AE4580 Introduction to Avionics Integration
Spring 2008 Homework #3
Due: Tuesday April 1, 2008 at 12:05pm (beginning of class) or before

1. Be prepared to discuss in class what you propose for your final project (1 point). For this assignment, please turn in a viewgraph that describes your proposed project. The intent of the final project is to: bring together the many different components we have covered so far (and will cover), to consider the integration of them into a useful system, and to do additional research beyond that covered in lecture. There are at least two approaches you may take for the project:
   (1) Develop the design of a new avionics system: develop requirements, select components, select architecture, analyze your design (does it meet requirements). Examples: Spacecraft attitude estimation system, radar-guided vehicle, integrated stability augmentation system, new cockpit interface, etc.
   (2) Analyze an existing avionics system: document history, describe components and architecture, explain why design choices were made, and suggest improvements. Examples: Airbus 380 avionics system, space shuttle avionics, Mars pathfinder spacecraft, the Pioneer unmanned air vehicle, etc.

   Your viewgraph needs to include: (1) Which of these approaches you plan to take, (2) What will be the scope of the work (what issues will be considered, and types of analysis will be performed – will you implement any algorithms and test in a simulation?), and (3) IMPORTANT What approach you will take to obtain necessary information.

Additional information on Project:

Class Project Written Report, due April 17:
It must be typed, turn in hardcopy.
*** Your project proposal (or a photocopy of it) with my comments must be included attached to the back of the document.***
The report must include:
- A descriptive title, title page (date, author(s), course)
- A 200-300 word abstract, summarizing the entire report
- An introduction (including purpose of the work)
- Main body, including elements specified in your proposal
- A brief summary with any conclusions
- Project proposal with my comments

References will be organized by the order they appear in the text. References to web pages should be avoided (however, it is recognized as an important source of current product information). References should be made to any private conversations or interviews. There is no minimum or maximum length requirement, however it is expected to require 2000 to 3000 words plus illustrations to describe the design/analysis you have proposed (this amount per person when working in a small group). This is only a rough guideline. For virtually all potential topics, it is expected to require at least one system block diagram, showing components and flow of information. Grading will be based on fulfilling objectives of proposed project, as well as technical writing (e.g., spelling, grammar, neatness, and organization).

Class Project Presentation:
It must be turned in electronically (PowerPoint is good), due the same day/time as the written report. E-mail them to me at: Eric.Johnson@ae.gatech.edu. Presentations will be given April 22, 24 (but be prepared to go on April 22). I will provide the computer/projector – with presentation you send me electronically. Presentation should be about 10 minutes long. This is about 4-5 slides, depending on density. Presentation grading will be based on clarity, accurate account of highlights of project report. There will be at least one question on the final exam from someone's report presentation. Points will be deducted for going over time, so be sure to practice.

2. An ideal (unaided) inertial navigation system (no errors in accelerometer or gyro measurements) is placed on a table in our classroom (6 points).

   (a) Unfortunately, it is tilted 0.1 arc minutes compared to where we thought it was (that is, the initial condition given to the INS is tilted with respected to the actual value – with the top tilted to the North). Use the simplified 3-state north-south (tilt error, velocity error, and position error) error analysis presented in class and in Kayton & Fried (p. 378), to predict how tilt error, velocity error, and position error will respond for the next 4 hours. Show *both* an analytic solution and plots from a linear or nonlinear simulation of the error dynamics – and turn in all source code (in whatever form) used to generate numerical result.

   (b) For a second case, predict what will happen with altitude error if the initial position estimate is 10 ft higher than the true height. You may use a simplified model for this analysis that only includes altitude, altitude rate of change, and vertical acceleration (2 states: altitude and rate of change of altitude). Show plots of altitude error and rate of change of altitude error for the next four hours. Again, show *both* an analytic solution (from linear analysis), and a nonlinear (use a one over R squared gravity model) numerical simulation – and turn in all source code (in whatever form) used to generate numerical simulation.

3. Develop an Extended Kalman Filter (EKF) design that utilizes three distance measurements from three DME stations, that each become available at the same fixed time interval (a simplification from real life, where they would be available at different time intervals), to estimate the 2-D (North, East) velocity and position of a vehicle in approximately steady/level atmospheric flight (8 points).
   (a) Write down all equations necessary to implement the filter, and indicate the order of operation.
   (b) In tabular form, list all parameters that must be selected in order to utilize your filter, including any required initial conditions – and describe how they might be obtained if your system was used for real. Include a reasonable value/guess for the given the scenario.
   (c) In MATLAB, implement and test your filter for the first 100 seconds after the initial condition. Use the following: (and use your answer to part (b) for any parameters missing here)
      (i) Aircraft starts at (0 North,0 East) and moves with velocity (400,300), units are *ft* and *ft/sec* respectively
      (ii) Initial guess for aircraft position and velocity estimates are (-1000,0) and (300,450) respectively (i.e., both state estimates are initially incorrect)
      (iii) DME stations are located at (30000,0), (10000,30000), and (-10000,20000), update rate is once per second for both – and both update at the same time

   Provide plots of the actual position, estimated position, north and east velocity estimate error (as a function of time), north and east position estimate error (as a function of time). On the position and velocity error plots, also include + 2*standard deviation and -2*standard deviation of each error (square root of diagonal elements of P corresponding to north and east position). For a "well tuned" filter, the errors should be within these limits about 98% of the time (that is, they are a true predictor of filter estimate accuracy – and a Gaussian error would be within 2 s.d. 98% of the time).
   Note: be sure to add *appropriate* zero-mean Gaussian noise to your simulated measurements used to test your design.