ENAE 791 - Spring, 2008
Problem Set 2

Due 3/13/08

1. Repeat Problem 2 from Problem Set 1, with the following changes:
   a. The decision has already been made to use LOX/LH2 for the upper stage. You need only calculate the three different propulsion cases for the first stage.
   b. Your objective is to minimize total nonrecurring costs for the vehicle, using the cost estimating relations for launch vehicles from the lecture notes.

2. For the winning vehicle from Problem 1, calculate the total program life cycle costs via the following steps:
   a. Calculate the year-by-year costs over 10 years of development, with beta function cost spreading assuming beta function cost spreading and using c_f=P=0.5.
   b. Calculate the nonrecurring costs of 50 flights on a mission-by-mission basis, using an 80% learning curve
   c. Assuming missions are flown at the rate of 5/year starting in year 11, plot the annual costs versus time. What is the total program cost? What will you have to charge per kg of payload to break even?
   d. Repeat c) assuming an annual discount rate of 10%. What is the total NPV cost of the program at the beginning?
   e. What will you have to charge per kg of payload to break even at 10% NPV?
   f. Given the year-by-year costs of c), show the real-year costs assuming an annual inflation rate of 4%. What is the total program cost expressed in real-year dollars?

3. You are designing a modular launch vehicle with a 6-3-1-1 staging pattern. Assume an individual module has a total mass of 50,000 kg, and a structural mass of 4000 kg, with an exhaust velocity of 3500 m/sec.
   a. Calculate the payload for this nominal configuration.
   b. If each module is 99% reliable, what is the overall reliability of the vehicle?
   c. For redundancy, a module is added to the first stage. You may now have one module failure on the first stage and still reach orbit. Calculate the new payload if all modules work correctly, and the new vehicle reliability.
   d. Following the results of c), you add one additional module to the second and third stages (new staging pattern 7-4-2-1). Assume that module failures occur at the beginning of a stage burn and the bad module is immediately jettisoned; the payload calculation is as if the the module doesn't exist after the failure. For example, a second stage module failure looks like a 7-4-2-1 module distribution to the first stage, but 3-2-1 for the second stage, 2-1 for the third stage, and 1 for the fourth stage. Analyze the payloads for the following cases:
      i. Failure of a first stage module
      ii. Failure of a second stage module
      iii. Failure of a third stage module

iv. Failure of modules in the first and second stages
v. Failure of one module in each of the second and third stages
vi. Failure of one module in each of the first and third stages
vii. Failure of one module in each of the first, second, and third stages

e. If feasible cases are those results in d) which provide equal or greater payloads to orbit than a), calculate the vehicle reliability for this case.

4. The space shuttle has flown 121 missions. There was a failure on mission 25, and on mission 113. On a mission-by-mission basis, plot the vehicle reliability assuming an 80% confidence level. [Note: This becomes more complicated after the first failure, but you don't need to calculate the reliability of every mission to plot the trends. You can just pick enough points to get a smooth curve.]

5. Given the equations for straight-line ballistic entry from the lectures, find the limiting entry angle which produces a peak deceleration of 7 g's, given an Earth entry velocity of 7600 m/sec and an entry altitude of 122 km.At what altitude does peak deceleration occur?