062

RADIO NAVIGATION

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
062 00 00 00	**RADIO NAVIGATION**	
062 01 00 00	**RADIO AIDS**	
062 01 01 00	**Ground Direction Finder D/F (including classification of bearings)**	
	– Principles	
	– Describe the role of a Ground Direction Finder	
	– Explain why the services provided are subdivided as	
	– VHF direction finding	
	– UHF direction finding	
	– Describe, in general terms, the propagation path of VHF/UHF signals with respect to the ionosphere and the Earth's surface.	
	– Describe the principle of operation of the VDF in the following general terms	
	– radio waves emitted by the radio telephony (R/T) equipment of the aircraft	
	– directional antenna	
	– determination of direction of incidence of the incoming signal	
	– Indicator	
	– Recognise the Adcock antenna with its vertical dipoles	
	– Presentation and Interpretation	
	– Describe the common types of bearing presentations on VDU and radar display	
	– Define the terms QDM; QDR; QTE;	
	– Explain how, using more than one ground DF station, the position of an aircraft can be determined and transmitted to the pilot.	

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	– Coverage and Range
	  – Calculate the line of sight range (quasi optical visual range)
	– Errors and Accuracy
	– Factors affecting Range and Accuracy
	  – Explain that the range is affected by gradients of temperature and humidity
	  – Differentiate between the phenomena ‘super refraction’ and ‘sub refraction’
	  – Explain how intervening terrain can restrict the range
	  – Explain why synchronous transmissions will cause errors
	  – Describe the effect of multipath signals	

062 01 02 00	**ADF (incl. NDB’s and Use of RMI)**
	– Principles
	  – Name the approved frequency band assigned to aeronautical NDB's (190 - 1750 kHz)
	  – Recognise typical antenna arrangements for ground station (NDB) and aircraft (ADF)
	  – Explain the difference between NDB and locator beacons
	  – State which beacons transmit input signals suitable for use by the ADF
	  – Define the abbreviation ‘NDB’
	  – Describe the use of NDBs for navigation
	  – Describe the use of locator beacons
	– Interpret the term 'cone of silence' in respect of a NDB.
	  – State that the transmission power limits the ranges for locators, en-route NDBs and oceanic NDBs.
	  – Explain why it is necessary to use a directionally sensitive receiver antenna system in order to	

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	obtain the direction of the incoming radio wave – Presentation and interpretation – Name the types of indicator in common use and state the indications given on the : – radio magnetic indicator – fixed card indicator/ radio compass – Describe and sketch the presentation on the following ADF indicators: – radio magnetic indicator (RMI) and – fixed card indicator/ radio compass – Describe the procedure for obtaining an ADF bearing including the following : – switch on instrument (on ADF), – scan frequency, – regulate volume, – receive and identify the NDB, – read bearing. – State the function of the BFO (tone generator) switch. – Calculate the compass bearing from compass heading and relative bearing. – Convert compass bearing into magnetic bearing and true bearing. – Describe how to fly the following in-flight ADF procedures (in accordance with DOC 8168 Vol.I) : – homing – tracking – interceptions	

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	– procedure turns – holding patterns – Coverage and range – Describe the influence of the transmission power on the range. – Differentiate between NDB range over land and over the sea – Identify the ranges of locators, en-route NDB's and Oceanic NDB's – Describe the propagation path of NDB radio waves with respect to the ionosphere and the Earth's surface – Errors and Accuracy – Define quadrantal error and identify its cause – State that compensation for this error is effected during the installation of the antenna. – Explain the cause of the dip error due to the bank angle of the aeroplane – Define the bearing accuracy as ± 6° – Factors affecting range and accuracy – Indicate the causes and/or effects of the following factors – multipath propagation of the radio wave (mountain effect) – the influence of skywaves (night effect) – the shore line (coastal refraction) effect – atmospheric disturbances (static and lightning) – interference from other beacons.	
062 01 03 00	**CVOR and DVOR (incl. use of RMI)**	

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	– Principles
	  – Name the frequency-band and frequencies used for VOR
	  – Interpret the tasks of the following types of VOR:
	    – En-route VOR
	    – conventional VOR (CVOR)
	    – Doppler VOR (DVOR)
	    – Terminal VOR (TVOR)
	    – Test VOR (VOT)
	  – Define a VOR radial
	  – Recognise antenna arrangements for ground facilities and for aircraft
	  – Explain the principle of operation of the VOR using the following general terms:
	    – reference phase
	    – variable phase
	    – phase difference
	  – Explain the use of the Doppler effect in a Doppler VOR
	  – Describe the identification of a VOR in terms of morse-code letters, continuous tone or dots(VOT), tone pitch, repetition rate and additional plain text
	  – Describe how ATIS information is transmitted via VOR frequencies
	  – Name the three main components of VOR airborne equipment
	  – Identify a VOR from the chart by chart symbol and/or frequency
	– Presentation and Interpretation	

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	– Read off the radial from the Radio Magnetic Indicator (RMI)
	– Read off the angular displacement, in relation to a pre-selected radial, from the HSI or CDI
	– Explain the use of the TO/FROM indicator to determine the aircraft position relative to the VOR considering also the heading of the aircraft
	– Interpret given VOR information as displayed on HSI, CDI and RMI.
	– Describe the following in-flight VOR procedures (in accordance with DOC 8168 Vol. 1) :
	  – homing
	  – tracking
	  – interceptions
	  – procedure turns
	  – holding patterns
	– Enter a radial on a navigation chart, taking into account the variation at the transmitter location
	– Coverage and Range
	  – Describe the range with respect to the transmitting power and the quasi-optical range in NM
	  – Calculate the range in NM
	  – Explain the sector limitations in respect of topography-related reflections
	– Errors and Accuracy
	  – Describe the use of a test VOR for checking VOR indicators in an aircraft
	  – Describe the signals emitted by the test VOR with respect to reference phase, variable phase and transmitted radial.
	  – Identify the permissible signal tolerance	

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	– State the 95% accuracy of the VOR bearing information is within ± 5°	
	– Factors affecting Range and Accuracy	
	– Explain why the Doppler VOR is more accurate than the conventional VOR	
	– Illustrate the effects of bending and scalloping of radials.	
062 01 04 00	**DME (distance measuring equipment)**	
	– Principles	
	– Identify the frequency band	
	– Illustrate the use of X and Y channels in military applications.	
	– Describe the tuning of the DME frequency by the pilot	
	– Describe the navigation value of the slant range measured by the DME	
	– Illustrate the circular line of position with the transmitter as its centre	
	– Describe, in the case of co-location, the frequency pairing and identification procedure	
	– Explain the function of the DME used in conjunction with the instrument approach systems (ILS)	
	– Recognise DME antennas on aircraft and on the ground	
	– Identify a DME station on a chart by the chart symbol	
	– Describe how the pairing of VHF and UHF frequencies (e.g. VOR/DME) enables selection of two items of navigation information (distance and direction, rho-theta) with one frequency setting	
	– Explain the combination of transmitter/receiver in the aeroplane (interrogator) and on the ground (transponder)	
	– Explain why airborne and ground equipment use different frequencies	
	– Describe the principle of distance determination using DME in terms of:	

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	– pair of pulses; – fixed frequency division of 63 MHz, – the propagation delay and – the 50 microseconds delay time – irregular transmission sequence – search mode – tracking mode – Explain how the combination of a DME distance with a VOR radial allows the aircraft's position to be determined – Presentation and Interpretation – Describe the identification (time sequence and frequencies) in the case of co-location with a VOR. – Interpret the direct distance (slant range) which is displayed in nautical miles. – Explain why DME indicators display distances up to a maximum of approx. 300 NM. – Calculate the slant range correction – Describe the use of DME to fly a DME arc (in accordance with Doc 8168 Vol. I). – Coverage and Range – Explain why a ground station can generally respond to a maximum of 100 aircraft. Identify which aircraft will be denied first, when more than the maximum number of interrogations is made. – Illustrate how the DME transponder processes more than 2700 interrogations in the DME's reception area. State how this affects the strongest signals and the closest aircraft units. – Describe how the range is related to the transmitter power and the quasi-optical range in NM. – Calculate the range in NM	

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	– Errors and Accuracy	
	– Interpret the 95% accuracy as stated in ICAO annex 10	According to ICAO Annex 10 Vol. I par 3.5.3
	– Factors affecting Range and Accuracy	
	– Interpret the relationship between the number of users, the gain of the receiver and the range.	
	– State the maximum number of aircraft that can be handled by a DME transponder. Explain what limits this value.	
	– Illustrate the effect of bank angle hiding the antenna from the transponder on the surface, taking into consideration the time limits of the memory circuit.	
	– Explain the role of the Echo Protection Circuit in respect of reflections from the earth's surface, buildings or mountainous terrain	
062 01 05 00	**<u>ILS (instrument landing system)</u>**	
	– Principles	
	– State the site locations of the ILS components in distances along the centreline of the runway	
	– Name the three main components of an ILS	
	– Explain why and how the three different markers are used in the ILS to determine the distance to the ILS touchdown point of the runway	
	– State the nominal glide path angle. Explain the reason why a marker beacon is sometimes replaced by be a DME paired with the LLZ frequency	
	– Compare the glide path indicated by approach light systems like PAPI with the glide path of the ILS	
	– Illustrate the position-finding function of the marker beacons in respect of ILS approaches and enroute navigation	
	– Describe the fan-shaped and bone-shaped radiation pattern of marker beacons	

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	– Name the frequency assigned to all marker beacons – State the task and use of the Z-marker or a fan-marker, in respect of the cone of silence at the NDB – Name the assigned frequency band of the LLZ transmitters and the GP transmitters (VHF/UHF) – Describe the use of the 90 Hz and 150 Hz signals in the LLZ and G/P receivers, stating how the signals at the receivers vary with angular deviation. – Interpret the difference in depth of modulation (DDM) with respect to the centreline for LLZ and the glide path – State that the difference in the modulation depth increases linearly with displacement from the centre line – Illustrate the use of the back CRS (as may be encountered published for a 'non-precision' approach) – With respect to the centre line and the glide path, state the angular deviation values when the indicator displays the deviation needle on the outer dot – Draw the radiation pattern with respect to the 90 Hz and 150 Hz signals – Explain the term "difference of depth of modulation (DDM)" – State the outer limit of the course sector of the LLZ with relation to the width of the beam between the full scale deflections left and right at the threshold of the runway – Describe how the UHF glide-path frequency is selected automatically – Presentation and Interpretation – Describe the ILS identification regarding frequency and Morse code and/or plain text – Calculate the rate of descent for a given glidepath angle and groundspeed of the aeroplane – Interpret the different identifications of the markers by means of sound, modulation, frequencies and lights	

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	– Explain how airway markers can be distinguished from other markers from the frequency of the ident and the colour of the light – Distinguish between marker beacons and Z-markers or fan markers, by reference to their emission diagrams (cylindrical and rectangular respectively) – Define the approach segment, minimum sector altitude and landing minima – Describe the circumstances in which warning flags will appear – Interpret the indications on course deviation indicators (CDI) and horizontal situation indicators (HSI) – Interpret the aircraft's position in relation to the extended runway centre line on a back-beam approach – Explain the setting of the course arrow of the HSI for front beam and for back beam approaches – Explain why, in the case of approaches using a CDI, the course corrections are to be performed towards the needle on the front CRS inbound, but away from the needle on the back CRS inbound	
	– Coverage and Range – 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 – State that a warning flag will appear in the event of a GP failure	
	– Errors and Accuracy – Interpret incorrect glide paths caused by side-lobe radiations above the correct G/P. – Describe and interpret the effects on indications of – beam bends – scalloping – beam noise	

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	– Explain why the accuracy requirements are progressively higher for CAT I, CAT II and CAT III ILS	
	– For the signals of the ILS ground installation, state the vertical accuracy requirements above the threshold for CAT I, CAT II and for CAT III	
	– Identify the existence of requirements for ground installation, aircraft installation and the qualification of the crew for each category	
	– Illustrate the function of the monitor stations	
	– Factors affecting Range and Accuracy	
	– Define the critical area in terms of	
	– defined dimensions about the LLZ and GP antennas where vehicles are excluded during all ILS operations	
	– unacceptable disturbance to the ILS signal.	
	– Define the sensitive area in relation to:	
	– critical area	
	– possible disturbances of the ILS-signal	
	– dimensions depending on the object creating the disturbance	
	– Describe the influence of snow and heavy rain on the ILS signal	
	– Describe the effect of FM broadcast stations that transmit on frequencies just below 108 MHz and the function of a FM immune filter.	
062 01 06 00	**<u>MLS (micro landing system)</u>**	
	– Principles	
	– Describe the information provided by MLS in terms of:	
	– horizontal course guidance during the approach	

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	– vertical guidance during the approach – horizontal and vertical course guidance for departure and missed approach – DME distance – transmission of special information regarding the system and the approach conditions – Identify the frequency band and the number of available channels – Explain the reason why MLS will be installed at airports on which, as a result of the effects of surrounding buildings and/or terrain, ILS siting is difficult. – Explain the working principle in terms of: – time referenced scanning beam – elevation and azimuth antenna – forward and backward sweep – constant angular velocity – time interval – angular deviation from desired course and desired elevation – DME-P, – three dimensional position – Presentation and interpretation – Interpret the display of airborne equipment designed to continuously show the position of the aircraft, in relation to a pre-selected course and glide path along with distance information, during approach and departure. – Define the special data in terms of: – station identification	

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	– system condition – runway condition – weather information. – Explain that segmented approaches can be carried out with a presentation with two cross bars directed by a computer which has been programmed with the approach to be flown – Illustrate that segmented and curved approaches can only be executed with DME-P installed – Explain why aircraft are equipped with a multi mode receiver (MMR) in order to be able to receive ILS, MLS and GPS – Explain why MLS without DME-P gives an ILS look-alike straight line approach – Coverage and range – Describe the coverage area for the approach direction in angular terms horizontally on both sides, vertically and in distance from the beacon (according to ICAO annex 10) – Errors and accuracy – State the 95% lateral and vertical accuracy within 2 NM (3.7 km) of the MLS approach reference datum and 60 ft above the MLS datum point (according to ICAO annex 10) – Factors affecting range and accuracy – Describe how the reflection of MLS signals by buildings and/or obstacles can be avoided by interrupting the scanning beam	
062 02 00 00	**BASIC RADAR PRINCIPLES**	
062 02 01 00	**<u>Pulse Techniques and Associated Terms</u>**	
	– Name the different applications of radar with the associated wavelength of the radar signals with respect to ATC, MET observations, airborne weather radar and navigation – Describe the echo principle on which primary radar systems are based.	

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	– Describe how the plan position indicator (PPI) utilises a cathode ray tube to give analogue target depiction, by distance and direction.
	– Sketch the radar lobe generated by reflection in a parabolic reflector or by interference from out-of-phase radiation from a flat-plate antenna.
	– State the influence of the size and shape of an antenna on the size of main lobe and side lobes
	– Explain, in general terms, how a side lobe suppressor avoids answers on interrogations via side lobes
	– Explain the relationship between the maximum theoretical range and the pulse repetition frequency (PRF)
	– Calculate the max. theoretical range if the PRF is given
	– Show the relationship between the display on the second deflection sweep, dead time, and theoretical range.
	– Define radial and azimuth resolution, target size and stretching
	– Calculate the radial resolution if the pulse length is given
	– Calculate the azimuth resolution if the beam width is given
	– Calculate the minimum range if the pulse length is given
	– Explain the dependence of the wavelength and pulse repetition interval on the range
	– Explain the need to harmonise the rotary speed of the antenna, the pulse duration, the pulse repetition frequency for optimum scanning rate, focussing and transmission power.
	– Describe, in general terms, the effects of the following factors with respect to the quality of the target depiction on the PPI:
	    – atmospheric conditions: super refraction and sub refraction
	    – attenuation with distance
	    – condition and size of the reflecting surface	

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	– Mention the use of permanent-echo erasure (moving target indication, MTI)	
	– Calculate the distance to the radar horizon in NM	
062 02 02 00	**Ground radar**	
	– Principles	
	– Explain the need for the differences in wave length and RPM of the primary radar systems used by the air safety authorities:	
	– RSR (En-route Surveillance Radar)	
	– TAR (Terminal Area Surveillance Radar)	
	– PAR (Precision Approach Radar)	
	– ASDE (Airport Surveillance Detection Equipment)	
	– Explain why the RSR needs a longer pulse-length and lower antenna RPM than a short range radar like the ASDE	
	– Define a Surveillance Radar Equipment (SRE) approach in terms of radar vectors	
	– Define a PAR (GCA) approach in terms of radar vectors	
	– State on which aerodromes, military or civil, PAR and SREs are used	
	– Explain why a PAR needs two antennas	
	– Explain why echoes that do not change in distance from the antenna, (i.e. relative speed zero), measured between subsequent hits of radar pulses, are dangerous with respect to ground radars equipped with a moving target indicator (MTI)	
	– Explain the cause of second trace returns	
	– Explain how second trace returns from the radar screen are removed by staggering the pulse repetition.	

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	– Presentation and Interpretation – State (for RSR, TAR, PAR and ASDE) that, using a plan position indicator (PPI), it is possible to obtain measurements of bearings, distances and/or elevation. – Interpret an azimuth/elevation screen with two separate parts indicating the position in relation to the centreline and in relation to the glide path – Explain the relationship between the direction in which the antenna is transmitting and the direction of the primary blips of aircraft on a RSR, PAR and ASDE screen – Explain the relationship between the travelling time of the radar pulse and the corresponding distance of the primary blips of aircraft on a RSR, PAR and ASDE screen – Coverage and Range – State typical ranges for the following different ground radar types: – En-route Surveillance Radar (RSR) – Terminal Area Surveillance Radar (TAR) – Precision Approach Radar (PAR) – Airport Surveillance Detection Equipment (ASDE) – Errors and Accuracy – State the azimuthal resolution in relation to the beam width – Calculate the radial resolution – Factors affecting Range and Accuracy – Explain how super refraction can extend the detection range of objects close to the earth's surface. – Explain how sub refraction can decrease the detection range of objects close to the earth's surface. – State, in general terms, the rate of absorption and reflection of radar waves of different wave lengths	

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	by all kinds of precipitation – State the relationship between the wavelength and the dimensions of the reflecting object to the reflectability (e.g. radar waves of 10 cm do not reflect from rain drops)	
062 02 03 00	**Airborne Weather Radar** – Principles – List the two main tasks of the weather radar in respect of weather and navigation – Identify the wavelength – Explain how the aerial is attitude-stabilised in relation to the horizontal plane using the aircraft's attitude reference system – Calculate the beam width in relation to wavelength and antenna diameter with the formula: beam width in degrees = 70 x wavelength / antenna diameter – Describe the two different antenna shapes with the associated radiation patterns – Explain how, besides a cone shaped radiation pattern, a parabolic antenna can also transmit a fan shaped beam (cosecant square) – Explain why a flat plate antenna should be tilted down for ground mapping – Indicate the movement of the antenna either in the horizontal plane or tilted in relation to the horizontal plane, depending on the setting of the tilt – Describe the pencil beam (conical shaped) of about 3° to 5° beam width used for weather depiction (NORM or WX) – Presentation and Interpretation – State the functions of the settings of control knobs on the CDU : – function switch, with settings WX, WX+T, WX (var), MAP, Gain, Normal Contour Intensity – range switch (e.g. 20, 50, 150 NM)	

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	– tilt – Name, for areas of differing reflection intensity, the colour gradations (green, yellow, red and magenta) indicating the increasing intensity of precipitation – Illustrate the use of azimuth marker lines and range lines in respect of the relative bearing and the distance to a thunderstorm or to a landmark on the screen – Coverage and Range – Calculate the range – Name the practical range for weather radar and for navigation – Explain how the sector sweep of the antenna is sufficient to provide for the needs of the role of the equipment – Errors and Accuracy – Calculate the radial resolution – Calculate the azimuthal resolution – Factors affecting Range and Accuracy – Explain the danger of the area behind heavy rain (shadow area) where no radar waves will penetrate – State the effect on radar energy of: – water in the antenna radome – ice on the radar radome – Explain how radar information can be improved by adjusting the gain properly, especially in the mapping mode – Explain why the tilt setting should be higher when the selected range increases and/or when the aircraft descends to a lower altitude	

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	– Explain why the tilt setting should be lower when the selected range decreases and/or when the aircraft climbs to a higher altitude	
	– Explain why a thunderstorm may not be detected when the tilt is set too high	
	– Navigation Application	
	– Describe the navigation function of the radar in the mapping mode	
	– State the limitations of the navigation function	
	– Explain why, for long range, a pencil beam is more useful than a cosecant square beam	
	– Calculate the true bearing (TB) when the relative bearing (RB) and the compass heading (CH) are given.	
	– Calculate the range by correcting for the slant range	
	– Plot the position on a navigation chart using the bearing and distance to a conspicuous point.	
	– Describe the use of the weather radar to avoid a thunderstorm (Cb)	
	– Explain why clear air turbulence (CAT) can not be detected with a weather radar	
062 02 04 00	**SSR (secondary surveillance radar) and Transponder**	
	– Principles	
	– Name the frequencies used for interrogation and response	
	– Identify the ground antenna	
	– Sketch the radiation pattern of a rotating slotted array which transmits a narrow beam in the horizontal plane	
	– Sketch the radiation pattern of the antenna of the aircraft which transmits omnidirectionally	
	– Define the terms: ‘interrogator’ (on the ground) and ‘transponder’ (in the aircraft)	
	– Explain that information from primary radar and secondary radar can be combined and that the	

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	radar units may be co-sited. – Explain the advantages of SSR over a primary radar – Explain the following disadvantages of SSR: – 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 – Presentation and Interpretation – Explain how an aircraft can be identified by a unique code – Illustrate how the following information is presented on the radar screen: – the pressure altitude – the flight level – the flight number or aircraft registration – the ground speed – Name and interpret the particular codes 7700, 7600 and 7500 – Describe how the antenna is shielded when the aircraft banks – Interpret the selector modes: OFF, Stand by, ON (mode A), ALT (mode A and C) and TEST – Explain the function of the emission of a SPI (Special Position Identification) pulse after pushing the ident button in the aircraft – Modes and Codes, including mode-S – Explain the function of the three different modes: – mode A	

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	– mode C	
	– mode S	
	– Explain why a fixed 24 bits address code will avoid ambiguity of codes	
	– Explain the need for compatibility of mode S with mode A and C	
	– Interpret the terms: selective addressing, mode 'all call' or selective calling	
	– State the possibility of exchanging data via communication protocols	
	– Name the advantages of mode S over mode A and C	
062 02 05 00	**<u>Use of Radar Observations and Application to In-flight Navigation</u>**	
	– Illustrate the possibility of determining the position of an aircraft by reading bearing and distance off the radarscope with the aid of electronic devices like Electronic bearing Lines and Variable Range Ring	
	– Explain the need for radar observations of aircraft by Air Traffic Control	
	– State the two main functions of the ground radar used by the ATC **(TCAS: 022 03 04 00)**	
062 05 00 00	**AREA NAVIGATION SYSTEMS**	
062 05 01 00	**<u>General philosophy</u>**	
	– Use of radio navigation systems or an inertial navigation system	
	– Define RNAV using the terms:	
	– method of navigation	
	– aircraft operation on any desired course	
	– coverage of station referenced navigation signals	
	– limits of self-contained capacity	
	– Describe how RNAV routes are developed to allow navigation outside standard routings so as to	

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	decrease traffic congestion and make optimum use of the available airspace – Indicate the role of radionav. systems and/or dead reckoning systems in respect of the most accurate and continuously updated position – Identify the navigational sources for RNAV equipment used to calculate position, route information, heading to steer, ground speed, wind, distances to go, cross track distances, drift angle, track angle error and wind. – Give a brief description of the navigational functions of the following components to be used for area navigation – a Navigation Computer Unit (NCU) – a flight data storage unit – a control display unit – a Radio Magnetic Indicator (RMI) – a Horizontal Situation Indicator (HSI) – an air data computer – a compass system – IRS and ILS/MLS/VOR/DME/GNSS receivers	
062 05 02 00	**Typical Flight deck Equipment and Operation (also mentioned in 022 00 00 00)** – Explain that area navigation may be executed by flight management and guidance systems (FMS) – Describe 3-dimensional RNAV in terms of lateral and vertical navigation – Identify the following functions: navigation, lateral and vertical flight planning, performance management, control of AP/FD and auto thrust (A/THR), flight envelope computations and display management Name the following main components and describe, in general terms, their individual functions : – flight management and guidance computer	

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	– multipurpose control and display unit – flight control unit – flight management source selector – display system – Identify and interpret the information presented by the Electronic Flight Instrument System (EFIS) on the Primary Flight Display (PFD) and the Navigation Display (ND) in accordance with the Boeing 737-800 concept or on conventional instruments – State the period of validity of the navigational data base for a Flight Data Storage Unit – Explain the function of the following data in the database of FDSU: – way-points, airways and company routes for flight planning – frequencies/ position and range of the different navigation beacons – holdings, airports, runways, SID's, STARS and procedures for departure and arrival – additional new way-points, nav. aids and runways defined by the pilot – State the necessity for a performance data base to carry out flight envelope computations – Explain the purpose of the following functions of a FMS: – navigation of the aircraft in the horizontal and vertical plane by position fixing – performance optimisation and flight envelope computations by the FMC (flight management computer) – the interaction possibilities between pilot and FMS by means of display management and CDU – Interpret the following guidance modes: – managed guidance in which the aircraft is automatically guided on the pre-planned route, altitude and speed profile by the FMS	

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	– selected guidance in which the aircraft is controlled to the selected value of a given parameter e.g. heading hold, fixed IAS/Mach to be selected on the Flight Control Panel (FCP) – State and interpret the four possible modes of operation for dual FMC installations: – <u>dual</u>: in which one FMC provides the master function and the other the slave function and selections and where inputs into one FMS are passed on to the other – <u>independent</u>: in which there is no communication between the two flight management systems – <u>single</u>: in which only one FMS is operational – <u>back up navigation</u>: in which there is limited use of the FMS functions as a result of flight management computer failures – State that, in the master/slave and in the independent mode, the navigational values presented on the EFIS and CDU may differ – Explain the master/slave function in the dual mode – Means of Entering and Selecting Way-points and Desired Track Angle (course) information (keyboard entry system) – Name and describe the methods of entering and selecting way-points, SIDs and STARs and desired course information with respect to the terms: – standard company route – ICAO designator of the departure and the destination aerodrome. – airway designator – way-points, using their designators. – way-points, by using their lat./long co-ordinates or range and bearing – Explain why the gate position should be entered before the automatic alignment of the IRS /INS – Identify the sources for position processing	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Means of Selecting, tuning and identifying ground stations – Explain why the IRS is called a self-contained system – Explain the auto-tune function of modern RNAV equipment – State that manual deselection/selection can be achieved by means of the MCDU – Explain the back up function of modern RNAV equipment for VOR/LOC approaches – Explain the need to tune the conventional VOR/DME receivers for raw data information to verify that they are correctly positioned on the RNAV equipment's numeric CDUs or on the navigation display – Explain that the user may delete satellites (that GPS automatically selected) in order to obtain the best geometry – List the hierarchy of nav aids for positioning – Define the modes radio/inertial, inertial and dead reckoning – Explain, using the rules of statistics, the validity of the triple mixed position, as determined from the positions given by three inertial reference units – Define the term 'hybrid navigation' – Explain the function of the navigational filter which derives a position error vector that points from the mixed (or single) IRS-position towards the FMS-position – Explain why the accurate development of the position error vector needs radio measurements – Explain the reason why the various navigation sensors must have complementary error characteristics, e.g. noise errors against drift errors, for optimisation of hybrid navigation – Explain how the IRS achieves very good short term stability but poor long term stability – Give the reason why radio nav systems have poor short time stability and good long time stability – Explain (in cases of additional estimation and calibration of velocity, attitude and sensor errors) that the error vector can be further developed by the filter over a specified period of time, in spite of the	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	absence of measurement data (i.e. radio, GPS) – Explain the importance of the quality and complexity of the Kalman filter design – State for which radio positioning facilities rho-rho and rho-theta algorithms are used – Indicate that a first update of the FMS-position is automatically performed before take off – Instrumentation for en-route track (course) guidance – Explain the use of the magnetic variation stored in the memory – Name and interpret the following items of a lateral flight plan: – take off runway – SID and en-route transition – en-route way-points and/or airways – en-route transition and STAR – missed approach – alternate flight plan – List the stages of a flight in which a lateral revision of the flight plan is possible – Describe the use of the vertical revision function in respect of changes to: – speed limits in climb and descent phases – altitude-, speed- and time constraints – step climb and step descent – wind data – Instrumentation for presenting distance traveled, distance to go and ground speed information only valid for some type of systems).	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Name and indicate the use of the EFIS presentation for en-route course guidance in respect of the following:	
	– the presentation of the current position in relation to a reference line or the intended track on the display	
	– the present co-ordinates	
	– the numerically and graphically presentation of the desired track angle and the distance to next way-point and aircraft heading, track and drift angle	
	– the presentation of the cross track error (XTK) and track angle error (TKE)	
	– Instrumentation for presenting current position data	
	– State the manner of presentation of the current position data on the CDU and on the navigation display of the EFIS	
062 05 03 00	**Instrument Indications**	
	– Illustrate the presentation of the cross track error on the HSI in elderly models with the RNAV coupled	
	– Interpret the cross track error presentation on the CDU display of some equipment showing a reference line in the middle, an aircraft symbol and some guidance lines	
	– Interpret the presentation of the route structure when RNAV is coupled with flight instrument displays such as EFIS	
062 05 04 00	**Types of Area Navigation Systems Input**	
	– Self-contained on-board systems (inertial navigation systems, Doppler)	
	– Indicate that the present position on the CDU (of self-contained navigation systems), whether in geographic coordinates or graphical form, is used as an input.	
	– External Sensor Systems	
	– For position fixing with radio nav aids, indicate the type of raw data delivered from:	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– GPS: – DME/DME – VOR/DME – Inputs – Name the required air data inputs for an area navigation system.	
062 05 05 00	**<u>VOR/DME Area Navigation (RNAV)</u>** – Principle of Operation – State the use of VOR/DME data in relation to phantom stations – Name the data to be entered into the control display unit (of the RNAV system) in order to define a phantom station. – Advantages and Disadvantages in the Use of RNAV – State the advantages of the RNAV system in terms of: – full use of the airspace – availability of phantom way-points – Explain the following disadvantage of the RNAV system: – phantom stations can only be defined within the range of the VOR/DME stations used – Accuracy, Reliability, Coverage – Explain how accuracy and reliability of navigation (using the RNAV system) is affected by the following factors: – path deflection of radials – slant range error of DME	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Flight Deck Equipment	
	– Describe, briefly and in general terms, the following components of the flight deck equipment of the RNAV system	
	– computer	
	– simple CDU (control display unit)	
	– CDI (course deviation indicator), RMI (radio magnetic indicator) or HSI (horizontal situation indicator	
	– Interpret read outs of CDU and CDI/HSI/RMI	
062 05 06 00	**Flight Director and Auto-pilot Coupling**	
	– State that it is possible to couple the flight director (FD) and/or the auto pilot (AP) to the RNAV system	
062 06 00 00	**SELF CONTAINED AND EXTERNAL -REFERENCED NAVIGATION SYSTEMS**	
062 06 01 00	**Doppler (No objectives necessary, Doppler not in use in transport fixed wing aviation))**	
	– Principles of operation (airborne system)	
	– Identify the frequency band and the wavelength of Doppler radar	
	– Explain, in outline, the basic principle of the Doppler effect.	
	– Analyse the term Doppler shift	
	– State and interpret the Doppler formula ($F_D=R_{REC}-F_{TRANS}$)	
	– Identify the antenna type used for Doppler radar	
	– Describe the properties of stabilised and strapped-down antennas	
	– Describe the properties of the Doppler beam referring to	
	– beam width	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– vertical and horizontal angle – Ground Speed and Drift Calculation – State that Doppler radar functions by continuous measurement of Doppler shift converting the measured values to: – ground speed (GS) – drift angle (DA) – Advantages and Disadvantages of Doppler Radar – State the advantage of Doppler radar in terms of an on board autonomous system – State the disadvantages of Doppler radar referring to errors induced by variations in surface reflection (e.g. sea bias) and errors induced by the compass system – Accuracy and Reliability – State that the accuracy and reliability of the measured Doppler values depends on the quality of the reflected signals – Interpret the quality of Doppler signals reflected from various types of surfaces (e.g. still water, rough water, sand) – State that the along track error is smaller than the cross track error causing an elliptical shape of position errors – Flight Deck Equipment – Describe the function of the switches on the Doppler control panel: – STBY/DR – slew switch – land/sea switch	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
062 06 02 00	**<u>Very low frequency systems - Omega (Outdated system, not available since Sept 1997)</u>**	
062 06 03 00	**<u>Loran-C (to be shut down in the US after the year 2000)</u>**	
	– Principle of Operation	
	– Explain that Loran-C is a hyperbolic navigation system	
	– Describe briefly the Loran principle of operation using the terms:	
	– “Master" and "Secondary" transmitters.	
	– propagation delay time difference	
	– hyperbolas	
	– State and define the notions "Base Line", "Bisector Line" and "Base Line Extension".	
	– Name the transmitting sequence of the stations is Master and slaves, resp. w, x, y and z	
	– Describe, briefly, the use of ground waves in relation to the basic accuracy of Loran-C	
	– Name the working frequency and the range of the ground wave over land and over water	
	– State that each transmitter emits omni-directional signals consisting of groups of pulses. Specify the advantage of a pulse group in stead of a single pulse	
	– Explain the necessity of a Secondary-specific delay between master and secondary transmission, (Emission Delay or coding delay)	
	– Explain that the lines of position form unambiguous hyperbola families. These are normally processed for use on special charts or in computers	
	– Describe the reason for different Pulse Repetition Intervals	
	– Explain how a Loran C chain is designated in reference to the Group Repetition Interval	
	– Explain that certain values of ‘propagation delay’ time differences are always measured in every chain as follows:	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Base line extension from secondary transmitter :------ secondary-specific delay – Right bisector :----- secondary-specific delay plus master/secondary propagation delay time – Base line extension from master transmitter :------ secondary-specific delay plus 2 x master/secondary delay plus propagation delay time	
	– Explain that phase difference measurements (between master and secondary signals), obtained by using the carrier wave, give results with an accuracy of ±10 µs – Give the reason why Cycle Matching is done at the end of the third cycle – Define and explain additional secondary phase factors (ASF) corrections – Apply sky wave corrections – State availability of Loran-C – State that modern receivers have software to calculate the position in lat. long co-ordinates	
062 06 04 00	**<u>Decca navigation system (will not be continued after the year 2000)</u>**	
	– Illustrate a Decca chain consisting of a master and three slaves (identified respectively as red, green and purple) and explain why different frequencies are used for each master/slave pair. – Explain why the Line Of Position (LOP) is a hyperbolic line determined by phase difference measurement. – Define a zone, lane and lane numbers – Explain why the lane numbers have to be set by the navigator or that, in modern equipment, the dead reckoning position has to inserted – State that the process of lane identification is made possible by the use of the ‘multipulse’ system – Identify the areas in which Decca is available – Give the reason why the coverage is limited to max. 300 NM by day and 200 NM by night from the baseline	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Apply corrections for delay in propagation (using the Decca datasheets)	
	– State that modern receivers have software which calculates the position in lat./ long co-ordinates	
	– Explain why Decca, on search and rescue helicopters and coastal vessels, has been replaced by GPS	
062 06 05 00	**<u>Global Navigation Satellite Systems GNSS: GPS/ GLONASS</u>**	
	– State the basic differences between the NAVSTAR/GPS system (GPS) and the GLONASS system regarding ellipsoid, time, satellite configuration, codes and frequencies	
	– Principles of System Operation	
	– State the four basic information elements supplied by GPS-Navstar.	
	– Explain why the measured distances are called pseudo ranges	
	– Explain why the minimum requirements, to establish the 3 spatial co-ordinates and a possible error in the receiver clock, consist of the measured distances to 4 satellites and a dead reckoning(DR) position.	
	– Define the use of the Keplerian orbit data.	
	– Describe the geometrical interpretation of the position fix using four spherical surfaces, with the satellite being in each case located at the centre of the sphere involved	
	– Name the synchronous time system used in the satellites	
	– Describe the C/A, P and Y code and state the use of these codes	
	– Explain how pseudo range measurement is achieved using satellite signals	
	– State that the conversion of pseudo ranges is carried out, by means of transformation equations, in order to obtain geodetic co-ordinates (φ, λ) and altitude over a reference ellipsoid.	
	– Basic GPS segments	
	– Control segment	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– List the components of the control segment – Describe the tasks of the Control segment – Space segment – Describe the satellite constellation concerning number of satellites, inclination of orbits, altitude and orbital period – State the different types of satellites – Describe the types and amounts of clocks in the satellites and the way to obtain the exact GPS time – Identify the main task of the space segment – User segment – Interpret the 3 categories of GPS receiver architecture: multi channel, multiplex and sequential – Explain why multi channel receivers are preferred for aviation – State the current use of GPS – Navigation performance – Explain the following terms in relation to the horizontal 95% accuracy: – Selective Availability (S/A) – Standard Positioning Service (SPS) – Precision Positioning Service (PPS) – Explain the term integrity in relation to GPS receivers – RAIM (receiver autonomous integrity monitoring) – Integrity messages from earth stations or communication satellites	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS

	– State the availability of GPS
	– Explain that the continuity is interrupted by switching to another satellite for the best GDOP
	– State the applications of GPS
	– Interpret the following Special Applications of GPS
	  – precise time measurement and time interval measurement
	  – altitude determination
	– Define the following Future Applications of GPS
	  – Enhanced Ground Proximity Warning System (EGPWS)
	  – Automatic Dependent Surveillance Broadcast (ADS-B)
	– Satellite Constellation and Geometric Dilution of Precision
	– Define the following parameters relating to GPS orbital configuration:
	  – orbit semi-major axis
	  – satellite ground tracks up to 55°N/S
	  – orbit satellite phasing
	  – satellite visibility angle,
	  – mask angle
	  – satellite coverage
	– Explain the use of Keplerian elements in respect of the orbit
	– Explain how the actual position of the satellite is found
	– Illustrate the use of the (X, Y, Z) Earth Centred/ Earth Fixed co-ordinate system to define position vectors	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Explain, in qualitative terms, how (x, y, z) co-ordinates can be transformed to co-ordinates (φ, λ , h) on the WGS-84 or on any other ellipsoid	
	– Indicate the influence of the following perturbation factors	
	– solar wind	
	– gravitation of sun, moon and planets	
	– Define the following terms:	
	– Geometrical Dilution of Precision (GDOP)	
	– Position Dilution of Precision (PDOP)	
	– Horizontal Dilution of Precision (HDOP)	
	– Vertical Dilution of Precision (VDOP)	
	– Time Dilution of Precision (TDOP)	
	– User Equivalent Range Error (UERE)	
	– Indicate the influence of elevation angle on dilution of precision	
	– Explain the influence of dilution of precision on navigational accuracy	
	– GPS Signals and Navigation Messages	
	– Name the desired GPS navigation signal properties and signal specifications	
	– Describe the GPS signals with reference to the following aspects:	
	– GPS frequencies	
	– signal characteristics: spread spectrum	
	– signal structure, pseudo-random noise P and C/A codes, navigation message	
	– Describe the level of the receiver Signal-to-Noise Ratio	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Describe the navigation message and list the data in the 5 different subframes	
	– Explain the relevance of ionospheric delays and indicate how their values are determined	
	– Illustrate the relationship between the satellites and the control segment in respect of signal formation and transmission	
	– GPS Generic Receiver Description	
	– Name the basic elements of a GPS receiver	
	– Name the primary information supplied by a GPS receiver:	
	– Describe the presentation and interpretation of GPS data on a typical receiver type	
	– Interpret GPS data presented on a control display unit	
	– Name the requirements for GPS hardware and integration	
	– Name the number of receiver channels required for various applications	To be specified by JARFCL
	– Describe the cockpit equipment connected with GPS receivers	
	– Describe in general terms the signal processing	According JAA leaflet 3, TSO C129a, DO208, FAA AC's
	– Explain the 12.5 minutes to read the complete almanac with the parameters of all the satellites	
	– In the algorithm to solve the position and receiver clock error from the pseudo range measurements, name the four unknown parameters.	
	– Explain the following terms (in connection with the applications and the navigation algorithms)	
	– pseudo-range	
	– Doppler shift	
	– phase angle	
	– Explain why, for accelerated satellite selection after a long suspension of use or a change in position,	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– approximate position, time and date should be entered to shorten the search of the sky – time to first fix may take up to 15 minutes – Describe the operation after a short suspension – Define the term 'Time to First Fix' – Signal Perturbations and Errors – Describe the method of Selective Availability (S/A) as used in the GPS system – State the intended aim of S/A – Name the errors produced in the receiver – Name the cause and the behaviour of ephemeris errors – Name the errors produced in the troposphere and in the ionosphere in relation to the elevation and mask angle – Indicate the influence of multipath propagation of GPS signals on navigational accuracy – Interpret the two methods used for the mitigation of multipath effects: – special antenna design – design of software in the receiver – Explain the effect of masking of satellites – Name the influence of satellite clock errors on the accuracy of GPS navigation – State possible interference sources for, and their effects on, a GPS C/A receiver – Differential GPS and Integrity Monitoring – Explain the elementary principle of Differential GPS – Name the major categories of Differential GPS	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS

	– Explain why, for Differential GPS, a ground-based reference station is required in order to obtain differential corrections
	– Name the method of error correction used in DGPS (data message, data links)
	– State which errors can not be diminished by DGPS
	– Describe the characteristics of local area differential GPS (LADGPS) with reference to :
	  – differential corrections
	  – integrity messages
	  – reference station in the vicinity of e.g. an aerodrome
	  – communication direct from ref. station to aircraft
	– Describe the characteristics of wide area differential GPS (WADGPS) with reference to :
	  – differential corrections
	  – integrity messages
	  – more than one reference station in a nation or continent
	  – communication from ref. stations via co-ordination centre to aircraft
	– Describe the characteristics of local area Augmentation system (LAAS) with reference to :
	  – differential corrections
	  – integrity messages
	  – reference station in the vicinity of e.g. an aerodrome
	  – communication direct from ref. station to aircraft
	  – pseudolite(s) to improve the dilution of precision (DOP)
	– Describe the characteristics of Wide Area Augmentation (WAAS) with reference to :	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– differential corrections depending on lat./ long co-ordinates – integrity messages – reference stations in a wide area – communication from co-ordination centre station via INMARSAT satellites to aircraft – INMARSAT satellites with nav. channel – Describe the characteristics of European Geostationary Navigation Overlay System (EGNOS) including reference to : – integrity messages – reference stations in the whole of Europe – communication from co-ordination centre station via INMARSAT satellite to aircraft – two INMARSAT satellites, Atlantic Ocean Region East and Indian Ocean Region, with nav. channel – Pseudolites – Describe the principle of the use of pseudolites – Name the data given by an integrated DGPS/Pseudolite installation: – Indicate the required aircraft antenna locations for GPS and for a pseudolite – Define 'Receiver Autonomous Integrity Monitoring' (RAIM) – State the minimum number of satellites necessary to perform RAIM – State the use of the failure detection and exclusion algorithm of RAIM – Integrated Navigation Systems using GPS – Define the term Multisensor System	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– GPS and INS Integration – State the advantages of GPS/INS integration with respect to redundancy and short and long term stability – Receiver Autonomous Integrity Monitoring (RAIM) Availability for GPS Augmented with Barometric Altimeter Aiding and Clock Coasting – Identify the possible extension of the use of RAIM to include barometric altimeter aiding and clock coasting – Combination of GPS and GLONASS – Explain the requirements of Civil Aviation with respect to the combined use of GPS and GLONASS – GPS Navigation Applications – GPS Applications for Air Traffic Control – Interpret the application of GPS within the context of air traffic control for – oceanic control – enroute control – basic area navigation (cf. JAA Leaflet 2) – terminal control – non-precision approaches – precision approaches – surveillance – Name the required augmentations relating to the use of GPS for precision approaches – GPS Applications in Civil Aviation – Interpret the requirements for the use of GPS in Civil Aviation with respect to	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– dynamics – functionality: GPS position integrated with Inertial positions presented on a (EFIS) screen – accuracy: en-route GPS, non precision approaches: DGPS, WADGPS or WAAS precision approaches LAAS and phase measuring – availability – reliability – integrity by differential stations – The following are to be described by LO's at a future date when the system architecture has been clarified and the use of GPS for automatic landings is accepted: – Automatic Approach and Landing with GPS – Precision Landing of Aircraft using Integrity Beacons – Future Implementations	