

ENAE 791 - Spring, 2008
Mid-Term Exam

Posted 4/10/08
Due 4/15/08 3:30 pm (class time)

Just to be sure everyone is on the same page, this is an **examination**. That means you can use notes, books, computers, whatever, but you cannot discuss it with each other or with anyone else. This must be your own, individual work. If you have any questions or need clarification, contact me via e-mail (dakin@umd.edu) and if it might be of general interest, I will also post the answer on the course web site (<http://spacecraft.ssl.umd.edu> and follow the academics link), so check the web site periodically during the exam period. Good luck!

1. To support extensive lunar exploration, a staging base has been constructed at the Earth-Moon L1 libration point. For the purposes of this question, assume that this is just a circular Earth orbit with a radius of 300,000 km. Your task is to calculate the details of a deorbit maneuver and atmospheric entry from this station. Your ideal entry condition is a flight path angle of -4° at a defined entry interface altitude of 122 km.
 - a. Calculate the ΔV to depart the circular orbit and enter Earth's atmosphere. What is the equivalent perigee altitude for the deorbit ellipse? (i.e., the perigee you would have if you did not encounter Earth's atmosphere or its surface.)
 - b. What is your velocity at entry interface?
 - c. What is the time interval from deorbit to entry interface?
 - d. Your deorbit burn is 1 m/sec lower than the calculated value in (a). What will your flight path angle and velocity be at entry interface on this trajectory?
 - e. What is the physical separation (Δ angle around the Earth) between the nominal entry interface and the actual one specified in (d)?
 - f. On the incorrect trajectory specified in (d), you get measurement data to realize that you are on the wrong trajectory three hours prior to entry interface. What is your orbital position and velocity at this point?

2. You are comparing two different launch vehicles: a single stage vehicle and a two-stage vehicle. The ΔV for the two-stage vehicle is split evenly between the two stages. Each stage of the two-stage vehicle and the single-stage vehicle all have the same inert mass fraction δ . At low values of δ , the single-stage vehicle has a better payload fraction λ than the two-stage. At high values of δ , the two-stage vehicle has a higher total payload fraction λ_o . Find the "cross-over" value of δ at which both vehicles have the same payload fraction. [Note: there are actually two values of δ where this is true. One of them is the trivial case of $\delta=0$. I want the other one.] [Hint: Find the expression for λ in terms of the mass ratio r , rather than ΔV , to keep the algebra simple.]

3. The uppermost stage of the Minotaur launch vehicle has an inert mass of 126 kg, a propellant mass of 771 kg, and a specific impulse of 290 sec. It carries a payload of 607 kg.
 - a. What is the inert mass fraction δ for this stage?
 - b. What ΔV does this stage provide?
 - c. You would like to increase the payload of the launch vehicle by replacing this stage with a higher-Isp stage. You must keep the total mass of the launch vehicle constant (i.e., the combination of the new upper stage and new payload will have the same mass as the old upper stage-payload combo.) If the new stage has an Isp=330 sec and $\delta = 0.10$, what is the new payload mass?
 - d. You would like to replace the original upper stage with a new one using LOX/LH2 (Isp=445 sec). You're not sure what inert mass fraction you can achieve in the new design. What is the limiting mass fraction δ - that is, at what inert mass fraction would the new LOX/LH2 stage have the same payload capacity as the original stage?

4. You are designing a single-stage-to-orbit launch vehicle. You have a choice of designing it with four engines (all critical to success) or five engines (capable of reaching orbit following one engine failure. Assume the reliability of a single engine is R.
 - a. What is the probability of successful launch for the system with four engines?
 - b. What is the probability of successful launch for the system with five engines?
 - c. Given that f is the fraction of engine failures that result in the intercorrelated failure of all the engines, at what intercorrelation failure fraction is the overall reliability of the two systems equal?

5. Your assignment is to perform the preliminary design of a launch vehicle to carry 30,000 kg of payload to low earth orbit. You should assume both stages are LOX/LH2, and use the appropriate values for V_e and δ from the notes. You should also use the "launch vehicle" nonrecurring and first unit production cost estimating equations from the notes.
 - a. Find the optimum distribution of ΔV between stages to maximize the value of $\frac{\lambda_o}{\delta_o^{0.55}}$
 - b. Calculate the nonrecurring and first unit production costs for the vehicle.
 - c. Spread the nonrecurring costs over a seven year period using the beta function with $c_f=0.4$ and $P=0.6$
 - d. Assume 10 flights/year in years 8 through 15. Assume that the vehicle is expendable, and you have a 77.5% learning curve on production. Calculate the year-by-year production costs.
 - e. Calculate the required cost per kg of payload to break even over the entire program against nonrecurring and production costs.
 - f. Repeat (e) assuming a 10% annual discount rate.
 - g. Repeat (e) assuming a 50% rate of return (discount rate).