ASEN 4114/5114 Project 1

The purpose of this project is to apply frequency domain modeling and design methods to control attitude of a spacecraft mockup. A combination of analytic and empirical modeling will be used to obtain a transfer function representation of the spacecraft dynamics. A controller will then be designed using frequency response methods, then implemented in a simulation of the hardware mockup. Predicted responses will be compared to simulated responses. Colocated versus non-colocated control issues will be explored.

The project can be carried out individually, or in small teams. Team projects (up to 3 team members) will submit a single report, and all members of a team project will receive the same grade. The report should include an introduction, separate sections for each of the following parts, and a conclusion pointing out interesting aspects or difficulties. All team members should contribute approximately equally to the conduct of the project and the write-up. Provide a statement of individual contributions in the report. **The report is due Monday, April 7 at 11:59 PM.**

1. [20 pts] Develop an analytic transfer function model to match the empirical frequency response obtained from the spacecraft mockup hardware (data posted on Canvas), for frequencies up through the first resonance/anti-resonance.

2. [20 pts] Examine the two loop transfer functions (analytic and empirical) via Bode plots and Nyquist plots using a proportional controller $C(s)=K$. Would the control system be stable for some values of K? For all values of K?

3. [30 pts] Design a compensator $C_1(s)$ so that the unity feedback control system with $C(s)=KC_1(s)$ has at least 40 deg phase margin, 10 dB of gain margin, and a closed loop (-3 dB) bandwidth as close to 1 Hz as possible. Use the analytic plant model in this design. Compute and plot the closed loop tracking frequency response.

4. [10 pts] Repeat part 4 using the empirical plant frequency response. Adjust the control design as necessary to try to maintain the stability and performance objectives. Comment on the effects of the unmodelled dynamics at high frequency.

5. [20 pts] Simulate the analytic model in a unity feedback control loop in Simulink using the control design from part 4. Plot the responses to a 0.5 rad step input, and to single-sinusoid inputs at 0.5 Hz and 2.0 Hz, each with amplitude 0.5 rad. Also plot the torque input signal, along with its limiting values. Compare these responses with expectations from loop gain analysis for closed loop frequency response, DC tracking accuracy, and stability margins.

6. [20 pts – graduate credit only] Suppose the spacecraft had a model where the first resonance occurred before the anti-resonance in frequency. Sketch this Bode plot, and determine if your controller designed in Part 4 would produce a stable system. Comment on the difficulty of achieving the above closed loop stability and tracking bandwidth performance with this “non-colocated” plant.