



Module 12

Modern Navigation Systems

Inertial Navigation, Doppler, and Atomic Clocks

Module 12E

The Research Project

Summary of Module 12

- The Keplerian equations from earlier modules are re-examined in terms of conservation of angular momentum, thus yielding expressions for the acceleration versus time of moving bodies. The Schuler frequency is introduced and analyzed in the context of a feedback control system, using as an example problem the inertial navigation of an aircraft flying from Dulles Airport to Beijing. Angular momentum is then re-examined in the context of circus acrobatic performances. (12A)
- Sensors that can measure these accelerations are explored, including mechanical gyroscopes based on rotating flywheels, mechanical gyroscopes that use micro-electrical mechanical devices (MEMs), and optical gyroscopes that exploit the relativistic Sagnac effect (e.g., the ring-laser gyroscope). (12B)
- Doppler techniques are introduced using the Cospas-SarSat system as a prototypical example. Students will watch a video that describes Cospas-Sarsat in detail. (12C)
- Atomic clocks and the Allan variance are introduced. A chip-scale atomic clock is described. (12D)
- **Students will begin submitting and/or presenting their final projects. (12E)**



Summary of the Project Requirements

- The research project will require a trip or visit to a site important in the history of navigation (e.g., the Mason and Dixon line), or a visit to an operational facility involved with navigation, such as an airport control tower.
- Alternatively, students can conduct telephone or email interviews with a person or persons involved with navigation.
- The fundamental requirement is that students identify and use a primary, rather than secondary, source of information. Using information obtained only from secondary sources (e.g., Wikipedia or textbooks) will not be acceptable.
- The report will be presented online to the instructor and interested students in the form of a trip report, rather than as a traditional research paper. Emphasis will be on creativity and originality, in contrast to the highly mathematical nature of the traditional homework assignments.



What the Research Project is and is not!

- The project is not a term paper
- It is about your activities, not a description of someone else's
- It is okay to crash and burn
- Think of this as a “VisionQuest” for suburbanites
- Get outdoors and do something that you would not otherwise do!



Some example projects

- Visit and GPS-locate sites on the Mason-Dixon Line
 - The Wedge
 - Fort Frederick State Park
 - New Castle, DE
- Get a tour of the operations center at a local airport
 - This sometimes enables a visit to the control tower
- Visit the latitude observatory near JHU's Montgomery County, MD site



Examples (cont'd)

- Visit the Coast Guard's GPS Laboratory or the US Naval Observatory
- Interview a harbor pilot
- Borrow a sextant and make your own celestial observations
- Visit some of the sites on the Underground Railroad



Examples, cont'd

- Visit a ship at Norfolk during the weekly open house
- Visit a historic ship
 - Constellation, in Baltimore
 - Nautilus, in New London
- Visit the Maritime Museum in Newport News



Examples, cont'd

- Note, however, that travel or additional expenses are not required
 - Something local can be identified and pursued just about anywhere in the world!



Assignment 12-4: the research project

1. Describe your research project, trip report, etc. online as a post to the Research Project discussion forum
2. Upload a brief ppt, .doc, or .pdf file describing your project to the assignments page by the last day of classes as listed in the JHU EP calendar for this term.



End of Mod 12E