Due: 11:59pm, Saturday 30 August 2025 **Value:** 25% of final mark

This assignment should take the average student 24 hours to complete.

This assignment tests your understanding of orbit determination concepts from Weeks 1-3. Each question builds on material covered in the tutorials and requires you to apply your knowledge to realistic space engineering scenarios.

Requirements:

- Show all calculations clearly
- Include units in all numerical answers
- Explain your reasoning for design decisions
- Use Python to verify calculations. Ensure each main function generates all expected outputs necessary to answer the question, and please use the provided visualisation functions where relevant.
- Please adhere to all submission requirements listed at the end of this assignment sheet.

Question 1 (30%)

You have been tasked with designing a satellite communications network which will provide a persistent communications channel to support NSW firefighters in remote bushland areas. In the initial roll-out, coverage is desired for part of the Blue Mountains National Park. The Rural Fire Service have provided the following specifications for the system:

- At least one satellite must always be in view of (33.610000 S, 150.464444 E).
- Timely alerts are crucial; one-way latency must not exceed 25 ms.

Some assumptions you may make:

- Bandwidth is not an issue.
- You may ignore processing time and other sources of delay when assessing latency – just consider the transmission time.
- There is no need to specify the satellite system details, just define the orbits.
- While budget is not an explicit concern, generally, the fewer satellites needed the better.

If you make any additional assumptions in answering the question below, you are expected to justify them.

1. Specify the orbital parameters for the satellites in the constellation (inclination, eccentricity, orbital altitude, etc) and justify your design choices for the orbits chosen (no need to consider the satellite system itself).
2. Select one of the satellites from your constellation. Using the orbital parameters for the satellite:
    a. Compute the orbital period of the satellite. Then, propagate the orbit for 24 hours.
    b. Generate 3D plots of the satellite's orbit in an Earth-Centred Inertial (ECI) frame.
    c. Perform the ECI → ECEF and ECEF → LLA coordinate transformations and use this to generate a ground trace for the chosen satellite.

Question 2 (70%)

You have been tasked with establishing a new ground station and outfitting it with an orbit determination system. Choose a ground station location (latitude, longitude, and altitude) somewhere in view of the satellite suitable for tracking the satellite. This ground station must also be outside the boundary of the Blue Mountains National Park.

1. **Ground station selection**
   a. Produce range, azimuth, and elevation plots of the satellite's trajectory over the sky above the ground station (your code should produce these plots, and they should be provided in your appendix).
   b. Note what the maximum elevation of the satellite and the percentage of time the satellite is in view over the 24-hour period.
2. **Tracking system evaluation.** Use the variables from 1.b. to generate three tracking options:
   a. A satellite laser ranging (SLR) system, capable of delivering 3 range observations
   b. A radiometric tracker capable of delivering 2 range observations and the time between them
   c. An optical tracker capable of delivering 3 bearing observations

   Write code for the following and present results:

   a. Orbit Determination with SLR: Use Gibbs Method with your SLR system to estimate the initial orbit parameters of your satellite.
   b. Orbit Determination with Radiometric Tracker: Use Lambert's Method with your radiometric tracker to estimate the initial orbit parameters of your satellite.
   c. Orbit Determination with Optical Tracker: Use Gauss's Method with your optical tracker to estimate the initial orbit parameters of your satellite.
3. **Error analysis.**
   a. For each of the tested orbit determination methods, apply an error of 0.1%, 0.5% and 1% to the range, range and time, and bearing measurements respectively.
   b. Discuss the impact of these errors to the orbit determination process.
4. **Initial System selection.** State which orbit determination system you would choose for the ground station and use the results of your testing to justify your choice.
5. **Noise assessment:** While we explored the impact of synthetic measurement errors, in practice there are many sources of noise that can impact our measurements and thus induce errors. For each of the orbit determination methods evaluated, research and identify the main sources of noise that would impact each. Where does the noise come from, and which have the most significant impact on measurements?
6. **Final System selection:** With consideration of the noise sources and their magnitude, would this change which orbit determination system you would outfit the ground station with? Why/why not?

Using AI

- How to use AI

The template below is to be used in your report for your report and code submission

Permitted Uses: I acknowledge that I am permitted to use AI tools for research, brainstorming, concept clarification, debugging assistance, and writing support, but NOT for directly answering assignment questions or generating my final code solutions.

Acknowledgement:
☐ I have not used any AI tools or technologies to prepare this assessment.

OR

☐ I acknowledge the use of [AI tool name and link] to assist with [select appropriate activities from the list below]:
a) Background research and concept exploration
b) Brainstorming design approaches
c) Understanding space engineering principles
d) Debugging code logic (without generating final solutions)
e) Writing assistance (grammar, structure, clarity)
f) Literature review support
g) Other: ____________

How I Used the Output: I used the AI output to [describe specific activities, such as]:
a) Gain foundational understanding before developing my own analysis
b) Generate initial ideas that I then researched and developed independently
c) Check my understanding of concepts before applying them to my solutions
d) Improve the clarity and structure of my written explanations
e) [Other appropriate uses]

Final Work Confirmation: I confirm that:
a) All mathematical calculations and engineering analyses are my own work
b) All code was written by me (though I may have used AI for debugging assistance)
c) All final answers and conclusions are based on my own reasoning and application of engineering principles
d) Any AI-generated content was used only as a starting point and was substantially modified and verified through my own work

Assessment Criteria

Item	Key Elements	Mark	Total
Q1 Code	- Correct calculation of orbital period and accurate orbit propagation for 24 hours. - Generates correct and labelled 3D orbit plot in ECI frame. - Correct transformation through coordinate systems to obtain LLA ground trace. - Clear code structure, appropriate visualisation and commented and readable.	2, zero otherwise 4, (2 partially correct) 4, (2 partially correct) 2	**12**
Q1 Report	- Well-supported reasoning for chosen constellation parameters (altitude, inclination, eccentricity, etc.). - Clearly connects orbital design to coverage or communication application (such as revisit time, global coverage, communication latency etc.). - Explains why the selected satellite was chosen and interprets its ground trace in terms of coverage zones. - Accurately links coordinate frames and orbital mechanics concepts to propagation results. - Report is logically organised, defines all terms and symbols, and is free of major grammar and spelling issues, neat formatting.	4 4 4 4 2	**18**
Q2 Code	- Generates accurate azimuth, elevation, and range plots over 24 hours for the ground station view. - Correct calculation of max elevation angle and percentage of time in view. - Accurate implementation of Gibbs method using three range vectors. Vectors must be realistic and in ECI frame. - Correct use of Lambert's Method with time-separated range measurements. - Correct implementation of Gauss's Method using three direction observations. - Code correctly applies errors to each measurement type - Clear code structure, appropriate visualisation and commented and readable. - Results are plotted or tabulated cleanly; labelled axes and consistent units etc.	3, zero otherwise 2, zero otherwise 5, (2 partially correct) 4, (2 partially correct) 4, (2 partially correct) 3, (1 partially correct) 2 3	**26**
Q2 Report	- Methodology and results for ground station tracking. - Methodology for orbit determination methods. - Results and discussion for orbit determination.	5 5 6 10	**44**

	- Discussion and analysis of tracking methods and combined perturbations. - Methodology for orbit determination comparison. - Results and discussion of which orbit determination method to use - Report is logically organised, defines all terms and symbols, and is free of major grammar and spelling issues, neat formatting.	6 9 3	
Total			**/100**

Report Quality

- Professional presentation with correct IEEE referencing
- Clear, concise writing within the page limit
- Well-justified design decisions with thorough yet concise analysis of results
- Legible and clear figures

Code Quality

- Well-structured, modular construction that enables code reuse
- Comprehensive commenting throughout
- Single executable script that completes in under 5 minutes on a standard laptop
- Use only standard mathematical and visualisation libraries

Reference Guide

- Report formatting guidelines: https://github.com/nackjaylor/formatting_tips-tricks

Submission Requirements

1. Code

- **File Requirements:**
  - Create a main file for each question named: Q[#]_mainA1.py (e.g., Q1_mainA1.py)
  - Include your name and SID in comments at the beginning of each main file
  - You may create additional .py files for functions/sub-scripts, but ensure your main file calls everything needed
  - Only the main file for each question will be executed for marking - any separate "instructions" will be ignored
  - Code must be self-contained (only libraries provided in the provided requirements.txt file allowed)
  - All Python files must be well-commented so code can be understood without your report
- **Marking:** Full marks for documented, clear, extensible, correctly functioning code; zero marks if code doesn't work
- **Missing Files:** No follow-up provided - missing code assumes no attempt for that question
- **Submission:** Zip all Python files as [SID]_Assignment1.zip via Canvas: "Assignment 1: Python Code Submission"

2. Report

- **Format:** PDF only (not scanned images - must be text-selectable)
- **What are we looking for in:**
  - **Methodology –** Describe the method in question within the context of what we are trying to achieve.
  - **Results –** Please do not dump results without explanation as to their causes and effect. Please be concise and utilise the appendix for additional plots/information
  - **Discussion –** Compare with other methods and always relate back to the context of the mission.
- **Structure:** Single report in the following order:
  - Your name and SID
  - AI declaration (using template from beginning of this document)
  - Question 1: Introduction, Methodology, Results and Discussion, and Conclusion
  - Question 2: Introduction, Methodology, Results and Discussion, and Conclusion
  - **What are we looking for in:**
    - **Methodology –** Describe the method in question within the context of what we are trying to achieve.
    - **Results –** Do not dump results without explanation as to their causes and effect. Be concise and utilise the appendix for additional plots/information
    - **Discussion –** Compare with other methods and always relate back to the context of the mission.
- **Appendix:** Can be added at end if needed, but will not be marked
- **Length:** (excluding appendix)
  - Question 1: 4 pages max
  - Question 2: 10 pages max
- **Include:** Your name and SID
- **Submission:** Submit PDF via Canvas: "Assignment 1: Satellite Orbit Report"

3. Administrative Matters

- **Late Penalty:**
  - 5% (5 marks out of 100) per day starting 11:59pm on due date (including weekends)
  - Assignments >10 days late receive zero with no feedback required
- **Special Consideration:**
  - Apply through Sydney Student portal: https://sydneystudent.sydney.edu.au/
- **Academic Dishonesty:** https://www.sydney.edu.au/students/academic-integrity/breaches.html
  - Results in zero marks, referral to Academic Honesty Coordinator and University Registrar
  - May cause automatic unit failure