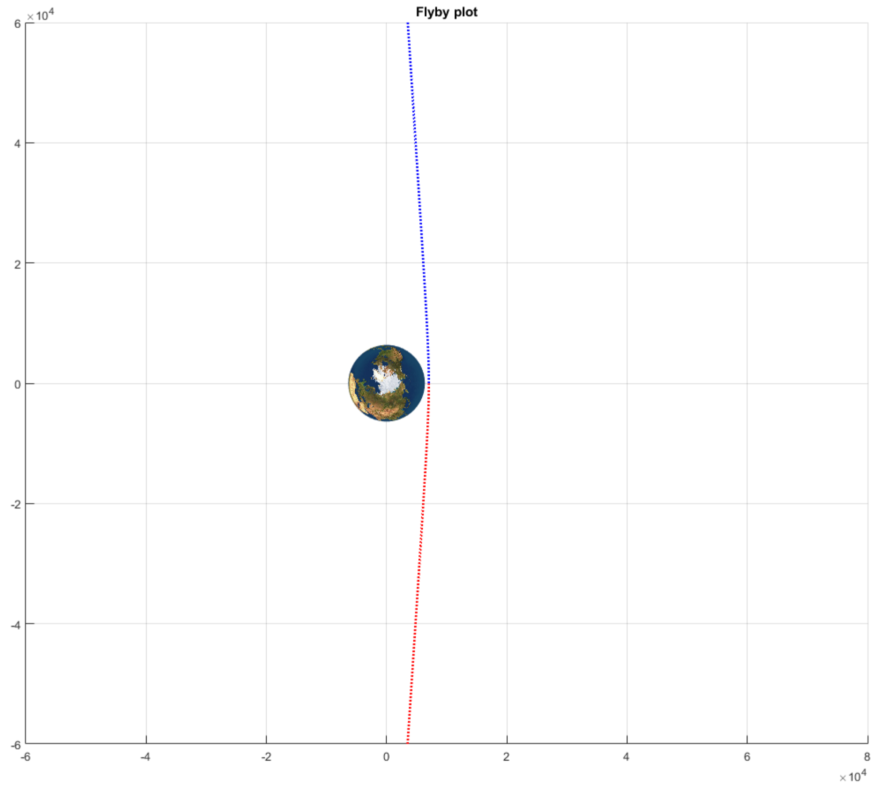
These results are the optimum ones reachable from the time windows selected. The Pork Chop diagram shows the $\triangle v$ function of departure and arrival date, considering also the powered GA manoeuver. In this graph the minimum $\triangle v_{tot}$ can be chosen and in this way also the Departure and Arrival date.
To simplify the graph all the $\triangle v$ bigger than 40 Km/s have been cancelled out.



To obtain this graph and the minimum $\triangle v$ the most general case has been considered.
The simulation considers all the possible Departure, GA, and Arrival date, and the code for all the combinations of these days gives in output a $\triangle v$.
The starting and arrival condition for the mission are circular orbit around plaets of ten times the radius of the planet considered.
The Departure date is near the start of the time window. This is because earlier dates means possibility to have an higher time of flight and then more possibility to have a lower $\triangle v$.

Regarding the $\triangle v$ the one at the starting date is high because the spacecraft has to escape from the gravittional attraction of the massive Jupiter.
The $\triangle v$ at the powered GA is the lowest as expected. This is due to two different reasons, the first one is that a part of the $\triangle v$ is provided by the Gravity Assis and the second one that the direction of the velocities of the two leg of the Lambert's arc are not so different.
The $\triangle v$ to rendezvous around Mercury is the highest because of the spacecraft must brake itself.
Another way to improve these results is to consider not a circular orbit around the planets, as parking orbits, but ellipses. In this way we can also find the minimum $\triangle v$ to randezvous the planet.

Part IV
Flyby



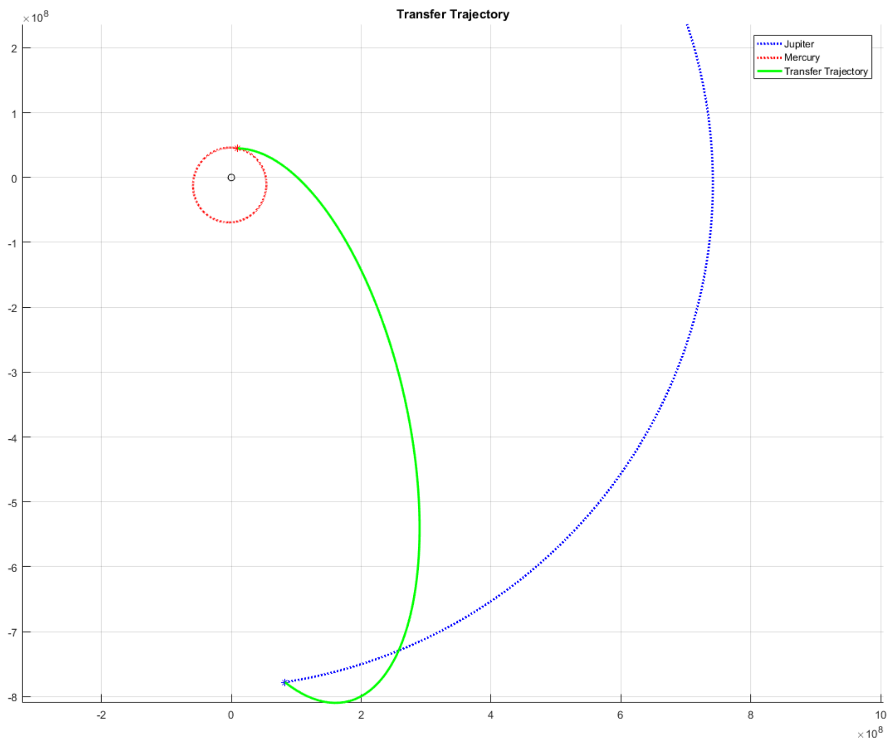
The total time required for the flyby and the minimum distance from Earth during flyby are:

$\triangle t_{tot}^{GA}$	h_{min}
19 min 28s	649.2 Km

Part V

Direct trajectory

The Previous results can be compared with a direct Lambert's from Jupiter to Mercury. Using the same time windows, the results are the following:



Jupiter Departure date	Mercury Arrival date	$\triangle v_{tot}$
2020/01/01	2023/03/12	$92.88\ {}^{km}/_{s}$

The $\triangle v$ of a single Lambert's arc is higher because of the lack of Gravity Assist Manoeuver, instead the time of flight is lower.
The optimum $\triangle v$ between the two solution is the one with the Gravity Assist. Maybe a way to reduce even more the $\triangle v$ is to exploit different GA.