DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	October 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 = Primary Flight Display.
> 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. 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)

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

3. RADAR (15 points)

[a] Sketch in a block diagram all essential elements of a primary surveillance radar. Explain the specific functions of these elements. (4 points)

[b] What aircraft variables or states can be measured with the primary surveillance radar? (2 points)

[c] Describe how the rotational velocity of a radar affects the radar range. (3 points)

[d] Describe how the pulse-repeat frequency of a radar affects the radar range. (4 points)

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

4. FLIGHT MANAGEMENT SYSTEM (15 points)

[a] Describe in detail, preferably at the hand of a sketch, the three main components of a Flight Management System. What are the functions of these three components of the FMS? (5 points)

[b] What are the three general functions of the FMS? Explain how the three FMS components are used to serve these functions. (4 points)

[c] What is the relation between the FMS and the automatic flight control systems? Are they one and the same? If so, explain *how* they are integrated. If not, explain *why* they are not integrated. (2 points)

[d] One of the relatively 'new' functions of an FMS is that it employs the so-called RNAV function.

1. What is RNAV? (2 points)
2. What are the main virtues of RNAV with respect to the other modes of navigation? (2 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)

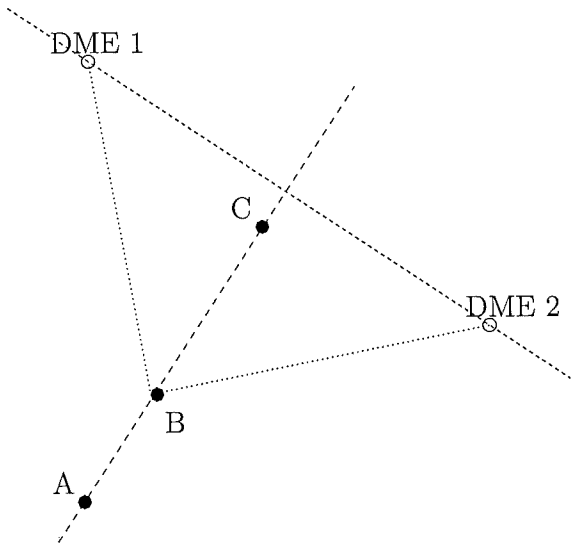

Figure 1: *Top view of a situation with two DME beacons.*

[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 1 showing two DME beacons from above.

- What is GDOP? (2 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)

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

6. INERTIAL NAVIGATION SYSTEM (15 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? (2

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? (1 point)
3. What are the advantages and disadvantages of both forms with respect to each other? (1 point)

[d] Consider Figure 2, 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 2. 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. (1 point)

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

Assume we have our strapdown inertial navigation system as indicated in Figure 2, but now the Earth is **not flat and is rotating**.

[g] What do we need to do to make this system work again? What are the consequences of these actions? (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:

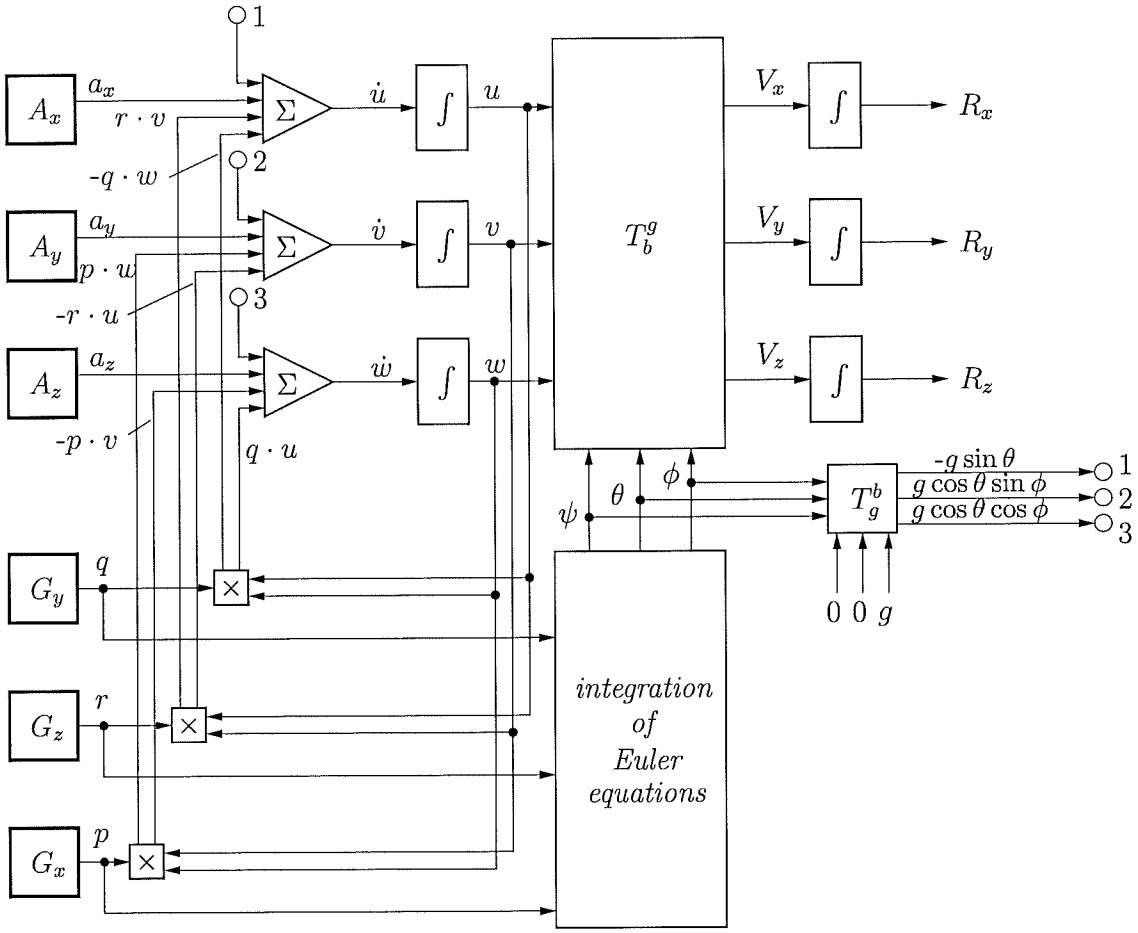

Figure 2: *Schematic diagram of the analytic platform. Note: the symbols used in this figure are identical to the ones used throughout the avionics lecture. They define the common aircraft flight dynamics and kinematics states. For instance, ψ, θ and ϕ are the aircraft Euler angles representing heading, pitch and roll.*