Problem Set 1
AA 279D, Winter 2018
Due: April 16, 2018 (Monday) at 1:30 pm

Notes:

Submission Instructions

Please briefly document all tasks below in a report which will grow during the course. You should include a table with change logs, and an index for sections.
Please submit your report as a PDF file to the course Canvas website. You should use typesetting software like LaTeX or Microsoft Word to produce your documents. Do not submit extra files.

Topics

Project kick-off. Interpretation of specifications. Mission selection. Orbit simulation.

Problem 1. Your Mission, Should You Choose To Accept It

Conduct a survey of distributed space systems, either proposed, under development, or operational. Make sure to look at a wide variety of mission domains, such as Earth sensing, space science, and technology demonstration. From your research, select a candidate system which will serve as the framework for your course project. You should attempt to provide the following information as far as can be found in public resources:

- Mission name and operator (agency, nation, company, etc.)
- Primary and secondary mission objectives
- Number and type of satellites
- Absolute and relative orbit parameters, including launch date
- Basic description of functioning/scientific principle
- Key guidance, navigation, and control (GNC) requirements
- Classification according to separation and control accuracy (e.g. formation-flying, constellation, rendezvous and docking, etc.)

Note: It would be wise to select a second candidate mission as back-up in the event that any issues emerge with your first choice.

Problem 2. Simulate That Orbit

We would like to explore the properties of unperturbed and J_2-perturbed absolute orbit motion using known analytical solutions and numerical integration. In other words, you will be simulating a single reference orbit for your mission. To this end, you are asked to:

(a) Define the initial conditions of your mission's reference orbit. Most likely the initial conditions are provided in literature by a set of Keplerian orbital elements and an initial launch date and time. You are allowed to choose some consistent initial conditions arbitrarily if not available.

(b) Treat these initial Keplerian elements as osculating quantities and compute the corresponding initial position and velocity in the appropriate inertial frame (e.g. Earth-Centered Inertial for an Earth-orbiting mission).

(c) Using Simulink, perform a numerical integration of the equations of motion (equation (2.1) in the Alfriend text) with position and velocity as state variables and the initial conditions from part (b). Neglect any perturbations beyond the two-body spherical gravity force acting on your orbit. Run your simulation for several orbit periods, then provide a 3D plot of the orbit path as seen in the inertial frame.

(d) Repeat the simulation from part (c), but this time account for Earth oblateness (J_2) effects. Be sure that your simulation duration is long enough to appreciate the effects of the J_2 perturbation in the resulting plot.
Hint: See equation (4.93) in the Alfriend text.

(e) Verify that your integrator performs properly by comparing the output from part (c) against an analytical Keplerian propagation. Plot the error in absolute position and inertial velocity expressed in the local vertical, local horizontal (RTN) coordinate system.
Hint: You should only observe numerical integration errors. Eventually reduce integrator step size to reduce numerical errors.

(f) Compute and plot osculating Keplerian orbital elements, eccentricity vector, angular momentum vector, and specific mechanical energy against time over the course of the numerical simulations of parts (c) and (d). Verify and show that these quantities are constant when excluding J_2 effects. What happens when you include J_2 effects instead? Are the results as expected from averaging theory?

(g) Now consider the linear differential equations for the mean Keplerian orbital elements (equation (2.115) from Alfriend) including J_2 effects. Verify and show the general consistency with the osculating elements of your simulation in part (d).

(h) You could encounter some inconsistencies when comparing osculating and mean orbital elements due the initialization procedure. In fact part (d) uses osculating states as inputs and provides osculating states as outputs, whereas part (g) uses mean states as inputs and provides mean states as outputs. How would you solve this problem?