AEM 3101 Project

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1 Introduction

The purpose of this assignment is for you to use your skills in modeling and numerical analysis, along with your knowledge of Matlab, to answer questions about an interesting aerospace problem.

The assignment due date is posted on the Canvas site. You can work in teams of 3-4 people. Teams need to be formed ASAP! Refer to the Canvas site for the project due date, and when teams need to be formed by. Your submission must include:

- 1-page executive summary. Briefly describe the project goals. Describe your approach (what work did you do?). Summarize your results.
- One published PDF that includes appropriate comments, plots, charts, etc.
- Additional published PDF files (as needed) for extra plots, results. etc. These would be appendices. Optional.
- All of the m-files your team wrote for the project.

Grading criteria:

- 20 pts. Is your 1-page executive summary clear and understandable?
- 20 pts. Is your code well-commented?
- 15 pts. Is your published PDF organized into logical sections?
- 15 pts. Does your published PDF (from Matlab) include plots or charts on the first few pages that show the main tradeoffs / results of your analysis?
- 15 pts. Have you properly labeled the axes (with units) and included legends (when needed) for all of the plots in your published PDF?
- 15 pts. Are your results reasonable and accurate?

Definite “yes” answers to all of the above will earn an A on the project.

2 Project Descriptions

Your team can choose one topic for the project. Three topics are summarized below. Additional details for each topic is available on the project assignment page on Canvas.

2.1 Mars Atmopspheric Entry Analysis

Your goal in this project is to study the kinematic trajectory and the heat profile of an Orion capsule entering the Martian atmosphere.

1. Calculate the circular orbit velocity for a parking orbit about Mars at a prescribed altitude (to be given).
2. Compute a delta-v that will induce atmospheric entry trajectory.
3. Numerically integrate the equations of motion as the capsule descends through the atmosphere.
4. Numerically integrate the heat transfer equations to approximate the temperature of the capsule exterior during reentry.
5. Terminate the simulation at a prescribed altitude (to be given).
6. What is the maximum temperature and at what altitude does it occur?
7. Record the final velocity, flight path angle, and duration.
8. Repeat the above process for several different initial delta-v's (from step 2) and comment on how the final conditions vary with that initial condition.

The equations for reentry and heat transfer will be provided. You will need to find and implement a model of the Martian atmosphere.

2.2 Launch to orbit

Your goal in this project is to study the dynamics and trajectory of a multi-stage launch vehicle. Using methods we have learned in class, you will simulate the launch of a payload into low-Earth orbit.

You may begin by using the flat-Earth model we discussed in class. But you will need to extend the model to include multiple stages. You may also elect to implement a spherical Earth model, but this is not necessary.

Pick 2-3 different example configurations of a rocket. Stage mass, thrust, Isp. For each, do the following:

- Numerically integrate the equations of motion during powered ascent. Use your payload mass, the pitchover angle and the altitude at which you initiate the pitchover as three independent parameters that you can tune as needed.
- Record the velocity and flight path angle at the end of powered ascent.
- Compute the required velocity for a circular orbit.
- Measure the vector difference between your terminal velocity and the required velocity.

You can use the above procedure with the bisection method, varying one of your independent parameters, so that the launch reaches circular orbit.

Repeat the analysis for at least 2 different rocket configurations, evaluate the trajectories, and comment on the differences between them.

2.3 Landing footprint analysis

Your goal in this project is to study the dynamics and trajectory of a multi-stage launch vehicle for a high-powered rocket launch contest. In particular, you will consider the effect of winds at different altitudes, and determine the probability of landing in a prescribed area.

You may begin by using the flat-Earth model we discussed in class. But you will need to extend the model to include multiple stages, as well as horizontal forces due to wind during descent.

- Develop a 2- or 3-stage rocket configuration that follows posted rules for the MN high powered rocketry competition (more detailed information will be provided as necessary).
- Numerically integrate the equations of motion during powered ascent. Use the azimuth angle, the pitchover angle and the altitude at which you initiate the pitchover as three independent parameters that you can tune as needed.
- Numerically integrate the equations of motion during the un-powered phase. This should include some time as the rocket continues to ascend un-powered to its maximum altitude.
- Assume a parachute is deployed at the maximum altitude, which has the effect of increasing the drag coefficient.
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- Use the NOAA website (and code from Prof. Mueller) to get winds aloft data for a part of the U.S.
- Include the effect of wind during the un-powered phase.

Run Monte carlo simulations with random variations in the wind profile. Analyze the results of your Monte Carlo simulations to pick one set of launch parameters (azimuth, pitchover angle, pitchover altitude) that will give you the best chance of landing in a prescribed area. What is the probability of landing in that area?

2.4 Build your own

If you have a different idea for a project, come talk to me and we'll see if we can work out a plan.