Problem 1. Trapped Particle Radiation

Assume two spacecraft orbit Earth, one at an altitude of 3000km, the other at 20,000km.

Part (a)

Remind yourself — are these orbits above or below geostationary?

Part (b)

Assuming they are both shielded with 4mm aluminum and have the same electronics, which spacecraft is more likely to suffer Single-Event Upsets? Why?

Problem 2. Upper Atmosphere Physics

Part (a)

What is the change in density of the exosphere at Hubble Space Telescope (HST) altitude between the date of its fourth Shuttle re-boost (Servicing Mission 3B) and the date of your new spacecrafts re-boost?

Part (b)

Using the NASA NRLMSISE-100 atmosphere model, list the following parameters for todays date and the HST altitude:

(a) Atomic oxygen species density

(b) Atmosphere mass density

(c) Exosphere temperature

Part (c)

What role do each of these environmental parameters play in the mission design of your spacecraft?

Problem 3. Orbital Debris and Ballistic Limit Equations (BLE)

Part (a)

Using eqn 2-3 of the NASA MMOD handbook and Fig 2-4 of the NASA Orbital Debris Engineering Model (both in MMOD folder on SmartSite), determine the critical particle diameter for a Probability of No Penetration (PNP) of 0.877. Assume 1m^2 exposed area and a two-week mission.

Part (b)

What would the critical particle diameter be for the same PNP if your spacecraft stayed attached to HST for a second re-boost in 2 years?

Part (c)

Consider a perpendicular impact of a particle of the size found in part a and another particle with 1mm diameter. Use the Design Equations 4-1 and 4-2 to compute the penetration depth for:

(a) Silicate particle at 0.5gm/cm^3 and 23 km/sec (micro-meteroid)

(b) Steel particle at 7 km/sec (orbital debris)

With target materials of:

(a) 6061-T6 Alum

(b) 7075-T6 Alum

Part (d)

No protection case: Use Performance Equation 4-6 to estimate the required spacecraft wall thickness to avoid detached spall due to impact of the 1mm particle for the four material cases in part c.

Part (e)

Compare your answers in part d to equation 4-4.

Part (f)

Whipple Shield design: For the two 1mm particle compositions/velocities in part c, use equations 4-21 and 4-22 to estimate the bumper and rear-wall thickness required to defeat the threat particles. Assume

(a) Particles are spherical

(b) Bumper standoff = 10.2cm (Fig 4-1)

(c) Rear wall: 2219-T87 Alum, 0.5cm thickness

(d) Perpendicular velocity impact ($\theta = 0$)

Part (g)

Estimate the protection capability limits for your Whipple Shields: Compute the critical projectile performance diameter using equations 4-23, 4-24, and 4-25 for various relative velocities, for two types of spherical particle, one silicate, the other steel. Assume the same parameters as for part f.

Problem 4. Acoustic Shielding

Part (a)

Download and install a sound-level app on your smartphone.

Part (b)

Measure the sound pressure level (dB) in some noisy environment (home stereo? EFL?).

Part (c)

Remind yourself: what is the definition of the Decibel, and how is the reference soundpressure level defined?

Part (d)

Use a Styrofoam cup (or similar) as a payload shroud for your phone. Plug the open end of the shroud with isolation (tissues?). Measure the change in dB sensed by your phone.

Part (e)

Add some kind of insulation to the inside walls of your payload shroud and repeat part d.

Part (f)

Discuss results.

Problem 5. Numerical Integration Review

Consider the first-order initial-value problem: $\frac{dy}{dt} = t + y$, $y(0) = 0$ with exact solution $y(t) = e^t - t - 1$

Part (a)

Program Euler and Runge-Kutta solvers (write your own) and plot the results over a range t=0 to 1.0, with step sizes h=0.01, 0.1, and 0.5. Plot results (y vs t) and compare to the exact solution.

Part (b)

Repeat step a with library functions for Euler and RK4