DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	November 2, 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) **INERTIAL SENSORS: OPTICAL GYROSCOPES**

   (a) What are the main advantages of optical gyroscopes over their mechanical counterparts? (2 points)

   (b) In strapdown inertial navigation systems only optical gyroscopes are used. Why can't mechanical gyroscopes be used in this particular system, i.e. what particular property of optical gyroscopes makes them superior in this case? (2 points)

   (c) How many optical gyroscopes are used in strapdown inertial navigation systems? What do they measure? (2 points)

   (d) Describe, at the hand of a sketch, the way in which a Ring Laser Gyro (RLG) operates. What are the basic principles? (7 points)

   (e) What is the 'lock-in' effect and what is done to overcome it? (2 points)

2. (15 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?

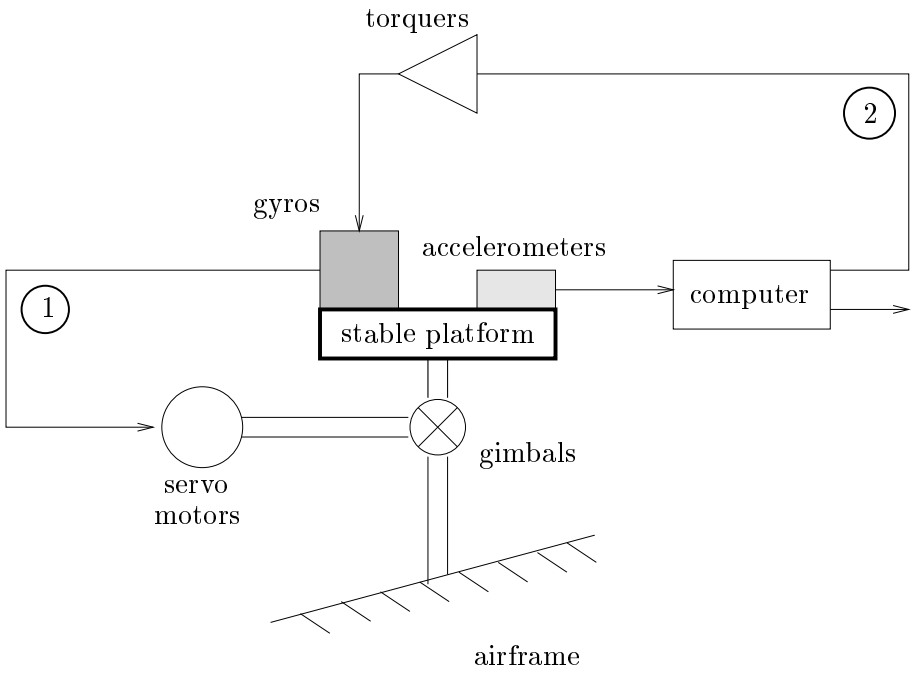

Figure 1: *A gimballed inertial navigation system platform. The circles with '1' and '2' indicate the two main INS feedback control loops.*

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

(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?

3. (15 points) **LANDING GUIDANCE SYSTEMS**

(a) What does ILS mean?

(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.

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

(d) Consider Figure 2, showing the localizer antenna. Using this figure, explain the various steps of how the ILS localizer signals are modulated. What signals are sent by the central antenna, the left antenna and the right antenna?

(e) Consider Figure 3, showing the localizer antenna of the previous question and an aircraft located in front of the antenna.

i. What signals are received when the aircraft is located at position A? Explain your answer.

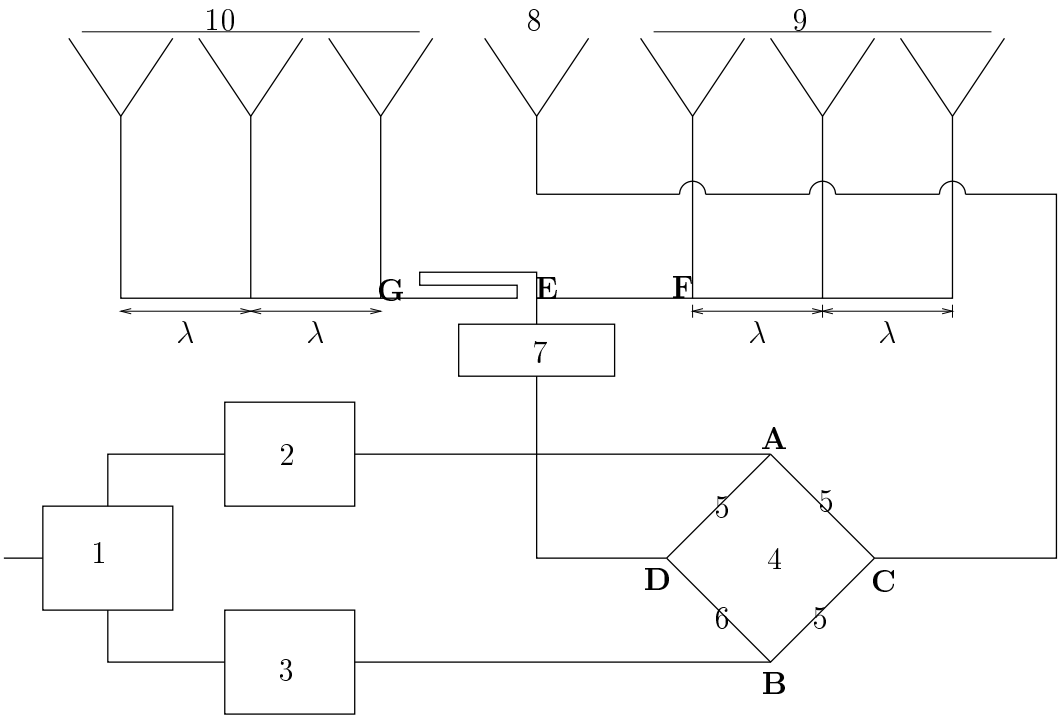

Figure 2: *The ILS localizer antenna. In this figure, the numbers indicate the following antenna components:* **1** *carrier wave generator,* **2** *90 Hz modulator,* **3** *150 Hz modulator,* **4** *antenna bridge,* **5** *length* $\frac{1}{4}\lambda$*,* **6** *length* $\frac{3}{4}\lambda$*,* **7** *90 degrees phase addition,* **8** *central antenna,* **9** *right antenna,* **10** *left antenna.*

ii. What signals are received when the aircraft is located at position B? Explain your answer.

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

4. (15 points) **SATELLITE RADIO NAVIGATION**

(a) Describe the *space* segment, the *user* segment and the *control* segment of the Global Positioning System. Which types of precision are provided by the GPS?

(b) Describe in detail the principle of determining the aircraft *position* using GPS. How many GPS satellites at least do we need? Explain your answer.

(c) Describe in detail the principle of determining the aircraft *velocity* using GPS. How many GPS satellites at least do we need? Explain your answer.

(d) GPS is often used together with the Inertial Navigation System (INS). Why is that, i.e. what benefits can be achieved with integrating the GPS and INS systems?

5. (15 points) **FLIGHT MANAGEMENT SYSTEM**

(a) Before the introduction of Flight Management Systems in the cockpit so-called Aircraft Operating Manuals (AOMs) were used. What is an AOM? And what were they used for?

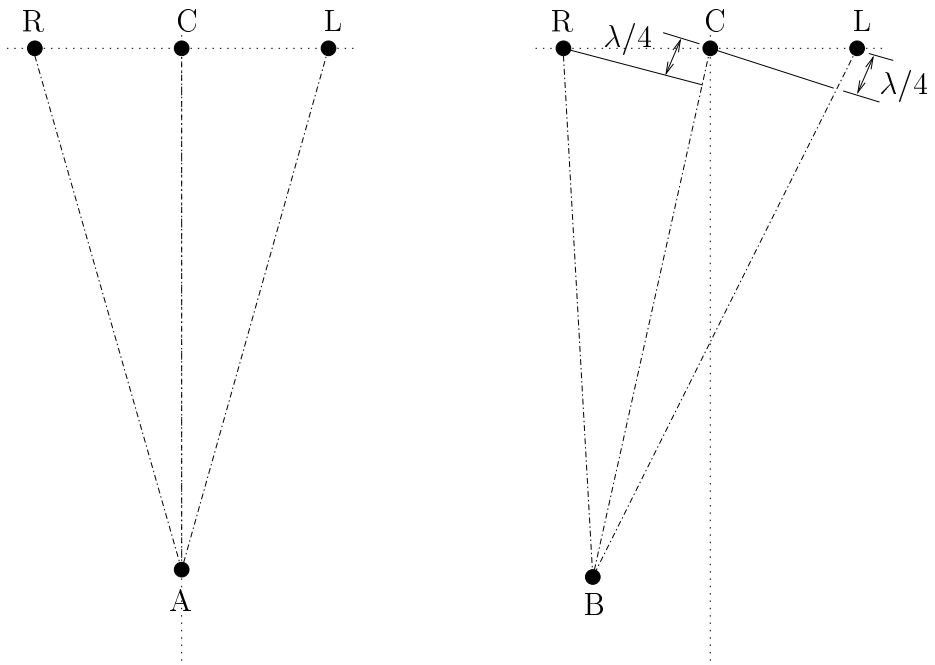

Figure 3: *Top view of the ILS localizer antenna. The aircraft can be located at either position A (left) or position B (right). Note: 'L', 'R' and 'C' indicate the positions of the left, right and central antenna, respectively.*

(b) Describe the main factors which have led to the development and introduction of the Flight Management System.

(c) Make a sketch of the main components of an FMS and, using this sketch, describe the function(s) of these components. How is the information from the FMS presented to the pilots? And through what device can pilots interact with the FMS?

(d) What are the three main tasks of an FMS?

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

(a) Describe the current generation of CNS (Communication, Navigation, Surveillance) services.

(b) What are the primary shortcomings of the current generation of CNS services?

(c) Describe the main upgrades of the current CNS services to allow the introduction of the Future Air Navigation System (FANS).