DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	February 1, 2006 from 9:00 until 14:00 hr
Remarks	:	Write your name, initials and student number on your work Answer all questions in English or Dutch and mark all pages with your name.

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. AVIONICS – GENERAL (10 points)

Give the exact meaning of the following acronyms and describe briefly what they stand for. (1 point each)

> *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] LORAN

[d] ADS-B

[e] EFIS

[f] STAR

[g] AMSS

[h] FIR

[i] FMS

[j] CNS

2. SURVEILLANCE SYSTEMS: RADAR (15 points)

[a] Sketch in a block diagram all essential elements of a primary surveillance radar. Explain the specific functions of these elements. (2 points)

[b] What aircraft variables or states can be measured with the primary surveillance radar? (1 point)

[c] Describe how the rotational velocity of a radar affects the radar range. (2 points)

[d] Describe how the pulse-repeat frequency of a radar affects the maximum radar range. (2 points)

[e] Describe how the pulse length of a radar affects the minimum radar range. (2 points)

[f] When the rotational velocity of a radar is 6 r.p.m., the pulse-repeat frequency is 200 Hz and the pulse width 4 μs, what is the maximum range of the radar and the minimum range of the radar in nm?
(1 nm = 1852 [m], speed of light $c \approx 300.000.000$ [m/s]). (2 points)

[g] Explain in detail how the radar resolution determines to a large extend the minimum separation distance between aircraft. (2 points)

[h] What other complementary radar system is often connected to the primary surveillance radar? What does this system measure? (2 points)

3. AIR TRAFFIC CONTROL & MANAGEMENT (15 points)

[a] What are the three Air Traffic Services which together form the Air Traffic Management (ATM) service? Describe the fundamental differences between them. (3 points)

[b] What are the CTR, the CTA, the UTA and the TMA? (3 points)

[c] Sketch how the controlled airspace is structured into different parts. Which part (or 'team') of the Air Traffic Control is responsible for which part of the controlled airspace? (4 points)

[d] What is a STAR? What is an SID? Why are they established? (3 points)

[e] Sketch and describe in general terms how an airplane, coming from an arbitrary airway, lands at an arbitrary runway of an airport. Which parts of the airspace structure are passed during this flight? At what moments is the responsibility of Air Traffic Control handed over between the different ATC teams? (2 points)

4. LANDING GUIDANCE SYSTEMS (15 points)

[a] ICAO has defined three categories of visibility for landing aircraft. Describe in detail how these categories are defined. (3 points)

[b] In low-visibility conditions, *how* does a pilot decide to continue or abort the landing? In other words, on which knowledge or information does a pilot base his or her decision? (2 points)

[c] Describe, using a sketch, the main components of the Microwave Landing System (MLS). (3 points)

[d] How does an MLS receiver determine its position relative to the runway? In other words, how does this system work? Explain your answer. (6 points)

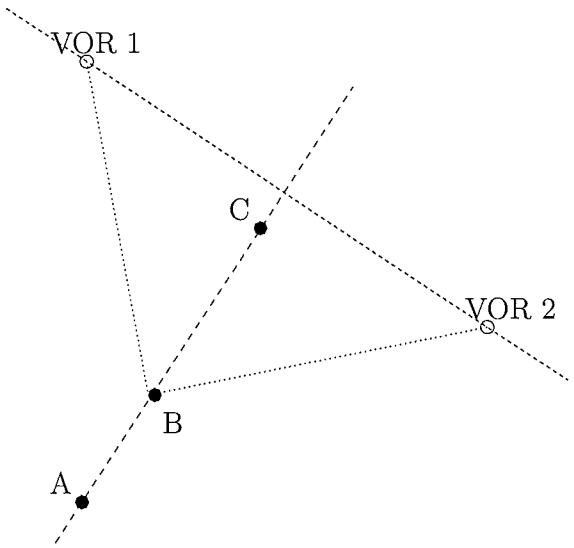

Figure 1: *Top view of a situation with two VOR beacons.*

[e] What are the main advantages of MLS over its predecessor, the Instrument Landing System (ILS)? (1 point)

5. TERRESTRIAL RADIO NAVIGATION (15 points)

[a] How do radio waves propagate on the Earth? Include in your answer the ground wave and sky wave propagation and the ways in which these two waves interfere. What are line-of-sight waves? (3 points)

[b] Describe the main working principle of a VHF Omni-directional Radio Range (VOR) beacon. How is the VOR information presented to the pilot? (6 points)

[c] Consider Figure 1 showing two VOR beacons from above.

- What is GDOP? (1 point)
- Explain the concept of GDOP using Figure 1. In your answer, place the aircraft receiver at positions A, B and C and describe if and how the GDOP changes. (3 points)

[d] With what other beacon is the VOR often collocated? Why is that? (2 points)

6. INERTIAL NAVIGATION SYSTEM (20 points)

[a] What are the main advantages of inertial navigation systems (INS) and what are the main disadvantages? (1 point)

[b] What is the underlying principle of inertial navigation? (1 point)

[c] Consider Figure 2, 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. (6 points)

[d] The INS building blocks are accelerometers and gyroscopes. Both are inertial

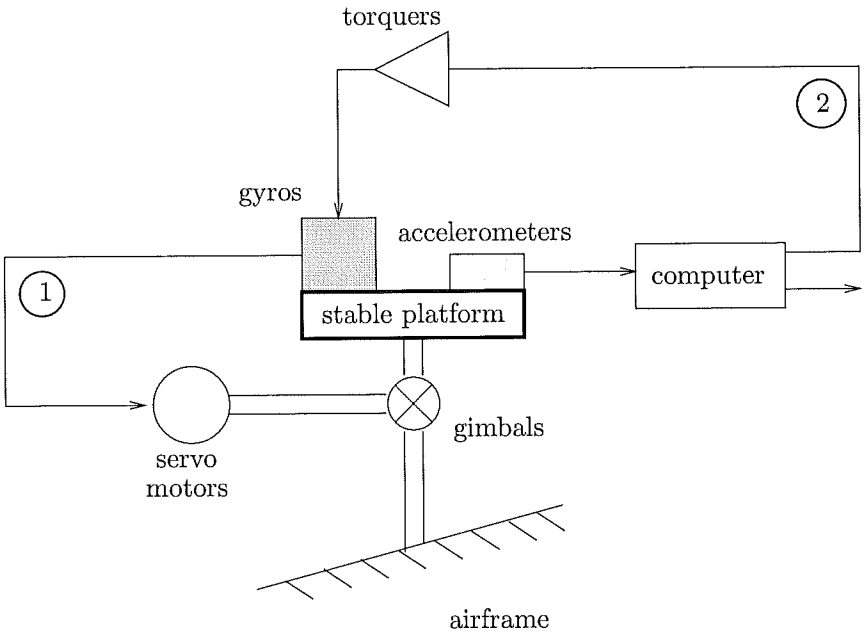

Figure 2: *A gimballed inertial navigation system platform. The circles with '1' and '2' indicate the two main INS feedback control loops.*

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? (3 points)

[e] Why do we call a typical INS a *Schuler tuned* system? Explain your answer. (3 points)

[f] When considering the sensor inaccuracy 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? (3 points)

[g] What are the characteristics of a typical INS in terms of accuracy, coverage, capacity and integrity? (2 points)

[h] What are the future trends in inertial navigation? (1 point)