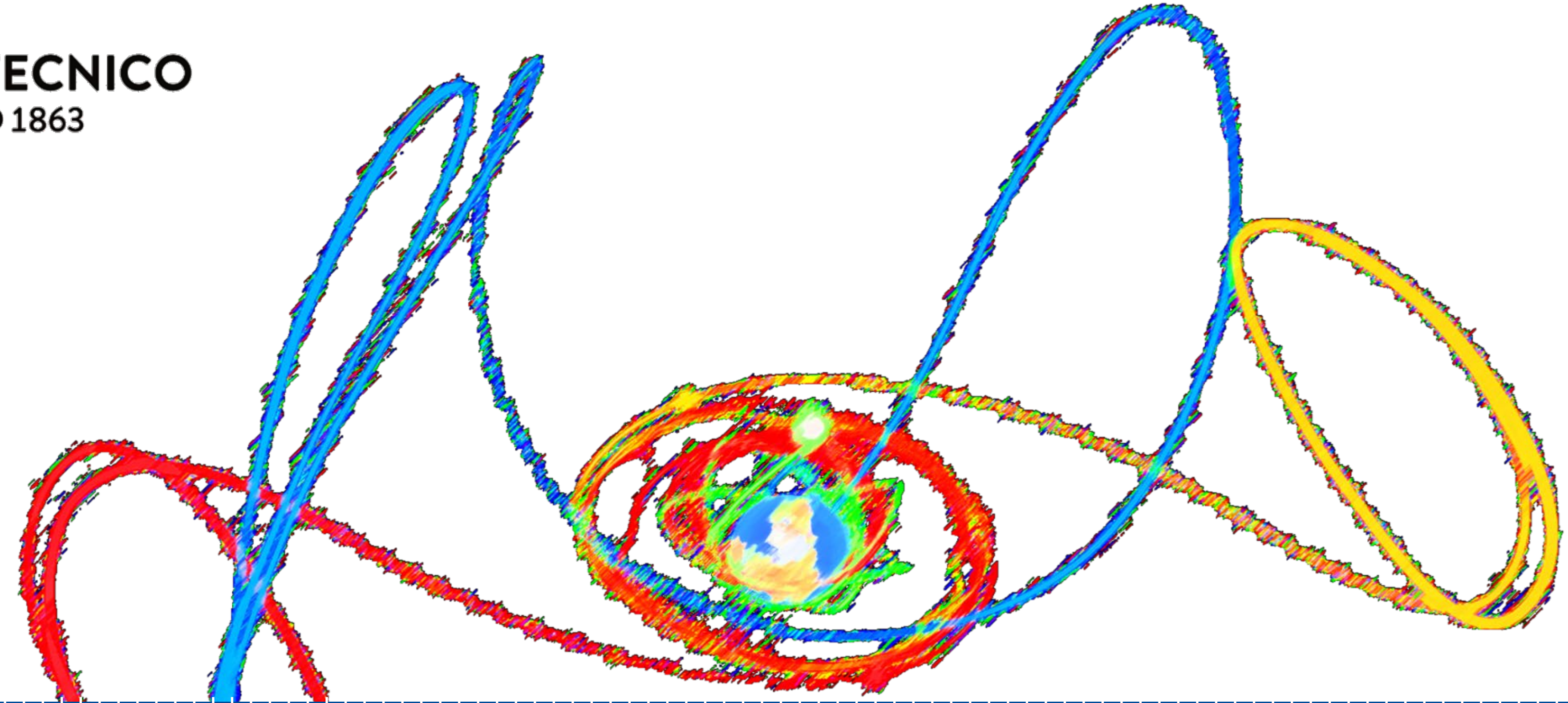

# Orbital Mechanics
# Lab Assignments

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Assignment 1

# INTERPLANETARY EXPLORER MISSION

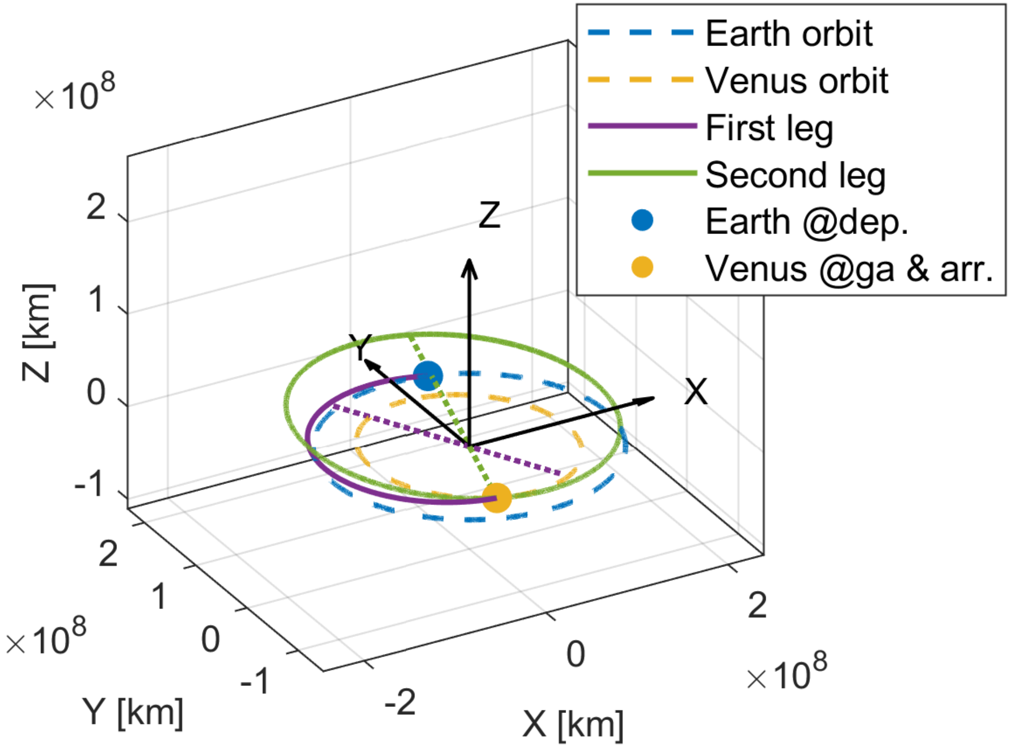
# Interplanetary Explorer Mission

## First Assignment

The **PoliMi Space Agency** is carrying out a feasibility study for a potential **Interplanetary Explorer Mission** visiting an asteroid in the Solar System, with an intermediate flyby on a planet.

As part of the **mission analysis team**, you are requested to perform the **preliminary mission analysis**. You have to study the transfer options from the departure planet to the arrival asteroid, with a powered gravity assist (flyby) at the intermediate planet, and **propose a solution based on the mission cost** (measured through the total $\Delta v$).

The departure planet, flyby planet and arrival asteroid have been decided by the science team. Constraints on earliest departure and latest arrival have also been set by the launch provider, the systems engineering team, and the Agency's leadership.



# Interplanetary Explorer Mission

## Mission requirements

- Each group has the following **mission requirements** (available in WeBeep):
  - Departure planet,
  - Flyby planet,
  - Arrival asteroid, identified by its ID in `ephAsteroids` (IDs available in WeBeep)
  - Earliest departure and latest arrival dates.
- Use the **method of patched conics and do not consider planetary departure and insertion**:
  - Initial heliocentric orbit is equal to that of the departure planet,
  - Final heliocentric orbit is equal to that of the arrival body.
- Use `uplanet` (in WeBeep) to compute the ephemerides of planets, `ephAsteroids` (in WeBeep) for the ephemerides of asteroids.
- The figure of merit for the mission is the total cost in terms of $\Delta v_{\text{tot}}$.
  - Other criteria should be considered, such as **altitude restrictions during the flyby**.

# Interplanetary Explorer Mission

## Mission analysis outputs (1/2)

The mission analysis should cover the following points:

1. **Design process**, detailing:
   - Initial choice for the time windows, justifying it based on the characteristics of the mission.
     - Do not just take the whole time interval provided in the mission requirements for both departure and arrival windows. Choose and justify them based on the characteristics of your mission.
   - Additional constraints considered (such as minimum altitude of the closest approach during the flyby). Note that also other constraints can be considered.
   - Strategy followed to **explore, analyse and compare** the different transfer options.
   - **Justified selection of a final solution.**
   - **Plots and data supporting your design choices** (e.g., $\Delta V$ cost plots, preliminary estimates,… ).

# Interplanetary Explorer Mission

## Mission analysis outputs (2/2)

The mission analysis should cover the following points:

2. **Final solution**, including:
   - **Heliocentric trajectory.**
     - Departure, flyby, and arrival times.
     - Characterisation of the interplanetary transfer arcs.
     - Plot of the heliocentric trajectory, together with the orbits of the three celestial objects and their positions at departure, flyby, and arrival.
   - **Flyby (powered gravity assist).**
     - Altitude of the closest approach.
     - Time duration of the flyby (considering a finite SOI).
     - Comparison of the total velocity change due to the flyby $\Delta v_{\mathrm{fb}}$ with the cost of the powered manoeuvre at pericentre $\Delta v_{\mathrm{ga}}$.
     - Plot of the incoming and outcoming hyperbola arcs.
   - **Cost of the mission in terms of $\Delta v_{\mathrm{tot}}$**
     - Detail the separate values of $\Delta v_{\mathrm{dep}}$, $\Delta v_{\mathrm{ga}}$, and $\Delta v_{\mathrm{arr}}$.

# GENERAL INSTRUCTIONS

# Project

## Auxiliar functions available in WeBeep

- For the assignments, you may use the auxiliary MATLAB functions **available in WeBeep**:
  - `astroConstants`: Use it to retrieve common astrodynamics constants (both assignments).
  - `lambertMR`: Use it for solving each Lambert arc (Assignment 1).
  - `uplanet`: Planets' ephemeris (do not propagate the planets' orbits yourself)
    - In Assignment 1, use it to compute the ephemerides of departure and flyby planets.
    - In Assignment 2, use it to compute the Sun-Planet position vector for SRP evaluation.
  - `ephMoon`: Analytical ephemeris of the Moon.
    - In Assignment 2, use it to compute the Moon position for third-body perturbation evaluation.
  - `ephAsteroids`: Ephemerides of several asteroids.
    - In Assignment 1, use it to compute the ephemerides of the arrival asteroid.
  - **timeConversion.zip**: Compressed folder with several time conversion routines

# Teamwork

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As in a **Mission Analysis team** at **ESA**, you will also work in a group:

- Members of the group must **cooperate**: you are advised to share the work among the team, but **everyone is responsible for all the work done in the project**. This means the work of the team must be checked by the whole team.
- Make decisions towards design solutions based on numerical/analytical/physical evidence and analyses: you must always be able to **motivate your design choices**. *You are supposed to perform the preliminary mission analysis of a real mission*.
- During the final review (oral exam), **any team member can be questioned about any part of the work**.

# Project deliverables and deadlines

## Overview

- Project evaluation includes:
  - **Deliverables** (1 submission per group)
    - **Project report**: A single PDF report on the assignments, of maximum **15 pages (total, no exceptions)**
    - **Simulation codes and results**
    - **Numerical results**, to be submitted via a form
  - **Peer evaluation**
  - **Oral exam** (both on theory and project)
  - **See Slide Lectures Chapter 0 for rules!!**

# Project deliverables and deadlines

## Submission procedure and deadlines

- The deliverables must be submitted through **WeBeep**
  - Submit a **single ZIP file** with **report and code**, named "`OrbitalMech_group_nnnn.zip`", where `nnnn` is the group ID (e.g., `OrbitalMech_group_2542.zip`).
  - WeBeep **submission file limit is 250MB**. Larger submissions sizes are not allowed (nor needed).
  - **Numerical results for specific questions** and **peer review** submitted via activities in WeBeep.
  - Submissions via any other means will not be considered.
  - Changes to the deliverables after the deadline will not be considered.
- Deadlines:
  - **Deliverables must be submitted by 7 January 2026**.
    - Delivering the project is a must condition for the oral exam and to pass the course.
    - The delivery activity in WeBeep closes automatically on 7 January 2026 at 23:59.

# Project deliverables and deadlines

## Report

- **Single PDF (both assignments in the same report)**
- Include a **front page** with:
  - Title,
  - Group number, academic year,
  - For each member: full name, matriculation number, and person code.
- The report should contain **explanations, data, figures, and tables supporting your design process and final solution.**
  - You may follow the structure described in the previous slides.
  - **Properly indicate the units of all numerical data**.
  - **Include labels, legends and titles/captions in all figures**. Also, ensure that all figures are appropriately sized, allowing readers to interpret them clearly without requiring excessive zooming.
  - **No need to include theory**, but properly introduce/reference all the formulas and models you use.
  - Include a *References* section with a list of all the sources you consulted and cite them in the text where appropriate.
  - Properly credit all images taken from other sources including lecture notes and slide.
  - Improper use of references will be considered in the mark
  - Provide comments and explanations of your results, with a **PARTICULAR FOCUS ON THE UNDERLYING PHYSICS OF THE PROBLEM**.

# Project deliverables and deadlines

## Code

- The codes for both assignments must be included inside a folder named `Code`, with **two separate subfolders for each assignment** as follows:
  - **Assignment 1**: Subfolder `Code\Assignment1\` containing:
    - `InterplanetaryMission_group_N.m`: main script that reproduces your results (`N` is the group ID).
    - `Code\Assignment1\functions\`: subfolder with **all the other functions you developed** for the first assignment.
  - **Assignment 2**: Subfolder `Code\Assignment2\`
- No need to upload the functions we provide to you in WeBeep, unless you modified them.

# Project deliverables and deadlines

## Code headers

- Each code file must include a **header** detailing:
  - Inputs and outputs (specify dimensions and units),
  - Authors,
  - Basic usage information

```
function dy = ode_2bp( t, y, muP )
%ode_2bp ODE system for the two-body problem (Keplerian motion)
%
% PROTOTYPE:
%   dy = ode_2bp( t, y, mu )
%
% INPUT:
%   t[1]         Time (can be omitted, as the system is autonomous)  [T]
%   y[6x1]       Cartesian state of the body ( rx, ry, rz, vx, vy, vz ) [ L, L/T ]
%   muP[1]       Gravitational parameter of the primary [L^3/T^2]
%
% OUTPUT:
%   dy[6x1]      Derivative of the state  [ L/T^2, L/T^3 ]
%
% CONTRIBUTORS:
%   Student 1
%   Student 2
%
% VERSIONS
%   2020-11-19: First version
%
```

# References

- Lecture notes and lab slides.
- Spacecraft orbital elements available at:
  - Space-Track: https://www.space-track.org
  - Celestrack: https://celestrak.com/NORAD/elements/
  - NASA/JPL's HORIZONS: https://ssd.jpl.nasa.gov/horizons/app.html
- Books:
  - D. Vallado, *Fundamentals of Astrodynamics and Applications, 4th Edition*, Springer, 2007, ISBN-13 978-0387718316.
    **Chapters 8 and 9 (very detailed).**
  - R. H. Battin, *An Introduction to the Mathematics and Methods of Astrodynamics, Revised Edition*, AIAA Educational Series, Reston, 1999.
    **Chapter 10 (Gauss and Lagrange equations derivation).**
  - H. Curtis, *Orbital Mechanics for Engineering Students, Second Edition*, Butterworth-Heinemann, 2009, ISBN-13 978-0123747785.
    **Chapter 12 (introduction to orbit perturbations).**