2014 Ph.D. Qualifying Field Exam – Space Systems

Instructions:

You are to answer **Part 1** and either **Part 2a** or **Part 2b**. The use of a calculator is permitted for numerical calculations but do not use any preprogrammed functions. We want to explicitly see all key equations.

Context:

You are interested in putting a small satellite cluster into a Low Earth Orbit (~400 km altitude) to serve as a coherent, multiple-aperture system to conduct optical observations. You have a choice of first stages: you can launch your second stage from a Virgin Galactic Space Ship Two at its 100 km apogee or you can use a traditional ground-based launcher.

Part 1:

Q1a. What are the advantages of an air-launch system compared to a ground-launch system? What are the disadvantages?

Q1b. Assume you launch directly east from Cape Canaveral into a 400 km 28.5-degree inclination orbit. How much delta-V do you need in the rocket portion of your Virgin Galactic launch and for the ground launch?

Q1c. Assume that the satellite has a total mass of 400 kg. The satellite booster's structure and rocket motor, which will be dropped after the satellite is in LEO, have a combined mass of 100kg. Assuming that we use cryogenic propellants (LH2 and LOX) and that we use only a single stage (even though this is not currently feasible), how much rocket propellant mass is saved using a Virgin Galactic launch vs. a ground launch. Make any other assumptions you need to solve the problem, but be sure to state your assumptions.

Q1d. Discuss the options for getting a satellite from a 28.5-degree inclination LEO orbit to geostationary orbit? How much delta-V would be required to change all the inclination at LEO? How much delta-V would be required to change all the inclination at GEO? Where in the LEO orbit do you have to burn to change the altitude? Where at GEO altitude do you have to burn? Where in the orbit do you have to burn to change the inclination?

Q1e. Assume that the two furthest separated satellites are 100 meters apart in the local horizontal plane. What's the ground resolution in the nadir direction for this visible-imaging system? What other optical attributes, besides resolution, need to be considered?

Answer one of the following two questions (Part 2a or Part 2b):

Part 2a:

Q2a. Please draw a high level schematic of the Virgin Galactic air-launched and the traditional ground launched launch vehicle including the major structural elements, propellant tanks, engines, avionics, crew (if applicable) and payload, estimate the approximate location of the C.M. at launch and make sure to add labels to your schematic. Then draw a Design Structure Matrix (DSM) - same as an N2-diagram - of the systems and identify the major structural, mass, energy and information interfaces in the system. What can you say about the architecture of the system? Which one is more modular? Which one is more complex and why?

Part 2b:

Q2b. Suppose you decide to consider risk in your trade space and decision-making.

1. What risks would you include in your decision about whether to launch the second stage from the Virgin Galactic or from a ground-based launcher. Include risks beyond just the technical risks.

2. In general, how could you mitigate these risks? How could process, management and organizational structure, and technical activities be used to manage these risks.