**Answers Avionics exam February 2006**

1. Avionics - general

   a) WAAS = Wide Area Augmentation System. Network of ground-based reference stations, designed to augment GPS: provides ground integrity broadcast (satellite status), wide area DGPS corrections improving accuracy, ranging function providing additional availability and reliability.

   b) HUD = Head Up Display. Vital in-flight data are presented at same level as pilot's line of sight when he looks outside the cockpit (head up position).

   c) LORAN = Long Range Navigation System. Utilizes chains of radio beacons on ground, composed of 1 master and at least 2 secondary stations (3 stations are req'd for fix). Receiver determines position, velocity from time difference between master and secondary station signal arrival times.

   d) ADS-B = Automatic Dependent Surveillance Broadcast: Surveillance technique using transponder in aircraft or surface vehicle. Broadcasting position, altitude, ID and other vital info for use by other aircraft/ vehicles/ground facilities.

   e) EFIS = Electronic Flight Instrument System: Instrument display system in cockpit, using LCD screens to present e.g. attitude and navigation data to pilot.

   f) STAR = Standard Terminal Arrival Route. Defines the route flown between ATS route (airway in CTA or UTA) and an approach fix (connects CTA through TMA with CTR). Controlled by APP.

   g) AMSS = Aeronautical Mobile Satellite Service. Includes provision of all aeronautical communications such as Air Traffic Services.

   h) FIR = Flight Information Region. Largest subdivision of airspace (e.g. FIR Amsterdam over NL) in which Flight Information Service and alerting service are provided.

   i) FMS = Flight Management System. Manages aircraft performance, provides guidance along optimal route, provides alternatives in case of changes

   j) CNS = Communication, Navigation, Surveillance. Provision of Air Traffic Services is based on availability of these CNS systems.

2. Surveillance systems: Radar
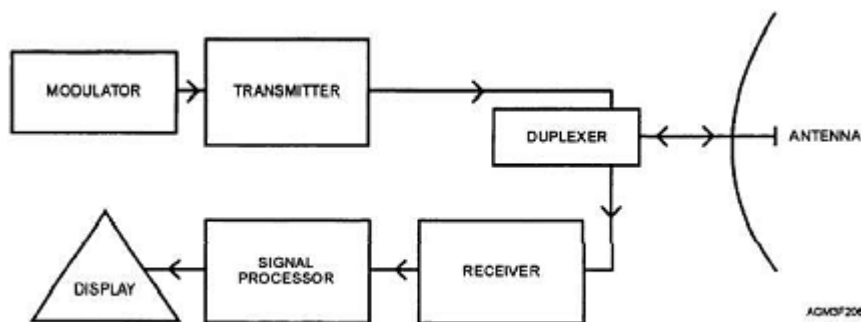
   a) Block diagram includes:
      - Modulator: tells transmitter when and how long to transmit
      - Transmitter: generates power
      - Antenna: concentrates radiated power into beam, pointing in desired direction and collect echo signal to deliver to receiver
      - Duplexer: connects transmitter to antenna during transmission of radiated pulse, connects receiver to antenna during time between radiated pulses
      - Receiver: amplifies weak echo signals picked up by antenna to a level sufficient to display them.

- Signal processor evaluates signal from receiver
- Visual display presents information contained in echo signal to an operator

b) Distance (slant range) and heading (relative to radar)

c) The larger the distance between the aircraft and the radar, the longer it takes for the reflected pulse to arrive back at the radar. If the radar rotates too quick, it will be pointing in a different direction by the time the pulse is back. So the faster it rotates, the smaller the range.

d) The radar doesn't transmit and receive at the same time, so the maximum range is determined by the time between two pulses (=1/PRF). Maximum range = $c/(2*PRF)$ where c is lightspeed =3e8 m/s

e) The minimum range is pulse length*c/2.

f) Minimum range = 4e-6*3e8/2=600 m =… nm. Maximum range = 3e8/(2*200) = 750 km. Within 1/200 seconds, the radar will have rotated by 36deg/s*1/200=0.18 deg so it is reasonable to assume it still points in the direction of the aircraft. So the rotational velocity is not a restriction wrt radar range.

g) Radar range is the ability to display multiple targets clearly and separately. Azimuthal resolution depends on beamwidth, if two aircraft are separated by less than a beamwidth, the radar is unable to separate the two and they will appear as one blur on the radar screen. Range resolution depends on pulse length: in-line targets must be separated by more than half a pulse length otherwise the return signals can't be separated. For instance in very crowded airspace, where Air Traffic Control is responsible for separating aircraft, they must be able to distinguish every aircraft to prevent collision. So all aircraft must maintain such a separation that they can be distinguished by the radar.

h) Height-finding radar. Target elevation is determined by a second antenna, pointed along the target azimuth, which scans in elevation.

3. ATC and ATM

a) ATC (Air Traffic Control): maintain a safe distance between aircraft and obstacles within a confined airspace and also on airport surface. ASM (Air Space Management): maximize, within a given airspace structure, the utilization of available airspace by dynamic time sharing and, at times, segregation of airspace among a competing categories of users based on short-term needs. ATFM (Air Traffic Flow Management): ensure an optimum flow of air traffic through areas during times when demands exceed (or is expected to exceed) the available capacity of the ATC service. ATFM and ASM assist ATC in meeting its objectives and achieving the most efficient utilization of available airspace and airport capacity while keeping delay cost to a minimum.

b) CTR = Control Zone: local ATC (TWR/tower) usually circular area around airport. TMA = Terminal Control Area: local ATC (APP/approach) incoming and outgoing flights between CTR and CTA (on SIDs and STARs). CTA = Control Area: general ATC (ACC/area control center) within FIR, below certain Flight Level (lower airspace). UTA = Upper Control Area: general ATC, across FIRs (upper airspace, e.g. Eurocontrol).

c) See b

d) STAR = Standard Terminal Arrival Route. Defines the route flown between ATS route (airway in CTA or UTA) and an approach fix (connects CTA through TMA with CTR). Controlled by APP. SID = Standard Instrument Departure: STAR = Defines the route flown between aircraft departure and an ATS route (connects CTR through TMA with CTA). Controlled by APP. Both are established for noise abatement, reduction of communication (between pilot and ATC), allows separation of incoming and outgoing traffic.

e) Coming from airway in CTA controlled by ACC (below certain FL) -> Aircraft begins STAR controlled by APP -> when on final approach in CTR, TWR takes over.

4. Landing Guidance Systems

   a) CAT I : DH>200 ft, RVR>=2600 ft. CAT II: DH>100 ft, RVR>=1200 ft, CAT III DH<100 ft, RVR<1200 ft.
   b) Based on Decision Height (DH), which is the height above the runway at which the landing must be aborted if the runway is still not in sight. Also the Runway Visual Range (RVR, visibility at runway surface) must have a certain minimum value.
   c) A basic MLS consists of azimuth (behind end of runway) and elevation (next to touchdown point on runway) ground stations, and a conventional DME.
   d) Azimuth and elevation angles are obtained by measuring the time-difference between two pulses (due to a TO and FRO scan beam) which are received if the narrow antenna pattern of the appropriate ground station passes the aircraft twice. This time difference can be directly related to the azimuth or elevation angle (by the MLS receiver in the cockpit?).
   e) MLS allows multiple approach paths while ILS has only one, with very limited azimuth and elevation range, MLS approach angles and range are much larger. MLS is insensitive to multipath effects, usable at any airport, larger number of channels.

5. Terrestrial Radio Navigation

   a) Up to 3 MHz (<HF), most of the energy follows Earth's curvature: ground waves. Up to 30 MHz (<VHF), most of the energy is reflected from the ionosphere: Sky waves. In areas where both ground and sky waves can be received, fading of the signal can occur due to phase differences: multipath effects. Line of sight waves follow a straight line, their range depends on transmitter and receiver height and the curvature of the Earth.
   b) VOR is a theta system, meaning that the Line of Position (LOP) of constant direction is a radial from the station. Two VOR stations are required to obtain a position fix. The station sends an omnidirectional signal using a limacon antenna with a cardioids pattern, which rotates at 30 rps. The VOR receiver on board interprets the changing amplitude of the signal due to this rotation as an Amplitude Modulation with a 30 Hz signal. Due to the cardioid rotation, the phase of the signal depends on the position of the aircraft wrt the VOR beacon. But the phase of the frequency modulated 30 Hz subcarrier hidden in the signal does not depend on the position of the aircraft. For instance, if the aircraft is at 0 deg MN, the signals are in phase, and if it is at 180 deg MN (south), the signals will be 180 deg out of phase. The on-board receiver uses this phase difference to determine on which of the 360 radials the aircraft is positioned wrt the beacon. The information is presented on a Radio Magnetic Indicator (RMI) or on a Horizontal Situation Indicator (HSI). By the way, the phase difference is independent of the aircrafts heading.
   c) Geometric Dilution of Precision, a measure for how large the area of uncertainty is where the aircraft can be positioned. GDOP is smallest when the aircraft is on two radials at right angles with each other.
   d) With a DME, so that you can obtain a position fix without the use of a second VOR station. The VOR delivers the direction wrt the station whereas the DME will give the (slant) range.

6. Inertial Navigation System