Learning Objectives 062 Radio Navigation

Syllabus reference	Syllabus details and associated Learning Objectives
060 00 00 00	**NAVIGATION**
062 00 00 00	**RADIO NAVIGATION**
062 01 00 00	**BASIC RADIO PROPAGATION THEORY**
062 01 01 00	**Basic principles**
062 01 01 01	**Electromagnetic waves**
LO	State that radio waves travel at the speed of light, being approximately 300 000 km/s or 162 000 NM/s.
062 01 01 02	**Frequency, wavelength, amplitude, phase angle**
LO	Define frequency. The number of cycles occurring in one second in a radio wave expressed in Hertz (Hz).
LO	Define wavelength. The physical distance travelled by a radio wave during one cycle of transmission.
LO	Define amplitude: The maximum deflection in an oscillation or wave.
LO	State that the relationship between wavelength and frequency is: wavelength (lambda) = $\frac{\text{speed of light (c)}}{\text{Frequency (f)}}$ or lambda (meters) = $\frac{300\ 000}{\text{kHz}}$
LO	Define phase: The fraction of one wavelength expressed in degrees from 000° to 360°.
LO	Define phase difference/shift: The angular difference between the corresponding points of two cycles of equal wavelength, which is measurable in degrees.
062 01 01 03	**Frequency bands, sidebands, single sideband**
LO	List the bands of the frequency spectrum for electromagnetic waves: - Very Low Frequency (VLF) 3 - 30 kHz - Low Frequency (LF) 30 - 300 kHz - Medium frequency (MF) 300 - 3000 kHz - High frequency (HF) 3 - 30 MHz - Very high frequency (VHF) 30 - 300 MHz - Ultra high frequency (UHF) 300 - 3000 MHz - Super high frequency (SHF) 3 - 30 GHz - Extremely high frequency (EHF) 30 - 300 GHz
062 01 01 04	**Pulse characteristics**
LO	Define the following terms as associated with a pulse string: - Pulse length - Pulse power - Continuous power
062 01 01 05	**Carrier, modulation**
LO	Define carrier wave: The radio wave acting as the carrier or transporter.
LO	Define modulation. The technical term for the process of impressing and transporting information by radio waves.
062 01 01 06	**Kinds of modulation (amplitude, frequency, pulse, phase)**
LO	Define amplitude modulation. The information is impressed onto the carrier wave by altering the amplitude of the carrier.
LO	Define frequency modulation. The information is impressed onto the carrier wave by altering the frequency of the carrier.

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LO	Describe pulse modulation. A modulation form used in radar, by transmitting short pulses followed by larger interruptions.
LO	Describe phase modulation. A modulation form used in GPS where the phase of the carrier wave is reversed.
062 01 02 00	**Antennas**
062 01 02 01	**Characteristics**
LO	Define antenna. A wave type transducer for the process of converting a line AC into a free electromagnetic wave.
LO	State that the simplest type of antenna is a dipole which is a wire of length equal to one half of the wavelength.
LO	State that in a wire which is fed with an AC (alternating current), some of the power will radiate into space.
LO	State that in a wire parallel to the wire fed with an AC but remote from it, an AC will be induced.
LO	State that an electromagnetic wave always consists of an oscillating electric (E) and an oscillating magnetic (H) field which propagates at the speed of light.
062 01 03 00	**Wave propagation**
062 01 03 01	**Structure of the ionosphere**
LO	State that the ionosphere is the ionized component of the Earth's upper atmosphere from 60 to 400 km above the surface, which is vertically structured in three regions or layers.
LO	State that the layers in the ionosphere are named D, E and F layers and their depth varies with time.
LO	State that electromagnetic waves refracted from the E and F layers of the ionosphere are called sky waves.
062 01 03 02	**Ground waves**
LO	Define ground or surface waves. The electromagnetic waves travelling along the surface of the earth.
062 01 03 03	**Space waves**
LO	Define space waves. The electromagnetic waves travelling through the air directly from the transmitter to the receiver.
062 01 03 04	**Propagation with the frequency bands**
LO	State that radio waves in VHF, UHF, SHF and EHF propagate as space waves.
LO	State that radio waves in VLF, LF, MF and HF propagate as surface/ground waves and sky waves.
062 01 03 05	**Doppler principle**
LO	State that Doppler effect is the phenomena that the frequency of an electromagnetic wave will increase or decrease if there is relative motion between the transmitter and the receiver.
LO	State that the frequency will increase if the transmitter and receiver are converging and will decrease if they are diverging.
062 01 03 06	**Factors affecting propagation**
LO	Define Skip Distance**.** The distance between the transmitter and the point on the surface of the earth where the first sky return arrives.
LO	State that skip zone/dead space is the distance between the limit of the surface wave and the sky wave.

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LO	Describe Fading. When a receiver picks up the sky signal and the surface signal, the signals will interfere with each other causing the signals to be cancelled out.
LO	State that radio waves in the VHF band and above are limited in range as they are not reflected by the ionosphere and do not have a surface wave.
LO	Describe the physical phenomena reflection, refraction, diffraction, absorption and interference.
062 02 00 00	**RADIO AIDS**
062 02 02 00	**NDB/ADF**
062 02 02 01	**Principles**
LO	Define the abbreviation NDB. Non Directional Beacon.
LO	Define the abbreviation ADF Automatic Direction Finder.
LO	State that the NDB is the ground part of the system.
LO	State that the ADF is the airborne part of the system.
LO	State that NDB operates in the LF and MF frequency bands.
LO	The frequency band assigned to aeronautical NDBs according to ICAO annex 10 is 190 – 1750 kHz.
LO	Define a locator beacon. An LF/MF NDB used as an aid to final approach usually with a range, according to ICAO annex 10, of 10-25 NM.
LO	Explain the difference between NDBs and locator beacons.
LO	Explain which beacons transmit signals suitable for use by an ADF.
LO	Describe the use of NDBs for navigation.
062 02 02 03	**Coverage and range**
LO	State that the range of an NDB over sea is better than over land due to better ground wave propagation over seawater than over land.
LO	Describe the propagation path of NDB radio waves with respect to the ionosphere and the Earth's surface.
LO	Explain that interference between sky and ground waves at night leads to "fading".
062 02 02 04	**Errors and accuracy**
LO	Define Quadrantal Error. Distortion of the incoming signal from the NDB station by re-radiation from the airframe. This is corrected for during installation of the antenna.
LO	Explain Coastal Refraction. As a radio wave travelling over land crosses the coast, the wave speeds up over water and the wave front bends.
LO	Define Night/twilight effect. The influence of sky waves and ground waves arriving at the ADF receiver with a difference of phase and polarisation which introduce bearing errors.
LO	State that interference from other NDB stations on the same frequency may occur at night due to sky wave contamination.
062 02 03 00	**VOR and Doppler-VOR**
062 02 03 01	**Principles**
LO	State that the frequency band allocated to VOR according to ICAO annex 10 is VHF and the frequencies used are 108.0 – 117.975 MHz.

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that the following types of VOR are in operation: - Conventional VOR (CVOR) a first generation VOR station emitting signals by means of a rotating antenna - Doppler VOR (DVOR) a second generation VOR station emitting signals by means of a combination of fixed antennas utilising the Doppler principle - En-route VOR for use by IFR traffic - Terminal VOR (TVOR) a station with a shorter range used as part of the approach and departure structure at major airports - Test VOR (VOT) a VOR station emitting a signal to test VOR indicators in an aircraft
LO	Describe how ATIS information is transmitted on VOR frequencies.
LO	List the three main components of VOR airborne equipment: - The antenna - The receiver - The indicator
LO	State that according to ICAO annex 10, a VOR station has an automatic ground monitoring system.
LO	State that the VOR monitoring system monitors change in measured radial and reduction in signal strength.
062 02 03 02	**Presentation and interpretation**
LO	State that when converting a radial into a true bearing, the variation at the VOR station has to be taken into account
062 02 03 03	**Coverage and Range**
LO	Describe the range with respect to the transmitting power and radio signal
062 02 03 04	**Errors and accuracy**
LO	State that DVOR is less sensitive to site error than CVOR.
062 02 04 00	**DME**
062 02 04 01	**Principles**
LO	State that DME operates in the UHF band between 960 – 1215 MHz according to ICAO annex 10-
LO	State that the system comprises two basic components: - The aircraft component, the interrogator - The ground component, the transponder
LO	Describe the principle of distance measurement using DME in terms of: - Pulse pairs - Fixed frequency division of 63 MHz - Propagation delay - 50 microsecond delay time - Irregular transmission sequence - Search mode - Tracking mode - Memory mode
LO	State that the distance measured by DME is slant range.
LO	Illustrate that a pos ition line using DME is a circle with the station at its centre.
LO	Explain that military TACAN stations may be used for DME information.
062 02 04 02	**Presentation and interpretation**

Syllabus reference	**Syllabus details and associated Learning Objectives**
LO	Calculate ground distance given slant range and altitude.
LO	State that a DME system may have a groundspeed read out combined with the DME read out.
062 02 04 03	**Coverage and Range**
LO	Explain why a ground station can generally respond to a maximum of 100 aircraft.
062 02 05 00	**ILS**
062 02 05 01	**Principles**
LO	Name the three main components of an ILS: - The localiser (LLZ) - The glide path (GP) - Range information (markers or DME)
LO	State the site locations of the ILS components: - The localiser antenna should be located on the extension of the runway centre line at the stop-end - The glidepath antenna should be located 300 metres beyond the runway threshold, laterally displaced approximately 120 metres to the side of the runway centre line
LO	Explain that marker beacons produce radiation patterns to indicate predetermined distances from the threshold along the ILS glide path.
LO	Explain that marker beacons are sometimes replaced by a DME paired with the LLZ frequency.
LO	State that in the ILS frequency assigned band 108.0 – 111.975 MHz, only frequencies with the first decimal odd are ILS frequencies.
LO	State that the LLZ operates in the VHF band 108.0 – 111.975 MHz according to ICAO annex 10.
LO	State that the GP operates in the UHF band.
LO	Explain that the back beam from the LLZ antenna may be used as a published “non-precision approach”.
LO	State that according to ICAO annex 10 the nominal glide path is 3°.
062 02 05 02	**Presentation and interpretation**
LO	State that in accordance with ICAO annex 10 an ILS installation has an automatic ground monitoring system.
062 02 05 03	**Coverage and Range**
LO	Sketch the standard coverage area of the LLZ and GP with angular sector limits in degrees and distance limits from the transmitter in accordance with ICAO annex 10: - LLZ coverage area is 10° on either side of the centre line to a distance of 25 NM from the runway, and 35° on either side of the centre line to a distance of 17 NM from the runway - GP coverage area is 8° on either side of the centre line to a distance of minimum 10 NM from the runway
062 02 05 04	**Errors and accuracy**
LO	Explain that ILS approaches are divided into facility performance categories defined in ICAO annex 10

Syllabus reference	Syllabus details and associated Learning Objectives
LO	Define the following ILS operation categories: - Category I - Category II - Category IIIA - Category IIIB - Category IIIC
LO	Explain that all category III ILS operations guidance information is provided from the coverage limits of the facility to, and along, the surface of the runway.
LO	Explain why the accuracy requirements are progressively higher for CAT I, CAT II and CAT III ILS.
LO	State the vertical accuracy requirements above the threshold for CAT I, II and III for the signals of the ILS ground installation.
062 02 05 05	**Factors affecting range and accuracy**
LO	Define the ILS critical Area. An area of defined dimensions about the LLZ and GP antennas where vehicles, including aircraft, are excluded during all ILS operations.
LO	Define the ILS sensitive area. An area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations.
LO	Describe the effect of FM broadcast stations that transmit on frequencies just below 108 MHz.
062 03 00 00	**RADAR**
062 03 01 00	**Pulse techniques and associated terms**
LO	Name the different applications of radar with respect to ATC, MET observations and airborne weather radar.
LO	Describe the pulse technique and echo principle on which primary radar systems are based.
LO	Explain the need to harmonise the rotation speed of the antenna, the pulse length and the pulse repetition frequency for range.
062 03 02 00	**Ground Radar**
062 03 02 01	**Principles**
LO	Explain that primary radar provides bearing and distance of targets.
LO	Explain that primary ground radar is used to detect aircraft that are not equipped with a secondary radar transponder.
LO	Explain why Moving Target Indicator (MTI) is used
062 03 02 02	**Presentation and interpretation**
LO	State that modern ATC systems use computer generated display.
LO	Explain that the radar display enables the ATS controller to provide information, surveillance or guidance service.
062 03 03 00	**Airborne Weather Radar**
062 03 03 01	**Principles**
LO	List the two main tasks of the weather radar in respect of weather and navigation.
062 03 04 00	**Secondary Surveillance Radar and transponder**
062 03 04 01	**Principles**
LO	Explain that the Air Traffic Control (ATC) system is based on the replies provided by the airborne transponders in response to interrogations from the ATC secondary radar

Syllabus reference	Syllabus details and associated Learning Objectives
LO	Explain that the ground ATC secondary radar uses techniques which provide the ATC with information that cannot be acquired by primary radar
LO	Explain that an airborne transponder provides coded reply signals in response to interrogation signals from the ground secondary radar and from aircraft equipped with TCAS.
LO	Explain the advantages of SSR over a primary radar.
062 03 04 02	**Modes and codes**
LO	Explain that the interrogator transmits its interrogations in the form of a series of pulses.
LO	Name and explain the Interrogation modes: 1. Mode A and C 2. Intermode: Mode A/C/S all call Mode A/C only all call 3. Mode S: Mode S only all call Broadcast (no reply elicited) Selective
LO	Explain that the decoding of the time between the interrogation pulses determines the operating mode of the transponder: - Mode A: transmission of aircraft transponder code - Mode C: transmission of aircraft pressure altitude - Mode S: aircraft selection and transmission of flight data for the ground surveillance
LO	Explain that the Mode S transponders receive interrogations from other Mode S transponders and SSR ground stations.
LO	State that Mode S surveillance protocols implicitly use the principle of selective addressing.
LO	Explain that every aircraft will have been allocated an ICAO Aircraft Address which is hard coded into the airframe (Mode S address).
LO	Interpret the following mode S terms: - Selective addressing - Mode “all call - Selective call
LO	State that Mode S interrogation contains either: - Aircraft address - All–call address - Broadcast address
062 03 04 03	**Presentation and interpretation**
LO	Explain how an aircraft can be identified by a unique code.
LO	Name and interpret the codes 7700, 7600 and 7500.
	ELEMENTARY SURVEILLANCE
LO	Explain that the elementary surveillance provides the ATC controller with aircraft position, altitude and identification.
LO	State that the elementary surveillance needs MODE S transponders with surveillance identifier (SI) code capacity and the automatic reporting of aircraft identification, known as ICAO level 2s.
LO	State that the SI code must correspond to the aircraft identification specified in item 7 of the ICAO flight plan or to the registration marking.

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that only the ICAO identification format is compatible with the ATS ground system.
LO	State that Mode S equipped aircraft with a maximum mass in excess of 5700 kg or a maximum cruising true airspeed capability in excess of 250 kt must operate with transponder antenna diversity.
	ENHANCED SURVEILLANCE
LO	State that the enhanced surveillance consists of the extraction of additional aircraft parameters known as Downlink Aircraft Parameters (DAP) consisting of: - Magnetic Heading - Indicated Airspeed - Mach Number - Vertical rate - Roll angle - Track Angle Rate - True Track Angle - Groundspeed - Selected Altitude
LO	Explain that the controller's information is improved by providing actual aircraft derived data such as Magnetic Heading, Indicated Airspeed, Vertical Rate and Selected Altitude.
LO	Explain that the automatic extraction of an aircraft's parameters, and their presentation to the controller, will reduce their R/T workload and will free them to concentrate on ensuring the safe and efficient passage of air traffic.
LO	Explain that the reduction in radio telephony between the air traffic controllers and the pilots will reduce the workload on a pilot and remove a potential source of error.
062 03 04 04	**Errors and Accuracy**
LO	Explain the following disadvantages of SSR (mode A/C): - Code garbling of aircraft less than 1.7 NM apart measured in the vertical plane perpendicular to and from the antenna - "Fruiting" which results from reception of replies caused by interrogations from other radar stations
062 04 00 00	**INTENTIONALLY LEFT BLANK**
062 05 00 00	**AREA NAVIGATION SYSTEMS, RNAV/FMS**
062 05 01 00	**General philosophy and definitions**
062 05 01 01	**Basic RNAV (B-RNAV)/precision RNAV (P -RNAV)/ RNP-PNAV**
LO	Define area navigation RNAV (ICAO annex 11). A method of navigation permitting aircraft operations on any desired track within the coverage of station-referenced navigation signal, or within the limits of a self-contained navigation system.
LO	State that basic RNAV (B -RNAV) systems require RNP 5.
LO	State that precision RNAV (PRNAV) systems require RNP 1.
062 05 01 02	**Principles of 2D RNAV, 3D RNAV and 4D RNAV**
LO	State that a 2D RNAV system is able to navigate in the horizontal plane only.
LO	State that a 3D RNAV system is able to navigate in the horizontal plane and in addition has a guidance capability in the vertical plane.
LO	State that a 4D RNAV system is able to navigate in the horizontal plane, has a guidance capability in the vertical plane and in addition has a timing function.

Syllabus reference	Syllabus details and associated Learning Objectives
062 05 01 03	**Required Navigation Performance (RNP) in accordance with ICAO DOC 9613**
LO	State that RNP is a concept that applies to navigation performance within an airspace.
LO	The RNP type is based on the navigation performance accuracy to be achieved within the airspace.
LO	State that RNP X requires a navigation performance accuracy ofX NM both lateral and longitudinal 95% of the flying time. (RNP 1 requires a navigation performance of 1 NM both lateral and longitudinal 95% of the flying time).
LO	State that RNAV equipment is one requirement, in order to receive approval to operate in a RNP environment.
LO	State that RNAV equipment operates by automatically determining the aircraft position.
LO	State the advantages of using RNAV techniques over more conventional forms of navigation: - Establishment of more direct routes permitting a reduction in flight distance - Establishment of dual or parallel routes to accommodate a greater flow of en-route traffic - Establishment of bypass routes for aircraft over flying high-density terminal areas - Establishment of alternatives or contingency routes on either a planned or ad hoc basis - Establishment of optimum locations for holding patterns - Reduction in the number of ground navigation facilities
LO	State that RNP may be specified for a route, a number of routes, an area, volume of airspace or any airspace of defined dimensions.
LO	State that airborne navigation equipment uses inputs from navigational systems such as VOR/DME, DME/DME, GNSS, INS and IRS.
LO	State that aircraft equipped to operate to RNP 1 and better, should be able to compute an estimate of its position error, depending on the sensors being used and time elapsed.
LO	Indicate navigation equipment failure.
062 05 02 00	**Simple 2D RNAV**
	Info: First generation of radio navigation systems allowing the flight crew to select a phantom waypoint on the RNAV panel and select a desired track to fly inbound to the waypoint.
062 05 02 03	**Navigation computer input/output**
LO	State that the system is limited to operate within range of selected VOR/DME station.
062 05 03 00	**4D RNAV**
	Info: *The next generation of area navigation equipment allowed the flight crew to navigate on any desired track within coverage of VOR/DME stations.*
062 05 03 02	**Navigation computer, VOR/DME navigation**
LO	State that the navigational database is valid for a limited time, usually 28 days.
LO	State that the navigational database is read only, but additional space exists so that crew created navigational data may be saved in the computer memory. Such additional data will also be deleted at the 28 days navigational update of the database.

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that the computer receives a TAS input from the air data computer, and a heading input in order to calculate actual wind velocity.
LO	State that the computer calculates track error in relation to desired track. This data can easily be interfaced with the automatic flight control, and when done so enables the aircraft to automatically follow the flight plan loaded into the RNAV computer.
LO	State that the computer is able to perform great circle navigation when receiving VOR/DME stations. If out of range, the system reverts to DR (dead reckoning) mode, where it updates the position by means of last computed wind and TAS and heading information. Operation in DR mode is time limited.
LO	State that the system has ”direct to” capability to any waypoint.
LO	State that the system is capable of parallel off-set tracking.
LO	State that any waypoint can be inserted into the computer in one of the following ways: - Alphanumeric ICAO identifier - Latitude and longitude - Radial and distance from a VOR station
062 05 04 00	**FMS and general terms**
062 05 04 01	**Navigation and flight management**
LO	Explain that development of computers combined with reliable liquid crystal displays, offer the means of accessing more data and displaying them to the flight crew.
LO	Explain that a flight management system has the ability to monitor and direct both navigation and performance of the flight.
LO	Explain the two functions common to all FMS systems: - Automatic navigation LNAV (lateral navigation) - Flight path management VNAV (vertical navigation)
LO	Name the main components of the FMS system as being: - FMC (flight management computer) - CDU (control and display unit) - Symbol generator - EFIS (electronic flight instrument system) consisting of the nav display including mode selector and the attitude display. - A/T (auto throttle) and the FCC (flight control computer)
062 05 04 02	**Flight management computer**
LO	State that the centre of the flight management system is the FMC with its stored navigation and performance data.
062 05 04 03	**Navigation data base**
LO	State that the navigation database of the FMC may contain the following data: - Reference data for airports (four letter ICAO identifier) - VOR/DME station data (three letter ICAO identifier) - Waypoint data (five letter ICAO identifier) - STAR data - SID data - Holding patterns - Airport runway data - NDB stations (alphabetic ICAO identifier) - Company flight plan routes
LO	State that the navigation database is updated every 28 days.

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that the navigational database is write protected, but additional space exists so that crew created navigational data may be saved in the computer memory. Such additional data will also be deleted at the 28 days navigational update of the database.
062 05 04 04	**Performance data base**
LO	State that the performance database stores all the data relating to the specific aircraft/engine configuration, and is updated by ground staff when necessary.
LO	State that the performance database of the FMC contain the following data: - V1, VR and V2 speeds - Aircraft drag - Engine thrust characteristics - Maximum and optimum operating altitudes - Speeds for maximum and optimum climb - Speeds for long range cruise, max endurance and holding - Maximum ZFM (zero fuel mass), maximum TOM (take-off mass) and maximum LM (landing mass) - Fuel flow parameters - Aircraft flight envelope
062 05 04 05	**Typical input/output data from the FMC**
LO	State the following are typical **input** data to the FMC: - Time - Fuel flow - Total fuel - TAS, altitude, vertical speed, Mach number and outside air temperature from the air data computer (ADC) - DME and radial information from the VHF NAV receivers - Air/ground position - Flap/slat position - IRS and GPS positions - CDU (control and display unit) entries
LO	State that the following are typical **output** data from the FMC: - Command signals to the flight directors and autopilot - Command signals to the auto-throttle - Information to the EFIS displays through the symbol generator - Data to the CDU and various annunciators
062 05 04 06	**Determination of the FMS-position of the aircraft**
LO	State that modern FMS may use a range of sensors for calculating the position of the aircraft including VOR, DME, GPS, IRS and ILS.
062 05 05 00	**Typical flight deck equipment fitted on FMS aircraft**
062 05 05 01	**Control and display unit (CDU)**
LO	State that the communication link between the flight crew and the FMC is the CDU.
062 06 00 00	**GLOBAL NAVIGATION SATELLITE SYSTEMS**
062 06 01 00	**GPS/GLONASS/GALILEO**
062 06 01 01	**Principles**

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that there are two main Global Navigation Satellite Systems (GNSS) currently in existence with a third which is planned to be fully operational by 2011. They are: - USA NAVSTAR GPS (**NAV**igation **S**ystem with **T**iming **A**nd **R**anging **G**lobal **P**ositioning **S**ystem - Russian GLONASS (**GLO**bal **NA**vigation **S**atellite **S**ystem) - European GAL**I**LEO
LO	State that all 3 systems (will) consist of a constellation of satellites which can be used by a suitably equipped receiver to determine position
062 06 01 02	**Operation**
	NAVSTAR GPS
LO	Name the three segments as: - Space segment - Control segment - User segment
	Space segment
LO	State that the space segment consists of a notional constellation of 24 operational satellites.
LO	State that the navigation message contains: - Almanac data - Ephemeris - Satellite clock correction parameters - UTC parameters - **I**onospheric model - Satellite health data
LO	State that it takes 12.5 minutes for a GPS receiver to receive all the data frames in the navigation message.
LO	State that the almanac contains the orbital data about all the satellites in the GPS constellation.
LO	State that the ephemeris contains data used to correct the orbital data of the satellites due to small disturbances.
LO	State that the clock correction parameters are data for correction of the satellite time.
LO	State that UTC parameters are factors determining the difference between GPS time and UTC.
LO	State that an ionospheric model is currently used to calculate the time delay of the signal travelling through the ionosphere.
LO	State that the GPS health message is used to exclude unhealthy satellites from the position solution. Satellite health is determined by the validity of the navigation data.
LO	State that GPS uses the WGS 84 model.
LO	State that satellites are equipped with atomic clocks, which allow the system to keep very accurate time reference.
	Control Segment
LO	State that the control segment comprises: - A master control station - Ground antenna - Monitoring stations

Syllabus reference	Syllabus details and associated Learning Objectives
LO	State that the master control station is responsible for all aspects of the constellation command and control
LO	State that the main tasks of the control segment are: - Managing SPS performance - Navigation data upload - Monitoring satellites
	User Segment
LO	State that GPS supplies three-dimensional position fixes and speed data, plus a precise time reference.
LO	State that the GPS receiver used in aviation is a multi-channel type.
LO	State that a GPS receiver is able to determine the distance to a satellite, by determining the difference between the time of transmission by satellite and the time of reception.
LO	State that the initial distance calculated to the satellites is called pseudo range because the difference between the GPS receiver and the satellite time references initially creates an erroneous range.
LO	State that each range defines a sphere with its centre at the satellite.
LO	State that three satellites are needed to determine a two-dimensional position.
LO	State that four spheres are needed to calculate a three dimensional position, hence four satellites are required.
LO	State that the GPS receiver is able to synchronise to the correct time base when receiving four satellites.
LO	State that the receiver is able to calculate aircraft groundspeed using the SV Doppler frequency shift and /or the change in receiver position over time.
	NAVSTAR GPS Integrity
LO	Define RAIM (Receiver Autonomous Integrity Monitoring). A technique whereby a receiver processor determines the integrity of the navigation signals.
062 06 01 03	**Errors and Factors affecting accuracy**
LO	List the most significant factors affecting accuracy: - Ionospheric propagation delay - Dilution of position - Satellite clock error - Satellite orbital variations - Multipath
LO	State that ionospheric delay is the most significant error
LO	State that errors in the satellite orbits are due to: - Solar wind - Gravitation of the sun, moon and planets
LO	State that Multipath is when the signal arrives at the receiver via more than one path (the signal being reflected from surfaces near the receiver).
062 06 02 00	**Ground , Satellite and Airborne based augmentation systems**
	Ground based augmentation systems
LO	Explain the principle of a GBAS : to measure on ground the signal errors transmitted by GNSS satellites and relay the measured errors to the user for correction
LO	State that for a GBAS station the coverage is about 30 km

Syllabus reference	Syllabus details and associated Learning Objectives
LO	Explain that ICAO standards provide the possibility to interconnect GBAS stations to form a network broadcasting large-scale differential corrections. Such a system is identified as GRAS , (Ground Regional Augmentation System)
LO	Explain that GBAS ground subsystems provide two services: the precision approach service and the GBAS positioning service The precision approach service provides deviation guidance for Final Approach Segments, while the GBAS positioning service provides horizontal position information to support RNAV operations in terminal areas.
LO	State that GBAS based on GPS is sometimes called LAAS : Local Area Augmentation System
	Satellite Based Augmentation Systems (SBAS)
LO	Explain the principle of a SBAS : to measure on the ground the signal errors transmitted by GNSS satellites and transmit differential corrections and integrity messages for navigation satellites
LO	Explain that the use of geostationary satellites enables messages to be broadcast over very wide areas
LO	Explain that SBAS station network measures the pseudo-range between the ranging source and an SBAS receiver at the known locations and provides separate corrections for ranging source ephemeris errors, clock errors and ionospheric errors. The user applies corrections for tropospheric delay.
LO	Explain that SBAS can provide approach and landing operations with Vertical guidance (APV) and precision approach service.
	EGNOS
LO	Stat e that (EGNOS) European Geostationary Navigation Overlay Service consists of 3 geostationary Inmarsat satellites which broadcast GPS look - alike signals.
LO	State that EGNOS is designed to improve accuracy to 1 - 2 m horizontally and 3 - 5 m vertically.
	Airborne Based Augmentation Systems (ABAS)
LO	Explain the principle of ABAS : to use redundant elements within the GPS constellation (e g. multiplicity of distance measurements to various satellites) or the combination of GNSS measurements with those of other navigation sensors (such as inertial systems), to develop integrity control.
LO	Explain that unlike GBAS and SBAS, ABAS does not improve positioning accuracy.