**DELFT UNIVERSITY OF TECHNOLOGY**
**FACULTY OF AEROSPACE ENGINEERING**

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| Course | : | Avionics I (ae4-393) |
| Date | : | January 22, 2001 9:00 to 12:00 hour |

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| Note | 1 | Put your name and all your initials on each sheet. |
| | 2 | Answer all questions and put your name on each sheet. |
| | 3 | Provide your answers in English or Dutch. |

This examination consists of 6 questions. The number of points you can gain with each question is indicated below. Your grade will be equal to one plus the total number of points divided by ten.

READ THE QUESTIONS FIRST BEFORE ANSWERING THEM (some things might be asked twice, but in a different context).

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1. (10 points) **AVIONICS – GENERAL**

   Give the exact meaning of the following acronyms and describe briefly what they stand for.
   *Example:* PFD = **P**rimary **F**light **D**isplay.
   The PFD is the main cockpit instrument, placed in front of the pilot, showing all primary flight information such as the aircraft attitude, airspeed and altitude.

   (a) WAAS

   (b) HUD

   (c) MFD

   (d) FANS

   (e) EFIS

   (f) STAR

   (g) AMSS

   (h) FIR

   (i) ACC

   (j) MLS

2. (15 points) **THE EARTH MAGNETIC FIELD: COMPASSES**

   (a) When using a conventional direct-reading magnetic compass, several errors are involved in the magnetic heading presented by the compass. Three of these errors are the *variation*, the *inclination* and the *deviation*. Give a definition of all three error sources, and, if possible, the countermeasures to decrease them.

(b) What is a *magnetometer*? Briefly describe the working principle of the magnetometer. What are the advantages of the magnetometer with respect to the direct-reading magnetic compass?

(c) Describe, using a simple but clear sketch, how the magnetometer can be combined with a directional gyro to constitute a *Magnetic Heading Reference System* (MHRS).

(d) In the MHRS, how do the magnetometer and the directional gyro compensate for each other's deficiencies?

3. (15 points) **THE NAVIGATION EQUATIONS**

(a) Two categories exist of navigation systems, namely *Positioning systems* and *Dead Reckoning systems*.

i. Give a definition of both categories, clearly indicating the main difference between them.

ii. Give one typical example of a navigation system for each category.

iii. Discuss the advantages and disadvantages of dead reckoning navigation systems with respect to positioning navigation systems.

(b) Any navigation system is subject to making errors. When considering the Global Positioning System (GPS), the GDOP measure is an important benchmark.

i. What does GDOP mean?

ii. When using GPS, what navigation system errors contribute to the GDOP?

iii. Can a GPS receiver use the GDOP measure to increase its *accuracy*? Briefly explain your answer.

iv. Can a GPS receiver use the GDOP measure to increase its *integrity*? Briefly explain your answer.

4. (20 points) **INERTIAL NAVIGATION SYSTEM**

(a) What are the main advantages of inertial navigation systems (INS) and what are the main disadvantages?

(b) What is the underlying principle of inertial navigation?

(c) Consider Figure 1, showing the two primary feedback control loops of a gimballed inertial navigation system. Describe *in detail* how these two loops work, i.e. what do they measure, what do they control, and why do we need them to make the gimballed inertial navigator practible.

(d) The INS building blocks are accelerometers and gyroscopes. Both are inertial sensors which can have various inaccuracies. What is the main inaccuracy of the gyroscope and how does this gyroscope inaccuracy propagate into a position error?

(e) Why do we call a typical INS a *Schuler tuned* system? Explain your answer.

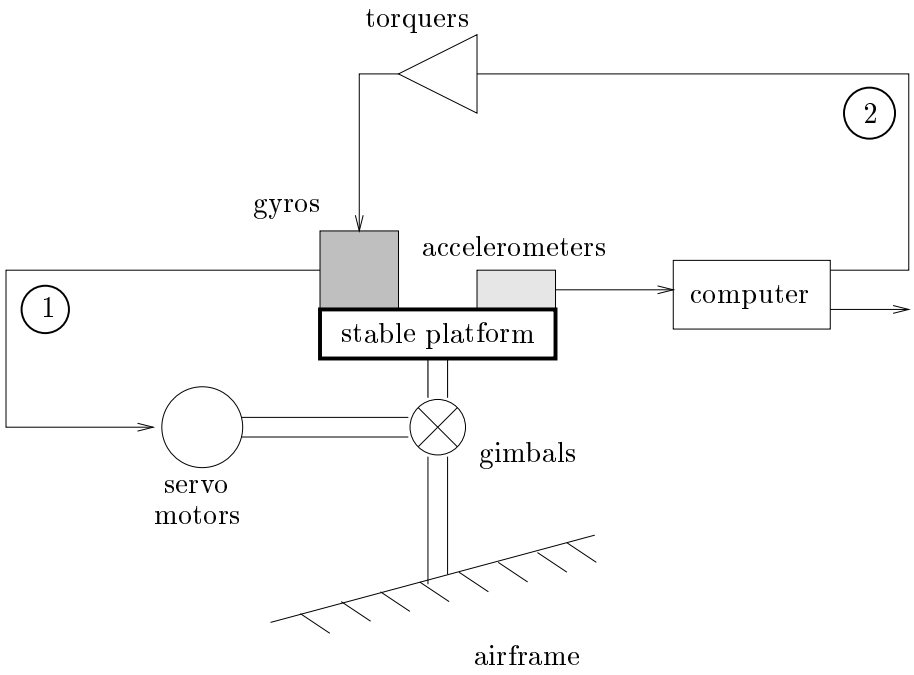


Figure 1: *A gimballed inertial navigation system platform. The circles with '1' and '2' indicate the two main INS feedback control loops.*

(f) When considering the sensor inaccuracies mentioned above, what effects does the Schuler tuning have on these inaccuracies. In other words, for a Schuler tuned INS how do the sensor inaccuracies propagate into the position error?

(g) What are the characteristics of a typical INS in terms of accuracy, coverage, capacity and integrity?

(h) What are the future trends in inertial navigation?

5. (15 points) **RADIO NAVIGATION**

(a) Give a detailed description of the main components and working principles of the Long Range Navigation system LORAN-C.

(b) Why is LORAN-C called a *hyperbolic* system?

(c) How many ground stations are necessary to determine the aircraft position with LORAN-C?

(d) Discuss the dependence of the accuracy of the LORAN-C navigation solution on the *geometry* of the situation.

6. (15 points) **AIR TRAFFIC CONTROL & MANAGEMENT**

Since 1995, all aircraft with more than 30 passenger seats operating in the United States airspace are required to be equipped with an ACAS.

(a) What is ACAS?

(b) How does an ACAS work? What is the main reason why the ACAS needs to be installed in aircraft?

(c) What information does an ACAS provide to the pilot?

(d) What is the main problem of current ACAS systems?

(e) What is the name of the most-widely used ACAS system?