AERO2705 - Space Engineering 1

Assignment 2 - Coordinate Frames, Orbital Injection and Transfer

Due: 11:59pm, Saturday, 23 September 2023 **Value:** 30% of final mark

This assignment should take the average student 40 hours to complete.

Assignment Objective

For this assignment, you will extend the orbital simulator developed in Assignment 1 to include 3D Earth-fixed coordinate frames, and generate an orbit ground plot. You will then work on designing and simulating both Earth-centric and interplanetary orbital transfers.

Question 1 - Earth-fixed frames and perturbations (25%)

Below is a Two-line Element (TLE) set for the ESA's XMM-Newton spacecraft:

```
ESA XMM
1 25989U 99066A   23210.35941833  .00000197  00000-0  00000+0 0  9993
2 25989  68.9499 297.7940 5497558  81.7865   0.2967  0.50135878 32080
```

a) Simulate the orbit of this satellite using the orbital parameters. You will build upon the basic Keplerian orbital model used in Assignment 1 to simulate the orbital motion in an Earth-centred, Earth-fixed (ECEF) frame. Simulate the satellite's orbit for one period, show 3D plots of the orbit in the Earth-centred Inertial (ECI) and ECEF frames, and produce a ground trace of the orbit (your Python code should produce these plots).

b) Discuss the relationship between the mission of XMM-Newton and it's orbit properties (for example, but not limited to, orbital period, Earth/Sun orientation, inclination, and ground trace). Use plots from your code to demonstrate the orbital properties described.

c) Extend your code to include the effects of the J2 perturbation, and present the results of this perturbation on the spacecraft. Ensure you discuss any assumptions made. Simulate your orbit for long enough to clearly visualise the effects of the J2 perturbation.

Question 2 - Orbital Transfer and Injection (30%)

a) Starting from an initial circular equatorial orbit at 500km altitude, design an optimal sequence of orbital manoeuvres to inject a spacecraft into the orbit of the XMM-Newton satellite from Question 1. Simulate the satellite throughout the orbital transfer, concluding with a simulation of the final orbit for one period.

b) Plot the path and velocity of the spacecraft from the start of its transfer, up to (and including) its final burn to insert itself into XMM-Newton's orbit, followed by propagation of that orbit for one period.

c) Write a report outlining your approach and methodology, and the rationale behind how you designed your transfer trajectory. Discuss the assumptions made and any other relevant particulars to executing your transfer.

Question 3 - Interplanetary Orbital Transfer and Injection (35%)

a) Starting from an initial circular equatorial orbit at 600km altitude, design an optimal sequence of orbital manoeuvres to reach the orbit of Comet C/2023 E1 (ATLAS). You do not need to rendezvous with the comet—we are simply interested in reaching it's orbit. Simulate the satellite throughout the orbital transfer, concluding with simulation of the final orbit for one period.

b) Plot the path and velocity of the spacecraft from the start of its transfer, up to (and including) its final burn to insert itself into the Comet ALTAS's orbit, followed by propagation of that orbit for one period.

c) Write a report outlining your approach and methodology, and the rationale behind how you designed your transfer trajectory. Discuss the assumptions made and any other relevant particulars to executing your transfer.

The orbital parameters for the Comet ATLAS can be found here (near the bottom of the page): `https://theskylive.com/c2023e1-info`.

Report and Code quality (10%)

The remainder of the marks will be awarded for clear code construction and commenting, and for good presentation and formatting of the report with correct referencing.

The report should be of professional quality - as if you are presenting it to your client, employer or investors. It is expected that your report is well-written, clearly formatted, design decisions are well justified, and the results are concisely but thoroughly analysed, and that your code is well-structured, legible, and properly commented. Figures must be legible and clear.

For an example on professional report writing:
`https://github.com/nackjaylor/formatting_tips-tricks`.

Marking Scheme

Item	Key elements	Mark	Total
Q1 Code	ECI to ECEF ECEF to geodetic LLA J2 Perturbation	5 5 5	15
Q1 report	Introduction and Methodology – transforms and J2 Results and discussion – orbit properties and J2 impact	5 5	10
Q2 code	Correct implementation of orbital transfers	15	15
Q2 report	Introduction – outline the maneuvers chosen and reasoning Methodology – calculation and implementation Results and discussion – results and justification of transfer design	5 5 5	15
Q3 code	Simulate multiple satellites cleanly in code Design and execution of maneuvers Relative position (and velocity) calculations and plots	5 5 5	15
Q3 report	Introduction – outline the maneuvers chosen and reasoning Methodology – calculation and implementation Results and discussion – results and justification of transfer design	5 7.5 7.5	20
Code Quality	Clear construction and commenting	5	5
Report Quality	Good presentation with correct referencing	5	5
Total			**/100**

Details of Submission

1. Code and documentation:
   - You will submit working Python code.
   - Your code must include the following files:
     - A main file named "mainA2.py" or "mainA2.ipynb", which will be run for marking. It should run all your code, and produce all your plots for this assignment.
     - These files (and only these files) will be run for marking.
     - Any other "instructions" to run other scripts, etc. will be ignored.
   - Your code must be self-contained (for example, it must not rely on external libraries for major functionalities - similarly to Assignment 1) and can include as many functions and sub-scripts as needed, ensuring that running "mainA2.{py,ipynb}" produces all the outputs for your assignment.
   - Marks for code will be allocated as per the marking criteria, with full marks for a correctly functioning code/function, and zero marks if the code does not work, unless you can provide an explanation in the report as to why it didn't work (only genuine implementation issues will be accepted).
   - Make sure you have included all the python files in your submission. There will not be any follow-up if code is missing, and it will be assumed that you didn't attempt that question.
2. Report:
   - Submit your report as a PDF. Any reports that are not submitted as a standalone, machine-readable PDF will not be marked.
   - The report will contain the following sections: "Introduction", "Methodology", "Results and Discussion", and "Appendix".
   - You may alternatively choose to split the report into sections for each question, each

containing separate "Introduction", "Methodology" and "Results and Discussion" subsections. The "Appendix" section is to be included at the end of the document.
    - You are required to include a copy of your code at the end of the Appendix. Your code will need to be in a machine-readable format - that is, it should be included as text and not as an image or screenshot.
    - The report has a 10-page limit (not including front-matter or the appendix).
3. Canvas Submission:
    - The assignment report (as a pdf) is to be submitted via the Canvas page: "Assignment 2: Orbit Transfer Report".
    - Your python code is to be zipped into a single file and submitted via the Canvas page: "Assignment 2: Python Code Submission".
        - Name the .zip file "**SID**_Assignment2.zip" where **SID** is your student number.
        - All Python code must be commented so that the code can be read and understood without the aid of the report.
4. Administrative Matters:
    - **Late Penalty:**
        - 5% (5 marks out of a possible 100) for each day late, starting from 11:59pm on the day the assignment is due and including weekends.
        - Assignments submitted more than 10 days late will receive zero.
    - **Special Consideration:** The Special Consideration process via Sydney Student.
    - **Academic Dishonesty:**
        - Any incidence of academic dishonesty or plagiarism will result in the issue being followed up with the Academic Honesty Coordinator and then onto the University Registrar, and will result in zero marks for this assessment, and may result in automatic failure of this unit of study.
        - For more information on academic honesty, see: `https://sydney.edu.au/students/academic-dishonesty-and-plagiarism.html`