DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	January 27, 2005 from 14:00 until 17:00 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.

1. AFTN
2. TCAS
3. RNAV
4. ADS-B
5. EFIS
6. STAR
7. AMSS
8. WAAS
9. ACC
10. MLS

2. LANDING GUIDANCE SYSTEMS (15 points)

[a] What does ILS mean? (1 point)

[b] Describe the three main components of an ILS system, and make a sketch indicating where these components are positioned with respect to the runway. (2 points)

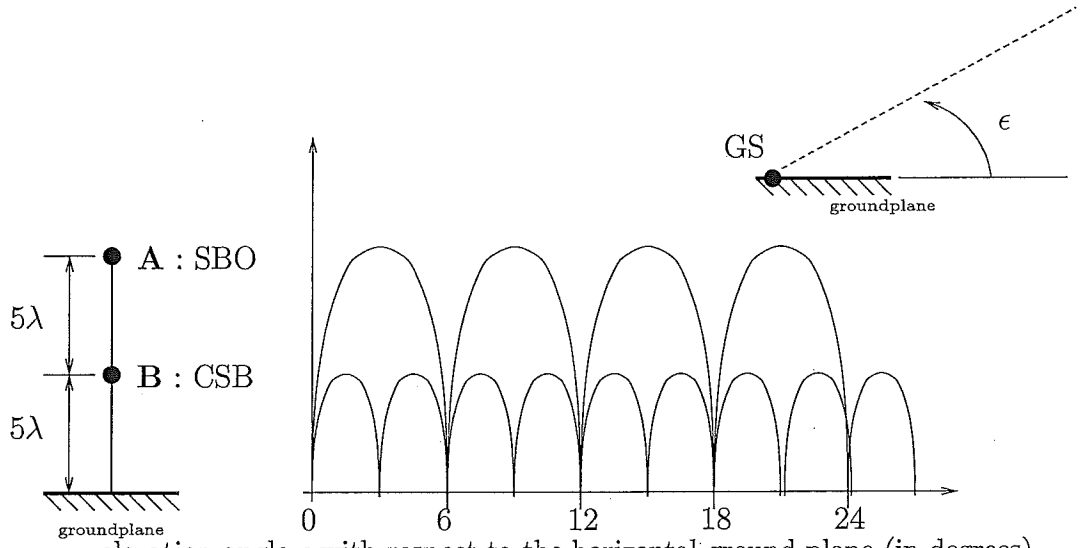

Figure 1: *The ILS glide slope (GS) antennas (left) and the corresponding lobe pattern (right) as a function of elevation angle ϵ (top right).*

[c] Describe in general terms the antenna patterns generated by an ILS. How are they used by the on-board equipment? (2 points)

Consider Figure 1, showing the glide slope antennas A and B (left) and the 'lobes' resulting from these two antennas (right). Antennas **A** and **B** are positioned 10 and 5 wavelengths λ above the Earth surface, respectively. This yields the lobe patterns as illustrated. Both antennas send the carrier wave amplitude modulated with a 90 Hz and a 150 Hz signal. Antenna **A** is sending the Side-Bands-Only (SBO), resulting in maxima at $\frac{3}{2}$, $\frac{9}{2}$, $\frac{15}{2}$, etc. degrees elevation. Antenna **B** is sending the Carrier-and-Side-Bands (CSB), resulting in maxima at 3, 9, 15, etc. degrees elevation. Note that the 90 Hz AM signal of the SBO antenna is 180 degrees lagging behind the 90 Hz AM signal of the CSB antenna.

[d] Based on the information above, explain in detail how the glide slope antenna works and how the glide slope receiver can use the transmitted signals. (7 points)

[e] What is a 'false glideslope'? At what elevation angle does it occur with the ILS Glide Slope antenna as discussed here? (2 points)

[f] Why can a conventional ILS installation only be used on flat terrain? (1 point)

3. COMMUNICATION, NAVIGATION, SURVEILLANCE (15 points)

[a] What aircraft variables or states can be measured or obtained with the secundary surveillance radar (SSR)? (2 points)

[b] Describe the two modes (Mode A, Mode C) of an SSR. How many codes can be selected in Mode A? (3 points)

[c] Describe the interrogation/reply process of an SSR and an aircraft transponder. How does the transponder know what reply it should give? What do the interrogation signals look like? (4 points)

[d] Describe the phenomenon of *side-lobe interrogation.* How is this problem solved for the SSR? (4 points)

[e] The SSRs can be upgraded with Mode S. What is Mode S and what primary virtue does it have with respect to the 'old' system? (2 points)

4. SATELLITE RADIO NAVIGATION (15 points)

1. Describe in detail the main working principle of the Global Positioning System (GPS). (5 points)
2. How do we get an estimation of our position? (2 points)
3. How do we get an estimation of our velocity? (2 points)
4. Describe in detail the principle of Differential GPS (DGPS). (2 points)
5. When the GPS navigation system is used as a *sole means* navigation system, e.g. in the context of the Global Navigation Satellite System (GNSS), it needs to be *augmented.*
   (a) Why does it need to be augmented? (1 point)
   (b) Describe the three main forms of augmenting GPS. (3 points)

5. TERRESTRIAL RADIO NAVIGATION (15 points)

In this question we consider the DME radio beacon.

[a] What does the acronym DME stand for? (1 point)

[b] How does the DME system work? In your answer, include:

1. a description of the ground equipment and the airborne equipment (if any),
2. the basic working principle of the DME,
3. the DME signal characteristics,
4. the different modes in which the DME can work,
5. the characteristics of the DME in terms of accuracy, integrity, availability, capacity and autonomy.

(4 points)

[c] Explain *in detail* how the aircraft equipment can distinguish between replies of the DME station for other aircraft and the replies of the DME station to the owncraft. (3 points)

[d] Consider Figure 2 showing two DME beacons from above.

- What is GDOP? (2 point)
- Explain the concept of GDOP using Figure 2. In your answer, place the aircraft receiver at positions A, B and C and describe if and how the GDOP changes. (3 points)

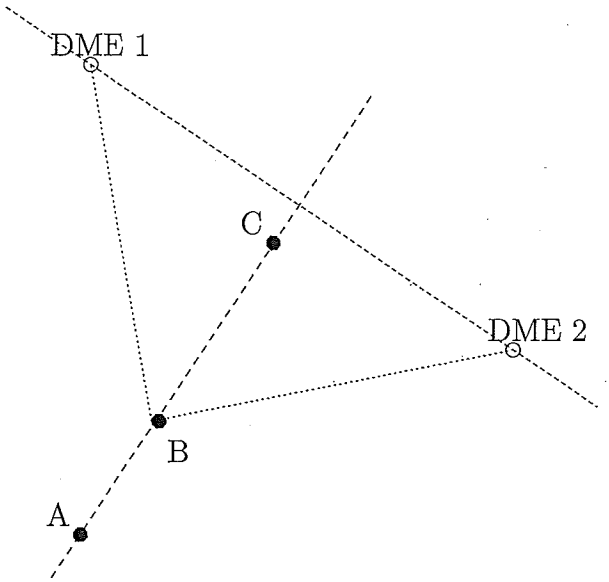

Figure 2: *Top view of a situation with two DME beacons.*

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

6. INERTIAL NAVIGATION SYSTEM (20 points)

[a] What is the underlying principle of the INS? (1 point)

[b] What are the main INS components? What are their function and how do they work together to enable the INS to generate a navigation solution? (4 points)

[c] Two elementary different forms exist of the INS. One of them is the so-called *strapdown inertial navigation system.*

1. What is the other form of implementing an INS called? (1 point)
2. What is the crucial difference between both INS systems? (2 points)
3. What are the advantages and disadvantages of both forms with respect to each other? (2 points)

[d] Consider Figure 3, which shows the basic 'analytic' functioning of a strapdown inertial navigation system in the situation of assuming a flat, non-rotating Earth.

1. What symbols in this figure represent the measurements (from the sensors)? In what reference frame do we measure them? Why? (1 point)
2. What symbols in this figure represent the navigation solution? In what reference frame are they defined? Why? (1 point)
3. In the strapdown inertial navigation system set-up as indicated by this figure, are we compensating for transport wander? Explain your answer. (1 point)

Again, consider Figure 3. The strapdown inertial system computations are done in four consecutive steps. These steps are, *in random (!) order*:

I Integration of the vehicle dynamics of motion.

II Resolution of the gravity vector.

III Computation of the navigation solution.

IV Integration of the Euler equations.

[e] Indicate, using a *clear and unambiguous sketch*, on the figure sheet (!) of the examination, which parts of the figure belong to the four computation blocks stated above. (2 points)

[f] In what order are these computations being executed? **Explain** your answer. (2 points)

[g] When you now consider your answer to the previous two questions, what do the calculations mean? That is, why are they necessary, why are they being done? For instance, what does 'resolution of the gravity vector' mean and why do we need to do this to make the strapdown INS a feasible system? Explain in detail. (3 points)

NOTE: THIS FIGURE INCLUDING YOUR ANSWER TO THE QUESTION STATED ABOVE MUST BE HANDED OVER TOGETHER WITH THE REST OF YOUR ANSWERS!!!!

Name:

Student number:

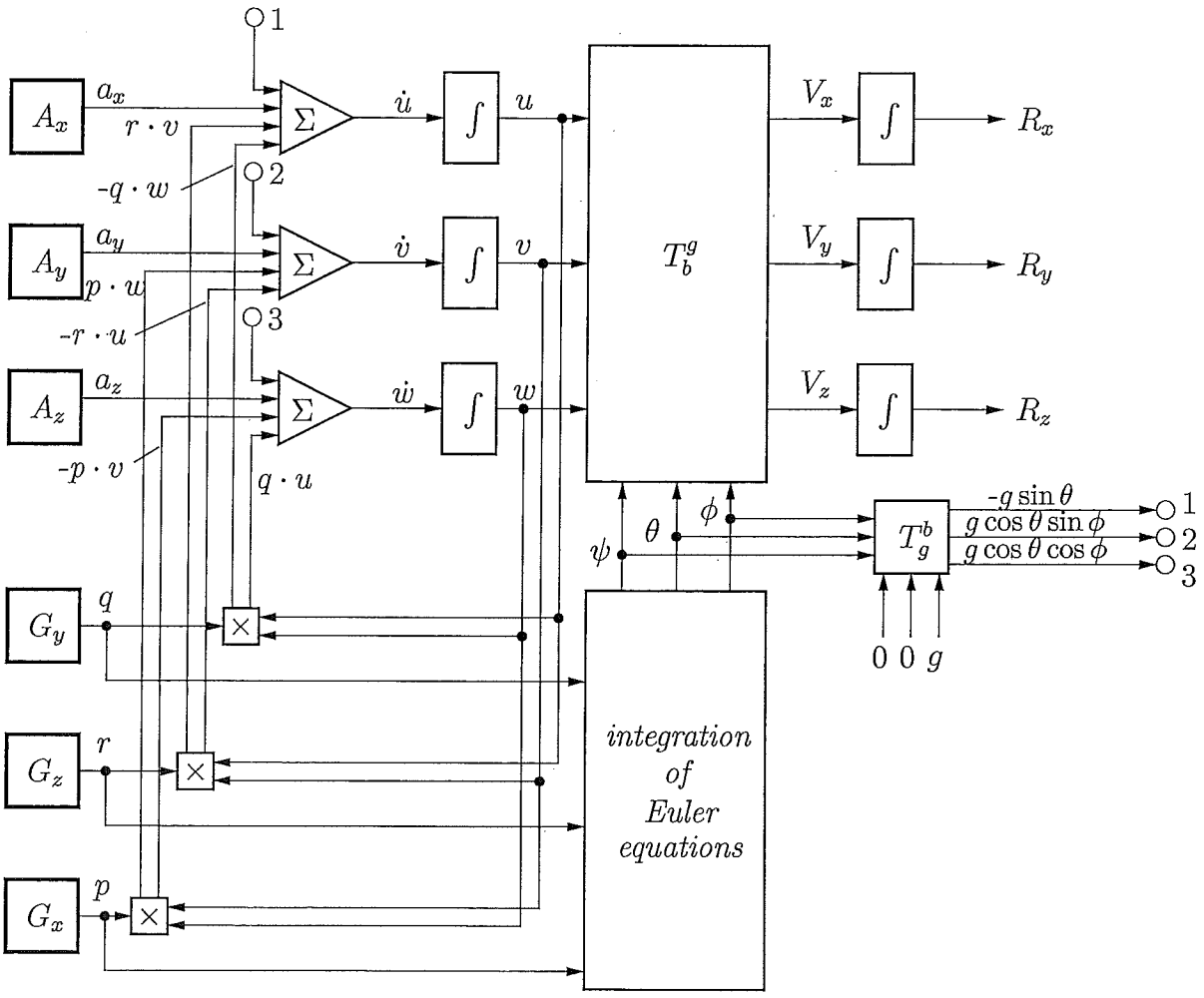

Figure 3: *Schematic diagram of the analytic platform. Note: the symbols used in this figure are identical to the ones used throughout the avionics lecture. They define the common aircraft flight dynamics and kinematics states. For instance, ψ, θ and ϕ are the aircraft Euler angles representing heading, pitch and roll.*