DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	June 25, 2001 9:00 to 12:00 hour
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. (15 points) **AVIONICS – GENERAL**

   (a) When a new navigation system is being developed a large number of design tradeoffs hold. Four of them are:

   - *accuracy*,
   - *autonomy*,
   - *availability*,
   - and *integrity*.

   Describe shortly what is meant by each one of these design tradeoffs.

   (b) Consider the autonomy issue. Autonomy can be subdivided into five subclasses. Describe these subclasses of autonomy and, for each subclass, give an example of a navigation system (e.g. DME) belonging to that subclass.

2. (15 points) **INERTIAL SENSORS: GYROSCOPES**

   (a) What are the disadvantages of mechanical gyroscopes with respect to optical gyroscopes?

   (b) What aircraft state variables can be measured with a vertical (mechanical) gyroscope?

   (c) The two fundamental properties of mechanical gyroscopes are *rigidity* and *precession*. Describe, using a simple sketch, what these two properties mean.

   (d) Consider Figure 1, showing a view from above the North Pole towards the Earth, where a not-moving observer located at the Earth equator (point **A**) is looking at a vertical gyroscope. After six hours of waiting the observer is located at point **B**. Make a simple but clear sketch showing the gyroscope at point **B**. What has happened?

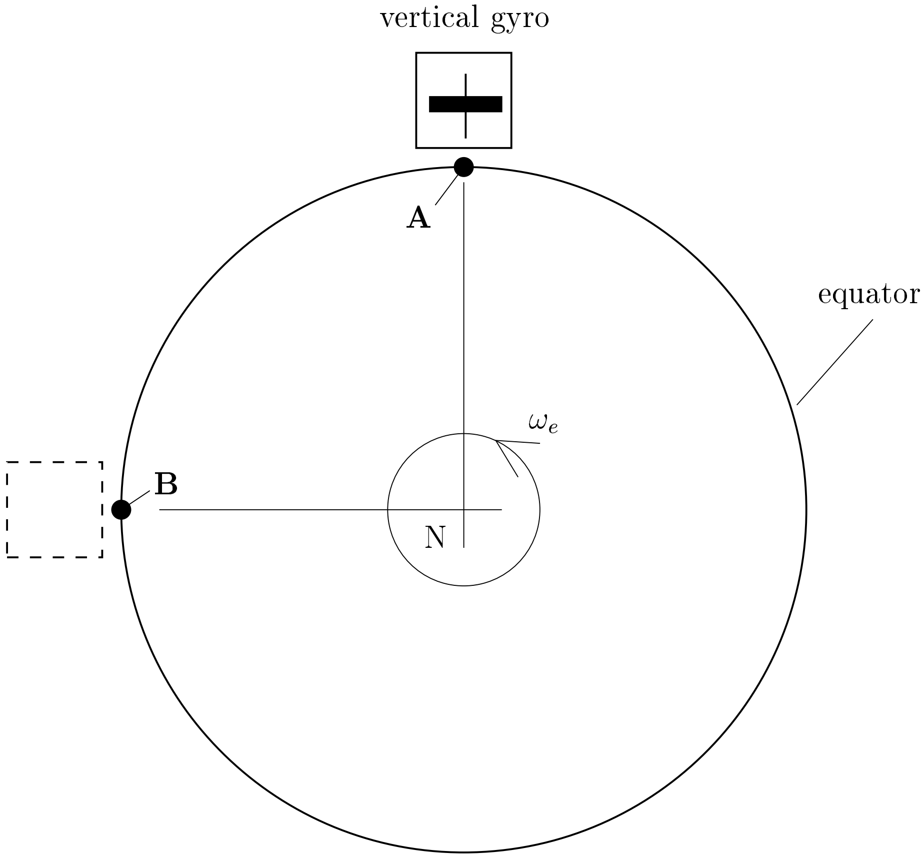

Figure 1: View to the Earth, looking from above the North Pole to the Earth's center. A vertical gyroscope is placed at the Earth equator at point **A**. ω_e is the Earth rotation velocity.

(e) In order to make a (mechanical) gyroscope useful for aircraft, it must be converted from what is called an *inertial machine* to an *Earth gyroscope*. What does this mean? And what are the two main corrections that have to be exerted on the gyroscope to make this possible?

(f) What are gyro *erection systems*? What are they used for?

3. (15 points) **SATELLITE RADIO NAVIGATION**

(a) Describe the basic principle of the Global Positioning System. How does the system work? How do we get an estimation of our position *and* velocity?

(b) What are the properties of the GPS navigation system in terms of accuracy, integrity, availability and continuity of service.

(c) Describe in detail the principle of Differential GPS (DGPS).

(d) 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*.

i. Why does it need to be augmented?

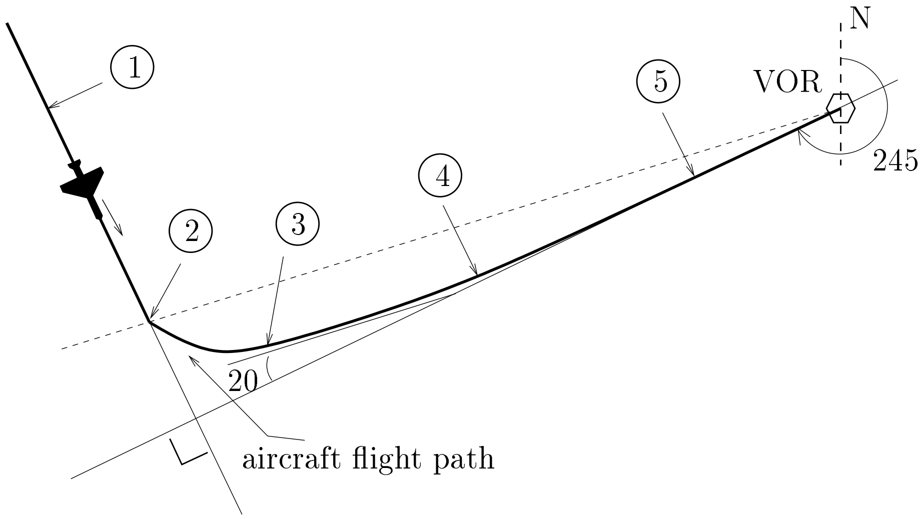

Figure 2: The aircraft flight path to the VOR beacon.

ii. Describe the three main forms of augmenting GPS.

4. (15 points) **AIRCRAFT INTEGRATED INSTRUMENTS**

(a) Describe the Attitude Director Indicator (ADI).

(b) Describe the Horizontal Situation Indicator (HSI). In a sketch, make clear how the HSI shows the aircraft position and heading with respect to a selected VOR radial.

(c) Modern commercial aircraft are equipped with a Flight Director. Describe the Flight Director system. In your answer, include the following:

- What does a Flight Director do?
- What information does it use and where does it obtain this information?
- On what display is the Flight Director information presented?
- What are the tasks of the pilot when using the Flight Director?

(d) Assume the pilot wants to fly to a VOR beacon, using the Flight Director. Further assume that there is *no wind*. Figure 2 shows the aircraft flight path, and the numbers 1 – 5 along the path depict five moments in time at which a photograph is made of the cockpit instrument panel, most importantly the ADI and the HSI, see for example Figure 3.

For all five moments in time, make a clear sketch of the photographs showing the ADI and HSI. **Describe all steps in detail**, i.e. what does the pilot do?, what does the Flight Director do?, how and why did the instruments change along the path? Start at phase 1. Assume that *just before* this phase, the pilot has selected the desired VOR radial.

5. (15 points) **COMMUNICATION, NAVIGATION, SURVEILLANCE**

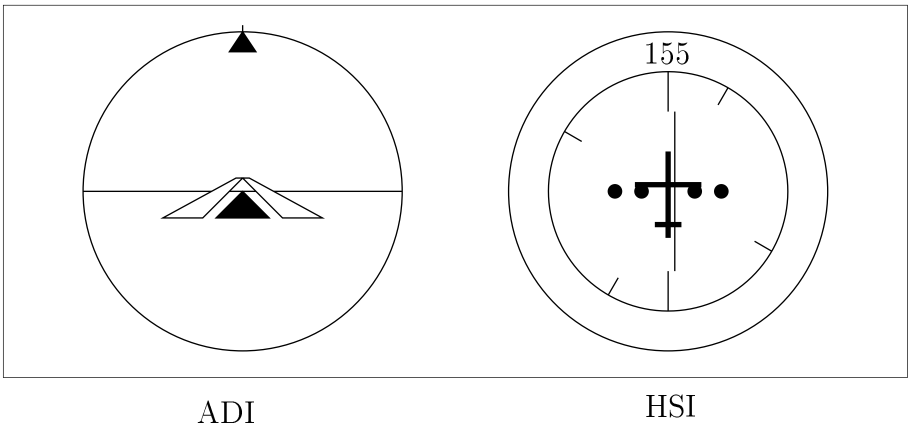

Figure 3: A photograph showing the ADI and the HSI display, *before* the aircraft flight towards the VOR beacon (i.e. before moment 1).

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

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

(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?

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

(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?

6. (15 points) **THE FUTURE AIR NAVIGATION SYSTEM**

(a) What are the main *technical* shortcomings of the current generation of CNS systems?

(b) Describe the future of Surveillance (the 'S' in CNS) in FANS. In your answer, include the roles of SSR Mode S, ADS and ACAS.

(c) What is ADS-broadcast?