MAE 468/568: Elements of Spacecraft Design
Spring Semester 2020 Class Project

Due: Tuesday, April 21th, 2020 by 5:00 pm.

This class project will combine the different pieces you learn in the course into a Pre-Phase A design of a Discovery class mission to Triton, a moon of Neptune or a Mars Ascent Module.

<u>Background</u>

Your team is a small engineering firm that specializes in the development of advanced concepts for spacecraft missions. Your firm has been approached by group of investors eager to start new commercial ventures in spaceflight and require you to answer questions related to the feasibility of two very different spacecraft missions.

The first topic is a NASA Discovery class, named TRIDENT, a mission to Triton, an icy moon of Neptune. Your investors are trying to determine the key details of this type of mission so they could submit a proposal to NASA in order to win government funding.

The second topic is a Mars Ascent Module designed to carry three astronauts from the surface of Mars to a parking orbit in Low Mars Orbit. The investors acknowledge they have been contacted by several large Aerospace prime contractors and need details to provide as part of their proposals in order to win subcontract funding from the large prime contractors.

Because your team is small, you are reluctant to take on the two topics at once and instead propose to your customers that you will provide very detailed information for one of the spacecraft missions. It is up to your team of highly trained experts to decide which spacecraft mission topic is within your interest and capabilities. Your investors are anxious to get started and require you provide a conceptual design study in two months.

The challenge for your team is to develop a conceptual mission that evaluates the technical complexity, cost, and schedule in order to determine feasibility and provide evidence to your investors.

<u>Mission descriptions</u>

TRIDENT

Trident would explore Triton, a unique and highly active icy moon of Neptune, to understand pathways to habitable worlds at tremendous distances from the Sun. NASA's Voyager 2 mission showed that Triton has active resurfacing—generating the second youngest surface in the solar system—with the potential for erupting plumes and an atmosphere. Coupled with an ionosphere that can create organic snow and the potential for an interior ocean, Triton is an exciting exploration target to understand how habitable worlds may develop in our solar system and others. Using a single fly-by, Trident would map Triton, characterize active processes, and determine whether the predicted subsurface ocean exists.

<u>The spacecraft will carry the following instruments all heritage from New Horizons and Cassini:</u>

Ultraviolet Image Spectrograph (ALICE), Imaging Telescope (Ralph), Radio Science Experiment (REX), Long Range Reconnaissance Imager (LORRI), and Dual Technique Magnetometer (MAG).

Because your company specializes in orbital missions and advanced spacecraft concepts, you enlist the help of another small company for development of the structures and mechanisms *Your team is responsible for the design of the outer spacecraft structural shape, propulsion, power, thermal, guidance, navigation, and communication subsystems for both design topics.*

The internal electronics generate an additional 80 W of continuous waste heat. The instruments can be on at various times, so the heat and power load can vary from 0 – max. Consider the instrument heat load to be equal to the power. Its total lifetime will depend on how long the interplanetary trip takes. Consider only gravity-gradient and solar pressure disturbances. For instruments, the spacecraft must maintain a z-axis pointing angle/accuracy of less than 5°.

The cost of the mission is based on the following:

- $0.2 million/kg for spacecraft development and construction
- $20 million/year for mission operations after launch
- Cost of the launch vehicle. The spacecraft must be launched on a commercial launch vehicle or a newly developed vehicle such as SLS. For commercial vehicles, use the user handbooks and data to help you pick a launch vehicle with sufficient lift capacity. The estimated cost for some of the vehicles is given in Table 1 in millions of dollars. Costs for unlisted vehicles can be extrapolated from similar data points.

Table 1. Estimated Launch Vehicle Costs in Millions of Dollars.

Launch Vehicle	Cost ($M)
Delta II **(2325-9.5)**	94.4
Delta II (2425-9.5)	96.2
Delta II (2925-9.5)	104.4
Delta II (2925H-9.5)	115.4
Atlas V (501)	145.8
Delta IV (4040-12)	127.7
Atlas V (401)	137.3
Atlas V (511)	149.9
Atlas V (521)	154.1
Delta IV (4450-14)	156.0
Atlas V (531)	158.2
Atlas V (541)	162.2
Atlas V (551)	166.4
Delta IV (4050H-19)	259.6
Falcon 9	62
Falcon Heavy	90

Mars Ascent Module

As NASA continues toward the goal of landing humans on Mars, a key part of the Mars mission architecture is the Mars Ascent Module. This module is designed to carry a crew of three from the surface to a Low Mars Orbit. This ascent module must be minimized for launch mass while maximizing the performance and capability of the vehicle. Reductions in mass of the ascent module will allow for additional landed mass on the surface. Many key parameters in orbital mechanics will need to be investigated such as launch location, maximum altitude parking orbit, and maximum inclination change as a function of mass. Safety of the crew is the most important part of the design and must be included in all the subsystems designs. Safety margins, subsystem redundancy, and dissimilar redundancy must be included. The mission must be capable of launching from any point on the surface and must carry enough environmental life system support and power for a maximum 24 hours in Mars orbit.

Because your company specializes in orbital missions and advanced spacecraft concepts, you enlist the help of another small company for development of the structures and mechanisms <u>*Your team is responsible for the design of the outer spacecraft structural shape, propulsion, power, thermal, guidance, navigation, and communication subsystems for both design topics.*</u>

<u>Project Deliverables</u>

A professional typed report where you describe the overall mission, the subcomponents, and the results of your calculations. A diagram of the orbits and trajectories is to be included. Show your math where appropriate, maybe in an appendix. Treat this like a report for a review committee. The report will be judged on accuracy, realism, and presentation. Turn in a digital copy to Canvas by email. No handwritten reports. Upload any code you developed to Canvas. Please comment the code.

The goal of the project is to come up with a conceptual design with the given constraints. Unless specifically stated, you make the decisions on the spacecraft and mission elements, with justification. You will need to present enough information and analysis to show the mission is feasible. A few things you will be graded on include the following:

- Orbital mechanics trajectory with transfer orbit, flyby orbits, Δv's, etc. with diagrams
- Launch and arrival dates
- Mass of the spacecraft and propellants
- Sizes and mass of the power and thermal systems
- Cost of the mission including launch vehicle and mission operations

This will get you to 90% of the total grade. For the last 10%, you must demonstrate mastery of the concepts and methods and optimize the mission for lowest cost and explain your trades and choices. Some suggestions include doing gravity assists or multiple gravity assists having multiple launch windows, searching out data for advanced components, more granularity on the spacecraft mass breakdown, etc. You may need to go out and find new resources and learn more details that what is covered in class.

<u>Other Resources</u>

TRIDENT project

To assist with the orbital mechanics portion of the project, a Matlab code of the Gauss method will be provided on Canvas.

Mars Ascent Module

To assist with the complexities of calculating delta V from various launch locations, a simulation program written in Matlab will be provided on Canvas.

<u>Project Report Format Outline</u>

A professional typed report where you describe the overall mission, the subsystems, and the results of your calculations. A diagram of the orbits and trajectories is to be included. Show your math where appropriate, maybe in an appendix. Treat this like a report for a review committee.

<u>Prepare a Cover Page with the following information:</u>

Name of your Team
Mission Topic
Team Members
Date

<u>Include the following:</u>

Table of Contents
List of Figures
List of Tables

<u>Structure your report similar to the list below:</u>

- I. Introduction (Describe what you are trying to accomplish)
- II. Background (Provide some information about the problem and key things the reader should understand before explaining how you developed your concept)
- III. Description of Analysis and Assumptions
  - a. Orbital Mechanics
    - i. Launch and Arrival Dates
    - ii. Delta V budgets
  - b. Propulsion Subsystem
  - c. Communication and Data Handling / GN&C
  - d. Power Subsystem
  - e. Thermal Subsystem
  - f. Structures & Mechanisms
  - g. Launch Vehicles
- IV. Summary of Results
  - a. Total Volumetric Sizing and Mass Breakdown (Spreadsheet of the Subsystems)
  - b. Cost and Schedule Estimation
  - c. Overall Results
- V. Conclusions (What are the advantages and disadvantages of this concept?)
- VI. References

  Be sure to cite where you found information (Use the AIAA standard format)

  Appendix