ME 239: Rocket Propulsion

Semester Team Project

(draft 04/15/14)
**Mission Goals and Description:**

A new large asteroid body has been discovered in our Solar system. This body has the following estimated physical and Heliocentric data:

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_p$</td>
<td>2.00 AU</td>
</tr>
<tr>
<td>$r_a$</td>
<td>5.00 AU</td>
</tr>
<tr>
<td>$d$</td>
<td>3000 km</td>
</tr>
<tr>
<td>$m$</td>
<td>$8.765 \times 10^{21}$ kg</td>
</tr>
</tbody>
</table>

A paper study to design a kinetic energy impact mission with accompanying scientific suite of instrumentation to monitor the resulting impact plume and subsequently excavated crater has been green-lit. It is determined that a mass between 300 and 500 kg will be needed to generate an energy (based on kinetic energy at impact) of 20 gigajoules. A great deal of the energy and momentum will go into moving the material that the asteroid crust is made of -- part of which is driven downward, the rest of which will be ejected from the crater site. This impact body will be made mostly of copper so as to minimize adding chemical impurities into the ejected plume. The body of the scientific stage (including rocket motor mass, structure, and scientific payload) is assumed to be 750 kg.

Orbital geometry illustrated to scale can be seen in Figure 1. At some time, observed elevation angles (as indicated in Figure 1) are 2.1 radians and 3.8 radians for $\nu_E$ and $\nu_A$, respectively.

**Figure 1:** Orbital geometries (to scale) with initial observed elevation angles indicated. Subscript $A$ is designated for the asteroid body and subscript $E$ is for Earth.
Design a mission based on existing lifting technologies to:

1. Place your vehicle into a geosynchronous orbit by utilizing existing launch technologies (such as Delta, Atlas, Ariane (Europe), Space-X, etc.)
   • You will need to find information regarding payload mass and parking orbit altitude capabilities.
   • I have some information but you are welcome to search for your own resources.

2. Perform transfer impulse from Earth parking orbit to achieve velocity at SOI required to reach large asteroid SOI (you must determine SOI) using third stage motor
   • You may research your own propulsion system for this phase.
   • You may use existing solid rocket systems from ATK (https://www.atk.com/products-services/star-motorsstages/)
   • Or you may assume a LO$_2$/LH$_2$ propulsion system for this stage and an $I_{sp}$ of 500 s.
   • Assume all thrust maneuvers are impulsive

3. Inject into parking orbit with altitude of your choice around asteroid within SOI
   • You may research your own propulsion system for this phase.
   • You may use existing solid rocket systems from ATK (https://www.atk.com/products-services/star-motorsstages/)
   • Or you may assume a LO$_2$/LH$_2$ propulsion system for this stage and an $I_{sp}$ of 500 s.
   • Assume all thrust maneuvers are impulsive

4. Separate impact payload and add impulse (via impulse payload propulsion system) to impact the crater delivering desired impact kinetic energy
   • Propulsion system on impact body is a LO$_2$/LH$_2$ system with an $I_{sp}$ of 500 s.

5. Scientific instrumentation must be within view of impact site at impact moment and is intended to remain for further resulting crater studies

You may choose to release the KE device before you enter SOI to save fuel stores but your scientific instrumentation payload must be within the SOI of the asteroid and on the same side of impact during the impact moment

Format of groups and grading:

You will be working in groups of 3. Any appreciable lack of effort on the part of any team member will have their overall project grade reduced. This will be of a competition-type format. The total project will be graded out of 100 pts. The project with the most impressive mission analysis will gain 10 extra bonus points.
Final Report shall contain the following sections (subject to change as the semester advances quickly to an end):

1) Introduction and Mission Objective

2) Description of Mission and Accompanying Illustration
   • Details on asteroid trajectory
   • Details on Earth trajectory

3) Section for Each Phase of the mission and justification for each component and fuel amount selected (ordering subject to how you handle your mission)
   3.1) Phase I: Launch and establishment into parking orbit
        -orbit details
   3.2) Phase II: Maneuver to desired SOI velocity for transfer
   3.3) Phase III: Arrival at Asteroid SOI
   3.4) Phase IV: Impact Body Separation and trajectory analysis
   3.5) Phase V: Scientific payload location analysis w.r.t. impact site

4) Time of flight analysis of mission
   • Obviously you must time your transfer trajectory for a successful asteroid intercept
   • Evaluate the time required to wait (if needed) from the initial elevation angle conditions given to perform your transfer

5) Total mass budget breakdown of mission
   • final mass of your vehicle must meet requirements of current lift technologies
   • choose a launch system that best suits your launch mass requirement and initial parking orbit requirement You may research your own propulsion system for this phase.
   • if you decide to use a heavy lift system where a heavy lift system is not needed you will be penalized

6) Conclusions and Justifications
   • why do you think your mission will succeed and should be chosen

Appropriate References

Appendix:

• Code for mission analysis
• Hand Calculations