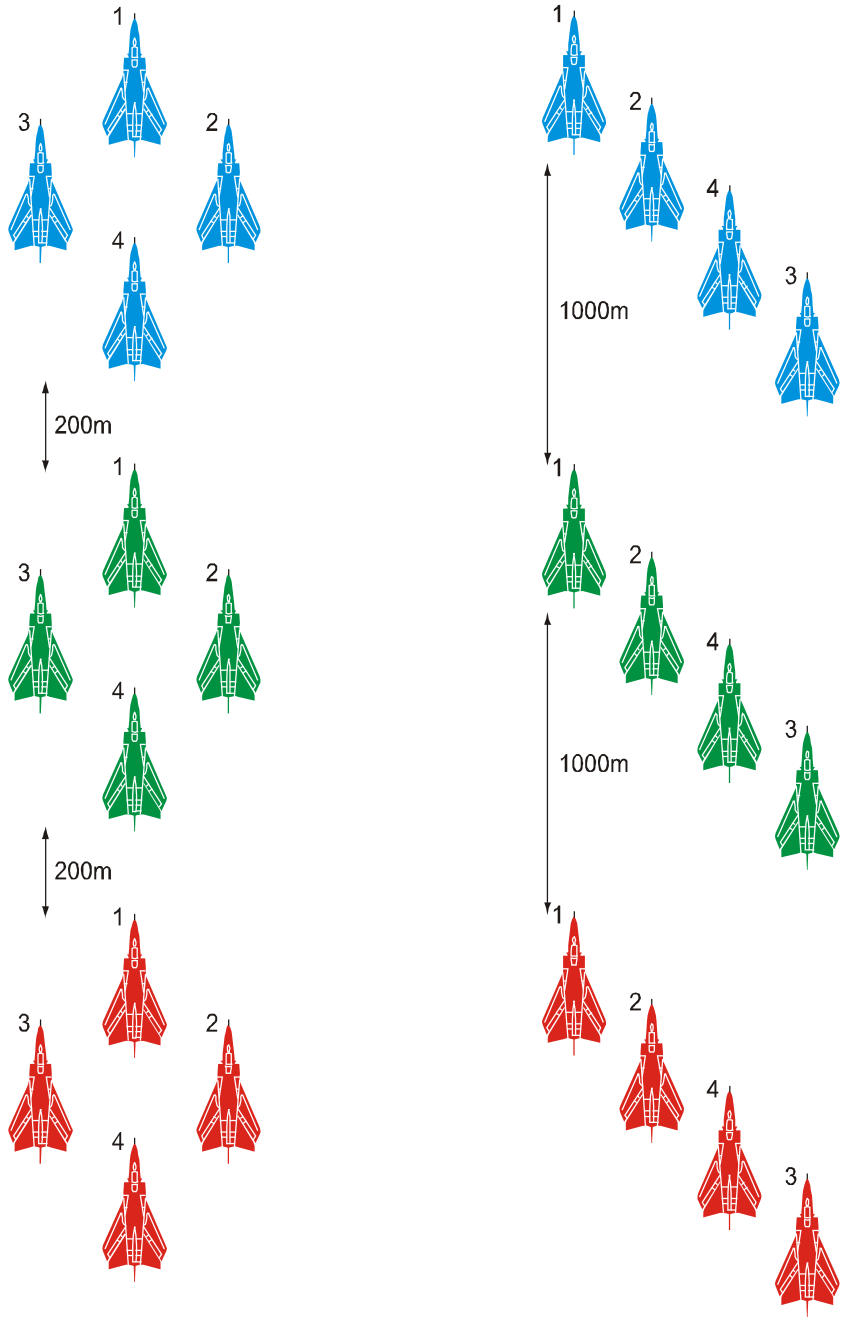
8-21 Fig 16 Large Formation Manoeuvring



TANKARD 1
"Tankard squadron for visual run in and break, sections form echelon right, 1,000m trail."
"Red section fall back and call clear - GO."

RED 1
"Red section clear."

TANKARD 1
"Green section fall back and call clear - GO."

GREEN 1
"Green section clear."

Whilst Tankard No 1 lines the whole squadron up at initials for the run in and break, the section leaders space out on the sections ahead and then put their own sections into echelon on the final run-in.

TANKARD 1
"Blue section echelon right - GO."

GREEN 1
"Green section echelon right - GO."

RED 1
"Red section echelon right - GO."

TACTICAL FORMATIONS

Introduction

66. Tactical formations are planned and flown to achieve as good a defensive posture as possible. Such a posture will depend upon how many aircraft are involved and the profile of the sortie. A 2-aircraft formation in line abreast may achieve good rearwards lookout but is relatively unwieldy in turns. The same 2-aircraft formation in long line astern is easily manoeuvred but cross cover is severely limited. Compromise formations are selected, therefore, to give optimum defensive cover and many are developed as the most appropriate for individual squadrons and for particular aircraft types. The three tactical formations described in this chapter are the more simple manoeuvres, generally taught in flying training schools, from which more advanced tactical formation profiles are developed. They are:

a. Fighting Wing.

b. Defensive Battle.

c. Arrow.

Considerations

67. **Range Estimation**. Range estimation improves with experience. Even so, exact distances tend to be a matter of opinion and cannot be assessed with any degree of accuracy. The correct distances between aircraft will more readily be described as 'a bit too close', or 'rather wide' or the like, and correct spacing will, with practice, become second nature. That said, since this terminology cannot be used in a written description, distances are described more precisely in this chapter.

Airmanship

68. **Lookout**. The purpose of a tactical formation is to take advantage of good lookout. The No 1 is responsible for formation security but relies upon his wingmen to give warning of other aircraft, be they hostile or friendly. Reports to the leader must be quick and accurate giving all the essential information in a dispassionate and unemotional manner.

69. **Slipstream**. Aircraft in formation should take care to avoid the slipstream of other formation aircraft. Apart from dangerous control difficulties, flying into turbulent air might lead to unacceptable rises in turbine gas temperature (TGT).

70. **Terrain and Collision Avoidance**. Each pilot in a tactical formation is responsible for maintaining a safe distance from other aircraft and from the terrain. It is particularly important to be aware of the briefed MSD when at low level and to break off, if necessary, for a safe rejoin.

71. **Sighting Reports**. A thorough lookout for threat aircraft must be maintained. All aircraft, whether believed to be hostile or not, must be reported when on a tactical communications frequency. In training, the briefing will usually require only threats or collision risks to be reported on an ATC frequency. Sighting reports should be given as follows:

a. Callsign of reporting aircraft.

b. Left/Right and clock code (relative to leader).

c. High, low or level.

d. Range.

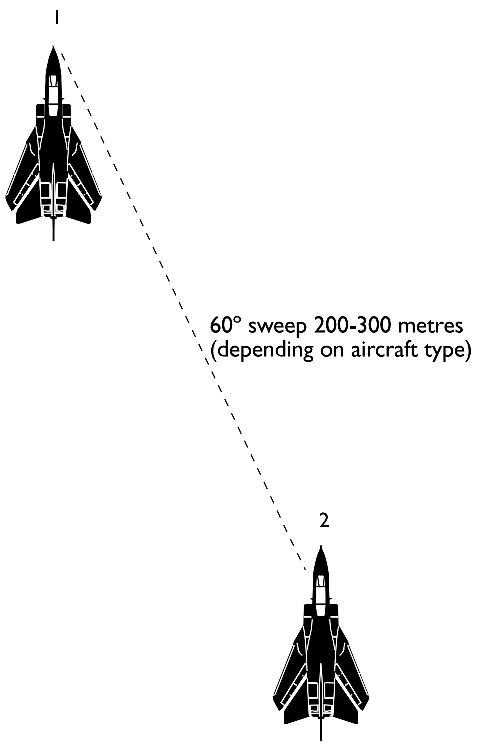
e. Type and number of aircraft.

f. What sighted aircraft are doing.

Fighting Wing Formation

72. **General**. Fighting Wing (Fig 17), in which the No 2 occupies a cone behind the leader of about 60º apex and 200 m to 300 m depth, offers the leader good cross cover and greater manoeuvrability than close formation. Fighting Wing is normally flown as two aircraft. With four aircraft, pairs 'in trail' would normally be flown. The rear pair should maintain the briefed trail separation which will be in the order of 1,500 m to 2,000 m depending upon conditions.

8-21 Fig 17 Fighting Wing Formation

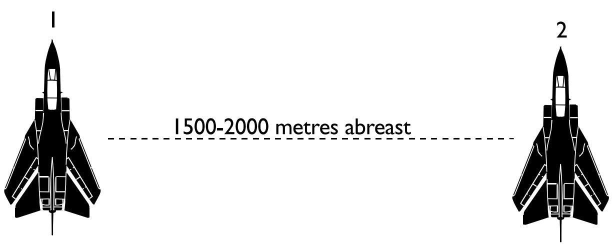


73. **Manoeuvres**. Manoeuvring to remain on station during turns is relatively easy and all-round lookout should be maintained by each pilot. Except when otherwise briefed, the No 2 maintains the altitude of his leader during turns thus limiting the vertical envelope of the formation. This makes transit at low level particularly effective.

Defensive Battle Formation

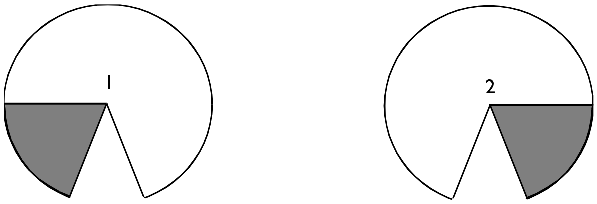
74. **Description**. Despite the relative effectiveness of Fighting Wing formation, Defensive Battle is the basic tactical formation used in the RAF. It is the best compromise between effective lookout, mutual support, manoeuvrability and reduction in vulnerability. The distance apart depends upon visibility and the expected weapon threat and, once the optimum has been decided, convergence and divergence must be countered continuously. The configuration for two aircraft is shown in Fig 18.

8-21 Fig 18 Defensive Battle Line Abreast



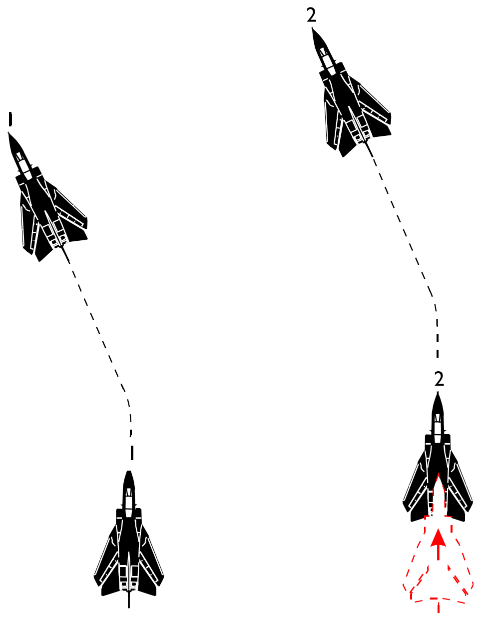
75. **Lookout and Search Areas**. Areas of responsibility for visual search and the lookout sectors are shown in Fig 19. Aircrew should spend about three quarters of their time searching their primary (blank) field and the rest searching the remainder of the sky (shaded). The entire sky, vertically as well as level, must be covered.

8-21 Fig 19 Defensive Battle Formation Lookout Sectors



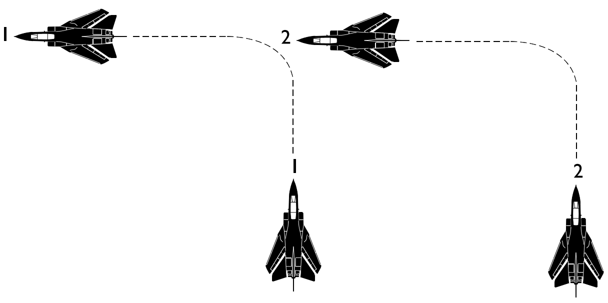
76. **Pre-planned Route Turns**. On a pre-planned route, turns will normally not be called. The leader will fly the briefed route and the other aircraft or elements should anticipate the turns and remain on station. A two-aircraft turn through 25º to the left is shown in Fig 20.

8-21 Fig 20 Pre-planned Route Turn - Left 25º



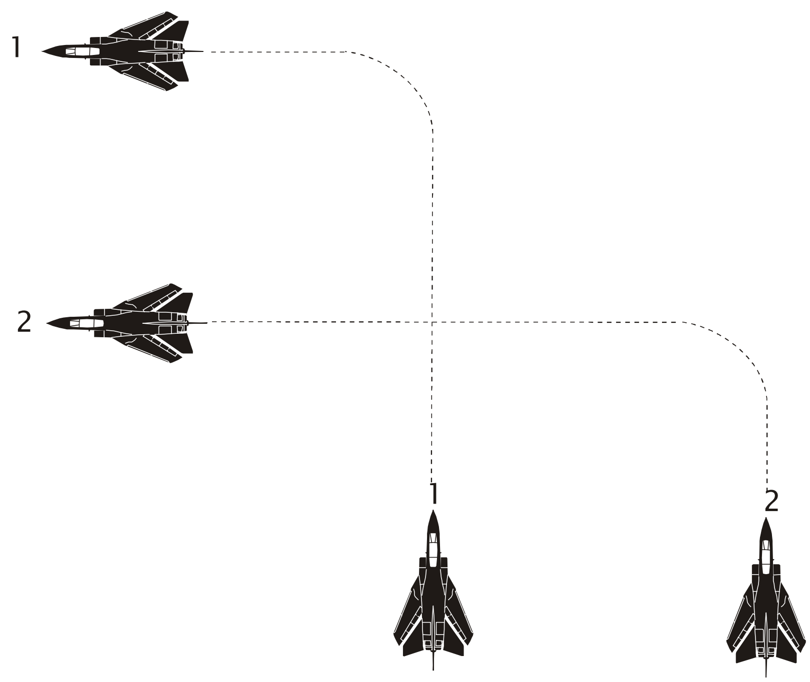
77. **In Place Turns**. 'In Place' turns involve all aircraft turning simultaneously through the appropriate number of degrees. Navigational turns will normally be of 30º or less and will require a small amount of manoeuvring if it is intended to remain in place. Larger turns will have to be well anticipated to remain in place or may be used to regain formation integrity or effect a formation change (90º is illustrated in Fig 21).

8-21 Fig 21 In Place Turn - 90º Left

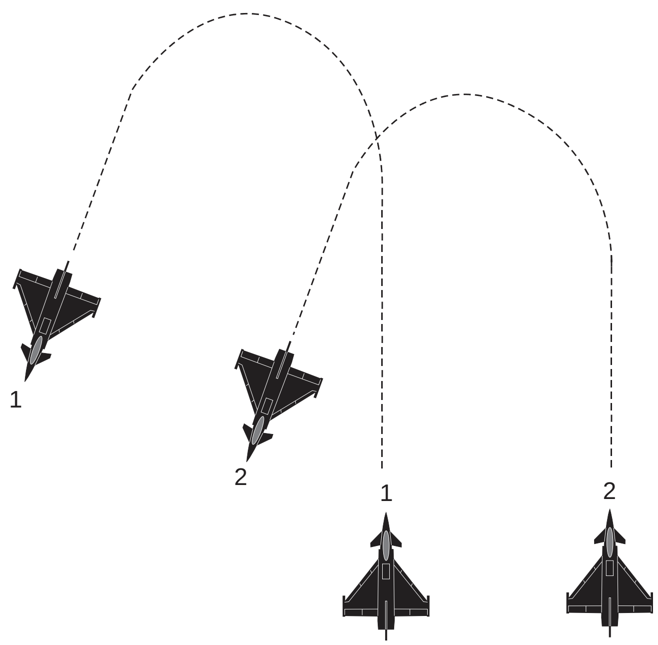


78. **Variable Delay Turns**. When making turns of greater than 60º and up to 180º, a variable delay may be employed as shown in Figs 22 and 23. For a two-aircraft formation, the outside aircraft initiates the turn and is responsible for collision avoidance. The inside aircraft delays, commencing the turn based upon the visual aspect and position of the other aircraft. For a 180º turn (a 'turnabout') no delay is necessary and both aircraft turn at the same rate simultaneously. It follows that the delay becomes progressively greater for turns of less than 180º down to 61º. The 90º delay may be used as a yardstick for judging the time to allow initially but accurate timings will come with increasing experience.

8-21 Fig 22 Variable Delay Turn 90º Left



8-21 Fig 23 Variable Delay Turn 160º Left

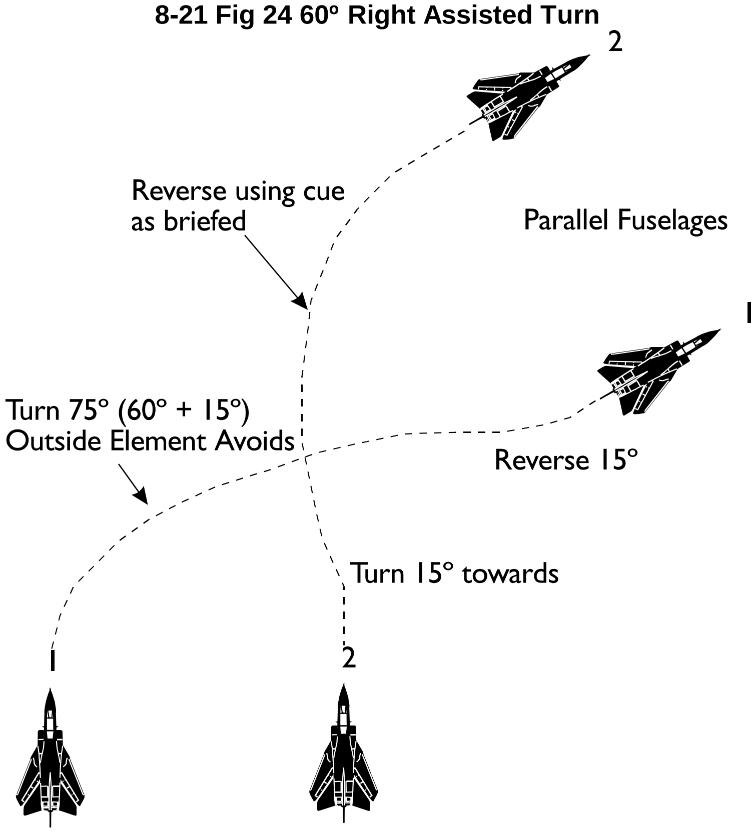


79. **Assisted Turns**. Assisted turns are generally used for turns between 30º and 60º. Assistance, in this context, is defined as an additional compensatory turn to **assist** in final positioning. By applying the right amount of assistance, the length of flightpath is the same for both aircraft and the manoeuvre ensures that both roll out close to the correct spacing. As a rule of thumb, the amount of assistance needed is calculated by halving the difference between the required turn and 90º as shown in Table 1. A 60º right assisted turn is illustrated in Fig 24.

Table 1 Assisted Turns - Calculating Assistance Required

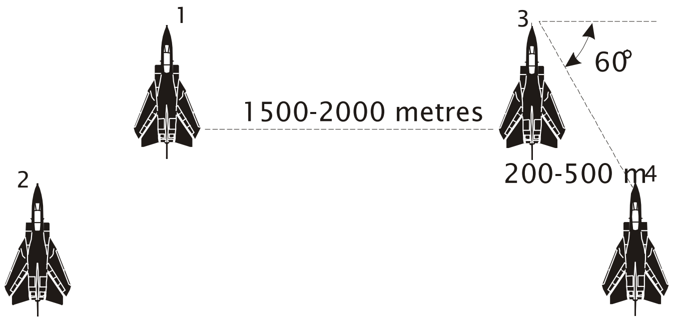
Degrees of Turn	Assistance Required
0	45º
30	30º
45	20º
60	15º
90	0º

8-21 Fig 24 60º Right Assisted Turn

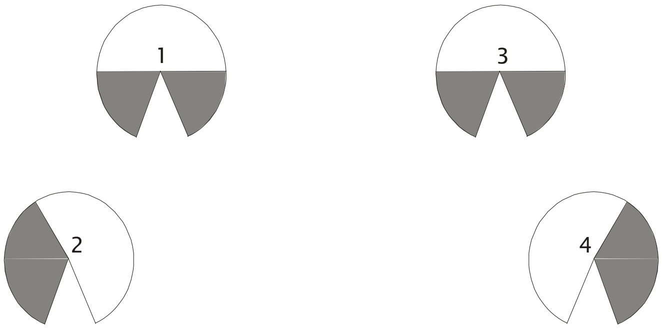


80. **Four Aircraft Profiles**. The four aircraft Battle formation is, essentially, two mirrored elements of Fighting Wing abreast in which the Nos 2 and 4 may assume a slightly longer trail. The profile and lookout areas of responsibility are illustrated in Fig 25. Once again, the illustrated primary (clear) areas should be scanned for about three quarters of the time and the shaded areas for the rest. The whole vertical extent of the sky must be included in the search. Turns of up to 30º may be carried out in place. Larger turns are conducted as for two aircraft Battle but the Nos 2 and 4 change sides for variable delay and assisted turns when their element leaders start to turn, adjusting to resume the lookout regime shown in Fig 25 on roll-out.

8-21 Fig 25 Four Aircraft Defensive Battle



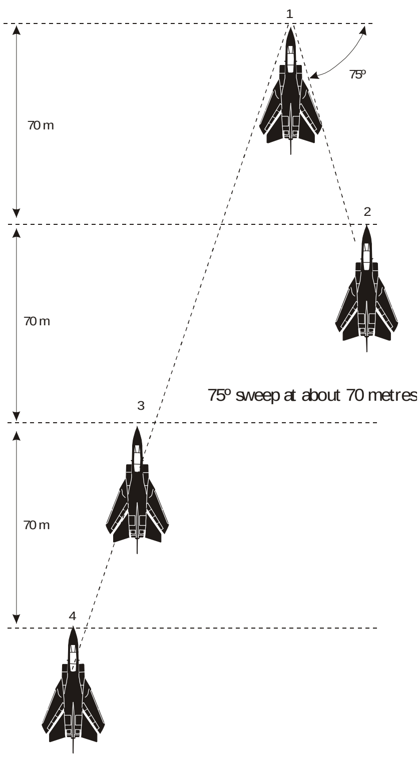
Lookout Areas



Arrow Formation

81. Arrow formation is used for manoeuvring four aircraft in poor weather conditions or restricted airspace and is illustrated in Fig 26. Rearward lookout tends to be restricted but flexibility remains high. The No 2 should position himself at 75º sweep and about 70 metres behind the leader (with small variations depending on aircraft type). The No 3 should be on the other side of the leader, swept 75º and at double the rearward spacing of the No 2. (ie about 140 metres in this example). The No 4 spaces himself outside the No 3 at 75º sweep and again about 70 metres behind.

8-21 Fig 26 Arrow Formation



82. **Turns**. Individual aircraft maintain longitudinal separation, do not normally change sides when turning, and will manoeuvre in plane. This makes Arrow less manoeuvrable than Fighting Wing and the leader must plan turns within the available height to avoid units changing sides.

Recovery

83. **Joining the** Circuit. All the tactical formations previously described will normally maintain position when joining the circuit but may be called to close up to accommodate time and circuit pattern limitations. Procedures are described below (in many training establishments, however, it will be routine to rejoin in close formation).

a. **Fighting Wing Rejoin**. Fighting Wing elements may join the circuit in formation. The No 2 should delay his break for the briefed interval or until the leader has cleared the 12 o'clock position, depending on circuit direction and formation configuration.

b. **Defensive Battle Rejoin**. Defensive Battle formations may maintain position when joining the circuit but will normally close up to not more than 800 metres abreast. The formation breaks in numerical order or as briefed. The No 2 should delay his break for the briefed interval or until the leader has cleared the 12 o'clock position. If on the outside, the No 3 should break at the same time as the No 2; if on the inside, the No 3 should delay until both the Nos 1 and 2 have cleared the 12 o'clock position. The No 4 should delay for the briefed interval or until the No 3 has cleared his 12 o'clock position.

c. **Arrow Rejoin**. The formation may join the circuit in Arrow and break in numerical order. The No 2 breaks after the briefed interval or when the leader has cleared his 12 o'clock. The remaining aircraft break after the briefed intervals.

JOINING CLOSE FORMATION FROM A TACTICAL FORMATION

General

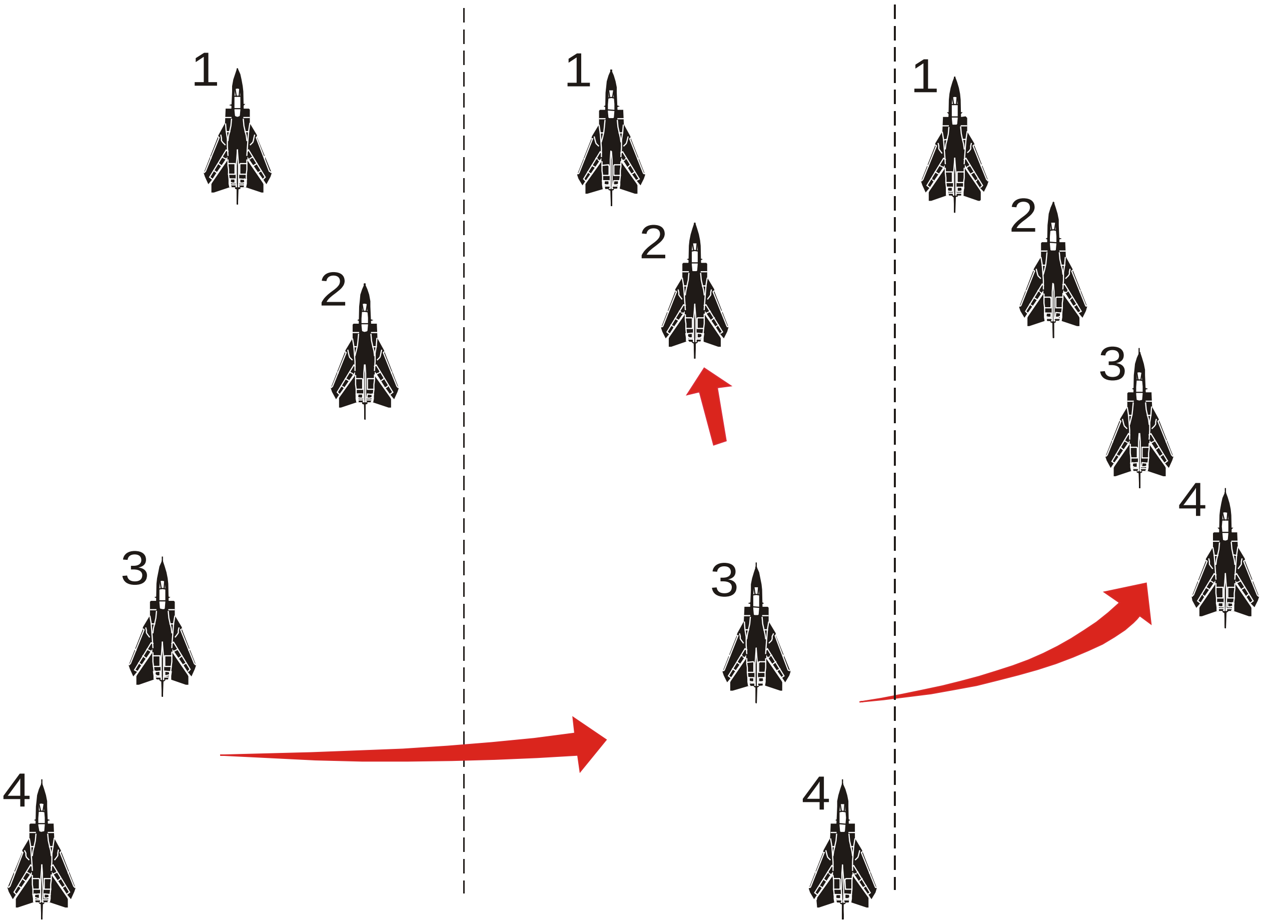
84. Occasions may arise when it is desirable to close up a tactical formation for ease of manoeuvre in difficult terrain (Arrow Formation), cloud penetration (Defensive Battle), or for a set-piece break into the visual circuit. It is not intended to cover joining close formation from all combinations of tactical formations, but a simple technique for changing into close Echelon from four aircraft Defensive Battle and Arrow is shown, the principles of which can be applied to other tactical formations not covered in this chapter. For all tactical formations the guiding principle is that the separate elements always stay together as a fighting unit eg No 2 with No 1 and No 4 with No 3. For this reason, the sequence of aircraft in Echelon will be seen to differ from that produced by manoeuvring a basic close formation into Echelon from Vic or Box. This is not a departure from the principle of 'minimum change', but it produces sequential numbering as a by-product of retaining the integrity of tactical formations.

Arrow and Defensive Battle Formations into Close Echelon

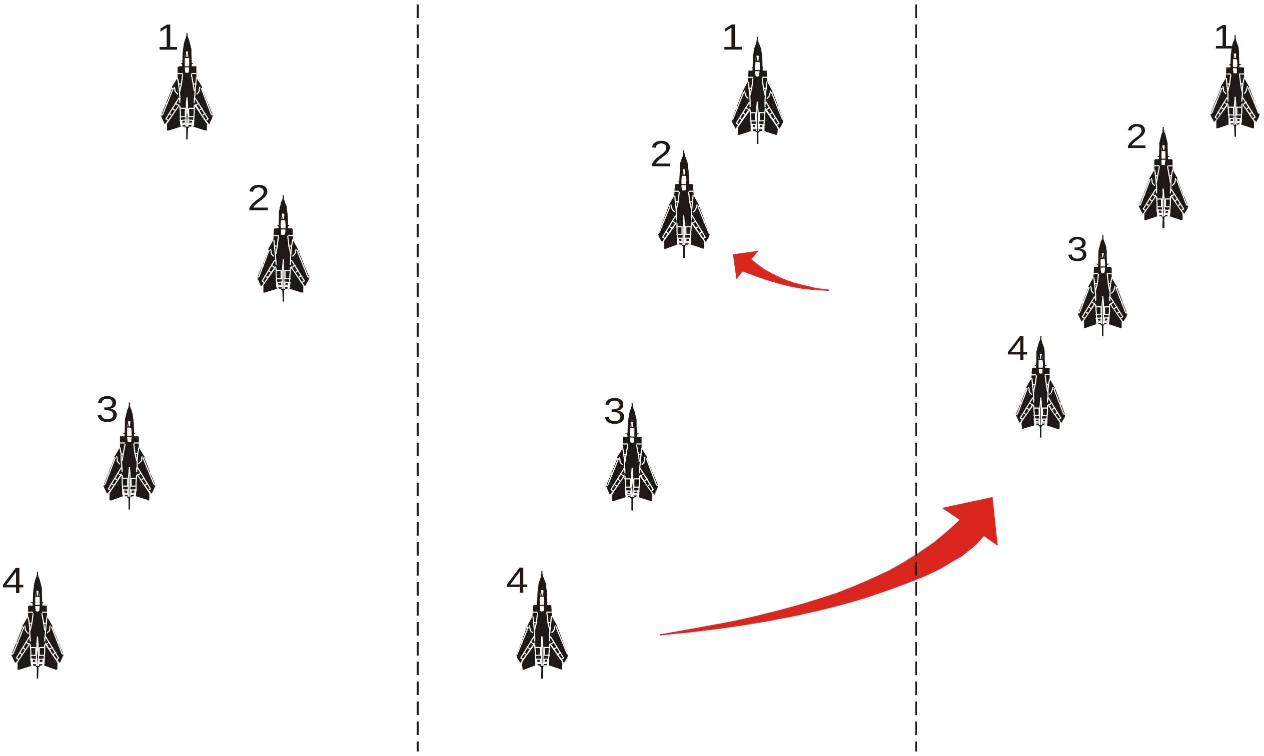
85. Changes into close Echelon from Arrow formation are shown in Figs 27 and 28 and from Defensive Battle in Figs 29 and 30. In all cases, the No 2 and No 4 maintain nose-to-tail clearance on their respective element leaders. Additionally, in the case of Arrow, No 3 keeps nose-to-tail clearance on No 2. From Arrow formation, No 2 may position himself initially on either side of No 1 and thereafter Nos 3 and 4 together move smoothly into their correct Echelon positions with No 4 on the outside of the formation. When a formation is required to change to Echelon from Defensive Battle, No 3's view of the other aircraft is better and his judgement made easier if the move is made through Arrow formation; this is the recommended technique. Once in Arrow formation, on the command "Tankard formation Echelon

Left/Right - GO", Nos 3 and 4 do nothing until No 2 has taken up position in close Echelon on the correct side of No 1. Nos 3 and 4 then move into Echelon as shown in Figs 29 and 30. Should it subsequently be found necessary to change the Echelon from one side to the other, the move should be accomplished by ordering the formation back into Arrow, before calling a change to the opposite Echelon. A direct move from one Echelon to the other is possible but open to confusion and misinterpretation. The good formation No 1 will always put his flight back into a manoeuvrable formation such as Arrow when confronted with a late change of runway or circuit direction. The moves described in this paragraph will place the aircraft in the correct numerical sequence for a run and break. Any requirement for an out-of-order break must be carefully pre-briefed.

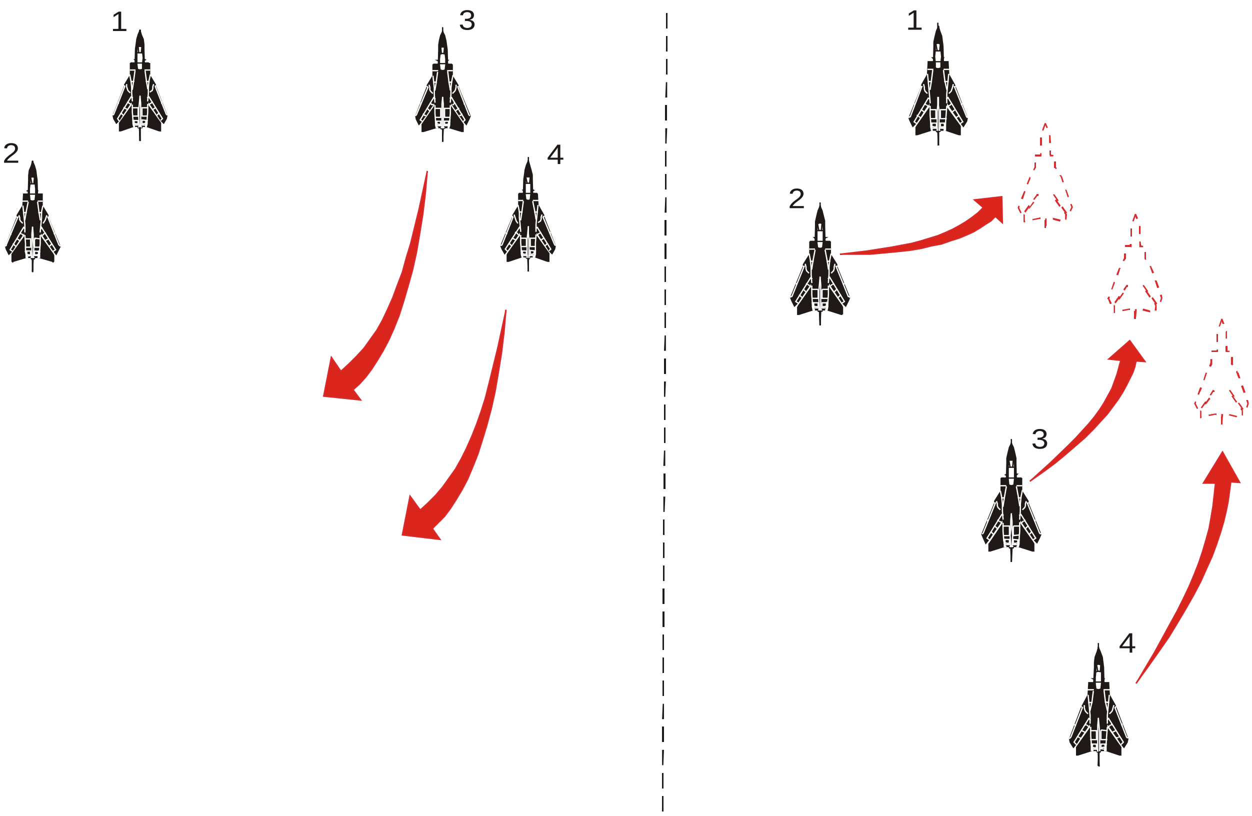
8-21 Fig 27 Arrow to Echelon Right



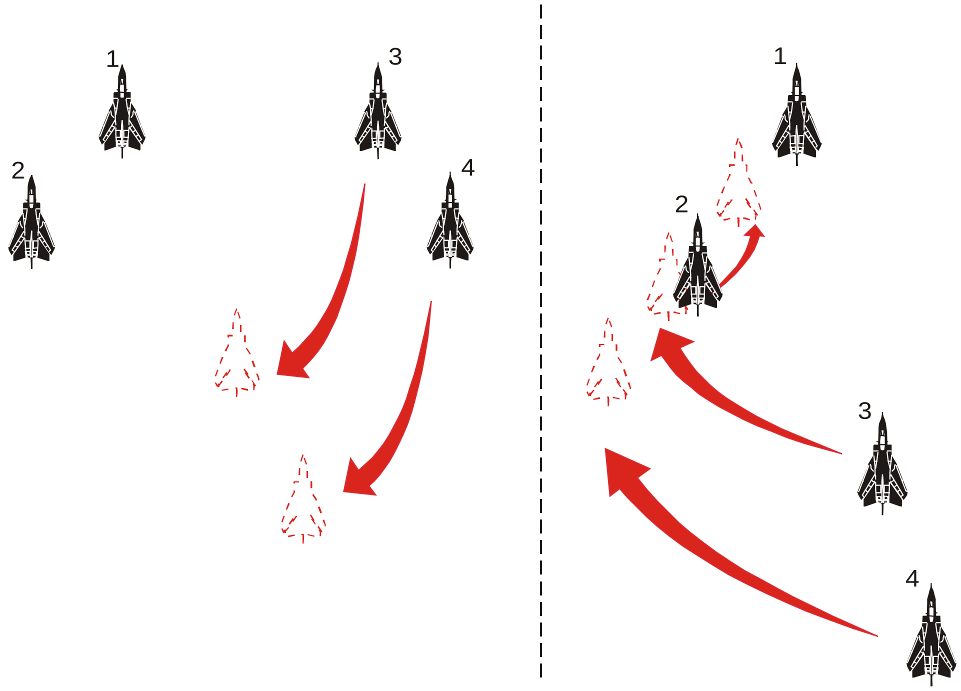
8-21 Fig 28 Arrow to Echelon Left



8-21 Fig 29 Defensive Battle through Arrow to Echelon Right Formation



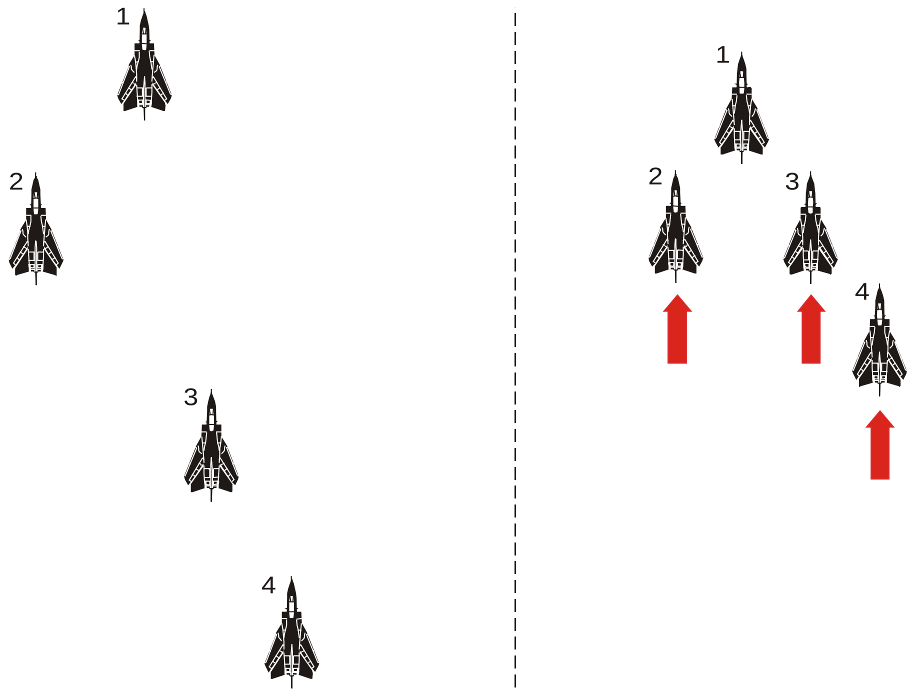
8-21 Fig 30 Defensive Battle through Arrow to Echelon Left Formation



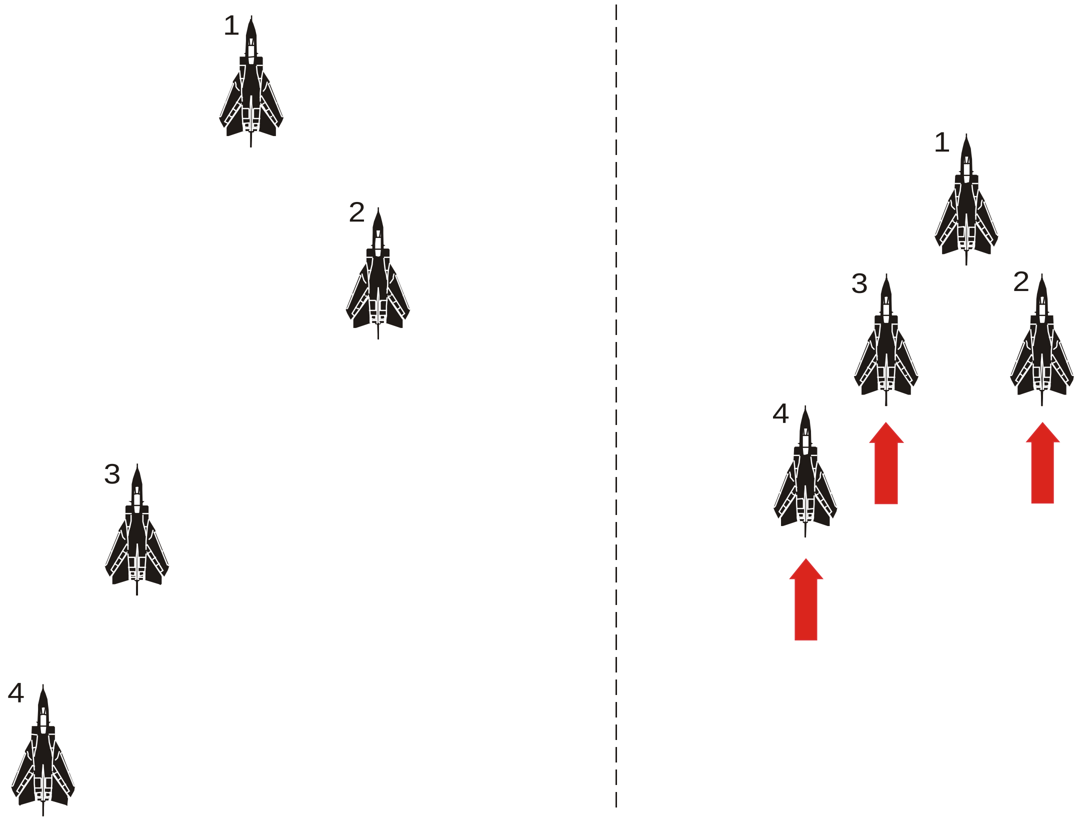
Arrow Formation into Finger Four

86. The Finger Four is a close formation not covered in previous paragraphs. It is occasionally used for recovery when little manoeuvring is required. It is formed from Arrow by Nos 2, 3 and 4 closing up on the No 1 into Echelon positions (Figs 31 and 32). A subsequent change from Finger Four to Echelon is not recommended because it may destroy the integrity of the elements. However, there is no reason why the No 1 should not pre-brief such a change, accomplished by No 2 moving to the end of the Echelon or Nos 3 and 4 moving to the opposite side. For normal operations, it is safer to return the formation to Arrow and then order a change into Echelon Left/Right. Penetration of cloud in Finger Four formation is not recommended, and may be prohibited by some authorities, because if the middle aircraft of the three-aircraft Echelon loses the No 1 in cloud his escape manoeuvre may embarrass the outside aircraft.

8-21 Fig 31 Arrow to Finger Four Right



8-21 Fig 32 Arrow to Finger Four Left



Human Factors and Formation Flying

Formation Flying is not only an integral part of operational flying but also highly satisfying to do well. However, aircraft flying in close proximity is not without it's dangers and can, as proved, be lethal. There is potential for a loss spatial disorientation and Situation Awareness. Formation flying is about sound planning, practice, communications and good leadership.

CHAPTER 22 - STANDARD FORMATION HAND SIGNALS

1. Standard formation hand signals are described in Table 1. The signals are agreed via STANAG 3379 and the standards described in AFSP-4, In-flight Visual Signals. MAA RA2350 – Aircraft Emergencies states that Aviation Duty Holders may issue additional in-flight visual signals but they should be consistent with STANAG 3379.

Table 1 - Standard Formation Hand Signals

(The signals marked by an asterisk (*) conform to AFSP-4)

EXECUTIVE SIGNALS		
Action	**Description of Signal**	**Action to be Taken at**
1. Running up.	Hand raised, forefinger extended upwards and revolved in horizontal plane.	Commencement of signal.
2. Ready for take-off?	Thumb up.	
3. Commence take off.	Tap on the forehead three times followed by a nod of the head.	Nod of head.
4. a. Increase power. b. Decrease power	a. Positive forward movement of head. b. Positive backward movement of head.	Cessation of signal.
5. Turning.	Forearm vertical, hand flat and parallel with line of flight then moved right or left as necessary.	Cessation of signal.
6. Straightening out.	Chopping motion forwards with edge of flat hand.	Cessation of signal.
7. Airbrakes 'in' or 'out'.*	Hold open hand horizontally at eye level, then move the fingers and thumb to simulate a biting motion.	Nod of head.
8. Flaps 'up' or 'down'.*	Hold open hand horizontally at eye level, with fingers and thumb flat, then tilt hand downward by bending the wrist.	Nod of head.
9. Undercarriage 'up' or 'down'.*	Hold a closed hand forward of your head and rotate it in a circular motion in the vertical plane.	Nod of head.
10. Lead Change.*	Point with an index finger to new leader, then hold open hand vertically at eye level, fingers together, and then move it horizontally forward with rotation to finish with hand held horizontally and arm fully extended.	Nod of head and manoeuvre to take the lead
11. Close formation or reform basic formation as briefed.	Lateral rocking of aircraft.	Cessation of signal.
12. Relax close formation.	Hand raised with palm outwards, fingers together, palm against canopy on the appropriate side.	Cessation of signal.
13. Change position.*	Index finger pointed at aircraft/pilot concerned, then pointed to the new position to which this pilot is to move.	Nod of head and manoeuvre to new the position
14. Line astern: a. Close b. Extended	a. Clenched fist, thumb extended to rear, moving back and forth. b. Clenched fist, tapping on the back of head.	Cessation of signal.
15. Climbing.	Forefinger point upwards.	Cessation of signal.
16. Descending.	Forefinger pointing downwards.	Cessation of signal.
17. Levelling out.	Sideways movements of either hand, palm down, fingers extended at face level.	Cessation of signal.

18. Break formation.	Rapid sweeping movement of the open hand, palm forward, fingers upward in front of the face.	Cessation of signal.
19. I am returning/you are to return to base.	Point at self/aircraft concerned, then point downwards.	
INFORMATIVE SIGNALS		
Action	**Description of Signal**	
20. Your aircraft is on fire.	Fly alongside and rock the wings to attract the attention of the pilot, then draw the edge of the hand across the throat in a cutting motion, afterwards pointing to the fire area. Continue this until acknowledged by thumbs up signal.	
21. Fuel state.* To indicate or query the amount of fuel remaining. To indicate or reply.	Make drinking motion with closed hand, thumb extended to touch the oxygen mask. < 10 minutes signal '*Desire to land as soon as possible*' To indicate a greater amount of fuel remaining, hold a closed hand at or above eye level with the appropriate number of fingers extended vertically as follows: 10 - 19 minutes 1 finger (index) 20 – 29 minutes 2 fingers 30 – 39 minutes 3 fingers 40 – 49 minutes 4 fingers 50 minutes or more 5 fingers (open hand)	
22. Receiver failure.*	Tap earphone with open hand and then move hand forward and backward over ear position followed by a thumbs down.	
23. Transmitter failure.*	Tap microphone with an open hand and then move hand up and down in front of face followed by a thumbs down.	
	The pilot with communications failure should attempt to attract attention visually by: a. Rocking the aircraft wings.: b. Flashing landing, taxi or other lights (except navigation lights) during darkness. c. Any other means.	
24. Affirmative/I will comply *	Nod head forward and back or a thumbs up.	
25. Negative/I will not comply *	Turn head left and right or a thumbs down.	
26. Terrorist Attack *	Hold pointed finger to the head with thumb sticking up to simulate a pointed gun to the head.	

DISTRESS SIGNALS (DAY)		
Action	**Description of Signal**	
27. Ejection.*	One or both closed hands pulled downwards from above the head, across the face to simulate pulling ejection blind.	
28. Desire to land.*	Hold an open hand horizontally above the shoulder and then move it forward and downward to shoulder level, finishing with a	

	movement in a simulated round-out.	
29. Systems failure * (HEFOM) **Note**: While HEFOM is in general use in the RAF, AFSP-4 uses the mnemonic HEFOE, where the second E represents *Engine*, vice *Motor*. The signals in both are identical and have the same meaning.	To indicate the nature of the problem or the malfunctioning system, hold a closed hand at or above eye level, and then extend vertically the appropriate number of fingers as follows: **H** Hydraulic one (index) finger. **E** Electrical two fingers. **F** Fuel three fingers. **O** Oxygen four fingers. **M** Motor five fingers (open hand). ***Note***: 1. The HEFOM signals are to be used only when radio contact is not possible. 2. If either the one finger signal is received, or the intercepting pilot is unable to understand the signals of the pilot requiring assistance, then the intercepting pilot is to assume that the aircraft in distress has one or more systems inoperative, e.g. airbrakes, flaps or undercarriage, and is to proceed with extreme caution.	
30. Receiver failure.*	Tap earphone with open hand and then move hand forward and backward over ear position.	
31. Transmitter failure.*	Tap microphone with an open hand and then move hand up and down in front of face.	
DISTRESS SIGNAL (NIGHT)		
32. In distress and desire to land.*	Repeated intermittent flashes with a torch, taking care not to dazzle other pilots. (The lead aircraft should assume that the aircraft in distress has one or more inoperative systems and proceed with extreme caution.) ***Note***: Because night signals will be difficult to understand, only the night signal given above will be used. AFSP-4 gives further details on signals for intercepted and intercepting aircraft at night.	

CHAPTER 23 - AIR-TO-AIR REFUELLING

Contents **Page**

Introduction

1. Air-to-Air Refuelling (AAR) is accepted as a means of increasing aircraft range without sacrificing other aspects of performance. The adoption of AAR by the RAF is such that almost all aircraft introduced into service today are given a flight refuelling capability. Details of AAR equipments and procedures are promulgated in ATP-3.3.4.2 (ATP 56(C)) - Air to Air Refuelling and ATP-3.3.4.2(C) National SRD-United Kingdom (formerly National Annex Y). These documents are authoritative and users should refer to them for detailed information.

AAR Objectives

2. The objective of AAR operations is to enhance combat effectiveness by extending the range, payload or endurance of receiver aircraft. Successful AAR depends on 3 major factors:

a. **Equipment Compatibility**. It is essential that aircraft requiring AAR are fitted with probes/receptacles and fuel systems compatible with the characteristics of the tanker aircraft employed, e.g. drogue/boom system, fuel surge pressures, fuel type etc.

b. **Performance Compatibility**. It is essential for tanker and receiver aircraft performance to be compatible in terms of AAR speeds and altitudes.

c. **Procedural Compatibility**. It is essential for tankers and receivers to employ pre-planned and compatible procedures for rendezvous, making contact, fuel transfer and departure.

3. The priorities of AAR are:

a. Support of Air Defence Aircraft.

b. Support of Interdictor Strike Aircraft.

c. Tactical Support of Maritime Operations.

d. Overseas support, deployments and exercises.

However, situations occur where the swift deployment of aircraft to counter a distant threat is a vital factor in military operations. Without AAR the speed of response could be seriously affected.

Refuelling Methods

4. There are two main systems for transferring fuel from the tanker to the receiver aircraft; the Boom, and the Probe and Drogue.

5. **The Boom Method**. The tanker is fitted with a flyable, telescopic boom; with the free end terminating in a probe-like fuel nozzle. Receivers are fitted with a reception coupling, or receptacle. The receiver flies a steady formation position whilst the boom operator manoeuvres and extends the boom to make contact with the receptacle. The boom equipped tanker is fitted with Pilot Director Lights (PDLs) to aid receiver positioning. A description of the PDL system is given in the appropriate National SRD.

6. **Boom Drogue Adapter**. The KC-135 and the C135FR boom can be modified to refuel some types of probe equipped aircraft by fitting a Boom Drogue Adapter (BDA) consisting of 3 m (9 ft) of hose attached to the end of the telescoping part of the boom. The hose terminates in a hard non-collapsible drogue. PDLs should not be used with this system. The BDA does not have a hose response system; therefore caution is required during the approach to contact, as excessive closure rates could result in a broken probe or hose. Also, attempts to disconnect which are not made down the correct withdrawal path, could result in the probe binding in the reception coupling. For this reason, the USAF recommends the use of ‘Flexitip’ probes with the BDA. Flexitip probes have some internal bracings removed which allows the probe mushroom valve tip some lateral movement within the probe structure, and makes an off-centre disconnect easier. A full description of the BDA is given in the appropriate National SRD. The BDA can only be fitted or removed on the ground.

7. **The Probe and Drogue Method**. From a power-driven hose drum (or reel), the tanker trails a hose which terminates in a reception coupling and a conical shaped drogue. When the hose is at full trail, a winding-in torque (response system) is applied to the drum; this counters the air drag of the drogue. The controlled balance between winding-in torque (response system) and air drag absorbs the impact of the receiver making contact; it also damps any tendency for the hose to whip as contact is made, provided excessive receiver closure rates are avoided. Receiver aircraft are fitted with an AAR probe which terminates in a fuel nozzle.

8. The receiver aircraft is flown to engage the probe into the drogue while maintaining a closing speed of 2 to 5 kt.. When contact is made, the probe engages coupling latches, which grip the probe to make a fuel tight joint; fuel valves in the coupling and probe then open. The receiver continues to move forward, pushing the hose back onto the drum. When sufficient hose has rewound onto the drum, the main fuel valve in the AAR equipment opens and fuel can be pumped to the receiver. After making contact the forward movement required of the receiver to open the fuel valve is typically about 2 m (6 ft); however, the distance varies according to AAR equipment type, details are provided in National SRDs. Most systems afford a considerable range of fore and aft hose movement within which fuel will flow to an in-contact receiver. When AAR is complete, the receiver pilot makes a small power reduction and drops back slowly to stabilize in the astern position. As the hose nears the full

trail position, the AAR equipment fuel valve closes. When the hose reaches full trail, the probe begins to pull out of the reception coupling; the coupling and probe fuel valves close, then the coupling latches release the probe.

9. If a Breakaway is commanded, the receiver drops back quickly. A sensor in the AAR equipment detects the high rate of hose movement and the hose drum brake is automatically applied; this achieves a swift, positive disconnect and occurs well before the hose reaches full trail.

Fuel Flow Rates and Pressures

10. Fuel flow rates vary widely according to AAR installation. Generally flow rates will be as described in Table 1, but will be affected by the specific gravity of the fuel and the limitations of the receiver fuel system. Fuel pressure is regulated in most systems not to exceed about 3.5 bars (50 psi) at the reception coupling.

Table 1 AAR System Fuel Flow Rates

Boom System	Up to 3650 kg.min (8000 lb/min)
Integral Hose System	2300 kg/min (5000 lb.min)
Podded Hose System	870 kg/min (2800 lb/min) to 1000 kg/min (3200 lb/min)

Hose Dimensions and Markings

11. Generally pod hoses are shorter, lighter and have a narrower bore than integral system hoses. The lengths of pod hoses vary between 15 m (50 ft) and 27 m (90 ft) whereas 24 m (80 ft) is typical of an integral system hose. Most hoses are marked with coloured bands but there is a wide variety of colours and marking patterns. Most hoses have a series of bands or a block of colour to indicate the optimum receiver refuelling position; this is achieved when the hose is pushed in so that the markings enter the hose fairing or tunnel. On some hoses, the refuelling position marks are bounded by additional markings indicating the start and stop positions for fuel flow. Usually, there is a series of closely spaced bands at the tanker end of the hose; these provide cues for the receiver pilot to assess rates of fore and aft movement after making contact, or during disconnect. Full details of hose markings and dimensions are contained in National SRDs.

12. To give greater flexibility of operation, the size of the probe nozzle and reception coupling have been standardized throughout NATO countries.

Lighting

13. Adjacent to the refuelling unit and facing aft, the tanker has a panel of coloured lights (red, amber and green) although some equipments may have only amber and green lights. On some systems, the signal lights are duplicated for redundancy. If required, refuellings can be made in radio silence solely by reference to these signal lights. Lighting equipment on the tanker, and probe lighting on some receivers, enable the refuelling to be done at night. The NATO standard light signals are:

Red Light	-	Breakaway, or do not make contact
Amber Light	-	Clear contact
Green Light	-	Fuel is flowing

Variations to the described lighting signals are detailed in the appropriate National SRD.

14. **Drogue Lighting**. Most drogues are illuminated to assist night AAR. Some drogues are lit internally by lights at the coupling; alternatively, the drogue periphery may be highlighted by a series of luminescent tritium light sources. On some tankers, reflective paint is applied to the inside of the drogue.

15. **Probe Lights**. Many receivers have a light which illuminates the probe. These lights should be used with caution, because they can dazzle the refuelling operator in the tanker; furthermore, their use may accentuate a tendency for receiver pilots to chase the drogue and therefore possibly overcontrol.

16. **Drogue Tunnel/Serving Carriage Lights**. The drogue tunnel or the serving carriage of most tanker AAR installations are lit from within. This is particularly useful for gauging the amount of hose pushed back onto the hose drum.

17. ***Boom Tanker Lighting***. Boom tankers are fitted with a rear-mounted floodlight, which illuminates the receiver, to assist the boom operator. The boom is fitted with a boom nozzle light to assist the operator in positioning the nozzle into the receptacle. Some receivers' receptacles are also internally lit; the Universal AAR Receptacle Slipway Installation (UARRSI) is usually lit, or highlighted by marker lights. A UARRSI is a modular AAR unit incorporating an AAR receptacle and slipway to guide the tanker boom nozzle into the receptacle. The UAARSI has a boom interphone capability.

Equipment Currently in Use in the RAF

18. The RAF tanker fleet currently consists of the A330-200 aircraft (see Fig 1), named Voyager K2/K3 in RAF service.

8-23 Fig 1 Refuelling from Underwing Pods

19. The refuelling units are of two types, the Fuselage Refuelling Unit (FRU) and the FRL 905E wing mounted AAR pod. The FRU is mounted at the rear of the fuselage and has a higher rate of flow than the pod. The FRU is primarily intended for use by tanker or transport aircraft but can be used by any type. The refuelling fit of the Voyager depends upon the Mark of aircraft. The fleet will comprise 14

aircraft and all will be fitted with 2 wing mounted pods, with 7 of the fleet also fitted with an FRU. Those aircraft which are only equipped with wing pods are designated Voyager KC Mk2 and those capable of being equipped with a FRU are designated Voyager KC Mk3. The refuelling equipment is operated by a Mission System Operator (MSO).

AIRCRAFT	**FRU**	**POD**
Voyager K2		2 x FRL 905E
Voyager K3	1	2 x FRL 905E

20. Specific details of the FRU and FRL 950E pod can be found in the National SRD (see paragraph 1). Brief details of the Voyager capabilities are as follows:

a. At the discretion of the Tanker Commander, receiver aircraft may be cleared to make simultaneous contacts on the wing pods.

b. The Voyager has an extensive array of lights, which are adjustable for brilliance. Formation keeping lights and I/R illuminators are also provided. For conducting night AAR, IR cameras and lighting sources are used.

c. The UK National SRD gives heights and speeds for AAR for the Voyager as Sea level to 35000 ft and the speed range as 180 to 325 kt, whereas the Release to Service Document (at the time of publication) limits the height band to 10000 to 25000 ft and the speed range as 260 to 300 kt. The discrepancy, due to the aircraft using an interim basket fit, will be resolved in the future.

d. The Voyager total fuel load is 109 000 kg (240,000 lb) and transferable fuel is dependent on sortie duration. About 75 000 kg (165,000 lb) is available for transfer during a 4 hour refuelling mission, assuming a fuel burn rate of 6 000 kg/hr (13,220 lb/hr).

e. Fuel is delivered to the receiver at the regulated pressure of 3.5 ± 0.35 bars (50 ± 5 psi).

f. The primary/usual type of fuel is F34 (JP8). Alternate fuels depend upon the airfield where it is uploaded. The Voyager can also accept F35, F40, F43 and F44.

g. The VOYAGER has the following radio, navigation, and RV aids:

i. VHF, UHF and HF radios and Satcom.

ii. VOR, TACAN, ADF, INS, GPS, and weather radar.

iii. UDF, A/A TACAN (bearing and DME), ETCAS, IFF and Link 16.

21. The Voyager wing pod markings and lighting signals are detailed in the National SRD (see paragraph 1).

FLYING TECHNIQUES

Flying Procedures

22. AAR procedures are described in detail in ATP-3.3.4.2 (ATP 56(C)) - Air to Air Refuelling (see paragraph 1).

Tanker Aircraft

23. As the receiver is approaching the drogue, the tanker aircraft should be flown as smoothly as possible because any movement of the aircraft will cause the drogue to oscillate and reduce the chances of a successful contact. It is incumbent upon the tanker captain, therefore, to find the best possible flying conditions conducive to a receiver making contact, i.e. air space relatively free from cloud or clear air turbulence. When a receiver is in contact, it is usually possible to hold position in all but the most turbulent conditions. At all times however, the tanker should be as stable as possible; turns may be made but they should be made smoothly and at such a rate as to allow the receiver to remain in contact easily.

24. Once a receiver has joined, the tanker captain assumes executive control of both aircraft. On large formations during accompanied flights the lead tanker captain is responsible for the safety aspects of the formation. In the event of a receiver emergency the course of action to be taken by the receivers is determined by the receiver leader.

Receiver Aircraft

25. The techniques for successful receiver flying are not difficult to acquire and are well within the capability of the average pilot. Techniques vary slightly but accurate and smooth flying is the basis for success for all types of receiver aircraft. The drogue is approached from behind and slightly below at an overtaking speed of 2 to 5 kt, care being taken in the final stage of the approach not to overcorrect on the controls. If the receiver makes contact too slowly the probe will not engage correctly in the coupling; this is termed a “soft” contact. If an approach is made too fast the drum will not be able to take up the hose quickly enough, the hose will bow and the resulting whip will probably break off the probe nozzle. Terminology used includes a ‘spokes contact’, defined as the receiver probe penetrating the ribs or canopy of the drogue, causing damage which can cause FOD and may cause the drogue to lose aerodynamic stability; further attempts to make contact are then not permitted. A ‘rim contact’ is made when the probe makes a hard contact on the rim of the drogue but does no damage

26. When at the end of an approach and the receiver is sure of making contact, a small amount of power is applied to counteract the drag from the drogue and to maintain the correct closing speed. Immediately a successful contact has been made and the probe is observed to be positively locked in the drogue, a definite reduction in closing speed should be made by slightly closing the throttles before moving up the refuelling position. The normal refuelling position, and one giving the largest refuelling flight envelope, is when the hose is lying at its normal trail angle with the forward edge of the orange band marked on the hose just entering the mouth of the pod, or the serving carriage of the FRU. In all types of receiver aircraft it is essential that pilots are capable of close formation flying for periods of ten minutes of more.

27. To break contact, the throttles are closed slightly and the receiver allowed to drop gently back along the line of the hose, with the aim of breaking contact with the drogue in the normal full trail position. In an emergency the throttles are fully closed and, because of the hose drum braking system, contact will be broken almost immediately with the hose partially wound on the drum.

Night Refuelling

28. Apart from requiring greater concentration, the techniques for night refuelling are identical to those used by day. Any additional difficulties are due mainly to the inability to judge final closing speeds and the distance of the probe from the drogue owing to lack of outside references.

OPERATIONAL USE OF AAR

Methods of Employment

29. **Tactical Applications**. Extending the radius of action, and/or endurance, of aircraft on operational sorties are possibly the most important applications of AAR. The developing range of operational requirements means a continuing process in evolving the tactical procedures necessary to make the best use of the available effort. For instance, the role of the air defence tanker (ADT), in support of the fighter on a CAP has increased in importance due to changing fighter tactics and the need to provide air defence over maritime areas. The method of close support of strike aircraft will vary with each particular attack sortie due to the variety and location of targets. Inevitably, such wide variations in operational requirements make flexibility paramount for an efficient Tanker Force. Similarly, detailed tanker Standard Operating Procedures (SOPs) are essential to cover every likely operating condition.

30. **Overseas Reinforcement**. There are two ways in which AAR can be used for aircraft deployment: accompanied and unaccompanied flights.

a. **Accompanied Flight**. On accompanied flights the receivers make a rendezvous with the tanker close to the receivers' airfield of departure. Thereafter the receivers remain in close proximity to the tanker, taking fuel as planned, until they reach their terminal airfield. In normal peace-time operations the refuellings en route are planned so that, if for some reason the receivers are unable to take on fuel, they have sufficient fuel remaining to either return to their departure airfield or divert to a suitable airfield near track. Accompanied flight is usually employed when the receiver aircraft have poor navigation or communications facilities and/or a short ferry range. After the last refuelling the receivers may leave the tanker and continue to their destination independently. In this way, by flying at their own optimum speeds and heights rather than those of the formation, the receivers' range may be increased. This 'departure' by the receivers may also be used when the tanker is required to land at an airfield other than the receivers' destination.

b. **Unaccompanied Flight**. On unaccompanied flights the receiver makes a rendezvous with the tanker at a convenient point along its track to the destination airfield. For maximum benefit the refuelling should take place at a point as far as possible from the airfield of departure commensurate with aircraft safety. After refuelling, the receiver proceeds alone to its destination. Although this method may be used with long range fighters, it is usually restricted to aircraft with good navigation and communications facilities and/or a large internal fuel capacity, e.g. bomber or transport aircraft.

Rendezvous Procedures

31. **Altimeter Settings**. Unless otherwise directed, an altimeter setting of 1013.2 mb (29.92 inches) is to be used for AAR operations at or above transition altitude, or when over water and operating in accordance with ICAO procedures. When not operating on standard pressure settings,

tanker crews are to include the altimeter setting in the RV Initial Call. To minimise the chance of dissimilar pressure settings between receivers and tankers, the following terminology is to be used:

Tanker and receiver altimeter set to:	Terminology used:
1013.2 mb (29.92 inches)	Flight Level
QNH or Regional Pressure Setting	Altitude
QFE	Height

32. **Vertical Separation**. Receivers are normally to join from below and are to maintain a minimum of 1000 ft vertical separation, unless otherwise stated at the planning or briefing stage, until visual contact and positive identification have been made. If conditions for AAR are unsuitable, the tanker commander may select an alternate flight level, altitude or height.

33. **Tanker Speed**. The tanker speed for RV is detailed in the National SRD (See also paragraph 20c). This is the speed that the tanker will fly if communication is not established with the receiver. If the tanker's speed differs from that listed, the tanker should advise the receiver in the RV Initial Call.

34. **Receiver**. The receiver should normally fly the speed prescribed in its flight manual and listed in appropriate tanker National SRD.

35. **Visibility**. Receivers will maintain altitude separation of at least 1000 ft until 1 nm from the tanker.

36. **Receiver Visual With Tanker**. Once the receiver(s) is visual with the tanker, receivers are clear to join and should initiate a progressive climb towards the tanker.

37. **Receiver Not Visual With Tanker**. If receivers are not visual with the tanker, the subsequent actions will be in accordance with the capability of the receiver.

a. Receivers without radar or with only Weather Radar shall not proceed inside 1 nm unless the tanker is in sight.

b. Where receiver national limitations permit, aircraft with a basic airborne intercept radar (i.e. target search available but lock capability not available) may climb to 500 ft below base AAR altitude, maintain this level and close to ½ nm.

c. If radar contact is lost inside of 1 nm without visual contact with the tanker, the receiver is to descend to 1000 ft below tanker altitude.

d. Where receiver national limitations permit, as long as radar lock is maintained, aircraft equipped with an AI radar may continue closure at no more than 10 kts of overtake inside of ½ nm maintaining 500ft vertical separation to a minimum range of 1500 ft.

e. When visual contact is established with the tanker, a progressive climb may be initiated in order to join the tanker.

f. If visual contact is not established by a range of 1500 ft, closure is to cease.

g. If radar lock is subsequently lost, the receiver shall re-establish at least ½ nm range and maintain a minimum of 500 ft vertical separation.

38. **Visual Contact Not Established**. If visual contact is not achieved at the appropriate minimum closure range, the receiver(s) may stabilise at the appropriate minimum range and maintain it until the tanker manoeuvres into an area of improved visibility. Alternatively, the receiver(s) may descend to 1000 ft below the tanker, drop back to 1 nm and either maintain this position until the tanker manoeuvres into an area of improved visibility or terminate the RV.

39. **Termination of AAR Due to Visibility**. AAR is to be discontinued when in-flight visibility is deemed insufficient for safe AAR operations.

40. There are several methods of effecting a rendezvous (RV) which are described in detail in ATP-3.3.4.2 (ATP 56(C)). A brief description of each RV procedure is given in the following sub-paragraphs.

a. **RV Alpha (Anchor RV)**. This is a procedure directed by a radar control station, whether ground based, seaborne, or airborne (AEW).

b. **RV Bravo**. This is a heading based procedure which utilises air-to-air equipment of both tanker and receiver. The tanker controls the procedure.

c. **RV Charlie**. This is a heading based procedure similar to the RV Bravo which allows receivers with an Airborne Intercept (AI) radar to control the procedure once positive AI radar contact is established.

d. **RV Delta (Point Parallel)**. This procedure requires the receiver to maintain an agreed track and the tanker to maintain the reciprocal track, offset a pre-determined distance.

e. **RV Echo (Timing)**. This procedure is intended for use in support of a combat air patrol (CAP); particularly during periods of EMCON constraints.

f. **RV Foxtrot (Sequenced)**. This procedure is normally used when the tanker and receiver operate from the same base.

g **RV Golf (En-route)**. This procedure facilitates join up on a common track to make good a scheduled time. The receivers may have departed either from the same or different bases. There are a number of enroute RVs.

Meteorological Aspects

41. Weather has an important influence on the conduct of AAR operations. In addition to taking account of the weather conditions at the operating and diversion airfields the following factors have to be considered.

a. **Rendezvous Weather**. Weather conditions in the actual area of the rendezvous can be critical. Although it is not impossible to make a rendezvous in thin cloud, it is much more difficult and hazardous than in clear conditions. A visual sighting can be made much more easily if the rendezvous is at a height at which contrails are found.

b. **En Route Weather**. During accompanied flights IMC can make visual station keeping in large formations very difficult. Although the internal radar of the tankers and receivers can be used to assist station keeping in cloud, such conditions are avoided as far as possible by small deviations in route and/or height. Contacts may be made in cloud but flight in heavy cumulo-nimbus formations or clear air turbulence can result in drogue oscillation and difficulties in making contact.

Planning

42. Before a deployment may be undertaken, it must be established that it is feasible. The purpose of the feasibility study is two-fold: to establish that the receiver is capable of undertaking the deployment format and to establish the tanker/receiver ratio required. Many factors are taken into account: the relative performance of the tanker and receiver aircraft, the availability of diversion airfields along the selected routes, the tanker effort allocated to the deployment, the availability of parking space at the staging airfields, and the climatology of the route and the staging and terminal bases. Receivers can normally be classified as high performance aircraft and in many cases the endurance is, apart from fuel, limited by the consumption of oil and oxygen. The endurance of the receiver frequently dictates the format of the deployment.

43. When the feasibility study has been completed, it is then possible to calculate the movement table which provides details of the daily movements of tankers and receivers. From this the personnel and equipment needed at en route bases for ground support can be determined.

The Refuelling Plan

44. When the tanker movements have been determined, the full refuelling plan is calculated; this plan sets out:

a. The positions where fuel is to be transferred to the receivers.

b. The quantity of fuel to be transferred.

c. The Abort Point (AP) - this is a geographical position on a receiver's track associated with a specific refuelling bracket. Should a receiver reach an AP without the planned transfer for the appropriate bracket having commenced, diversion action must be taken. This will allow the receiver to arrive overhead the planned diversion with the minimum fuel reserve.

d. The nominated diversion airfields to be used if a planned fuel transfer fails for any reason or if diversion is necessary for other contingencies.

e. The fuel remaining in the tanker after each transfer, and overhead the planned destination airfield.

Human Factors and AAR

AAR is a physical and mental challenge requiring high levels of concentration and dexterity. Fatigue can rapidly set in leading to stress to a lesser or greater degree. Good training and plenty of practice will remove 'gremlins' from the mind! Beware of visual distortion and closure speeds (the tanker will appear very small…..until the last moments when it 'blosoms' into the cockpit!!)

CHAPTER 24 - ASYMMETRIC FLIGHT AND ENGINE-OUT PERFORMANCE

Contents **Page**

Figures

Introduction

1. Asymmetric flight is generally accepted to mean the condition applying to multi-engined aircraft, following loss of power from an engine(s). Unusual configurations are not considered in the discussion on handling, although the degradation of performance obviously applies. The term 'multi-engined' in this chapter means more than one power plant mounted laterally either side of the centre line.

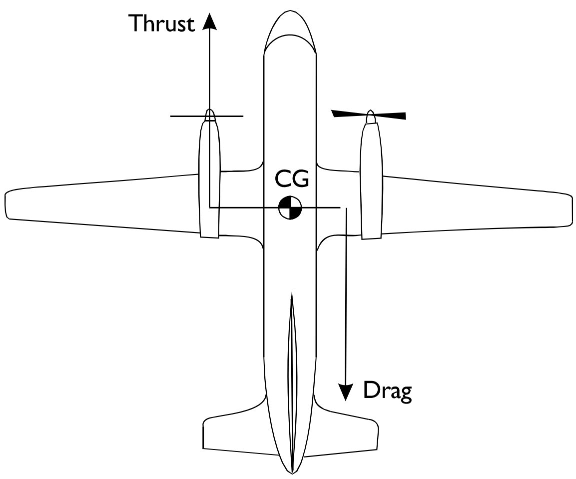
2. Aircrew Manuals give details of the technique and speeds required when using asymmetric power, the information in this chapter being of a general nature. The relevant documents and orders should be studied before practising the use of asymmetric power.

Basic Conditions

3. If a multi-engined aircraft suffers engine failure when airborne, there are two immediate effects:

a. The initial one is the yawing moment that occurs due to the asymmetry of the thrust line (Fig 1). The size of this initial yawing moment depends upon the engine thrust, the distance between the thrust line and CG, and the aircraft's directional stability, which tends to oppose the asymmetric yawing moment. The yawing moment is also affected by the rate of thrust decay of the 'dead' engine and possibly by its drag. On propeller-driven aircraft, the yaw is aggravated by the drag effect of the windmilling propeller. The total moment can be very large, particularly when at high power and low speed.

8-24 Fig 1 Asymmetry of Thrust Line



b. The initial yawing moment results in a subsequent rolling moment which can be very marked. On propeller-driven aircraft, the yaw-induced roll is increased by the reduction in slipstream velocity, and hence lift, over the wing behind the failed engine. Although this effect can be very pronounced, it should be within the capacity of the ailerons to counter it in all but abnormal cases outside design limits.

4. If corrective action is not taken, the aircraft yaws and rolls towards the failed engine resulting in a spiral towards the failed engine.

5. It is important to understand that although the yawing moment is the root cause of the problem, due to the pronounced rolling effects outlined above, it is imperative to control the roll with aileron as well as controlling the yaw with the application of rudder. On older, non-Performance Group certificated types, a combination of rudder and power reduction on the live engine(s) may be required to maintain control, especially immediately after take-off.

Forces Acting on the Aircraft

6. An aircraft can maintain a constant heading under asymmetric power with an infinite number of bank and sideslip combinations.

7. The forces acting on the aircraft, in the plane of the wings are:

a. The sideforce on the body and fin, due to sideslip

b. The sideforce caused by rudder deflection, pivoting the aircraft about the CG.

c. Any horizontal component of lift, produced by banking.

d. Thrust from the live engine(s).

e. Total drag.

8. In addition to these major factors, in the case of propeller-driven aircraft, there are the minor, but appreciable, effects of:

a. **Torque**. Propeller torque, which increases with power, tends to roll the aircraft in the opposite direction to that of propeller rotation. Torque has a slight effect on control while using asymmetric power; if the torque reaction tends to lift the dead engine, then its effect is beneficial.

b. **Failure of the Critical Engine**. Asymmetric Blade Effect, as discussed in Volume1 Chapter 23, effectively displaces the thrust lines towards the downgoing blade on each propeller. For example, if the propellers rotate clockwise when viewed from the rear the thrust line is displaced to the right. This displacement results in a greater yawing moment when the critical engine fails due to the longer thrust moment arm. The critical engine is the No1 engine in this example.

c. **Slipstream Effect**. Each engine will have a different effect on the yawing characteristics of the aircraft due to its slipstream. The spiral path of the slipstream may impact the fin and rudder producing a side force.

d. **Drag of Failed Propeller**. The amount of drag will depend on many factors including whether the failed propeller has been feathered. A windmilling propeller gives more drag than a feathered one and therefore increases the yawing moment towards the failed engine.

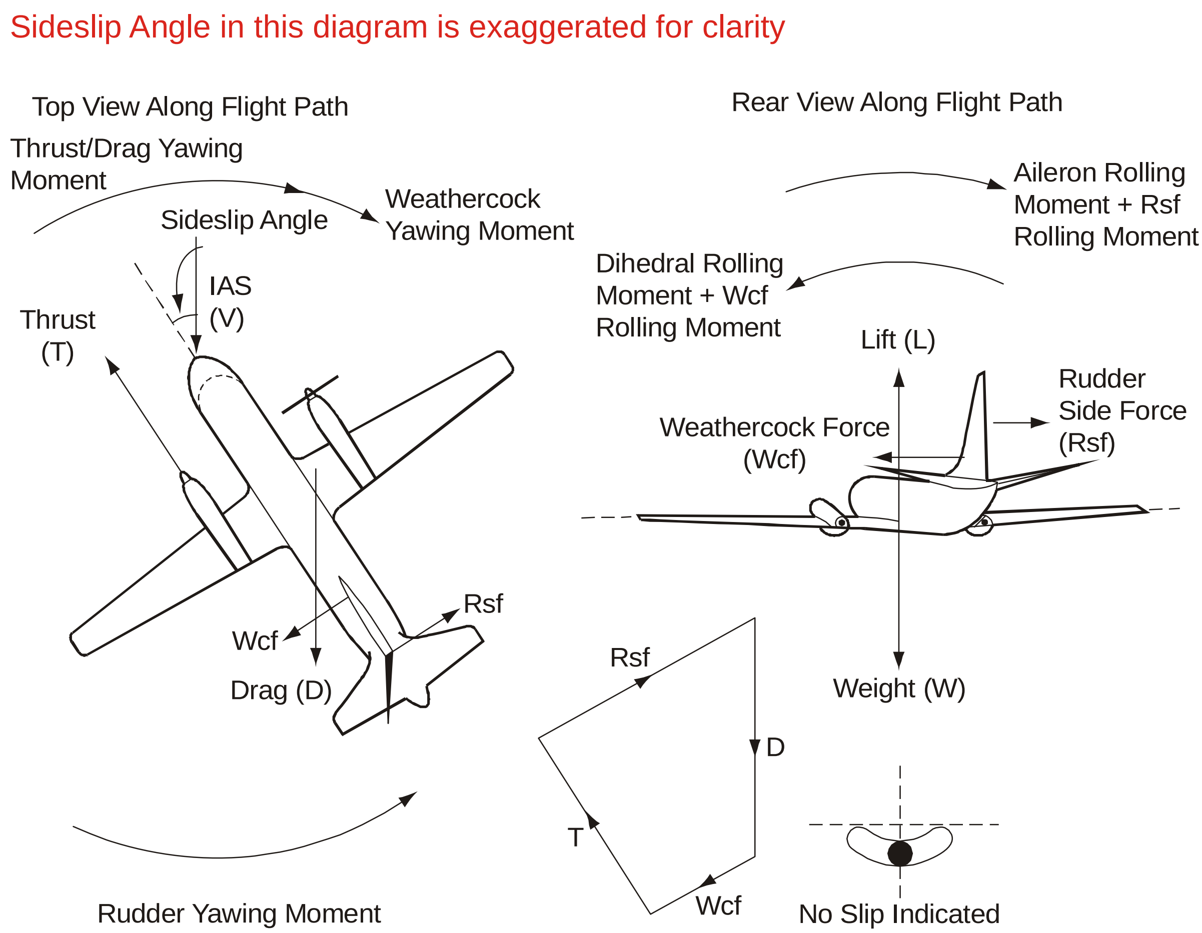
Balanced Flight

9. In straight and level, unaccelerated flight all forces acting on the aircraft, in all 3 axes, are balanced and the moments in equilibrium. The forces are shown to be balanced when their vectors form a closed polygon. An imbalance of forces will cause the aircraft to change its flightpath, ie climb, descend or turn. When the moments are balanced, the aircraft's attitude remains unchanged. When discussing the forces involved in asymmetric flight only the forces and moments acting in the normal (yawing) and longitudinal (rolling) planes are considered. This is because the initial reaction of an aircraft suffering the effects of asymmetric power is to yaw and then roll. All the inputs are to counter the initial yaw and the further or subsequent effects.

10. **Wings Level Steady Flight (Fig 2)**. The initial effects of yaw and roll are controlled by levelling the wings, stopping the yaw with rudder and centring the slip ball. The aircraft will sideslip towards the failed engine. Whilst this sideslip angle is small and its effects imperceptible to the pilot, it will generate a weathercock force requiring a greater rudder sideforce to balance. To maintain a constant heading the

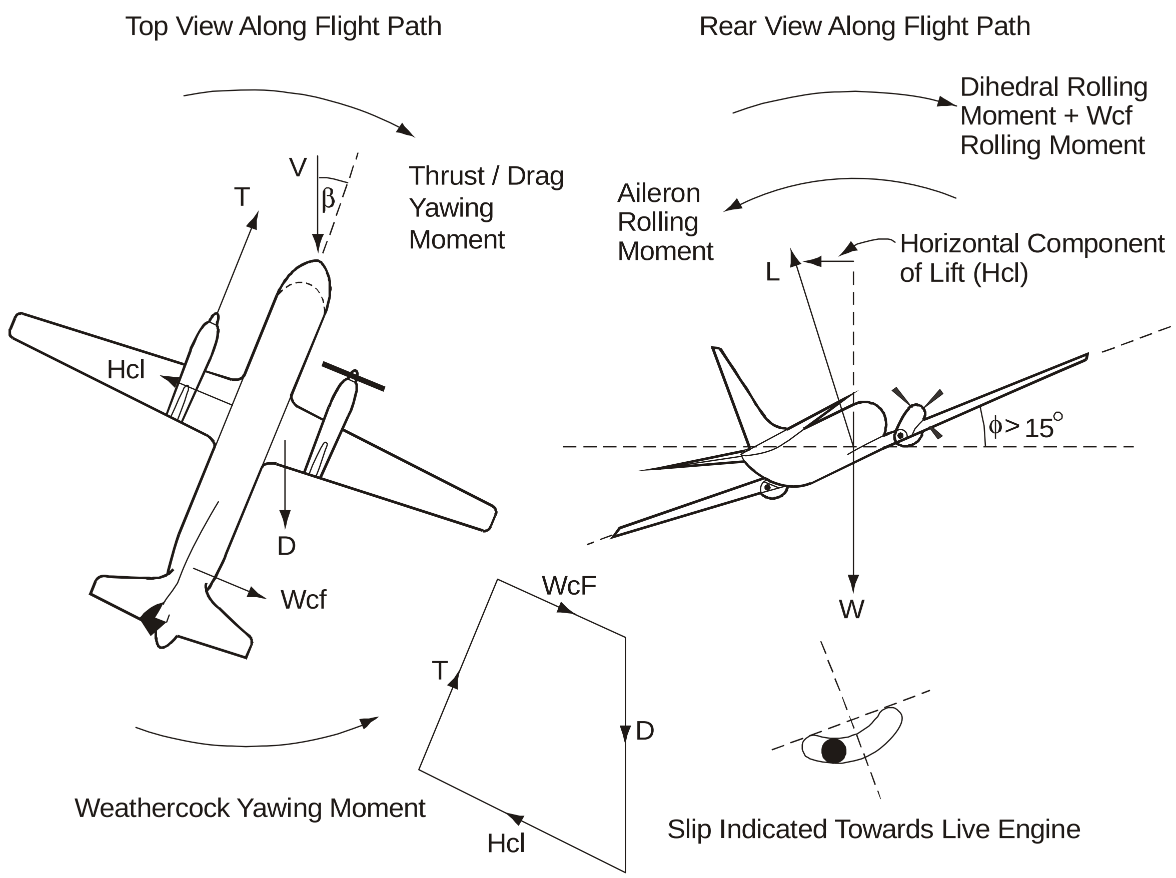
rudder moment is opposing the combined effect of the thrust, drag and weathercock moments. As the aircraft is sidesliping towards the failed engine, dihedral effect will roll the aircraft away from the failed engine. The weathercock force also provides a rolling moment away from the failed engine. The rudder side force acts above the centre of gravity and therefore provides an opposing rolling moment towards the failed engine. Fig 2 shows how the opposing forces interact. Passengers should not notice any discomfort and the freight will not be subjected to extra lateral strains. It is for this reason, together with the fact that wings level and slip central are easily definable states, that this is the preferred technique for controlling the aircraft in the event of an engine failure.

8-24 Fig 2 Wings Level Steady Flight



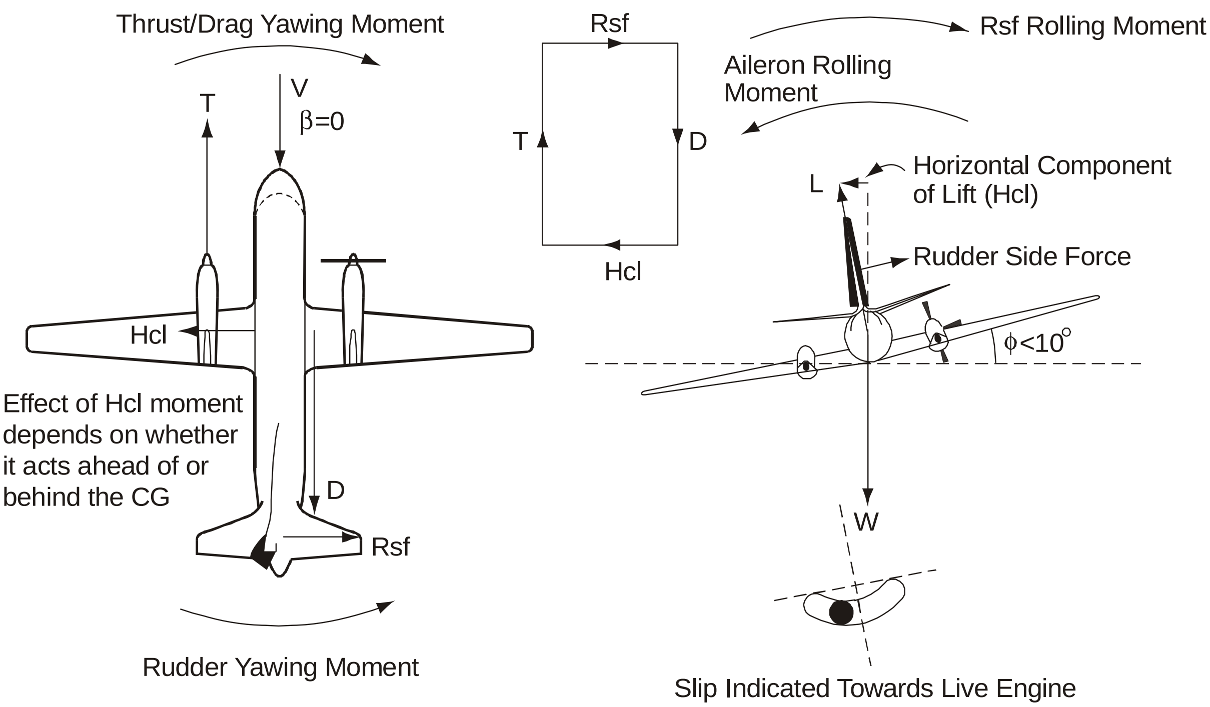
11. **Rudder fixed or Free (Fig 3)**. If the rudder is not available, more bank is needed to provide a larger horizontal component of lift to compensate for the loss of rudder side force. This additional bank will cause the aircraft to sideslip away from the failed engine creating a weathercock force towards the live engine. The weathercock moment and the horizontal component of lift combine to counter the thrust and drag moments. The dihedral effect and weathercock rolling moment both act towards the failed engine balanced by aileron deflection. Although this method is aerodynamically sound, it is uncomfortable for passengers and will provide the maximum strain on the freight. Furthermore, it is difficult to fly accurately, especially on instruments, as the wings are not level and the slip ball is displaced towards the live engine.

8-24 Fig 3 Rudder Fixed or Free



12. **Combination of Bank and Rudder (Fig 4)**. Between the two extremes of control methods detailed above –one using all rudder to control the yaw with wings level and one using all bank to control yaw with rudder fixed or free – there is an infinite number of combinations of rudder and aileron inputs. One such combination occurs when flying at or close to V_{mca} following the loss of an engine. It is unlikely that rudder alone will achieve directional control and therefore must be augmented by an amount of bank – usually up to 5 deg AoB towards the live engine. Use of this combination of bank and rudder will reduce the sideslip angle compared to the use of bank or rudder alone. Fig 4 shows a special case using a combination of bank and rudder where the sideslip angle is reduced to zero, thus eliminating the weathercock force and the dihedral effect. The pilot will have no way of knowing whether he has achieved this configuration, and in most cases using bank and rudder directional control will be maintained with a balance of all the available forces – thrust, drag, horizontal component of lift, rudder side force and weathercock force.

8-24 Fig 4 Combination of Bank and Rudder



IDENTIFICATION OF FAILED ENGINE

Jet

13. On jet aircraft, simple failures (e.g. flame-outs) are always shown by falling rpm and TGT. Internal mechanical engine failures are sometimes masked by apparently normal engine indications, and engine vibrations may be the only clue to a possible mechanical failure. In this case, it may be necessary to throttle back each engine in turn in an attempt to isolate the source of vibration. When the vibrating engine has been identified, it should normally be closed down and not left at idling rpm.

Turboprop

14. Loss of power will be shown on the torque meter, confirmed by falling turbine inlet temperature. The drag from a windmilling propeller can be very large and some installations feather, or partially feather the propeller automatically if the torque loss exceeds a certain figure.

SAFETY SPEED, V_{MCG} and V_{MCA}

Factors Affecting Controllability

15. The factors affecting controllability are:

a. **Power Output of Live Engine**. As the force initiating the yaw is proportional to the thrust of the live engine, then for a given IAS, more rudder is required to maintain directional control as the thrust is increased. Therefore, the higher the thrust from the live engine, the higher is the IAS at which the pilot reaches full rudder deflection and directional control is lost.

b. **Critical Engine**. The critical engine is usually the engine which, when failed, gives the greatest asymmetric effect. However, on certain types it may be defined by the loss of critical aircraft systems, this will be documented in the Aircrew Manual/Handling Notes. On 4 engine aircraft an outboard engine will usually be the critical engine due to the increase in the yawing moment arm.

c. **Altitude**. The thrust from the live engine for a given throttle setting decreases with height and therefore the asymmetric effect for full power at altitude is less than at sea level.

d. **Temperature**. Temperature affects density and therefore the thrust from all engines is affected although this is more marked on a jet engine.

e. **Weather Conditions**. On a day with rough and gusty conditions the margin of control is reduced. If a control surface is almost fully deflected to control the asymmetric effect, a limited amount of movement is available for further correction necessitated by air turbulence.

f. **Loading (CG Position)**. An aircraft with the CG at the aft limit is less directionally stable due to the reduction in the control moment arm (see Volume 1, Chapter 17, Para 12). Conversely with the CG at the forward limit the aircraft is more directionally stable. . Provided the CG is within the trim envelope no insurmountable handling difficulties should be encountered.

g. **Flap Setting**. The position of the flaps may have a marked effect on the airflow over the control surfaces dependant on aircraft type. If it is significant it is mentioned in the Aircrew Manual.

h. **Asymmetric Drag**. Asymmetric drag may be produced by a windmilling propeller or seized engine. This drag may be reduced by feathering the propeller of the failed engine.

i. **Strength and Skill of the Pilot**. On many aircraft, when high thrust is being used at low speed, the foot loads may be considerable…These forces should be controllable as V_{MCG} and V_{MCA} limit the maximum rudder pedal force to 150 lb and do not assume exceptional skill or strength.

Safety Speed (V_2)

16. Safety speed is the speed to which the aeroplane should be accelerated after take-off. It is a speed which provides a safe margin above the stalling speed for the purposes of manoeuvre before the flap retraction height is reached and which also provides a safe margin above V_{MCA}. It increases with all up weight. The ability to accelerate on asymmetric power depends on the amount of power that can be used while control is retained and the reduction that can be made in drag. Engine failure in the most adverse configuration and at the highest weight, makes it essential that the drag be reduced to a minimum so that the aircraft can accelerate to a safe speed on the power available. The undercarriage and flaps should therefore be raised and jettisonable stores released as soon as possible (as recommended in the Aircrew Manual/Handling Notes).

V_{MCG} (Minimum Control Speed - Ground)

17. V_{MCG} is the minimum speed, under take-off power conditions, at which in the event of a sudden and complete failure of the critical engine, it is possible to recover control with the use of rudder alone and without reducing power on the live engines. It will then be possible to maintain a path parallel to the runway centreline, not more than 30 ft displaced from the centre-line. The effect of nosewheel steering has been disregarded in the derivation of this speed, although the nosewheel is assumed to be in contact with the ground.

V_{MCA} (Minimum Control Speed - Air)

18. V_{MCA} is the minimum speed at which, in the event of sudden and complete failure of the most critical engine in the take-off configuration, it is possible to maintain directional control using full rudder deflection and a maximum of 5º of bank to the live engine.

ENGINE FAILURE DURING TAKE-OFF (COMBAT AIRCRAFT)

Considerations

19. On transport aircraft, full control can be maintained after engine failure at any stage and the take-off continued if the failure occurs after V_1 (see Volume 2, Chapter 9). The considerations of this part of the chapter concerns aircraft on which control can be lost, or which have marginal climb performance, after an engine failure. This latter category includes most modern fast twin-jets. Engine failure during take-off, on such an aircraft, can be considered under four main headings:

a. Engine failure below go speed (V_{go}). (V_{go} is defined at para 20).

b. Engine failure below stop speed (V_{stop}). (V_{stop} is defined at para 21).

c. Engine failure above stop speed but below safety speed:

(1) On the ground.

(2) In the air.

d. Engine failure above safety speed.

Go Speed (V_{go})

20. Go speed is the lowest IAS during take-off from which, after recognition of the failure of the critical engine, take-off can be safely continued and the appropriate speeds and heights can be achieved. Reference must be made to the aircraft ODM to determine whether a V_{go} capability exists.

Stop Speed (V_{stop})

21. Stop speed is the highest IAS during take-off from which, after the failure of the critical engine, an aircraft can be safely stopped within the ASDA using all normal methods of retardation.

V_{stop}/RHAG

22. V_{stop}/RHAG is the highest IAS during take-off from which, after the failure of the critical engine, an aircraft can be safely decelerated to maximum cable entry speed if the aircraft is fitted with a hook and the runway with a compatible cable arresting gear.

23. **Engine Failure Below V_{go}.** Normally V_{stop} is greater than V_{go}; therefore, only V_{stop} needs to be considered for take-off planning. However, if V_{go} exceeds V_{stop} a speed band exists in which an engine failure will result in the aircraft engaging an arrester cable or barrier, or entering the overshoot area. Some aircraft which do not have a V_{go} capability use V_{stop} in isolation.

24. **Engine Failure Below V_{stop}.** If engine failure occurs below V_{stop}, the take-off should be abandoned. If for some reason it becomes apparent that the aircraft cannot be stopped or obstacles avoided, the undercarriage may have to be raised on runways without barriers or cables. The decision to deliberately swing the aircraft with the wheels down is seldom justified in view of the more extensive damage incurred when the undercarriage structure collapses under a side load.

Engine Failure Above V_{stop} but Below Safety Speed or V_{go}

25. **On the Ground**. If engine failure occurs below V_{go}, the take-off should be abandoned and the arrester cable or barrier engaged. On some types it may be prudent to raise the wheels. On other types, such as those not cleared for barrier engagement, it may be necessary to eject.

26. **In the Air**. On some heavily-laden aircraft an engine failure below safety speed may mean a forced landing straight ahead, or ejection. The live engine(s) should be used, within the limits of directional control, to select the best landing area. However, if the critical speed has been attained, and if the overall conditions allow power to be reduced on the live engine(s), then the immediate corrective use of rudder, assisted if necessary by a slight amount of bank towards the live engine, may enable the aircraft to maintain heading. The undercarriage should be raised and all jettisonable external stores should be dropped, and, on propeller-driven aircraft, feathering action should be taken. The pilot should never apply more power than he can hold with rudder, and if a yaw commences with full control applied, the pilot must throttle back until the yaw ceases.

Engine Failure Above Safety Speed

27. An engine failure above safety speed should raise few problems on a modern aircraft since directional control and climb performance are guaranteed.

ASYMMETRIC POWER PROBLEMS AT HIGH SPEED

Directional Control

28. For high-performance, multi-engined aircraft, the failure of an engine or engines at high speeds may have more serious consequences than engine failure at low air speeds. Asymmetric engine failure at high air speeds may generate sideslip excursions large enough to exceed sideslip limitations and cause structural damage or catastrophic component failures. The asymmetric power problems may be compounded by reduced directional stability at high supersonic Mach numbers and high altitude. These problems may result in a maximum air speed or Mach number (as functions of engine thrust settings) being imposed on the aircraft.

CHAPTER 25- INSTRUMENT FLYING

Contents **Page**

Table of Figures

Introduction

1. With the advent of automatic landing systems and the wide everyday use of pilot-interpreted aids, the present day RAF possesses a complete all-weather capability. Moreover, increasing congestion in and around regulated and controlled airspace means that a pilot must spend a good deal of time referring to instruments, flying controlled procedures and communicating with ground stations. Furthermore, when flying at night, external visual references may be limited. Therefore, it is essential that every military pilot should possess a sound basic skill in instrument flying.

2. During visual flight, emphasis is placed on attitude flying; however, no matter how well an attitude is maintained visually, at least one instrument must be checked to confirm that the attitude is known to be correct. If a correction is necessary, the attitude change is made with reference to the visual horizon. However, during instrument flying, the real horizon is no longer visible so an artificial horizon is used instead. Thus, there is no basic change in technique: the artificial horizon is used instead of the real horizon and becomes the master instrument.

3. This master instrument can be an artificial horizon (AH) or an attitude indicator (AI). For ease of presentation throughout this chapter, the master instrument will be referred to as the AI.

4. **The Control Instruments**. The combination of attitude and power is fundamental to aircraft performance and determines IAS and the flight path. For example, if an attitude is selected to give an IAS, as in a climb, the power determines the flight path. Similarly, if power is used to adjust the IAS, as in straight and level flight, then the selected attitude determines the flight path. Thus, because aircraft performance is controlled by attitude and power, the AI and the instruments indicating power are called the control instruments.

5. **The Performance Instruments**. The remainder of the flying instruments show what effect the power/attitude combination is having on the aircraft performance. They are known, therefore, as the performance instruments.

6. **Analogue/Digital Instrument Displays**. The text for this chapter refers solely to the techniques used for instrument flying using a standard instrument panel with analogue instrumentation. It is possible however, in modern aircraft, to convey instrument information digitally to the pilot by means of a TV screen and/or by a head-up display unit. A brief explanation of these alternative methods of display is given at paragraphs 50 and 51.

Power Control

7. Most instrument flying procedures are flown using the recommended power settings given in Aircrew Manuals. When flying manoeuvres such as steep turns, which are not part of normal instrument flying procedures, the same power settings as used in visual flight should be used. To make power selections promptly and accurately, without unduly disrupting the concentration on instruments, the following procedure should be followed:

   a. First, make an estimated throttle movement.

   b. At the next suitable opportunity, check the result on the power gauges.

   c. After this initial change, re-adjust the throttle in small stages, monitoring each against the power gauges, until the desired power setting is achieved.

8. A useful method of measuring small power changes is to use some characteristic of the throttle lever or quadrant design against which these small adjustments of the lever can be felt.

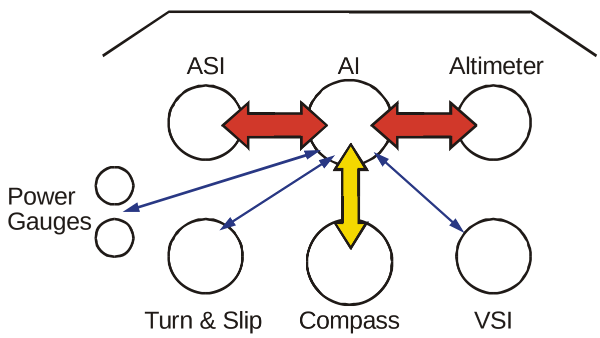
Attitude Control

9. To fly accurately, a pilot must be able to select and trim the correct attitude for a given stage of flight. The AI will give an indication of the magnitude of any attitude change made, but the pilot should confirm the result of any attitude change by monitoring the performance instruments. If they show that the desired flight path is not being achieved, the power/attitude combination should be adjusted again, and the aircraft re-trimmed. Thus, attitude control changes are achieved by reference to the AI and power gauges, with the results of any change appearing on the performance instruments.

Selective Radial Scan

10. In order to take in all the information shown by the instruments, the pilot has to scan them in a methodical manner. An obvious method would be to look at each instrument in turn in a clockwise or anti-clockwise direction. Although no instruments would be omitted from this scan, priority would not be given to the master instrument or to the performance instruments important for any particular manoeuvre, e.g. the compass or directional gyro on rolling out from a turn. The technique therefore is to scan radially out from the AI to the performance instruments and back to the AI. Furthermore, since the performance information required differs for each manoeuvre, the scan is made selective. Thus, each performance instrument will be interrogated according to its importance at any given moment. This method, illustrated in Fig 1, is called the selective radial scan. Note that two performance instruments are never scanned in succession; the route from one to another invariably goes through the master instrument.

8-25 Fig 1 Selective Radial Scan



Note: In all the figures in this chapter:

a. A thick red arrow denotes a constant scan.

b. A medium yellow arrow denotes a less frequent scan ratio of 1: 3.

c. A thin blue arrow denotes 'as required'.

Rates of Scan and Attitude Control

11. The rate at which the instruments should be scanned will vary with manoeuvre and aircraft type. During manoeuvre, the required scan rate is lowest when maintaining a trimmed attitude and highest during power and attitude changes. The rate of scan should also be increased with increased aircraft performance. Consequently, since required attitude changes are perceived only as the scan routes through the AI, the reaction time varies directly with scan rate. However, when the AI is interrogated more frequently, there is a risk of over controlling and perhaps 'chasing' the correct attitude. To reduce this risk during periods of high activity, AI adjustments should be limited to 1º-2º. Periods of low activity should be used to carry out routine airmanship checks, e.g. engine and oxygen checks; these should be broken down into small sections, giving an opportunity to monitor the AI between each section.

Instrument Interpretation

12. The control instruments require no interpretation, since their indications are direct and respond immediately to control changes. On the other hand, the performance instruments give both direct and indirect indications and most are subject to lag of one form or another.

13. An example of a direct indication is airspeed. However, for a given power setting and aircraft configuration, if the airspeed is steady it also means that the pitch angle is constant, thus giving an indirect indication of pitch. Table 1 lists the instruments included in the standard instrument panel and shows the direct and indirect indications available from them.

Table 1 Direct and Indirect Indications from 'Standard' Instruments

Instrument	Direct	Indirect
CSI/ASI	Airspeed	Pitch
Altimeter	Altitude	Pitch
Compass	Heading	Bank or imbalance
VSI	Rate of climb/descent	Pitch
Turn needle	Rate of turn	Bank or imbalance
Ball	Balance	Bank or Yaw

Trimming

14. Instrument flying is made easier by accurate trimming. No change from visual trimming techniques is necessary; control pressures are removed in the same way. However, to ensure a smooth flight (a necessary ingredient of instrument flying) hurried changes and any temptation to fly on the trim should be avoided. The aircraft is properly trimmed if it maintains the selected attitude when the pressure on the controls is relaxed.

Balance

15. The only direct indication that the aircraft is in balance is shown by the ball, usually situated in the turn and slip indicator. The indirect indications of imbalance can be:

a. A slight reduction in airspeed.

b. The presence of an angle of bank.

c. A slow change of heading when the wings are level.

An imbalance situation in single jet operations is unlikely and, if present, is usually caused by cross-controlling. However, imbalance is more likely to occur during propeller-driven and multi-engine operation particularly if the pilot becomes tense or fixated on one instrument, thus stopping the selective radial scan.

16. During propeller-driven and multi-engine operation, if the wings are known to be level, rudder should be used to maintain a constant heading on the compass with the balance ball confirmed central. This is of particular importance during power changes, which would otherwise cause yaw.

BASIC INSTRUMENT FLYING

General

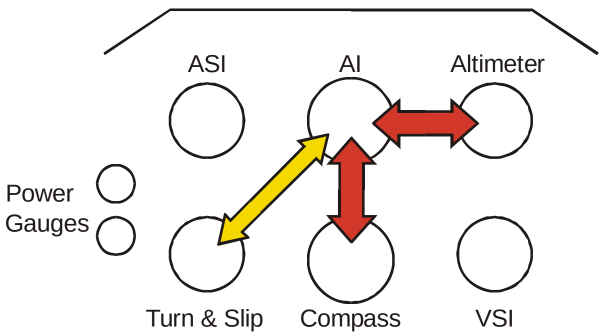
17. The following explanations assume an understanding of the visual flying techniques and procedures relevant to a particular aircraft.

Straight and Level Flight

18. Straight and level flight during instrument flying is best thought of in terms of three separate actions: achieving, maintaining and correcting.

19. **To Achieve Straight and Level Flight**. To achieve straight and level flight, cruising power should be set, the straight and level attitude should be selected on the AI and a coarse trim change made. If the attitude selected is correct, the altimeter and compass will become stationary. Any movement in the altimeter should be stopped by altering the AI pitch indication in a series of small stages. Each stage should be equivalent to a half or whole horizon bar width (the amount varying with aircraft type), with each attitude change being trimmed. If the compass is moving, first confirm that the aircraft is in balance and then apply a small bank correction to the AI to stop the turn, even though the AI may be indicating wings level. A correction of this sort is only necessary when the AI is erected to a false vertical; normally it is not necessary. Thus, straight and level flight is achieved using the AI, altimeter, compass and, on those aircraft prone to imbalance, an occasional glance at the ball (see Fig 2). For the sake of simplicity, airspeed is dealt with later.

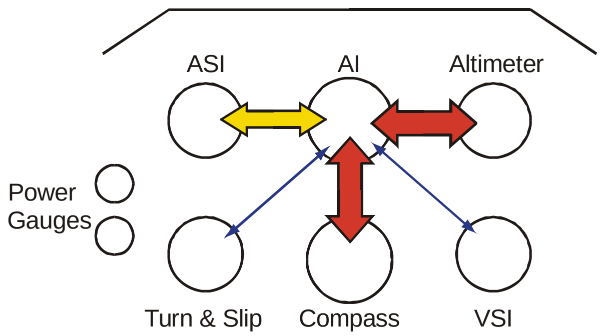
8-25 Fig 2 Achieving Straight and Level Flight



20. **To Maintain Straight and Level Flight**. The scan used to maintain straight and level flight is shown at Fig 3. With the correct attitude selected on the AI and the aircraft trimmed, the compass and altimeter are scanned to maintain the datum height and heading. The correct speed is confirmed from the ASI and the balance ball in the turn and slip indicator is centralized. Occasional checks of the VSI will indicate any small trend of climb or descent. Errors in height will be indicated on the altimeter, and are corrected with reference to the AI by changing the aircraft attitude and re-trimming. When flying in turbulence, the needles on pressure instruments may show fluctuations from the datums being flown. To maintain straight and level flight in turbulence, more emphasis needs to be given to scanning the attitude on the AI (which will confirm that the wings are held level) and ensuring that the balance ball is centralized. The temptation to 'chase' temporary excursions from the datums should be resisted. In conditions of severe turbulence, as well as flying at the recommended turbulence speed, the pilot must continue to monitor the airspeed carefully. In severe updrafts and downdrafts, the speed of the aircraft may increase or decrease markedly, even with the straight and level attitude held steady by

reference to the AI. In this case, the airspeed should be held as close as possible to the turbulence speed by throttle movement alone, without changing attitude.

8-25 Fig 3 Maintaining Straight and Level Flight



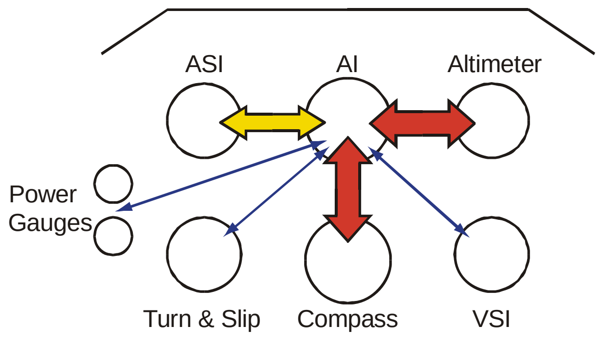
21. **Correcting Back to Straight and Level Flight**. The following sub-paragraphs explain the techniques, should it be necessary to make substantial corrections to recover back to straight and level flight:

a. **To Correct an Altitude Error**. Should it be necessary to correct to an altitude, the amount of attitude correction to be applied will depend upon the aircraft type and the magnitude of the error. On low performance aircraft, a 50 ft error will require an adjustment of 1º to 2º of pitch. For larger height errors, as well as an attitude adjustment of 3º to 4º of pitch, it may be necessary to make a small adjustment to the power. On high-performance aircraft, small corrections, of about 300 ft, can be made by pitch adjustment alone, without a change in power or an appreciable change of trim. Since the rate of closure is determined by the AI adjustment, once a correction is started the VSI should be ignored and reliance placed on the altimeter (using the scan shown in Fig 2). Fractionally before the desired altitude is reached, the straight and level attitude should be adopted with reference to the AI. If necessary, cruising power may once again be set and the 'maintaining straight and level' scan (Fig 3) resumed.

b. **To Correct a Heading**. To correct a heading, bank should be applied on the AI in the appropriate direction, the amount varying according to TAS. At low speeds, an angle of bank equating to half the error may be used, ie for 10º heading error use 5º of bank. At high speeds, an angle of bank equating to the error may be used. If the aircraft has been correctly trimmed in straight and level flight before entering a turn, very little back-pressure will be required on the control column to maintain level flight in the turn. As the heading is regained, the wings should be levelled on the AI and the 'maintaining' scan (Fig 3) continued. On aircraft liable to imbalance, once the wings are levelled on the AI, the ball should be centralized.

c. **Increasing Speed**. To increase speed, the power should be increased as for visual flight and initially the attitude on the AI maintained. On aircraft with a slipstream effect, the heading should be maintained by balancing the aircraft with rudder. As the speed increases, the first indications of a departure from straight and level flight will be a climb indicated on the altimeter, confirmed by the VSI. This climb should be anticipated and, as the speed increases, countered by small progressive nose-down pitch adjustments with reference to the AI, to stop the altimeter moving, and to maintain straight and level flight. In addition, the scan should be extended to include the ASI. During a speed change, the VSI will normally indicate a trend before the altimeter indicates an error. Initially, therefore, the straight and level 'maintaining' scan is used, but as power and speed are increased, the scan should be extended to include the ASI and the power gauges (see Fig 4).

8-25 Fig 4 IAS Control in Straight and Level Flight



d. **Reducing Speed**. To reduce speed, the IAS attitude should be maintained and the power reduced to the required setting. If the speed reduction warrants it, the airbrakes should be extended. The 'maintaining' scan should be continued, with the ASI being progressively included. On aircraft with a slipstream effect, the maintaining scan should be continued, with use of the rudder to balance as necessary. As the speed decreases, the first indications of a departure from straight and level flight will be a descent indicated on the altimeter, confirmed by the VSI. This should be anticipated and, as the speed decreases, countered by small progressive nose-up pitch adjustments with reference to the AI to stop the altimeter moving and to maintain straight and level flight. As the new speed is reached, the airbrakes should be retracted and, if necessary, small power adjustments made to achieve an accurate speed.

Level Turning

22. Normally, instrument turns are flown at Rate 1 (i.e. 3º per second) or at 30º of bank, whichever is the lesser, but operational requirements may demand a higher rate. As a means of increasing instrument flying proficiency, steep turns at 45º to 60º of bank are practised. For a small heading change, (i.e. through an angle smaller than the angle of bank used for a Rate 1 turn) the bank should be restricted as follows:

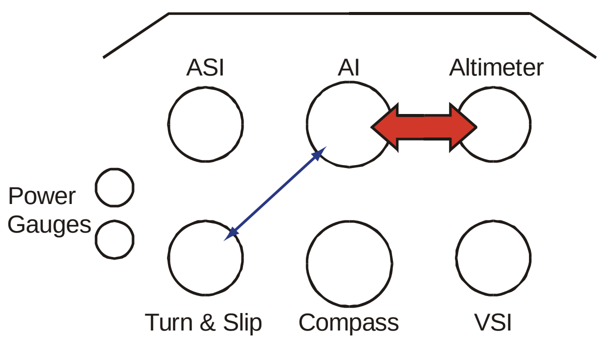
a. At speeds of 100 kt or less, use a bank angle equal to half the numbers of degrees of turn required.

b. At speeds in excess of 100 kt, use a bank angle equal to the number of degrees of turn required.

Medium Turns

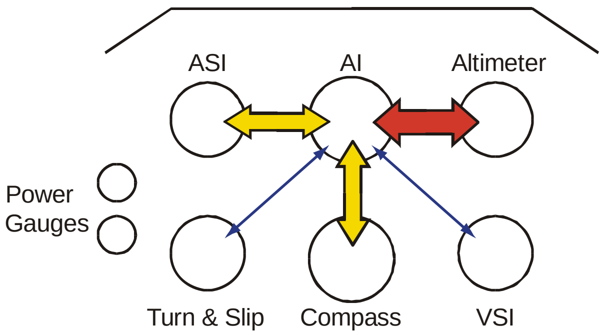
23. **Entry**. To enter a turn, bank is applied by reference to the AI and the pitch indication is supported by cross-checking the altimeter to maintain level flight (see Fig 5).

8-25 Fig 5 Entering a Medium Turn



24. **Maintaining**. The AI is used to maintain both pitch and bank during turns. Bank is kept constant using the bank scale, and pitch using the pitch scale. When using a mark of instrument not graduated in pitch, only experience can be used to assess the correct indication. The VSI and altimeter should be used to support the AI, in the same manner in which they are used during straight and level flight. The technique for maintaining height is the same, by applying small adjustments with reference to the AI. As the turn proceeds, the compass is progressively included into the scan to monitor the roll-out heading (see Fig 6).

8-25 Fig 6 Maintaining a Medium Turn

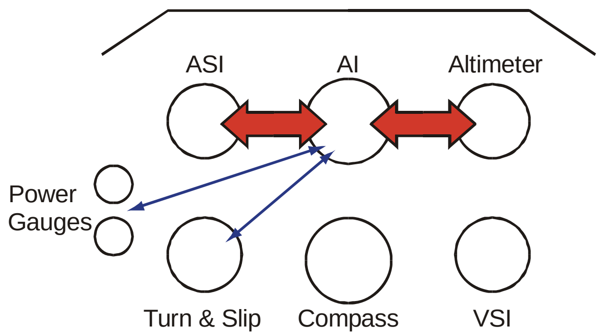


25. **Roll-Out**. To roll out from a medium turn, the heading should be anticipated by the angle used in visual flight. The straight and level attitude should be selected by reference to the AI. However, if the speed has been allowed to reduce during the turn, a slightly higher pitch attitude will be necessary to maintain level flight. As cruising speed is regained, the pitch attitude will have to be progressively lowered using the techniques detailed in para 23.

Steep Turns

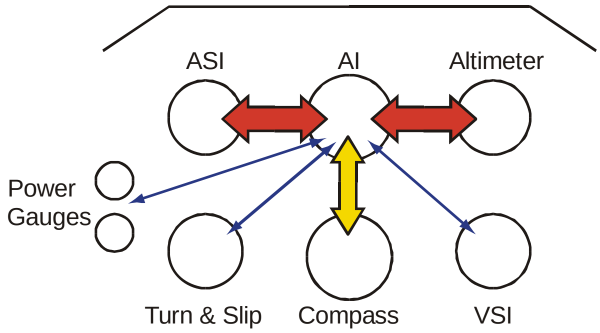
26. **Entry**. To enter a steep turn, bank should be applied by reference to the AI, with back-pressure introduced to adopt a steep-turn attitude. Power should be increased to maintain the entry airspeed. The application of bank, back-pressure and power should be completed simultaneously. The associated scan is shown in Fig 7.

8-25 Fig 7 Entering a Steep Turn



27. **Maintaining**. Whilst maintaining a steep turn, the scan is basically the same as that used during a medium turn except that the ASI is scanned more frequently. This is necessary to confirm that the increase in power selected is holding the required airspeed. Experience and judgement should determine throttle movements. The higher rate of turn makes it necessary to scan the compass more frequently (see Fig 8).

8-25 Fig 8 Maintaining a Steep Turn

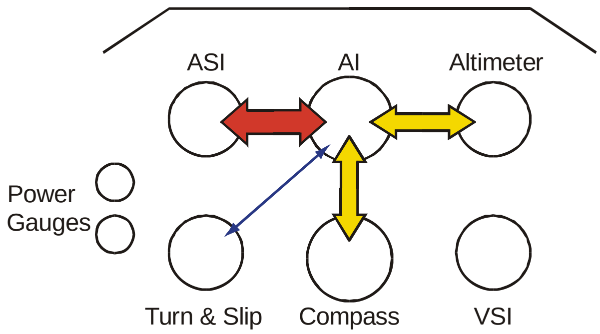


28. **Roll-Out**. To roll out from a steep turn, the heading should be anticipated by the angle used in visual flight. The straight and level attitude should be selected by reference to the AI and, as bank is reduced through 30º, the power should be reset to the entry airspeed setting.

Climbing

29. **Entry to the Climb**. The entry to a climb will vary with aircraft type. If the climbing speed is the same as, or less than, the normal cruising speed, then the power and attitude can be changed simultaneously. If the climbing speed is greater than the straight and level speed, climbing power should be applied and the speed should be increased whilst straight and level, before changing to the climbing attitude. If the aircraft is in balance, heading will be maintained by keeping the wings level. However, on propeller-driven aircraft, in addition to keeping the wings level, rudder will have to be used to maintain balance during the power and attitude changes, prior to re-trimming. The initially-selected attitude should be held constant, by reference to the AI, until the airspeed settles. Attitude adjustments are then made at a constant airspeed. The scan to be used for climbing is shown in Fig 9.

8-25 Fig 9 Climbing



30. **Maintaining the Climb**. The scan used to maintain a climb is the same as that used for entering it (Fig 9). Pitch adjustments to correct the airspeed should not be hurried; at full power the airspeed is relatively slow to react to attitude changes and there may be a temptation to hurry the process by making a larger attitude change than required. To avoid this, only small pitch adjustments should be made, allowing time for any change to take effect before any further adjustment.

31. **Climbing Turns**. No change of scan is necessary when turning during a climb. Bank should be applied by reference to the AI, and the nose lowered fractionally to maintain the airspeed. The roll-out technique is the same as for a level roll-out, except that the ASI is the main support instrument for pitch.

32. **Levelling Off**. To level off at a required height, it is essential to use some anticipation. The attitude change should be initiated at a point prior to the required height, equivalent in vertical distance to 10% of the rate of climb (e.g. for a 2,000 feet per minute rate of climb, use a point 200 feet below the required level). At that point, the pitch should be reduced so that straight and level flight and the required height are achieved simultaneously. The power is then adjusted to reach cruising speed. As the attitude change is commenced, the scan should be changed from 'climbing' to 'achieving straight and level' (see Figs 9 and 2). However, the scan pattern should be extended to include the power gauges and ASI as power is reduced. On propeller-driven aircraft, balance should be maintained during the power change by using rudder. As the altimeter reading becomes steady, the aircraft is flown as for straight and level flight, at a predetermined airspeed.

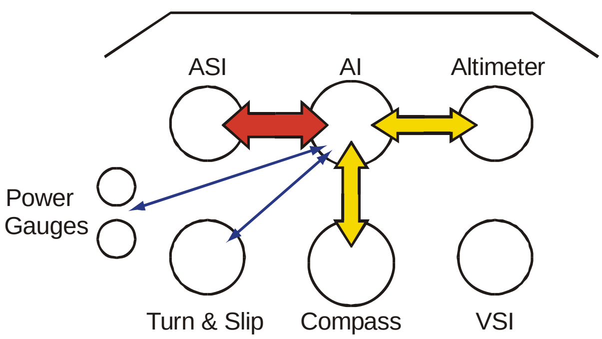
Descending

33. An instrument descent requires no change from the techniques and procedures observed visually. Thus, power and airbrakes (if fitted) should be used in accordance with the appropriate Aircrew Manual. The pilot should be thoroughly conversant with the recommended power settings used for each stage and type of descent. During descents that can be affected by aircraft weight and the wind strength, e.g. when using a runway approach aid, the recommended power settings may require adjustment if an accurate descent path is to be maintained. Usually these adjustments are small and may be made by 'feel', as indicated in paragraphs 7 and 8.

34. **Entry**. The descent should be entered from a level speed that will enable the descending speed to be attained during, or soon after, the power/attitude change. Thus, if the descending speed is less than the level speed, the speed should be reduced before lowering the nose. When entering the descent, the scan should be extended to include the power gauges as and when necessary. On propeller-driven aircraft, it will be necessary to maintain balance with rudder. Once the descending attitude is selected, the AI should be supported by the ASI and compass.

35. **Maintaining**. Airspeed corrections during a descent should be made by small pitch adjustments with reference to the AI, and heading should be maintained by bank adjustments. When it is necessary to maintain a specific power setting, the power gauges should be monitored and, on propeller-driven aircraft, it is essential to include the ball within the scan. The altimeter should be monitored throughout the descent. The scan used is detailed at Fig 10.

8-25 Fig 10 Maintaining the Descent



36. **Levelling Off**. The level-off should be anticipated by the method described in para 32, this time using 10% of the rate of descent. At that point, the straight and level attitude should be selected by reference to the AI. Power should be reset as appropriate for the aircraft type. Once the attitude change is commenced, the 'achieving straight and level' scan should be used (see Fig 2).

Descending Turns

37. Descending turns are normally made using Rate 1 or a maximum of 30º angle of bank (whichever is the lesser). No change from the 'maintaining the descent' scan (see Fig 10) is required, although during the early stage of the turn, the frequency at which the compass is included can be safely reduced. As the turn proceeds, the compass should be progressively re-included into the scan to monitor the roll-out heading. The roll-out is the same as for a level turn, except that the ASI is the main pitch support instrument.

EXTREME ATTITUDES AND UNUSUAL POSITIONS

Introduction

38. **Extreme Attitudes**. If an aircraft inadvertently enters cloud from a dynamic manoeuvre (such as aerobatics, spinning or tail chasing), it may result in an extreme attitude that can be very difficult to recover from safely on instruments.

39. **Unusual Positions**. The term 'unusual position' (UP) is used to describe any situation when the aircraft is not in the attitude the pilot thinks it is. A UP may be a temporary loss of orientation caused by distraction during normal instrument flying. For a pilot to be in a UP does not necessarily mean that the aircraft is in an extreme attitude.

40. **Attitude Indicators**. Modern electrically-driven AIs are extremely reliable. Power failure is normally clearly indicated by a warning flag, and most AIs can only be toppled with difficulty during extreme manoeuvres. Air-driven AIs, however, are not as stable and are easier to topple. They are also more prone to erection errors. It is essential therefore, with an air-driven AI, to monitor the vacuum gauge whilst flying on instruments. However, a toppled AI may give a steady presentation, and it will only be possible to detect this false indication by cross-reference to the performance instruments.

Recovery Techniques

41. The technique used to recover from an extreme attitude or an unusual position depends upon the reliability of the AI:

a. **Full Panel Recovery**. The technique used when the AI is confirmed as reliable is called a 'Full Panel Recovery', and is detailed in para 43.

b. **Limited Panel Recovery**. If the AI has failed, or is suspected to be unreliable, the 'Limited Panel Recovery' technique must be used (see para 44). The latter case would include any situation where the serviceability of the AI has not been checked for a longer period than normal.

42. Regardless of the type of instrumentation available, the recovery from a UP is made in three distinct stages in the order: power, bank, and pitch.

a. **Use of Power**. The use of power during a recovery from an UP will be determined by the trend indicated on the ASI. If the airspeed is decreasing critically, full power should be applied. Conversely, if the speed is rapidly increasing, the throttle should be fully closed to avoid any unnecessary height loss, and airbrakes, if available, may be extended.

b. **Change of Bank**. A banked attitude will delay, or in the case of an extreme attitude, prevent a safe selection of a level pitch attitude, therefore, the second recovery action must be to level the wings.

c. **Change of Pitch**. Once the speed is under control and the wings are level, the final action is to pitch to level flight. Care must be taken not to exceed the airframe 'g' limitations during this phase of the recovery.

43. **Full Panel Recovery**. A full panel recovery, based on the use of an AI follows the three-stage recovery technique outlined in the previous paragraph:

a. **Power**. First, the airspeed must be checked to ensure it is within acceptable limits. If it is not, action should be taken to bring it under control.

b. **Bank**. The AI should then be checked for power failure. With the horizon bar or pitch markings in view, the aircraft should be rolled until the wings are level. However, even in an extreme attitude with a serviceable AI, the horizon bar should still be readable, but may be partially obscured by the instrument facing.

c. **Pitch**. Finally, to obtain level flight, the aircraft is pitched so that the aircraft datum moves towards the horizon bar in the correct sense.

Scanning of the performance instruments should then be made to confirm the action taken, and to regain balanced straight and level flight. If, having initiated a full panel recovery, the performance instruments do not agree with the AI indications, or disorientation still remains, the limited panel recovery must be implemented without delay.

44. **Limited Panel Recovery**. Following the same three-stage principle, the actions required in a Limited Panel Recovery are:

a. **Power**. The first action in a limited panel recovery is to control the speed in exactly the same way as for a full panel recovery. However, if the aircraft is in an extreme nose-up attitude which results in a very low or rapidly decreasing airspeed, any attempts to manoeuvre the aircraft with large control deflections could worsen the situation. Whenever there is insufficient speed to make a safe controlled recovery, the controls should be held as directed in the Aircrew Manual until the aircraft has settled into a descent of its own accord. The aircraft should then be allowed to accelerate to a safe flying speed before attempting to initiate a recovery.

b. **Bank**. In a limited panel recovery with an unserviceable or unreliable AI, the turn needle has to be used as the master indication of bank to level the wings. Any positive g force above 1g will cause the turn needle to over-read. Therefore, positive g must be reduced to 1g by pitching the aircraft and checking the accelerometer. On propeller-driven aircraft, it will be necessary to reduce any extreme imbalance by centralizing the ball. However, time should not be wasted obtaining accurate balance; once any positive g force has been reduced to 1g, and the aircraft is roughly in balance, a positive aileron movement should be made to centre the turn needle. This corrective roll should be checked before the turn needle is actually centred, the amount of anticipation required varying with airspeed and rate of roll.

c. **Pitch**. The last stage of the recovery should be made using the information displayed on the altimeter - the only instrument that indicates level flight accurately, and almost instantaneously, throughout the entire speed range. Positive elevator should be applied against altimeter movement, ensuring that the ailerons are kept neutral. The control deflection should be maintained until the altimeter slows almost to a standstill, then a check movement made to hold a constant pitch attitude. The aircraft will then be in an approximate straight and level attitude; the power can be adjusted, and the instruments cross-referred to achieve accurate flight and to assess their serviceability. It may also be possible to re-erect the AI at this stage.

EMERGENCIES

General

45. Most modern aircraft have duplicate, or even triplicate, displays for vital instruments, each with associated power supplies. Therefore, a single instrument failure causes few problems. In the majority of cases, an emergency will develop in stages, beginning with an apparently insignificant malfunction that only becomes critical in unforeseen circumstances, or in the event of an additional emergency. Thus, the potential loss of both primary and standby flight instruments must be considered.

46. If, during manoeuvre, apparently ambiguous instrument indications are observed, or the instruments do not respond correctly, the aircraft should be recovered immediately to straight and level flight and the cause investigated. Manoeuvres should not be continued whilst attempting to analyse the problem, since delay could bring about other complicating factors such as pilot disorientation. The procedure for recovery will vary with aircraft type and the attitude obtained. If a master AI is available for use and is not itself suspect, it should be used to select the straight and level attitude. If the master AI is considered unreliable, the standby AI can be used instead or, if no standby attitude instruments are carried, then a limited panel recovery will be necessary.

Loss of Airspeed Indication

47. If all the airspeed indications are lost, the aircraft can still be effectively operated using the basic power/attitude concept provided that an accurate airspeed is not essential. By using the known standard operating power settings and attitudes, it is possible to perform straight and level flight, or manoeuvres such as turning and climbing, without difficulty. Similarly, the initial stages of descent can be performed safely. However, as the aircraft approaches lower heights, and the speed is reduced, it becomes more critical to maintain a safety margin above the stall. Consequently, the safest method of recovering to an airfield is to formate upon, or be shepherded by, another aircraft. When a formation let-down is not practicable, the continued use of the known power/attitude concept down to Decision Height remains the only option.

Loss of Heading Information

48. In the event of losing all visual and instrument heading information, ground-based direction finding (D/F) and radar facilities provide the only means of obtaining assistance. In these circumstances, the ground controller will request that all turns are flown at Rate 1. On aircraft not fitted with a turn needle, it is desirable that turns are executed at the calculated angle of bank for Rate 1.

Loss of Direct Attitude Indication

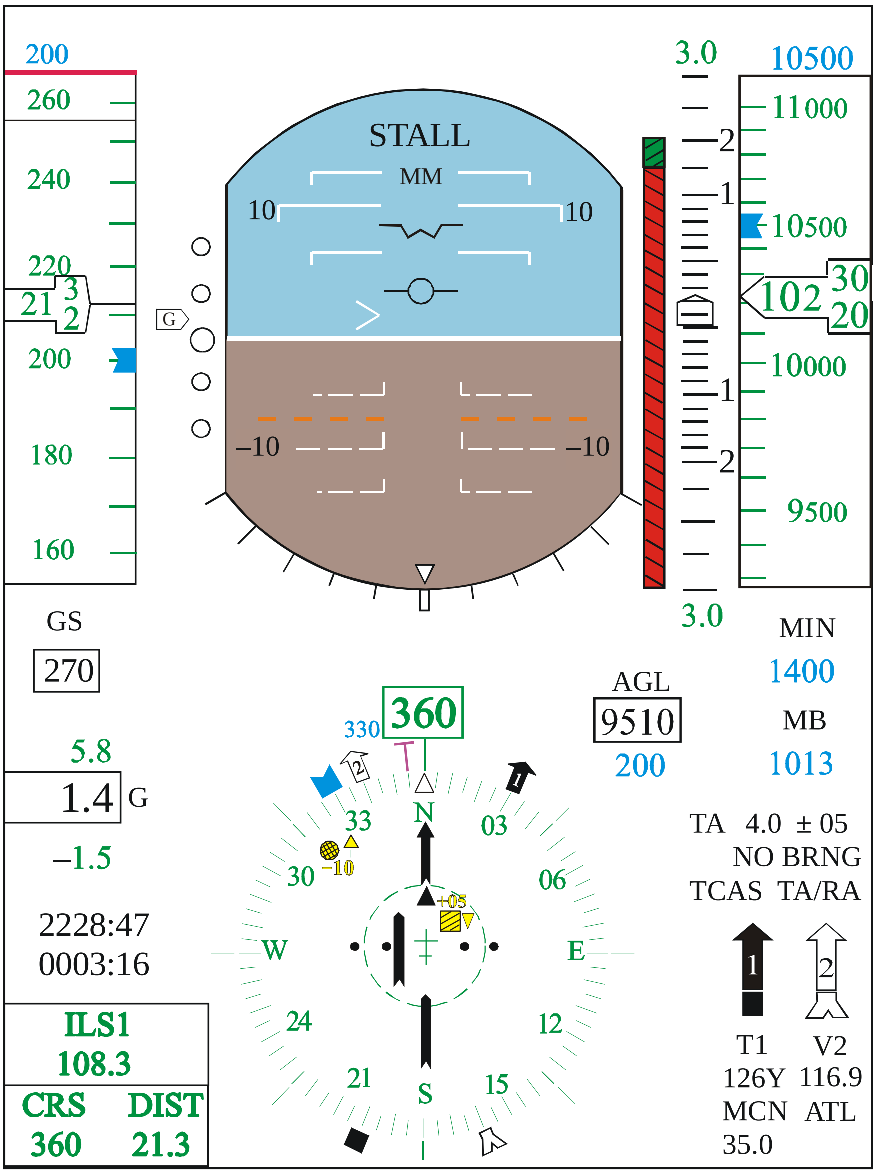
49. The loss of all direct indications of attitude will vary in importance with the type of instrumentation. On aircraft fitted with the standard basic instrument panel, the attitude can be deduced and controlled in all three planes without undue difficulty. On aircraft fitted with instrumentation that does not include a turn needle on which to control bank, control is possible only in pitch, with the wings being kept level by reference to the direct-reading magnetic compass.

ALTERNATIVE INSTRUMENT PRESENTATIONS

Flat Screen Displays

50. Some modern aircraft have the flight instruments presented in digital format on flat screens. A propensity towards such displays within a cockpit is often referred to as a 'glass cockpit' (see Volume 7, Chapter 21). An example of a TV instrument display is at Fig 11. Depending on the complexity and reliability of the digital system, there is sometimes a set of stand-by analogue instruments (ASI, AI and altimeter) available to the pilot The instrument flying techniques used when flying an aircraft with this type of instrument presentation are exactly the same as for the analogue instruments as explained in this chapter.

8-25 Fig 11 Flat Screen Display

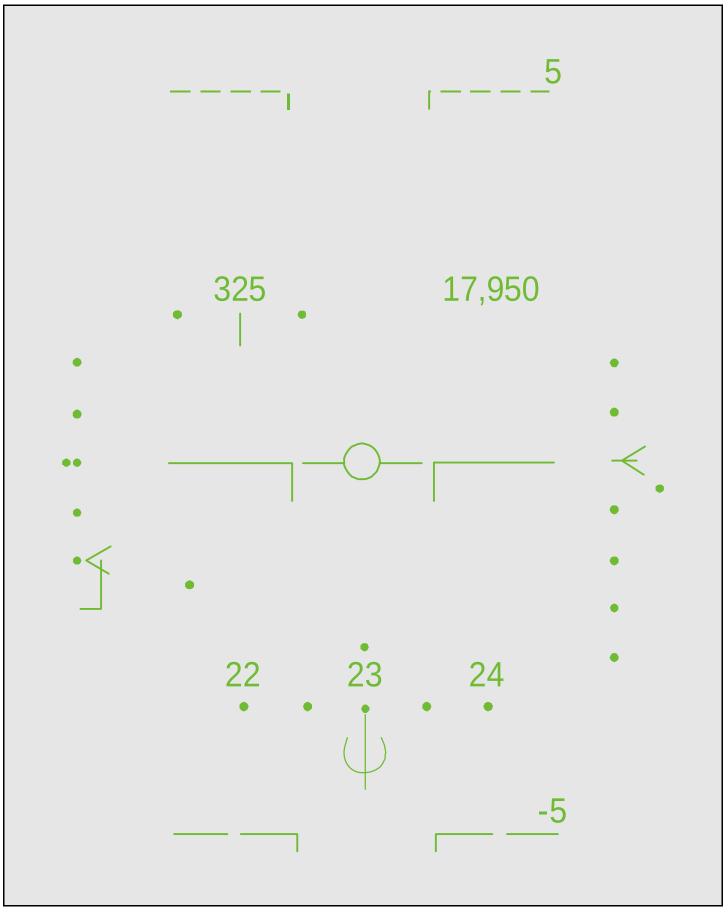


Head-up Displays

51. It is possible to project flight instrument information onto a flat glass screen in front of the pilot at eye level. The display is collimated and, as well as basic flight instruments, can include extra information such as radar ranging and target information. Such displays are known as 'head-up' displays and are described in detail in Volume 7, Chapter 20. An example of a head-up display used

in an aircraft for advanced flying training is illustrated at Fig 12. Where a head-up display is fitted, there will also be a set of conventional instrument displays in the cockpit, to provide the normal 'head-down' information. The instrument flying techniques used with a head-up display will differ slightly from those described within this chapter, depending on how the information is displayed. However, the principle of the selective radial scan can still be used.

8-25 Fig 12 Head-up Display



Human Factors and Instrument Flying

It is very easy to miss the big picture when Instrument Flying as the mind is focussed on 'numbers and dials'. Focussed attention can lead to time distortion and, potentially, loss of Situation Awareness. Follow training regimes and learn from the experienced, get a good scan routine going and if in doubt communicate.

CHAPTER 26 - NIGHT FLYING

Contents **Page**

Definition

1. For the purpose of flying training and the recording of night flying time, 'night' is defined as the time between the end of civil twilight in the evening and the beginning of civil twilight in the morning. For the purpose of standardization of air traffic control procedures, 'night' is defined in the CAA Air Navigation: The Order and Regulations (CAP 393 – usually referred to as the Air Navigation Order (ANO)), as the time between 30 from after sunset to 30 minutes before sunrise (both times inclusive), at surface level.

Introduction

2. The ability to fly an aircraft as efficiently by night as by day is required of every Service pilot. By day, the aircraft is controlled mainly by reference to ground objects and the visual horizon, supplemented by certain flight instruments. In the absence of external visual references, all of the flight instruments are used. Similarly at night the aircraft is controlled by a combination of external and instrument references, provided that the pattern and perspective of lights on the ground can be interpreted, and sufficient of the natural horizon is discernable. On a dark night, with no external lights visible on the ground, the problem is much the same as flying in cloud. It follows, therefore, that accurate instrument flying is of paramount importance if night flying is to be carried out safely and efficiently. At the same time, it must be emphasized that, although night flying poses additional problems to a similar flight during the day, none of the demands upon the pilot is unusual. With a properly equipped aircraft and the benefit of good pre-flight preparation, the average pilot should find night flying operations well within his capabilities.

Preparation for Night Flying

3. **Knowledge of Control Layout**. Before night flying is carried out, the crew must be thoroughly familiar with the location and function of all controls, cockpit and emergency lighting, crash exits and emergency equipment, so that the correct actions or selections can be carried out under subdued lighting conditions, or even in complete darkness.

4. **Dark Adaptation**. Before night flying, bright lights should be avoided whenever possible to allow the eyes to become adapted to the darkness. Full dark adaptation takes about 30 minutes, but exposure to bright lighting can destroy it in less than a second. Dark adaptation and night vision is significantly affected by a reduction in oxygen level. It follows, therefore, that heavy smoking is detrimental to night vision.

5. **Flight Planning**. Flight planning for a night sortie is similar in most respects to that for a day flight, but consideration should be given to the following factors where applicable:

a. Preparation of maps, charts and logs for ease of reading under low levels of illumination. (Note that markings in red will be illegible under red lighting and some other colour should be used for marking in danger areas, power cables etc.)

b. Possible limited availability of navigational assistance outside airfield normal operating hours (e.g. V/UDF).

c. Limited visibility for identifying ground features.

d. Changing light patterns in urban areas, particularly after the extinction of domestic lighting late at night.

e. Position of moon (visibility reduced down-moon).

f. Changes in accuracy of navigational equipment due to movement of the ionospheric layers. This effect is particularly marked during the dusk/dawn periods.

g. If the sortie is intended to employ astro-navigation, the possibility of upper cloud obscuring the sky.

h. Selection and identification of airfield identification beacons and marine lights.

6. **Night Flying Briefing**. All aircrew engaged on night flying duties should attend a briefing, or carry out self-briefing, to ensure that they are familiar with the following:

a. Airfield layout, dispersal areas, taxi pattern and obstructions.

b. Airfield and approach lighting, and obstruction lighting.

c. Serviceability of navigational aids.

d. Availability of diversion airfields.

e. Forecast weather conditions for period and area of flight.

f. Night flying orders, including marshalling signals to be used and emergency procedures.

g. Standard lamp and pyrotechnic signals.

Pre-flight Checks

7. Prior to night flying, all external and internal lighting should be checked in addition to the carrying out of normal daytime pre-flight checks. Warning and indicator light day/night screens or irises should be set to the required position to avoid undue glare in the cockpit. A torch should be carried to assist with external checks, and to provide an emergency source of cockpit lighting.

Engine Starting and Taxiing

8. **Engine Starting**. The daytime engine starting procedures are supplemented at night by the use of the aircraft external lighting to signal the intentions of the pilot to the groundcrew. On many aircraft servicing platforms (ASP) the level of illumination from floodlights is sufficient for the use of normal daytime signals but, to avoid any possibility or ambiguity or confusion, these signals should always be confirmed by the appropriate light signals as detailed in the unit Flying Order Book. The same principle should be observed when an external intercommunications system is used between the pilot and groundcrew.

9. **Taxiing**. When ready to taxi, the appropriate light signal is given to the groundcrew who will remove the chocks and then commence marshalling with illuminated batons (see AFSP-2 – Aircraft Marshalling Signals). If taxi lamps are used whilst being marshalled, care should be taken not to dazzle the marshaller and thus limit the assistance he can give the pilot. Before leaving the dispersal area, the cockpit lighting should be adjusted if necessary to avoid glare or distracting reflections in the cockpit canopy. The judgement of speed and distance is more difficult at night than in daytime due to the lack of visual cues. Care must be taken, therefore, to keep taxiing down to a safe speed. A good lookout must be kept for aircraft taxiing ahead, as the tail lights can be difficult to distinguish, particularly in the absence of any anti-collision lighting. If the pilot is at any time in doubt about the taxiing clearance available, or suspects the presence of obstructions, the aircraft should be stopped and full use made of landing lamps or hand-signalling lamps to illuminate the suspect area.

Take-off and Climb

10. Before take-off, the cockpit lighting level should be checked and adjusted to an acceptable minimum to reduce the contrast between internal and external references. When flying an unfamiliar aircraft at night, or when out of night flying practice, the aircraft should be held momentarily on the runway while the pilot assesses the perspective of the runway lighting in order to assist in the judgement of a subsequent correct landing attitude. Throughout the take-off run, and immediately after becoming airborne, the direction and attitude of the aircraft should be judged by reference to the runway lighting. When clear of the ground, and before external visual references are lost, attention should be transferred to the flight instruments and the aircraft placed in a steady climb as in normal instrument flying technique. Once the aircraft has reached circuit height, external visual references may again be used, if available, to supplement the instrument indications.

Engine Failure After Take-off

11. For a multi-engine aircraft, loss of an engine at night is no different from a similar emergency during daytime from the point of view of aircraft performance and emergency action to be taken. However, the fact that the aircraft may have to be flown entirely by instruments imposes an additional burden on the pilot. The case of a single-engine aircraft is rather more serious, and, following an engine failure at low level, the recommended course of action will almost invariably be to abandon the aircraft if possible. This presents no problem on aircraft equipped with ejection seats, but the minimum height for successful abandonment without the assistance of an ejection seat will normally preclude any possibility of escape from the aircraft at or below normal circuit heights. In such circumstances, the pilot is faced with no alternative but to attempt a forced landing within some 30° of the aircraft's original heading, aided only by the aircraft landing lights. The chances of success can be considerably enhanced by local knowledge of the terrain in the vicinity of the airfield, and its suitability or otherwise for forced landings. The location of suitable areas should be included in the night flying briefing where applicable.

Circuit Flying

12. The circuit pattern for night flying is normally the same as by day, except that local flying orders may require the aircraft to be climbed straight ahead after take-off until reaching circuit height. With omnidirectional runway lighting, the circuit pattern presents no problems, but with unidirectional lighting it may be advantageous to make use of the compass to assist in flying an accurate downwind leg parallel to the runway. A careful listening watch should be kept on the R/T so that the movements and intentions of other aircraft in the circuit are noted, and the circuit planned accordingly.

Approaching to Land

13. The approach to land is judged by the changing perspective of the runway lighting. On most airfields the pilot is assisted in judging attitude and descent angle by lighting extending out along the approach path from the runway threshold, and also by PAPIs (see Volume 8, Chapter 13).

Landing

14. Most large aircraft have landing lamps of sufficient intensity that the final round-out and touch-down can be judged largely by the use of normal daytime visual cues. On aircraft not so equipped, or in the event of failure of the landing lamps, the landing phase must be judged by looking well ahead and observing the changing perspective of the runway lighting. Peripheral vision plays an important part in this judgement; for most pilots, the runway lighting, as observed by peripheral vision whilst looking straight ahead, appears to be up around the level of the shoulders or ears when the aircraft is about to touch down. As mentioned in para 10, this effect can best be observed while the aircraft is lined up on the runway prior to initial take-off. During the landing run, care should be taken to reduce speed progressively and, before turning off the runway, a positive check should be made to ensure that the speed is within acceptable taxiing limits.

Overshoot Procedure

15. The procedure for overshooting is the same at night as for a normal instrument overshoot, with the addition of extinguishing the landing lamps, if used, to avoid the possibility of causing distracting reflection from any cloud or mist patches, and to avoid confusion to other aircraft.

Navigation at Night

16. Subject to the considerations discussed in para 5, night navigation is similar in most respects to navigation by day.

17. The amount of map reading that is possible at night depends largely upon the prevailing conditions. On a bright moonlit night, almost as many major features may be seen as during the day. When there is no moon, or when flying under a complete cloud layer, it may be very difficult to see any ground features that are not illuminated. Visibility is better when looking into the moon than down-moon.

18. Coastlines and large water features such as navigable waterways and lakes can often be seen under all but the most adverse conditions, thus forming valuable pinpoints or position lines. Towns are easily visible whilst the street and domestic lighting is on, but it should be remembered that the majority of domestic lights are switched off for the latter part of the night. The apparent shape and size of towns can therefore vary considerably with the time of night. Railways can usually be seen on bright nights and dual carriageways and motorways can often be identified.

19. Flashing/occulting lights from lightships or lighthouses on the coast, and aerodrome identification beacons inland can be seen at fairly long ranges and, because they flash or occult in distinctive groups or in Morse code, give a positive position; civil airfield beacons flash in green and Service airfield beacons flash in red. Distances are deceptive at night and the correct estimation of range from an identified feature requires practice.

20. The use of a red light to illuminate the map should be avoided; under this light all markings in red on the map may be unreadable. Accurate flying and timing becomes even more important at night than by day, because of the reduced number of features that can be seen. Strict adherence to the flight plan is necessary if turning points cannot be seen or identified.

Night Emergencies

21. In addition to engine failure after take-off, the only other emergencies which pose additional problems at night are radio failure and total electrics failure. In both these cases, assuming the absence of a stand-by radio, the emergency can only be communicated to ATC by rejoining the circuit and flying the appropriate emergency pattern as detailed in the local Flying Order Book. Although the procedures may be subject to local amendment, in VMC, those most widely used for these emergencies are for the aircraft to fly a circuit at 500 ft AGL whilst squawking 7600 and monitoring the ILS speech facility. On final approach, a descent is made to 300 ft in front of the caravan or ATC, flashing navigation, taxi and/or landing lights (radio failure), or varying engine noise (total electrics failure). For the latter, ATC should switch on floodlights to enable a visual check of undercarriage position on a subsequent similar circuit. Undercarriage position will be indicated by three successive pyrotechnics, green for down, red for up. The aircraft should be landed following a further green pyrotechnic (or aldis) signal from ATC.

Human Factors and Night Flying

It is very easy to miss the big picture when Night Flying as the mind is focussed on 'numbers and dials' without a visual reference. Focussed attention can lead to time distortion and loss of Situation Awareness. Normal day time references are not available and perceptions of distance can be corrupted. Cockpit lighting needs to be adjusted accordingly. Keep to a good scan pattern routine and if in doubt communicate.

CHAPTER 27 - SURFACE LIGHTING

Contents **Page**

Table of Figures

Table

Introduction

1. Details and specifications of aerodrome surface lighting can be found in The Manual of Aerodrome Design and Safeguarding, issued by the Military Aviation Authority (MAA) and is authoritative over AP3456. Airfield lighting is also detailed in STANAG 3316.

Aerodrome Identification Beacons

2. An identification beacon (I Bn) should be provided at an aerodrome that is intended for use at night. The beacon should be visible from all directions of approach and will flash a Morse group of one or more letters every 12 sec. The colour of the light is red at military aerodromes and is normally green at civil aerodromes. Not all aerodromes display a beacon.

3. Aerodrome beacons (A Bn) may display alternating white/green or flashing white lights and are normally only located at civil aerodromes.

4. The identification codes are promulgated in the appropriate En Route Supplements within the Nav section of the aerodrome entry in the form:

Airfield	Beacon Type	Morse Ident	Lights
Baldonnel (EIME)	A Bn		Wh Wh Gn
Barkston Heath (EGYE)	I Bn	BA	Red
Akureyri (BIAR)	A Bn		Wh Gn
Cambridge (EGSC)	I Bn	CI	Gn
Details correct Jun 2014			

Aerodrome Obstruction Lighting

5. The marking and/or lighting of obstacles is intended to reduce hazards to aircraft operating at low level under visual flight conditions or moving on the surface by indicating the presence of the obstacles. In areas beyond the obstacle limitation surfaces of an aerodrome, objects that extend to a height of 150m or more above ground elevation are regarded as obstacles. Other objects of a lesser height that are assessed as hazards to aviation are also to be treated as obstacles and should be marked and/or lighted.

6. Low intensity obstacle lights should be used on obstacles less than 45m high. Where this is deemed to be inadequate medium or high intensity lights should be used.

7. Low intensity (10 candela (cds) minimum) lights should be used for obstacles on the movement area where 200 cds lights may cause dazzle.

8. Low intensity (200 cds) lights should be used away from the movement area or in areas on the movement area with high levels of background luminance.

9. Medium intensity steady red obstacle lights should be used, either alone or in combination with other medium or low intensity obstacle lights from 45m up to, but not including 150m in height.

10. Where physically practicable high intensity flashing white obstacle lights should be used to indicate the presence of an obstacle if its height is 150m or more. High intensity obstacle lights are intended for day and night use and care is needed to ensure that they do not create dazzle.

11. Except in the case of a chimney or other substance emitting structure one or more obstacle lights should be located as close as practicable to the top of the object. The top lights should be so arranged as to at least indicate the points or edges of the object highest in relation to the obstacle limitation surface. In the case of a chimney or other substance emitting structure, the top lights should be placed sufficiently below the top so as to minimise contamination by smoke.

12. The number and arrangement of the obstacle lights at each level to be marked should be such that the object is indicated from every angle in azimuth. Where a light is shielded in any direction by another part of the object, or by an adjacent object, additional lights should be provided on that object in such a way as to retain the general definition of the object to be lighted. If the shielded light does not contribute to the definition of the object to be lighted, it may be omitted.

13. All fixed obstacle lighting located on the aerodrome should be under the control of ATC.

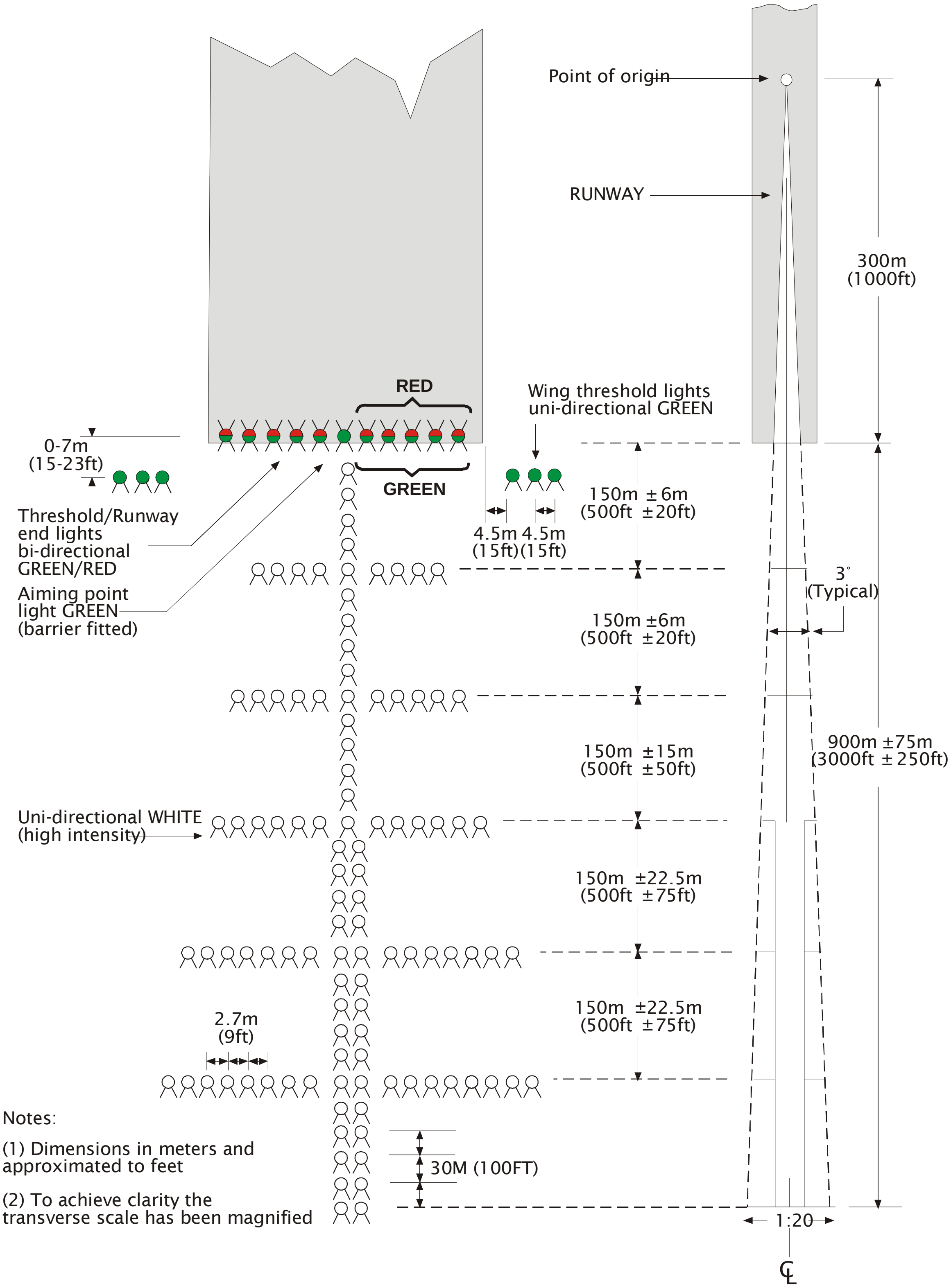
Approach Lighting

14. **Purpose**. The most critical stage of an instrument approach, whether at night or in poor visibility, is the transition from instrument flight to visual flight immediately prior to touchdown. The aim of runway approach lighting is to provide the pilot with visual external references during this transition, and for the remainder of the approach. The presentation of the lighting gives indications of the aircraft's alignment with the runway and, in most cases, the angle of approach, the aircraft's attitude in roll, and the safe touchdown point. The correct approach angle can be maintained, both day and night, by reference to the Precision Approach Path Indicators (PAPI) described in Volume 8, Chapter 13.

15. **Familiarity with Types**. In order to obtain the maximum assistance from the approach lighting, the pilot must be familiar with the type of system installed at his destination. Military aircraft may be required to make use of a wide variety of airfields, military and civil, local and foreign, all employing different standards and types of lighting. Details of the pattern of approach lighting at any particular airfield can be found by consulting the appropriate planning documents. The diagrammatic presentations given in the Terminal Approach Procedure Charts (TAPs) are particularly useful when planning a landing at an unfamiliar airfield at night or in poor visibility.

16. **Main Instrument Runway**. Provided that terrain conditions permit, a centre-line and five cross-bar high intensity white approach system extending to 900 m (3000 ft) from the threshold, with a low-intensity red T superimposed, is installed at the end of the main runway intended for instrument approaches (see Fig 1). Where the installation of the full pattern is impracticable, an abbreviated system is provided.

8-27 Fig 1 Approach Lighting



Notes:

(1) Dimensions in meters and approximated to feet

(2) To achieve clarity the transverse scale has been magnified

17. **Main and Subsidiary Runways**. There are prescribed minimum scales for lighting which depend upon the runway and type of approach. The Manual of Aerodrome Design and Safeguarding gives full details of the requirements (Table 6-4), some of which are reproduced in Table 1

Table 1 Minimum Prescribed Scales of Airfield Lighting

	Operating Category			
	CAT II Precision App	**CAT I Precision App/ PAR**	**Non-Precision App**	**Non-Instrument App**
Aerodrome beacon	O	R	R	R
Simple Approach			R	O
HI C/L 5 Bar Approach	R	R		
Supplementary Approach	R	O		
PAPI	R	R	R	R
Runway Edge	R	R	R	O
Threshold	R	R	R	R
Threshold Wing Bar	R	R	R	O
Runway End	R	R	R	O
Runway Centre-Line	R	O		
Touchdown Zone	R			
Stopway	R	R	R	R
Taxiway Centre-Line	R	O[1] R[2]		
Taxiway Edge		R[1]	R	R
Stop Bars	R			
Illuminated Runway Signs	R	R	R	O
Obstacles	R	R	R	R

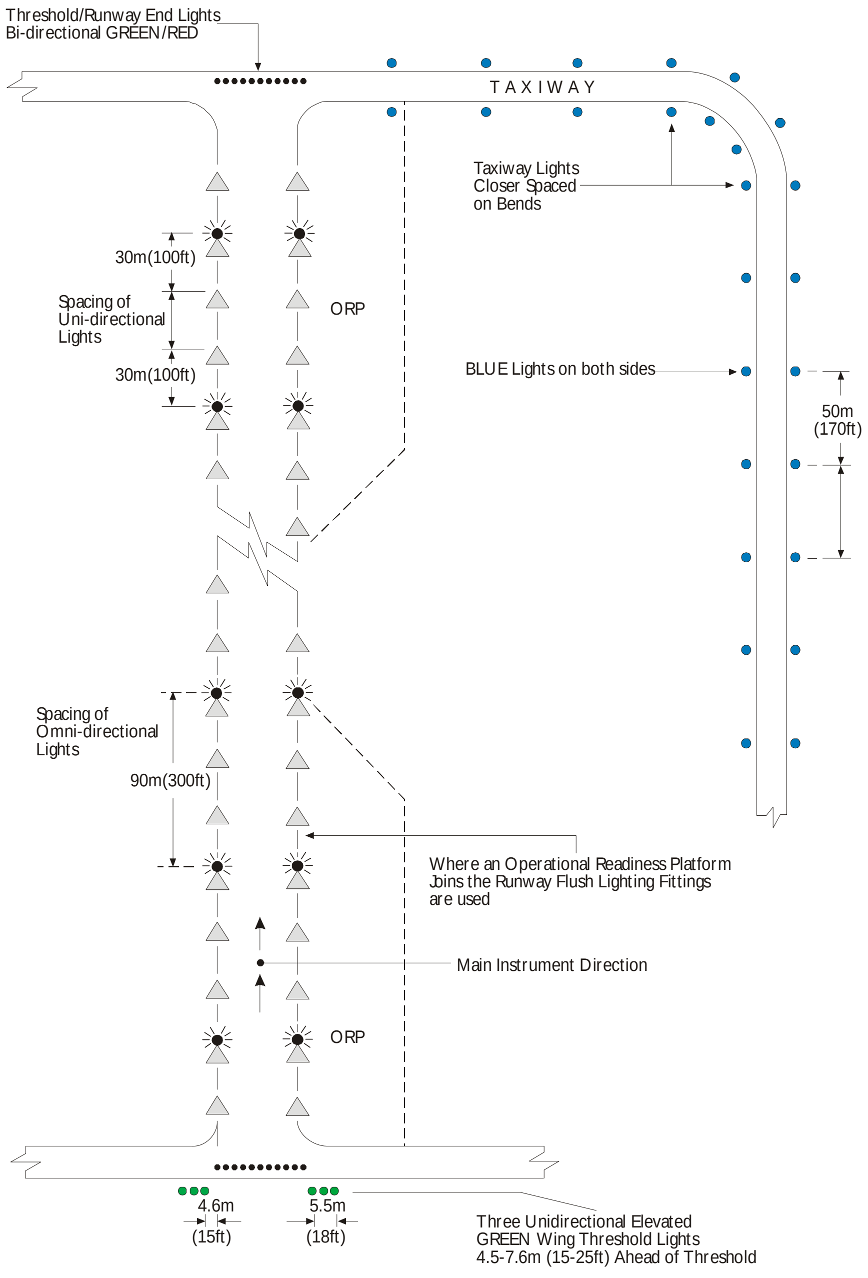
R = Required **O = Operationally Desirable**

1. Taxiway edge lighting may be replaced by taxiway centre-line lighting.
2. Centre-line lighting will be provided on taxiways with a width greater than 18m.

Runway Lighting

18. **Main Runways**. Main runways are equipped with high-intensity unidirectional elevated edge-lights for both directions of landing, and with omnidirectional elevated edge-lights operative for both directions of landing (see Fig 2).

8-27 Fig 2 Runway and Taxiway Lighting



19. **Subsidiary Runways**. Subsidiary runways are equipped with omnidirectional elevated edge-lights if the administrative authority concerned is satisfied that there is a requirement for an officially maintained subsidiary runway which will be used for night flying.

20. **Spacing of Runway Lighting**. The nominal longitudinal spacing of runway lighting is:

a. Unidirectional 30 m (100 ft).

b. Omnidirectional 90 m (300 ft).

Threshold/Runway-end Lighting

21. All runways with a lighting installation have threshold and runway-end lights. Threshold lights show green in the direction of the runway approach. Runway-end lights show red towards the direction of landing. Threshold and runway-end lights are to provide adequate definition of the threshold and runway-end regardless of intensity setting.

22. The minimum requirement for main runways is ten threshold lights at each end to define clearly the commencement of the normal landing area. The minimum requirement for main runways is eight runway-end lights at each end to define clearly the termination of the normal landing area. When the threshold is at the runway-end, bi-directional fittings may be used as a combination of threshold and runway-end lights.

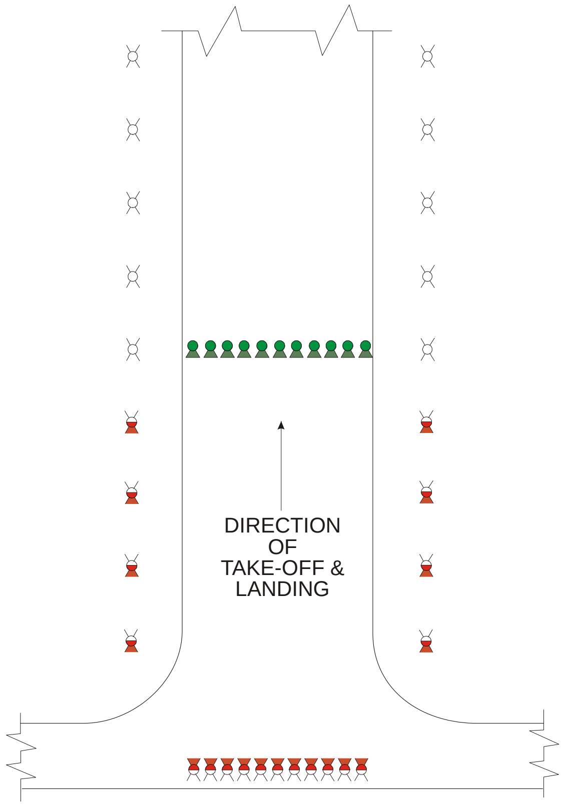
23. Threshold lights may be supplemented by 'wing bars' consisting of three unidirectional elevated high-intensity green lights at each side of the runway. (See Fig 1).

24. Where an arrester barrier is installed, the centre light of the runway-end lighting is fitted with a filter of a distinctive colour from the other end bar lights (e.g. green).

25. *Lighting of Displaced Thresholds.* Where the touchdown point is displaced from the runway end, it is delineated by unidirectional green lights in the approach direction and the displaced portion of the runway by high-intensity unidirectional red edge-lights which are installed and spaced in the same manner as the runway-edge lights (see Fig 3). Where suitable, the displaced portion of the runway may be used for take-off.

Note: In the reciprocal landing direction, the area beyond the displaced threshold (upwind) is deemed to be part of the runway and accordingly is to show high intensity unidirectional white edge lights. The runway end is to be identified by unidirectional red lights.

8-27 Fig 3 Runway Lighting - Displaced Threshold



Zone and Distance Markers

26. **Caution-Zone Lights**. These lights are provided at certain aerodromes to indicate the amount of runway remaining for either take-off or landing. They are located 700 m (2,400 ft) from the upwind end of the runway at right angles to the runway edge. They are yellow and extend 4.5 m (15 ft) inboard of the runway edge.

27. **Illuminated Runway Distance Markers**. Illuminated runway distance markers should be installed on all main runways as follows:

a. The markers are placed on both sides of the main runway on a line parallel and normally equidistant to the centre line of the runway.

b. The unit of distance is 300 m (1,000 ft). The markers indicate the runway distance remaining in thousands of feet (the last three digits being omitted). Where the length of the runway is other than a multiple of 300 m (1,000 ft), then half the odd length is used at each end of the runway for computing the position of the markers.

c. The markers are numbered from the point of origin, increasing towards the beginning of the runway.

d. The colour of the numbers is white on a contrasting background.

Taxiway Lighting

28. Taxiway lighting facilities are governed by the width and purpose of the taxiway (main or access):

a. **Taxiways less than 18 m (60 ft) wide**.

(1) Main routes are lit by blue edge lights 50 m (170 ft) apart with closer spacing on bends.

b. **Taxiways 18 m (60 ft) or more wide**.

(1) These taxiways are lit by green centre-line lights only, spaced at a maximum of 30m (100 ft) apart, with close spacing on bends. The last four lights of the taxiways entering a runway are spaced 2 m (6 ft) apart.

Note: At some aerodromes, sections of the main taxiway are fitted with green centre-line lights in addition to normal edge lights.

(2) Warning of the entrance/exit to a hardstanding is given by a bar of five yellow taxiway lights known as a ‘taxiway stub bar’. Stub bars are provided where aircraft have a choice of direction, one of which is a right angled turn giving direct access to a hardstanding. Where entry to a hardstanding is via a secondary route then a stub bar is provided at the entrance/exit to the secondary route. Where a hardstanding exit, or secondary route exit from a hardstanding, joins a main taxiway, the centre of the junction is indicated by a single yellow light to warn pilots of approaching soft ground.

c. **Turning Areas**. At aerodromes where turning facilities for aircraft are provided at the runway ends they are lit as follows:

(1) Taxiway Loops. These are lit in accordance with 'a' above.

(2) Turning Circles. These are lit with blue edge lighting.

29. **Holding Position Sign**. An illuminated red board incorporating the runway designator and the word HOLD in white characters is sited at the holding point on either side of the runway, 22.5 m (75 ft) from the outer edge of the taxiway and visible only from the taxiway side. Holding positions are further identified according to the type of taxiway lighting in use:

a. A taxiway lit by blue lights, has two holding position lights at right angles to the taxiway on its inside edge with relation to the runway.

b. A taxiway lit by green centre-line lights, has two holding position lights in the middle of the taxiway at right angles to the centre line.

30. **Lighting of Hardstanding and Other Areas**:

a. **Hardstandings**. Only the entrances to hardstandings are indicated by blue taxi lights.

b. **Aircraft Servicing Platforms and Operational Readiness Platforms**. Aircraft servicing and operational readiness platforms are outlined by blue taxi lights. To achieve uniformity and minimize the risk of taxiing and other accidents, the following instructions are observed in the illumination of aircraft servicing platforms and dispersals:

(1) Dispersal lighting fittings are not to infringe runway or taxiway criteria.

(2) Illumination is not to interfere with the aerodrome lighting system or lighting aid, either by intensity or siting.

(3) No pattern of lights is to give a false indication to a pilot on the ground or in the air.

(4) All lights are to be screened to prevent dazzle on the ground or in the air.

Aerodrome Lighting During NVG Operations

31. The lighting that can adversely affect the use of NVG includes the airfield lighting that is controlled by ATC, however, other lighting on and adjacent to the airfield including lighting not provided for aviation purposes should be considered. Such lighting will not necessarily be under the control of military authorities and may be legally required to fulfil general safety requirements.

32. Different lighting requirements may be needed for fixed wing NVG (FWNVG) operations than for helicopter NVG (Helo NVG) operations. Simultaneous FWNVG and Helo NVG operations will need to be carefully planned as will simultaneous operations with and without NVG. Airfields which undertake NVG operations should have a NVG Operation Control Plan to ensure, as far as possible, that such measures of lighting control as are necessary to ensure that the performance of NVG is not significantly affected by any light on or adjacent to the airfield.

33. Where NVG operations are to take place all personnel involved should receive training that includes the light control measures and operational procedures to be used when NVG operations are taking place.

34. Only personnel whose presence is essential for safety and efficiency reasons should be on the manoeuvring area during NVG operations.

35. The Manual of Aerodrome Design and Safeguarding contains further advice on NVG operations. See also STANAG 7134.

CHAPTER 28 - AIRCRAFT EXTERNAL LIGHTING

Contents **Page**

Table of Figures

Navigational Lights

1. **Purpose**. Navigational lights are shown by aircraft at night in order to:

   a. Avoid collision.

   b. Determine direction of movement of the aircraft.

   c. Identify the class of aircraft, (see para 2).

2. **Description**. Navigation lights are displayed by various classes of aircraft as follows:

   a. **Powered aircraft** - As shown in Fig 1.

   b. **Gliders** - One red light visible from all sides.

   c. **Free Balloons** - One red light between 5-10 m (15-30 ft) below the crew basket, and visible from all sides.

   d. **Captive balloons** - One white light between 5-10 m (15-30 ft) below the underside of the balloon, and one red light 4 m (12 ft) vertically below, both visible all round. Additional similar groups of red/white lights are shown at 300 m (1,000 ft) intervals down the cable. The ground attachment point is marked by three flashing lights, two red and one green, arranged in a 25 m (80 ft) equilateral triangle, with the attachment point midway between the red lights (Fig 2).

   Note: Lights are only shown when the balloon is flown above 60 m (200 ft), or within 2 nm of an airfield or controlled airspace. In a designated danger area lights may not be shown at any height.

   e. **Airships** - As for powered aircraft with the addition of a white nose light showing over a horizontal forward sector of 220º.

On aircraft where the arrangement of flying surfaces, etc precludes the placing of lights in the standard position, additional lights of the same colour may be used so that the required sector is covered.

3. **Regulations**. Navigation lights are to be displayed during the period of darkness by aircraft in flight, taxiing, being towed, and when being ground run, (MAA RA2307(1)). Exceptions to this rule include aircraft participating in certain exercises, and also aircraft which have had a failure of navigation lights in flight, and have been authorized to continue the flight by the appropriate ATC unit.

8-28 Fig 1 Powered Aircraft Navigation Lights

Fig 1a Front View

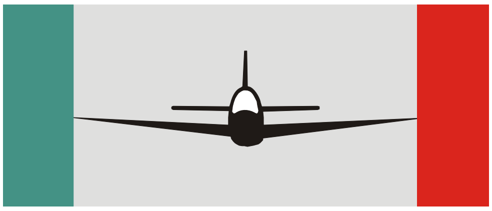


Fig 1b Plan View

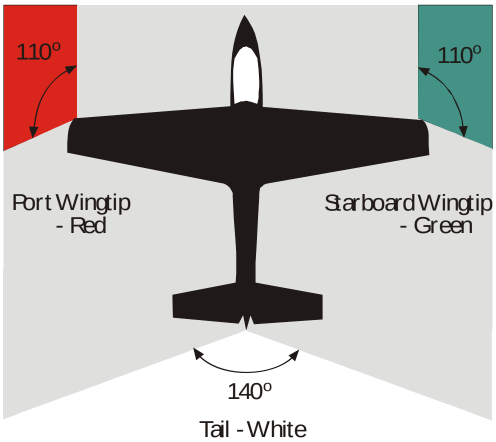
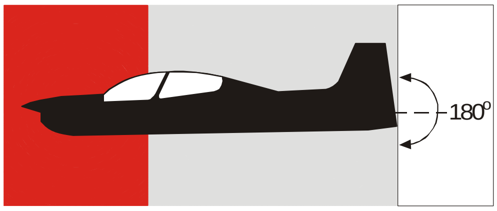
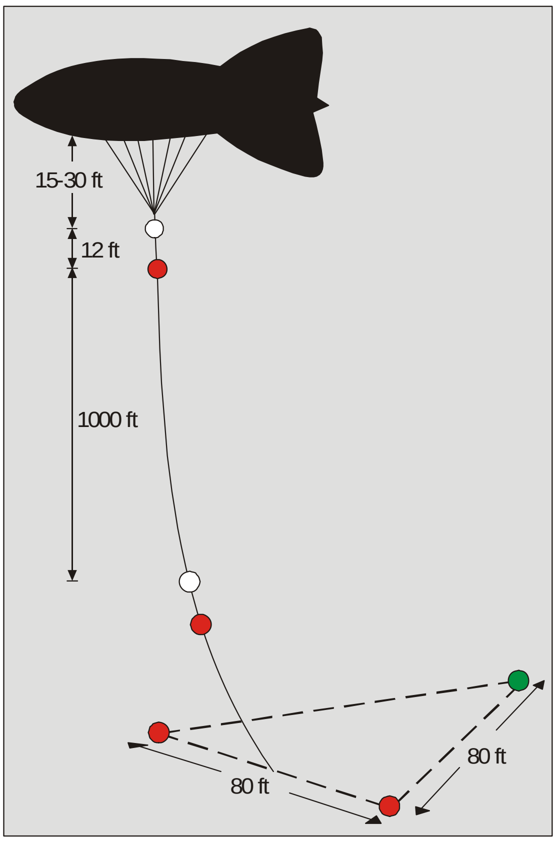


Fig 1c Port Side View



8-28 Fig 2 Captive Balloon Lighting



Anti-collision Lights

4. **Purpose**. Anti-collision lighting increases the range at which visual contact can be made with an aircraft. The flashing characteristic of the lights make them easier to distinguish against a background of other lights or stars.

5. **Description**. The most common form of anti-collision lighting consists of a high intensity rotating red beacon which gives the appearance of 90 flashes per minute. The number of beacons used on an aircraft depends upon that aircraft's size and configuration; the beacons are located so that at least one beacon is visible from any direction. A typical installation would have one beacon on the underside of the fuselage near the nose, and another beacon on the rear top surface of the fuselage or on top of the tail fin. Some installations use a red strobe light in place of the rotating beacon. Civil practice now tends towards the use of white strobe lights at the aircraft extremities in addition to the red anti-collision beacons. Some older installations have high intensity white anti-collision lighting but, in most cases, this is now supplemented by the red beacon. Provision is made in some aircraft for the upper anti-collision lighting to be switched off independently; this avoids interference with the taking of astronomical observations.

6. **Regulations**. Anti-collision lights, when installed, should be used at all times during flights.

Taxi and Landing Lights

7. Aircraft may be equipped with separate or combined taxi and landing lights, and these may be remotely adjusted from the cockpit. Care should be taken to observe any limitations on use as detailed in the appropriate Aircrew Manual.

Miscellaneous External Lighting

8. **Leading Edge Lights**. Leading edge lights are installed on most passenger carrying aircraft, and provide a means of inspecting the leading edge of the wing in flight to assess ice accretion, or checking wing mounted engine installations. On propeller driven aircraft, it is common practice to use this lighting to illuminate the propeller disc while manoeuvring or when stationary on the ground.

9. **Formation Lights**. Formation lights assist in formation station keeping at night. Fixed wing tactical transport aircraft show a cruciform display of white lights extending along the upper surface of the fuselage and wing. Some fighter aircraft display miniature navigation lights on the trailing edge of the wing tips. Helicopters which are required to fly in formation at night have rotor tip lights to define the area of the rotor disc.

10. **Flight Refuelling Lights**. Flight refuelling lights include the FR tanker floodlighting, signal lighting, and drogue lighting, and the receiver aircraft probe lighting (see Volume 8, Chapter 23).

11. **Undercarriage Lights**. Aircraft operated in the pilot training role and having a retractable undercarriage are equipped with an external undercarriage position indicator light which is illuminated whenever the undercarriage is locked down. On some installations the steady white light has been superseded by a flashing light.

12. **Servicing Lights**. A number of aircraft have built in servicing lights to assist with maintenance and servicing at night. Other aircraft have portable servicing lights which can be connected to power sockets provided both inside and outside the aircraft.

CHAPTER 29 - NIGHT FLYING CALCULATIONS

Contents **Page**

Table of Figures

Definitions

1. **Night**. For the purpose of flying training and the recording of night flying time, 'night' is defined as the time between the end of civil twilight in the evening and the beginning of civil twilight in the morning. For the purpose of standardization of air traffic control procedures, 'night' is defined in the CAA Air Navigation: The Order and Regulations (CAP 393 – usually referred to as the Air Navigation Order (ANO)), as the time between 30 from after sunset to 30 minutes before sunrise (both times inclusive), at surface level.

2. **Sunrise and Sunset**. Sunrise and sunset are respectively defined as the point when the upper limb of the Sun just appears above (sunrise) or disappears below (sunset) the observer’s visible horizon. At these times, the Sun’s centre is 50' of arc below the celestial horizon (see Volume 9, Chapter 9 for further details).

3. **Twilight**. The period of diffused light before sunrise and after sunset is known as twilight. The amount of illumination varies with the Sun’s depression and also with atmospheric conditions. Three twilights, each occurring at a particular depression value, are recognized:

a. Civil Twilight

b. Nautical Twilight

c. Astronomical Twilight

For a full explanation of twilight, see Volume 9, Chapter 9. However, only Civil Twilight needs to be considered within this annex.

4. **Civil Twilight**. Civil twilight occurs when the Sun’s centre is 6º below the observer’s visible horizon. Light conditions are such that everyday tasks are just possible without artificial light.

5. **Local Mean Time**. Local Mean Time (LMT) is explained in Volume 9, Chapter 11. The mean Sun crosses an observer’s meridian at 1200 LMT, i.e. local noon.

Calculation of Civil Twilight

6. The times of the beginning of morning civil twilight and the end of evening civil twilight are tabulated in AP 1602, The UK Air Almanac, at three-day intervals for latitudes between 60º S and 72º N. The times given are the UTC of the occurrences at sea level on the Greenwich Meridian, and they may also be regarded as the LMT of the occurrences at other meridians.

7. The calculation process consists of two parts:

   a. Extraction of LMT/UTC Greenwich for the occurrence.

   b. Adjustment for Arc to Time, for Meridian of Longitude.

8. The Air Almanac includes examples of twilight calculations. However, further explanation of the processes involved is contained here.

Example 1. Calculate the beginning of Morning Civil Twilight, at Cranwell, on 11th January 2005.

Cranwell is at N 53º 02', W 000º 29'. From the Morning Civil Twilight, 2005, Table on page 11, the start of morning civil twilight can be extracted (Fig 1). By interpolation, the LMT of morning civil twilight for 53º 02', on 11 Jan 05, can be taken as 07 h 29 min.

The conversion of 0º 29' of arc, to its equivalent in time, is taken from Page 78 of the Air Almanac (see Fig 2). This gives a correction of 1 min 56 sec (round up to 2 mins). As the longitude of Cranwell is *west*, this time equivalent is *added* to the time previously extracted from the table.

07 h	29 min	LMT
+	02	
07	31	UTC

8-29 Fig 1 Extract from Air Almanac - Morning Civil Twilight Jan 05

	MORNING CIVIL TWILIGHT, 2005					
	Dec	January				
Lat.	30	2	5	8	11	14
	h m	h m	h m	h m	h m	h m
N 72	10 48	10 39	10 29	10 19	10 07	09 55
70	09 52	09 48	09 42	09 36	09 29	09 20
68	09 18	09 16	09 12	09 07	09 02	08 55
66	08 54	08 52	08 49	08 46	08 41	36
64	35	34	31	28	25	20
62	19	18	16	14	08 11	08 07
N60	08 06	08 05	08 04	08 02	07 59	07 56
58	07 55	07 54	07 53	07 51	49	46
56	45	44	43	42	40	38
54	36	35	25	34	32	30
52	28	28	27	26	25	23
N50	07 20	07 20	07 20	07 19	07 18	07 16
45	07 04	07 05	07 05	07 04	07 04	07 02

Note: Where the precise date and latitude is not listed, then dates and locations may be obtained by interpolation.

8-29 Fig 2 Extract from Arc to Time Conversion – Cranwell

CONVERSION OF ARC TO TIME

0° - 59°			60° - 119°			120° - 179°						300° - 359°			0´ - 59´		
°	h	m	°	h	m	°	h	m	°	h	m	°	h	m	°	h	m
0	0	00	**60**	4	00	**120**	8	00				**300**	20	00	**0**	0	00
1	0	04	**61**	4	04	**121**	8	04				**301**	20	04	**1**	0	04
2	0	08	**62**	4	08	**122**	8	08				**302**	20	08	**2**	0	08
3	0	12	**63**	4	12	**123**	8	12				**303**	20	12	**3**	0	12
4	0	16	**64**	4	16	**124**	8	16				**304**	20	16	**4**	0	16
25	1	40	**85**	5	40	**145**	9	40				**325**	21	40	**25**	1	40
26	1	44	**86**	5	44	**146**	9	44				**326**	21	44	**26**	1	44
27	1	48	**87**	5	48	**147**	9	48				**327**	21	48	**27**	1	48
28	1	52	**88**	5	52	**148**	9	52				**328**	21	52	**28**	1	52
29	1	56	**89**	5	56	**149**	9	56				**329**	21	56	**29**	1	56

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to LMT (*added if West, subtracted if East*) to give UT or vice versa.

Example 2. Calculate the end of Evening Civil Twilight, at Valley, on 11th January 2005.

Valley is at N 53º 15', W 004º 32'. From the Evening Civil Twilight, 2005, Table on page 11, the end of evening civil twilight can be extracted (Fig 3). By interpolation, the end of evening civil twilight for 53º 15', on 11 Jan 05, can be taken as 16 h 48 min (LMT).

The conversion of 4º 32' of arc, to its equivalent in time, is taken from Page 78 of the Air Almanac (see Fig 4). This gives a correction of 18 min 08 sec (round down to 18 mins). As the longitude of Valley is *west*, this time equivalent is *added* to the time previously extracted from the table.

16 h	48 min	LMT
+	18	
17	06	UTC

8-29 Fig 3 Extract from Air Almanac - Evening Civil Twilight Jan 05

	EVENING CIVIL TWILIGHT, 2005					
	Dec	January				
Lat.	30	2	5	8	11	14
	h m	h m	h m	h m	h m	h m
N 72	13 18	13 30	13 42	13 56	14 10	14 28
70	14 14	14 21	14 29	14 38	14 48	14 59
68	14 47	14 53	14 59	15 07	15 15	15 24
66	15 12	15 16	15 22	28	35	43
64	31	35	40	15 46	15 52	15 59
62	15 46	15 50	15 55	16 00	16 06	16 12
N60	16 00	10 03	16 07	16 12	16 17	16 23
58	11	14	18	23	27	33
56	21	24	28	32	36	41
54	30	33	37	40	45	49
52	38	44	44	48	52	16 56
N50	16 45	16 48	16 51	16 55	16 58	17 02
45	17 01	17 04	17 06	17 10	17 13	16

Note: Where the precise date and latitude is not listed, then dates and locations may be obtained by interpolation.

8-29 Fig 4 Extract from Arc to Time Conversion - Valley

CONVERSION OF ARC TO TIME

0° - 59°			60° - 119°			120° - 179°						300° - 359°			0´ - 59´		
°	h	m	°	h	m	°	h	m	°	h	m	°	h	m	°	h	m
0	0	00	60	4	00	120	8	00				300	20	00	0	0	00
1	0	04	61	4	04	121	8	04				301	20	04	1	0	04
2	0	08	62	4	08	122	8	08				302	20	08	2	0	08
3	0	12	63	4	12	123	8	12				303	20	12	3	0	12
4	0	16	64	4	16	124	8	16				304	20	16	4	0	16
30	2	00	90	6	00	150	10	00				330	22	00	30	2	00
31	2	04	91	6	04	151	10	04				331	22	04	31	2	04
32	2	-8	92	6	-8	152	10	-8				332	22	-8	32	2	08
33	2	12	93	6	12	153	10	12				333	22	12	33	2	12
34	2	16	94	6	16	154	10	16				334	22	16	34	2	16

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to LMT (*added if West, subtracted if East*) to give UT or vice versa.

Calculation of Sunrise/Sunset

9. The times of sunrise and sunset are tabulated in AP 1602, The UK Air Almanac, at three-day intervals for latitudes between 60º S and 72º N. The times given are the UTC of the occurrences at sea level on the Greenwich Meridian, and they may also be regarded as the LMT of the occurrences at other meridians.

10. As with the calculation of twilight, the process consists of two parts:

a. Extraction of LMT/UTC Greenwich for the occurrence.

b. Adjustment for Arc to Time, for Meridian of Longitude.

11. The Air Almanac includes examples of sunrise/sunset calculations. However, further examples are illustrated.

Example 1. Calculate sunrise at Cranwell on 11th January 2005.

Cranwell is at N 53º 02', W 000º 29'. From the Sunrise, 2005, Table on page 10, the time of the occurrence can be extracted (Fig 5). By interpolation, the LMT of sunrise for 53º 02', on 11 Jan 05, can be taken as 08 h 09 min LMT.

The conversion of 0º 29' of arc, to its equivalent in time, is taken from Page 78 of the Air Almanac (see Fig 2). This gives a correction of 1 min 56 sec (round up to 2 mins). As the longitude of Cranwell is *west*, this time equivalent is *added* to the time previously extracted from the table.

08 h	09 min	LMT
+	02	
08	11	UTC

8-29 Fig 5 Extract from Air Almanac - Sunrise Jan 05

	SUNRISE, 2005					
	Dec	January				
Lat.	30	2	5	8	11	14
	h m	h m	h m	h m	h m	h m
N 72	—	—	—	—	—	—
70	—	—	—	—	—	—
68	—	—	11 28	11 08	10 52	10 37
66	10 31	10 26	10 20	10 12	10 04	09 56
64	09 51	09 48	09 44	09 40	09 34	28
62	24	22	19	09 16	09 11	09 06
N60	09 03	09 02	09 00	08 57	08 53	08 49
58	08 46	08 45	08 43	41	38	35
56	32	31	30	28	25	22
54	19	19	18	16	14	11
52	08 08	08 08	08 07	08 06	08 04	08 02
N50	07 59	07 58	07 58	07 57	07 55	07 53
45	38	38	38	38	37	37

Note: Where the precise date and latitude is not listed, then dates and locations may be obtained by interpolation.

Example 2. Calculate sunset at Valley, on 11th January 2005.

Valley is at N 53º 15', W 004º 32'. From the Sunset, 2005, Table on page 10, the time of the occurrence can be extracted (Fig 6). By interpolation, sunset at N 53º 15' on 11 Jan 05, can be taken as 16 h 06 min (LMT).

The conversion of 4º 32' of arc, to its equivalent in time, is taken from Page 78 of the Air Almanac (see Fig 4). This gives a correction of 18 min 08 sec (round down to 18 mins). As the longitude of Valley is *west*, this time equivalent is *added* to the time previously extracted from the table.

16 h	06 min	LMT
+	18	
16	24	UTC

8-29 Fig 6 Extract from Air Almanac - Sunset Jan 05

	SUNSET, 2005					
	Dec	January				
Lat.	**30**	**2**	**5**	**8**	**11**	**14**
	h m	h m	h m	h m	h m	h m
N 72	—	—	—	—	—	—
70	—	—	—	—	—	—
68	—	—	12 43	13 06	13 24	13 42
66	13 35	13 43	13 52	14 02	14 12	14 23
64	14 15	14 20	14 27	34	14 43	14 51
62	14 42	14 46	14 52	14 58	15 05	15 13
N60	15 03	15 07	15 12	15 17	15 23	15 30
58	20	23	28	33	38	44
56	34	38	42	46	15 51	15 56
54	46	15 50	15 54	15 58	16 02	16 07
52	15 57	16 00	16 04	16 08	12	17
N50	16 07	16 10	16 13	16 17	16 21	16 25
45	27	30	33	36	40	43

Note: Where the precise date and latitude is not listed, then dates and locations may be obtained by interpolation.

Note: These examples calculate the occurrence of sunrise and sunset. If the calculation is required by ATC, in accordance with the definitions used in para 1, then the appropriate adjustment of ± 30 minutes must be made. Applying this factor to the examples shown, gives an end of night time at Cranwell of 0741hrs in Example 1, and a start of night time at Valley of 1654 hrs in Example 2.

Summary

12. In para 1 there are two slightly different definitions of 'night'. The worked examples in this annex show how to calculate the relevant times according to these definitions. Intentionally, the same locations and dates have been used to show that the two methods produce slightly different results. In the case of Cranwell, the twilight method shows that night ceases at 0731 hrs whereas the sunrise

method gives night ending at 0741 hrs. Similarly, for Valley, by twilight calculation, night starts at 1706 hrs, whereas the sunset method gives a result of 1654 hrs. These discrepancies are seasonal, being greatest in June and December (the Summer and Winter Solstices) and least in March and September (the Spring and Autumn Equinoxes).

CHAPTER 30 - AIRWAYS FLYING PROCEDURES

Contents **Page**

Table of Figures

Tables

Introduction

1. The Air Traffic Control (ATC) services and provision of relatively accurate navigation aids have made it possible to sustain the all weather operation of civil and military air traffic. Topics covered by this chapter include the divisions of airspace, the use of radio aids in procedural operations, departures from and arrivals at an airfield, flight in controlled airspace and general considerations when planning an airways flight.

2. This chapter assumes knowledge of the avionics equipment appropriate to aircraft type, knowledge of the appropriate Flight Information Publications (FLIPs), and an ability to fly accurately on instruments. Occasionally, within the chapter, reference is made to authoritative sources where more detailed information may be obtained.

DIVISION OF AIRSPACE

Flight Information Regions

3. The International Civil Aviation Organization (ICAO) has divided the world's airspace into Flight Information Regions (FIRs). An FIR is airspace of defined dimensions, within which flight information and alerting services are provided.

   a. ***Flight Information Service (FIS)***. An FIS supplies advice and information for the safe and efficient conduct of flights.

   b. **Alerting Service**. An alerting service notifies the appropriate organizations regarding aircraft in need of assistance.

4. An FIR often coincides laterally with national boundaries; larger countries may have several FIRs within their national airspace. In a maritime, or mainly maritime region, an FIR may be known as an Oceanic FIR.

5. An FIR extends vertically from ground level to a specified upper limit. Some nations provide an Upper Flight Information Region (UIR) in upper airspace. Each FIR will have an associated Flight Information Centre (FIC) or Area Control Centre (ACC).

UK Flight and Upper Flight Information Regions (FIRs/UIRs)

6. UK airspace, including that over the surrounding waters, is divided into 2 FIRs. Above each of these FIRs is a UIR. These 4 regions are collectively termed the London and Scottish FIRs/UIRs. The airspace boundaries are detailed in RAF Flight Information Publications (FLIPs).

7. The London and Scottish FIRs/UIRs are divided vertically into the following bands:

a. UIR. Upper Airspace (UAS) from FL245 to unlimited.

b. FIR. Lower Airspace (LAS) from surface level to below FL245.

Operational Air Traffic/General Air Traffic

8. **Operational Air Traffic**. Military pilots frequently conduct routine training flights under the control or authority of the military Air Traffic Services (ATS) organization. Such flights are termed operational air traffic (OAT). OAT flights can be conducted in free airspace, along TACAN routes or similar military corridors.

9. **General Air Traffic**. General air traffic (GAT) is the term used for flights that are conducted in accordance with the regulations and procedures for flight promulgated by the State Civil Aviation Authorities and operating under the control or authority of the civil ATS organization. Airways flying will normally be conducted as GAT.

10. **GAT/OAT Mixed**. It is permissible to fly one portion of a route as GAT, and then convert to OAT, or vice versa. In such cases, the Flight Plan (see para 37) must indicate the point of change.

11. There are differences between the ATS rules and procedures applicable to OAT and GAT. However, in principle, a flight may be conducted as OAT or GAT irrespective of whether the aircraft operating authority is civil or military. The decision to fly as OAT or GAT will be made by the pilot according to the availability of ATS and the nature of the flight. A military pilot crossing Controlled Airspace (CAS) in the FIR usually proceeds as OAT. Conversely, a military pilot wishing to make use of the CAS route structure and services must proceed as GAT.

12. Access to CAS by pilots of aircraft operating as OAT is permissible provided that the pilot conforms to the associated regulations and procedures concerning ATC clearance and ATS; such details may be found in RAF FLIPs. Aircraft operating under Airspace Surveillance and Control System (ASACS) control, must conduct their flights in accordance with the rules laid down for access to CAS in the instructions issued by parent HQs.

13. Pilots of military aircraft operating as GAT must conduct their flights in accordance with the ATC rules applicable to the airspace. The rules are described in the UK Aeronautical Information Publication (AIP) and RAF FLIPs. However, there are differences between the rules applying to civil GAT and those applying to military GAT. Military pilots are not subject to the speed limit of 250 kts specified for civil flights below FL100 and the VMC criteria applicable to military aircraft are specified in the MAA RA 2307(1).

The UK National Air Traffic Services

14. In the United Kingdom, the National Air Traffic Services (NATS) has the following responsibilities:

a. To provide air traffic services for the safe and expeditious operation of civil and military aircraft in UK national airspace and in airspace for which the UK holds responsibility under international arrangements.

b. To meet the differing operational requirements for both civil and military interests without according preferential treatment to either.

c. To plan airspace arrangements taking into account the requirements for all user interests.

d. To represent the UK on air navigation services matters at specific international meetings.

Air Routes/Airways

15. Air routes are segments of controlled airspace in the form of corridors, known as 'airways', and in many countries, they have an associated structured communication plan. The rules for the use of air routes in the UK are published in the UKAIP. A summary of the rules can be found in the UK Military Aeronautical Planning Document (MAPD) Volumes 1 and 3.

Classes of Airspace

16. Within an FIR airspace is broadly defined as either CAS or uncontrolled airspace. CAS is a generic term and is used to describe airspace which is 'notified' as such in the UK AIP; within this airspace civil pilots are required to comply with ATC and other regulations forming part of the UK Air Navigation Order (ANO) and Rules of the Air Regulations. In essence CAS comprises different types of control zone and control area to which are assigned one of the ICAO Airspace Classifications A to E; Classes F and G are reserved for 'uncontrolled' airspace. Although a brief summary of the division of airspace is included here, the UK Aeronautical Information Package (UKAIP) (see paragraph 19) is the authoritative document on this subject and should be consulted for further details.

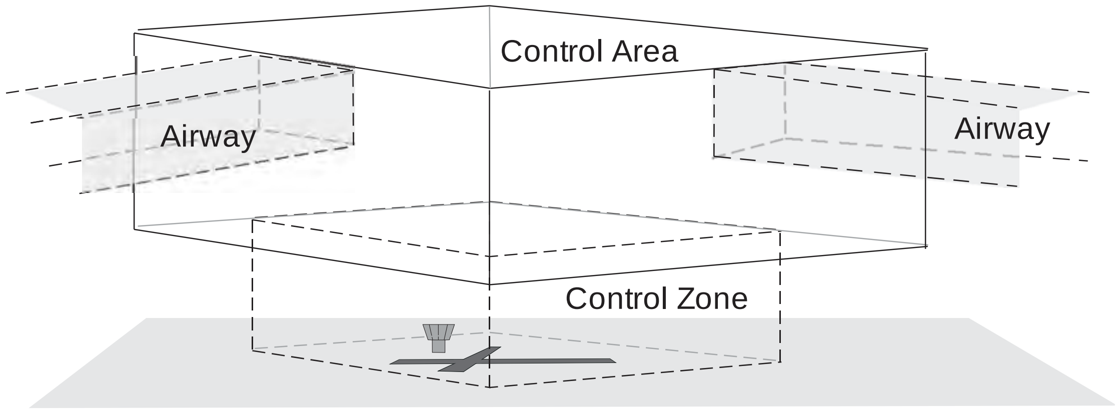
17. **Functional Types of CAS**. CAS is divided into two main functional types; control zones and control areas, but for the purposes of this chapter airways are also considered separately (see Fig 1):

a. **Control Zones (CTZ)**. A Control Zone (generically abbreviated to CTZ but in some cases CTR) is established around an airfield to protect all aircraft flying within it. A CTZ extends vertically from the surface of the earth to a specified upper limit.

b. **Control Areas (CTA)**. A Control Area (CTA) is usually established to cover approaches and departures from a major airport. Many of the control areas over land are classified as terminal control areas (generically abbreviated to TCA or in specific cases TMA). In addition, vast control areas exist over ocean regions. These are called oceanic control areas (OCAs). Control areas extend vertically between promulgated lower and upper limits.

c. **Airways**. An airway is a control area, or portion thereof, established in the form of a corridor equipped with radio navigational aids.

8-30 Fig 1 Illustration of The Relationship between Control Zones, Control Areas and Airways



International Civil Aviation Organization (ICAO)

18. **The International Civil Aviation Organization (ICAO)**. ICAO exists to regulate the purely civilian aspects of international aviation. It promulgates standards and recommended practices which member states agree to observe whenever possible. The Ministry of Defence has no direct link with ICAO but by policy it conforms to ICAO standards and practices provided that they do not conflict with military requirements. Amongst the tasks of ICAO is airspace classification which UK military aircraft recognise.

ICAO Airspace Classifications

19. **Airspace Classification**. Most countries, including the UK, have adopted the ICAO classification system by which airspace is divided into 7 classes (A to G). Of these, classes A to E are controlled airspace, whilst classes F and G are uncontrolled airspace. The ICAO airspace classification scheme is explained in the UK Aeronautical Information Package (UKAIP) which is available via the Civil Aviation Authority (CAA) website; http://www.caa.co.uk/homepage.aspx?catid=3 (www) and also on the AIDU milFLIP site. The classes of airspace are briefly described below but readers should note that **the UKAIP is the authoritative document and should be consulted for the most up to date information and promulgated changes**.

Controlled Airspace – ICAO Definition

Controlled Airspace is defined as airspace of defined dimensions within which air traffic control service is provided to IFR flights and to VFR flights in accordance with the airspace classification. Under ICAO, controlled airspace is defined as:

a. Class A. IFR flights only are permitted. All flights are provided with air traffic control service and are separated from each other.

b. Class B. IFR and VFR flights are permitted. All flights are provided with air traffic control service and are separated from each other. This class of airspace is not designated in the UK.

c. Class C. IFR and VFR flights are permitted, all flights are provided with air traffic control service and IFR flights are separated from other IFR flights and from VFR flights. VFR flights are separated from IFR flights and receive traffic information in respect of other VFR flights.

d. Class D. IFR and VFR flights are permitted and all flights are provided with air traffic control service, IFR flights are separated from other IFR flights and receive traffic information in respect of VFR flights, VFR flights receive traffic information in respect of all other flights.

e. Class E. IFR and VFR flights are permitted. IFR flights are provided with air traffic control service and are separated from other IFR flights. All flights receive traffic information as far as is practical. Class E shall not be used for control zones.

Uncontrolled Airspace- ICAO Definition

Generally under ICAO, uncontrolled airspace is as follows:

a. Class F. IFR and VFR flights are permitted, all participating IFR flights receive an air traffic advisory service and all flights receive flight information service if requested. This class of airspace is not designated in the UK.

b. Class G. IFR and VFR flights are permitted and receive flight information service if requested.

Airspace over the UK

20. The structure of the airspace over the UK and surrounding waters, which is subdivided into the seven various ICAO classes, is described in the UKAIP. The following paragraphs contain extracts from the UK AIP and briefly describe the UK airspace structure. Table 1 gives an overview of the different classes of airspace in the UK with more detail being given in subsequent paragraphs. It will be seen from Table 1 that Classes B and F are not currently designated in UK airspace but Tables 3 and 7 are included as users may encounter B and F airspace when flying in other parts of the world.

Table 1 An Overview of UK Airspace Classes

<table>
<tr><th>Class</th><th>Type of Flight</th><th>Separation</th><th>Service Provided</th><th>Radio</th><th>ATC Clearance</th></tr>
<tr><td rowspan="2">A</td><td>IFR</td><td>All IFR by ATC</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td>VFR</td><td colspan="4">VFR flight not permitted</td></tr>
<tr><td>B</td><td colspan="5">This class of airspace is not designated in UK airspace</td></tr>
<tr><td rowspan="2">C</td><td>IFR</td><td>All IFR by ATC</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td>VFR</td><td>VFR from IFR by ATC
Traffic Info on other VFR</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">D</td><td>IFR</td><td>All IFR by ATC
Traffic info VFR flights and traffic avoidance on request</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td>VFR</td><td>Nil
Traffic info VFR and IFR flights and traffic avoidance on request</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">E</td><td>IFR</td><td>All flights by ATC
Traffic info on VFR flights as far as practicable</td><td>ATC</td><td>Yes</td><td>Yes</td></tr>
<tr><td>VFR</td><td>Nil
Traffic info as far as practicable</td><td>Traffic info as far as practicable</td><td>Nil
Pilots advised to contact ATC</td><td>No</td></tr>
<tr><td>F</td><td colspan="5">This class of airspace is not designated in UK airspace</td></tr>
<tr><td rowspan="2">G</td><td>IFR</td><td rowspan="2">ATC separation not provided
Traffic advice on acft under Procedural of Deconfliction services</td><td>UK FIS</td><td>No</td><td>No</td></tr>
<tr><td>VFR</td><td>UK FIS</td><td>No</td><td>No</td></tr>
</table>

UK Controlled Airspace (ICAO Classes A to E)

21. **Class A**. The UK airspace designated as Class A is detailed in the UKAIP, ENR 1.4 ATS Airspace Classification section. Class A airspace comprises all Control Areas (Airways) below FL195 with some exceptions listed in the UKAIP, some areas of the Channel Islands TCA and the following Control Areas: Clacton, Cotswold, Daventry, London TCA, Manchester TCA, Portsmouth, Worthing (all below FL 195), the Shanwick Oceanic Control Area and the North Sea Control Area (CTA2 and CTA3 – FL 175 to FL 195). Consult the UKAIP for full details and updates to the above.

Table 2 Class A Controlled Airspace ATC Services Description (ICAO)

	IFR	VFR
Service	Air Traffic Control service	VFR flight not permitted
Separation	Separation provided between all IFR flights by ATC	
ATC Rules	Flight Plan required. ATC Clearance required. Radio Comms required. ATC instructions mandatory.	
VMC Minima	At or above FL 100 (see below) Below FL 100 (see below and note 1)	
Speed Limitation	As published or ATC instruction.	

(1) VMC minima in Class A airspace for; climbs and descents maintaining VMC, powered aircraft crossing Airways or other penetration of Airways are:

	Flight visibility	**Horizontal** (distance from cloud)	**Vertical**
At or above FL 100	8 km	1500 m	1000 ft
Below FL 100	5 km	1500 m	1000 ft

22. **Class B**. No UK airspace is currently designated as Class B.

Table 3 Class B Controlled Airspace ATC Services Description (ICAO)

	IFR	VFR
Service	Air Traffic Control service.	
Separation	Separation provided between all flights by ATC	
ATC Rules	Flight Plan required. ATC Clearance required. Radio Comms required. ATC instructions mandatory.	
VMC Minima	Not applicable	At or above FL 100 8 km flight visibility and clear of cloud. Below FL 100 5 km flight visibility and clear of cloud.
Speed Limitation	As published or ATC instruction.	

23. **Class C**. Within the London and Scottish FIR/UIRs, Class C airspace extends from FL195 to FL660 which includes the Hebrides Upper Control Area (HUTA) and a network of domestic and international routes for use by GAT. See the UKAIP ATS Airspace Classification section for full details of airspace designated as Class C.

Table 4 Class C Controlled Airspace ATC Services Description (ICAO)

	IFR	VFR
Service	Air Traffic Control service.	
Separation	Separation provided from IFR flights by ATC.	Separation provided from IFR flights by ATC. Traffic information provided from other VFR flights and traffic avoidance on request.
ATC Rules	Flight Plan required. ATC Clearance required. Radio Comms required. ATC instructions mandatory.	
VMC Minima	Not applicable	At or above FL 100: 8 km viz; 1500 m horizontal and 1000 ft vertical from cloud. Below FL 100: 5 km viz; 1500 m horizontal and 1000 ft vertical from cloud.
Speed Limitation	As published or ATC instruction.	Below FL 100: 250 kt IAS **OR** As published or ATC instruction.

24. **Class D**. Class D CAS comprises CTAs and/or CTRs surrounding notified aerodromes, including some military aerodromes, together with part of the Scottish TMA and sections of some airways. See the UKAIP ATS Airspace Classification section for full details of airspace designated as Class D and rules to be followed when flying in Class D airspace.

Table 5 Class D Controlled Airspace ATC Services Description (ICAO)

	IFR	**VFR**
Service	Air Traffic Control service.	
Separation	Separation provided between all IFR flights by ATC. Traffic Information provided on VFR flights and traffic avoidance advice on request.	ATC separation not provided. Traffic information provided on IFR and other VFR flights; traffic avoidance advice on request..
ATC Rules	Flight Plan required. ATC Clearance required. Radio Comms required. ATC instructions mandatory.	
VMC Minima	Not applicable	At or above FL 100: 8 km viz; 1500 m horizontal and 1000 ft vertical from cloud. Below FL 100: 5 km viz; 1500 m horizontal and 1000 ft vertical from cloud.
Speed Limitation	Below FL 100: 250 kt IAS **OR** As published or ATC instruction.	

25. **Class E**. Class E CAS comprises the parts of the Scottish TMA below 6000 ft and parts of some airways. See the UKAIP ATS Airspace Classification section for full details of airspace designated as Class E.

Table 6 Class E Controlled Airspace ATC Services Description (ICAO)

	IFR	VFR
Service	Air Traffic Control service.	Traffic information as far as practicable.
Separation	Separation provided between all flights by ATC. Traffic Information provided on VFR flights as far as practicable.	Separation not provided. Traffic information provided as far as is practicable.
ATC Rules	Flight Plan required. ATC Clearance required. Radio Comms required. ATC instructions mandatory.	None. However, pilots are encouraged to contact ATC and comply with instructions.
VMC Minima	Not applicable	At or above FL 100: 8 km viz; 1500 m horizontal and 1000 ft vertical from cloud. Below FL 100: 5 km viz; 1500 m horizontal and 1000 ft vertical from cloud.
Speed Limitation	Below FL 100: 250 kt IAS **OR** As published or ATC instruction.	

Advisory Airspace (ICAO Classes F and G)

26. **Class F**. No UK airspace is currently designated as Class F.

Table 7 Class F Advisory Airspace (ICAO)

	IFR	**VFR**
Service	Air Traffic Advisory Service	UK Flight Information Services as required (Basic Service, Traffic Service).
VMC Minima	Not applicable	At or above FL 100: 8 km viz; 1500 m horizontal and 1000 ft vertical from cloud. Below FL 100: 5 km viz; 1500 m horizontal and 1000 ft vertical from cloud. **OR**: At or below 3000 ft amsl: **Aircraft**: 5 km viz and clear of cloud in sight of the surface. **Aircraft**: **140 KIAS or less**; 1500 m viz and clear of cloud in sight of the surface. **Helicopters**: At a speed which, having regard to the visibility, is reasonable: At least 1500 m viz, clear of cloud and in sight of the surface.
Speed Limitation	Below FL 100: 250 kt IAS **OR** As published or ATC instruction.	

27. **Class G**. All UK airspace, including that above FL 660, not included in Classes A to F is designated Class G airspace.

Table 8 Class G Airspace (ICAO)

	IFR	VFR
Service	UK Flight Information Services as required (Basic Service, Traffic Service, Deconfliction Service or Procedural Service).	
Separation	ATC separation cannot be provided. Deconfliction advice is provided under a Procedural or Deconfliction Service which aims to achieve planned deconfliction minima.	
ATC Rules	Instructions issued by Controllers to Pilots are not mandatory, however services rely on pilot compliance.	
VMC Minima	Not applicable	At or above FL 100: 8 km viz; 1500 m horizontal and 1000 ft vertical from cloud. Below FL 100: 5 km viz; 1500 m horizontal and 1000 ft vertical from cloud. **OR**: At or below 3000 ft amsl: **Aircraft**: 5 km viz and clear of cloud in sight of the surface. **Aircraft**: **140 KIAS or less**; 1500 m flight visibility and clear of cloud in sight of the surface. **Helicopters**: At a speed which, having regard to the visibility, is reasonable: At least 1500 m flight visibility and clear of cloud in sight of the surface.
Speed Limitation	Below FL 100: 250 kt IAS **OR** As published or ATC instruction.	

28. **ATC Services**. Aircraft flying airways will normally receive one of two types of control:

a. Radar Control where radar surveillance is available.

b. Procedural Control where there is insufficient radar cover. Safe separation is maintained by use of position reports.

29. **Formations of Aircraft**. Procedures for operating formations of aircraft within CAS are set out in the MAA RAs 2307(1) and 3234 and also in the UK Military Aeronautical Information Publication (Mil AIP). Normally, aircraft are treated as one unit, so long as elements are contained within one nm laterally and longitudinally, and are at the same level or altitude. Formations should be in order and at the cleared level before entering CAS. In the event of a loss of formation integrity, a clear, unambiguous statement of the situation is to be made to inform ATC.

PREFLIGHT PLANNING

General Study

30. Details of ICAO and national procedures appear in the UK Military AIP and the UK Civilian AIP (see Volume 9, Chapter 13). Information on the associated nav/comms equipments - VOR, ILS, DME, GPS, ADF, transponders and VHF/UHF communications is in Volume 7.

31. The No 1 Aeronautical Information Documents Unit (AIDU) (RAF) Terminal Charts Specification & Legend contains important information including holding procedures, decodes for symbology and a list of abbreviations.

32. **Preferred Routes and Standard Routeing Scheme**. FLIPs and the UKAIP list some 'preferred routes' which ATC require aircraft to use when travelling through busy TCA, or between certain points. Preferred routes usually present efficient transit, but are not always the shortest. However, requesting to fly these routes will usually reduce ATC clearance times. In the upper airspace, the Route Availability Document (contained within the En-Route Bulletin) offers a similar facility. If there is a route available, that meets your requirements, it should be used and followed to the exit point.

33. **Use of Magnetic Datum**. Airway centrelines and tracks depicted on arrival and departure procedures are based on the magnetic datum. In addition, headings given by ATC will be magnetic.

34. **Flight Planning**. Planning for airways and overseas flights must be comprehensive.

Instrument Flight Rules

35. Instrument Flight Rules (IFR) are a set of rules governing the conduct of flight under instrument meteorological conditions, although they might be applied under visual meteorological conditions. IFR are set out in the MAA RA 2307(1) and the UK Mil AIP.

36. Aircraft flying within CAS are normally expected to fly under IFR irrespective of the actual meteorological conditions. In some classes of airspace (usually airways and OCAs), IFR is mandatory at all times.

37. The following conditions are to be complied with when the flight is proceeding inside CAS as GAT:

a. A Flight Plan (Form CA48/RAF Form 2919) must be submitted to the appropriate Air Traffic Control Centre (ATCC).

b. Clearance for the flight must be obtained from the appropriate ATCC.

c. A pilot must have a valid instrument rating.

d. The aircraft must carry appropriate radio equipment operating on the notified radio frequencies.

e. The aircraft must carry radio-navigation equipment as specified in FLIPs.

f. The flight must be conducted in accordance with the ATC clearance and instructions received.

Area Navigation (RNAV)

38. Historically, airway routes have been structured around navigation aids to enable aircraft fitted with simple displays to fly direct from one beacon to another. However, use of narrow airway corridors can lead to aerial congestion and delays. The advent of Flight Management Systems (FMS) has enabled aircraft to route direct from point to point (based on latitude and longitude waypoints) under ATC clearance, thus avoiding airways. Area Navigation (RNAV) is the term given to this navigational method, permitting aircraft to operate on any desired flight path, within coverage of ground-based navigation aids or using self-contained navigation aids, or combination of both.

39. **Required Navigation Performance**. ICAO has developed the concept of Required Navigation Performance (RNP) as part of the methods of reducing horizontal separation between aircraft. To be permitted to fly RNAV, an aircraft must have a navigation system meeting a specified RNP. In the European region, Basic Area Navigation (BRNAV) specifies a RNP of $\pm$ 5 nm on 95% of occasions (also referred to as RNP5) and Precise Area Navigation (PRNAV) specifies an RNP of $\pm$ 1 nm on 95% of occasions (RNP1).

40. **RNAV Certification**. In addition to RNP standards, there is a list of minimum equipment and essential functions that form part of the RNAV certification process. In simple terms, the aircraft must have automatic position determination from one or more navigations systems (VOR/DME, INS, GPS etc) and, additionally, the equipment must have specified displays, including indications of position relative to track, bearing and distance to the active waypoint, display of groundspeed or time to the active waypoint, and failure indications.

41. **RNAV in European Civil Air Conference (ECAC) Airspace**. The minimum RNP required to fly RNAV in ECAC airspace above FL 95 is presently BRNAV. There will be a progressive mandate for aircraft to carry instrumentation meeting BRNAV criteria as RNAV procedures spread into TCA/TMAs and other areas of the lower airspace.

42. **RNAV Routes**. An RNAV route is an airway defined by latitude and longitude co-ordinates (WGS 84 datum) and which does not necessarily coincide with radio navigation aids. If the aircraft is RNAV capable, crews should plan to fly on RNAV routes. When flying RNAV, aircrew should anticipate possible re-routeing by ATC.

Minimum Navigation and Communications Equipment

43. The national requirements for minimum navigation and communications equipment are listed in the UK MAPD Vol 3, International Planning, Section 2-2. Aircraft that cannot comply with the required minimum must obtain suitable exemption prior to flight.

44. In the UK FIR (except when overruled by the RNAV requirement for RNP5), for flight under IFR within CAS, the minimum combination of radio and navigation equipment is:

a. VHF radio.

b. VOR Receiver, DME and ADF.

c. For landing at certain aerodromes within Control Zones, ILS.

Reduced Vertical Separation Minima

45. Reduced Vertical Separation Minima (RVSM) has been introduced to some CAS in order to increase capacity of traffic by utilizing intermediate Flight Levels previously avoided. As the name implies, a reduced vertical separation is employed between aircraft. This change in procedures has been made possible due to improved accuracy in modern altimeter systems. In order to fly in RVSM airspace, the aircraft must have been awarded the status of 'RVSM compliant' (ie it meets specific requirements for altimeter equipment, engineering practices and crew training), or have been granted exemption from RVSM rules.

Fuel Planning

46. Fuel planning procedures are covered in Volume 9, Chapter 15. When planning to land at civilian airfields, there is a requirement that the captain satisfies himself before take-off that there is sufficient fuel for the intended flight plus a safe margin to allow for contingencies.

47. **Holding Fuel**. Aircrew should plan a reserve of fuel to permit a period of holding time at civilian airfield destinations. Minimum hold times are specified by operating authorities (usually in the order of 30 minutes).

48. **Contingency Fuel**. When route planning for long distances (and overseas) it is advisable to include a small amount of extra fuel (e.g. 5%) to cover slight deviations along route. Contingency fuel may be mandated by operating authorities.

49. **Hold-off/Island Holding Fuel**. Some destinations do not have a diversion airfield nearby (e.g. on remote islands). In such circumstances, it is necessary for the aircraft to carry a reserve of fuel to allow for a period of holding-off, which may be needed to provide an opportunity to land after any inclement weather has moved away. The minimum hold-off time will be specified by operating authorities, and may be in the order of 1 or 2 hours.

Communications Failure

50. Communications failure procedures are covered in Volume 8, Chapter 8.

51. Aircrew should study the UK MAPD Vol 3 International Planning, and the Radio Communication Failure - National Procedures handbook to identify procedures specific to areas of operation. In many countries the ICAO procedures will apply, however careful study is still necessary, in order to understand the requirements at different stages of flight.

DEPARTURE PROCEDURES AND TECHNIQUES

Pre-flight Equipment Checks

52. It is normal practice to check flight instruments and nav/comms equipment before take-off in accordance with the relevant Aircrew Manual.

53. **Pre-take-off Selection of Aids**. The appropriate communication and navigation aid frequencies should be selected before or at the holding point. Setting-up will vary with particular ATC procedural requirements or operating authority SOPs. In training, the first en-route VOR is normally selected on NAV 1 and a suitable recovery aid for the departure airfield (e.g. ILS) on NAV 2 (where fitted).

Clearance to Fly Within Controlled Airspace

54. A flight plan must be filed for any flight in CAS, and a clearance must be obtained before joining. ATC clearance for GAT flights in CAS can be given only by the ATC authority operating the relevant CAS.

a. **Pre-flight Clearance**. When the point of entry to CAS is within 10 minutes flying time from the aerodrome of departure, pre-flight clearance should be requested.

b. **In-flight Clearance**. When the point of entry is more than 10 minutes flying time from the aerodrome of departure, in-flight clearance should be requested by the pilot either direct from the controlling authority of the airspace on the appropriate RT frequency or through another air traffic service agency, e.g. ATCC or ATCRU.

Note: During the issue of any pre-flight Clearance, the phrases 'Take off' or 'After Take-off' should not to be used. The Phrase 'After Departure' may be used but the aircraft is not to proceed beyond the Holding Position until ATC has issued the clearance to 'Line up' or 'Take off' as a separate message.

Pre-flight Clearance

55. A pre-flight clearance is passed by RT; at large airfields a dedicated frequency (eg 'Clearance Delivery') may be set aside for this purpose, otherwise the ground control frequency may be used. The tower frequency is only used at airfields where clearance requests are few.

56. The clearance contains the following information in this order:

a. Aircraft callsign.

b. Clearance limit, ie the destination or some specified point en route.

c. Route and flight levels allocated, ie those available and not necessarily those requested on a flight plan or other flight notification.

d. Any further information ie departure instructions, RT frequencies, transponder setting or expiry time of clearance.

57. The clearance must be logged and read back to ATC with the essential items verbatim. Shorthand notes, confirming or amending the pilot's copy of the F2919/CA 48, provide a practical means of checking off the clearance as it is received.

In-flight Clearance

58. Where the departure airfield is more than 10 minutes flying time from the entry point, clearance should be requested in the air. The departure instructions will include any pertinent flight limitations, transponder setting and the frequency on which to contact the airways controller. The initial call to the airways controller should request entry at the chosen point, for example "London Control, ASCOT 3456 request joining clearance ___ (airway) at ___ (position)." ATC may request further flight details including position and heading, level and flight conditions, and estimated time of arrival (ETA) at entry point.

Standard Instrument Departures

59. Some airfields publish outbound routeings from each runway; these provide obstacle clearance, help to optimize the flow of air traffic and keep RT to a minimum. These routeings are known as standard instrument departures (SIDs). A SID is an approved procedure for departing safely from a runway and climbing into the en route or airways structure.

65. As it is possible to be allocated one of a number of SIDs when leaving an airfield on a particular route, it is essential to study all possible relevant SIDs before flight.

66. **Joining Airways**. A SID terminates with the aircraft established in the required airway. Where a SID is not available, crews must plan an alternative joining procedure. This will normally be at a reporting point or beacon, approaching through the minimum amount of CAS (normally at 90º to the airway to be joined). Aircraft must remain clear of CAS until clearance has been received, and the pilot should ensure that the first cleared Flight Level has been attained before entering the airway. The transponder should be set to Mode C well before the entry point. Approximately 2 minutes before the entry point the navigation aids should be set up for the first leg. At the joining point the aircraft should be turned onto the required heading, the time should be checked and, if required, the controller should be advised.

Noise Abatement Procedures

67. Many airfields are situated in sensitive areas where it is essential to keep aircraft noise to a minimum. Noise abatement procedures, designed for this purpose, are published within the SID or in separate Special Procedures for the airfield concerned.

Airborne Submission of Flight Plans

68. It is permitted to file a flight plan whilst airborne. This procedure might be used, for example, when an aircraft has departed VFR, but finds deteriorating weather, and chooses to enter CAS. In such event, the Captain should contact the appropriate civil ATS unit on the Flight Information Service (FIS) frequency, or military ATCRU on the Initial Contact Frequency (ICF); the message starts with the words "I wish to file an airborne flight plan". Aircrew should anticipate re-allocation to a 'quiet' frequency, and be ready to transmit the remainder of the flight plan request details in an expeditious manner. At least 10 minutes prior warning of entry to CAS must be given.

EN ROUTE PROCEDURES AND TECHNIQUES

Airways Procedures

69. Airways are normally 10 nm wide; upper ATS routes and advisory air routes have no width but are usually deemed to be 10 nm wide. Centreline datums are magnetic and usually delineated either by VOR radials, NDB bearings or marker beacons. The lower limit of an airway may be either an altitude or a flight level. In the UK airspace, the upper limit of an airway is normally FL 245 with upper ATS routes continuing to FL 460. Except for RNAV routes a radio navigation aid is normally located where there is a change in direction. DMEs are frequently collocated with (or in close proximity to) VORs; significant points are occasionally indicated by 'fan markers' (see para 84), but their use is becoming less common.

70. **Flight Management Systems**. Most aircraft now have a flight management system (FMS), which can hold a library of waypoints to facilitate route flying. Retrieval of waypoints from the database should be carried out with care, watching for ambiguity and cross-checking bearings by dead reckoning.

71. **Position Reporting**. It is essential that the controlling authority is constantly aware of the positions and flight levels of all aircraft using an airway. Historically, this has been achieved by aircraft passing 'position reports' over the radio to ATC (a system still employed when using Procedural

Control). The use of radar and transponders for identification of position, and Mode C for flight levels, reduces the need for position reports (AIPs state national requirements). Within most controlled airspace in Europe and North America, the controller will place the aircraft under radar control and, after giving initial clearances, only call the aircraft with changing information, e.g. frequency changes or new flight level etc. Aircrew should anticipate making a position report to the controller at designated compulsory reporting points (marked by a solid triangle on en route charts), the remainder being on request (marked by a hollow triangle). A position report is also required when being handed from one controlling authority to another. A radio flight log (such as RAF Form 441H) should be used for flight planning and recording RT messages and position reports.

72. **Format**. The format of the position report is:

a. The aircraft identification.

b. The aircraft position.

c. The time of the position (Note 1).

d. The altitude or flight level (Note 2).

e. The next position and its estimate (Note 2).

f. The following position (Note 2).

Note 1: The time should be passed in minutes unless this would result in ambiguity when hours and minutes Co-ordinated Universal Time (UTC) should be used.

Note 2: Subject to national requirements, elements e and f may be omitted. Element d may also be omitted if SSR Mode C is continuously available.

73. **Other Reporting**. There are other occasions when, in addition to routine position reports, the aircraft may be required to confirm or report position, altitude or FL. These include:

a. **Change in Flight Level**. A request for change in flight level should include the aircraft identification, the new level requested and the revised estimate at the next reporting point if applicable. Even where the Flight Plan has pre-notified an intended change of flight level, ATC must give permission before it is actioned.

b. **Change in True Airspeed (TAS)**. ATC should be advised if the average TAS varies by more than $\pm$5% of that notified in the flight plan (F2919/CA 48), or last approved by ATC.

c. **Change in Time Estimates**. ATC should be advised if the ETA at the next notified reporting point or destination changes by more than 3 minutes.

d. **Deviation from Track**. It is sometimes necessary to deviate from track to avoid localized areas of bad weather. The need for such a deviation should be anticipated, and requested from ATC in good time. If such a deviation causes the aircraft to leave controlled airspace, then positive clearance must be obtained to re-enter controlled airspace.

e. **Change in Route**. A request for a change in routeing should be made in the following form:

(1) Aircraft Identification.

(2) Type of flight plan (normally IFR).

(3) Description of new route, including flight levels and speeds commencing from the position/time that the change is requested.

(4) Any other information e.g. new destination and alternate if changed.

f. **Other In-flight Reports**. The following reports should be made without being requested by ATC:

(1) The time and flight level on reaching a holding point or a point to which cleared.

(2) The time when leaving a holding point.

(3) When leaving one flight level on being assigned a different flight level.

(4) On reaching a new assigned flight level.

Note: Holding points will be considered later in this chapter.

Flying Techniques

74. **General Tracking Procedure**. On airways and RNAV routes an aircraft is required to approach and leave designated waypoints on specified radials - a procedure known as tracking. The sequence, to track either in or out, is:

a. Determine position relative to required radial.

b. Fly a heading towards radial (interception).

c. Determine the drift.

d. Fly a heading to maintain radial.

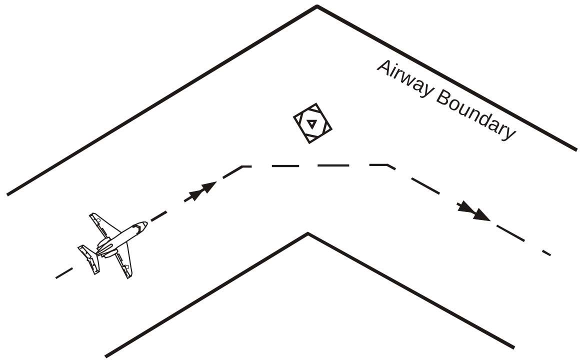
In carrying out the interception, any suitable angle may be used. Normally, it is only necessary to use the 'double track error' method (i.e. calculate the 'track error' between actual bearing and required bearing and double it) to determine the interception angle, up to a maximum of 45º.

75. **Primary Navigation Reference**. Where a radial defines the airway centreline, the primary means of maintaining that centreline is by reference to the VOR or NDB on which the radial is based. In this manner, all aircraft utilize the same navigation reference.

76. **Tracking using a Horizontal Situation Indicator (HSI)**. The centreline of an airway is normally defined by a radial from a beacon. The procedure for tracking down a radial, using an HSI presentation, is explained in Volume 9, Chapter 21.

77. **Turning at a Beacon**. When approaching the overhead of a beacon, the bearing indication may fluctuate. If this occurs, the pilot should concentrate on maintaining a steady heading. Where the route demands a large turn at the beacon, it is accepted practice to anticipate the overhead and cut the corner slightly (see Fig 3). This will prevent a large overshoot towards the edge of the airway.

8-30 Fig 2 Anticipating the Beacon



78. **Tracking Out**. Because an aircraft will normally commence tracking out close to or overhead the waypoint, an interception of up to 30º will be adequate in most cases.

79. **Changes of Level**. Pilots of aircraft commencing a climb or descent in accordance with an ATC clearance should inform the controller if they anticipate that their vertical speed will be less than 500 ft per minute, or if it actually becomes so.

Timing

80. Apart from a GPS or INS fix, there are a number of ways of checking flight progress and amending estimates between waypoints. These include:

a. Dead Reckoning.

b. DME Ranges.

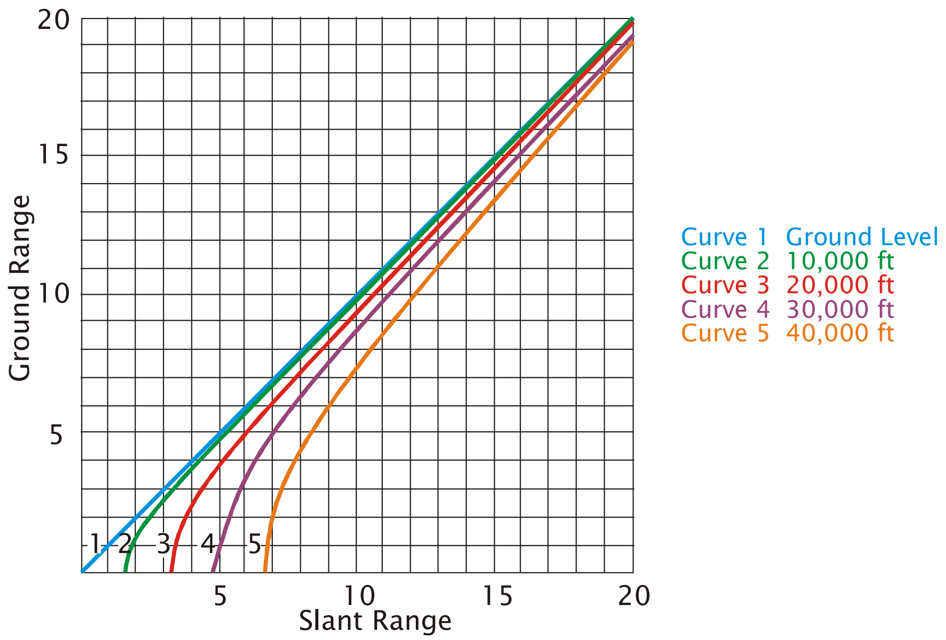
c. Passing abeam other VORs.

d. Marker beacons.

81. **Dead Reckoning**. The basic timing and flight progress is calculated at the flight planning stage. The estimates for significant points are not likely to exceed 3 min in error for short legs. However, minor errors will be proportionally greater on longer legs; e.g. 2 mins late on a 10 min leg - no amendment of estimate necessary, but a 20 min leg (in the same direction at the same groundspeed) would be 4 mins longer, therefore estimate revision would be necessary. The same technique over the flight as a whole may be used to amend the ETA at the destination.

82. **DME**. DME is frequently collocated with VOR, providing a simple means of checking timing. As the equipment indicates slant range, there will be an increasing error between plan and indicated ranges within 20 nm of the overhead; one means of deriving a correction is the graph at Fig 4. Directly overhead a DME, the range will equal the height of the aircraft (e.g. at FL 420 the DME would read approx 7 nm).

8-30 Fig 3 Slant Range Graph



83. **Crossing a VOR Radial**. Where DME is not collocated with VOR at a reporting point, crossing a radial from another VOR at or near a right angle to track can provide an accurate timing check.

84. **Marker Beacons**. Marker beacons give an aural and visual indication of passing a significant point, the accuracy of this indication decreasing with increase in height. Although most marker beacons are associated with ILS, some are situated along airways; these are fan markers and provide range information. Note that the signal strength required to provide an aural indication is less than that needed to operate a light.

Alterations to Cleared Route

85. ATC may sometimes change the clearance of an aircraft en route. This may be an actual re-routeing or simply a radar vector for separation followed by an instruction to resume normal navigation to the original reporting point. It is not unusual to be routed directly to a waypoint or beacon further down the airway. It is good practice to be aware of possible alternative routeings and to have any adjacent charts available. A sound knowledge of the route, through pre-flight planning, will allow a re-route instruction to be executed expeditiously.

86. When a re-routeing is given, the following actions should be carried out before reaching the starting point of the new section:

a. Write down the new clearance. Resolve any ambiguity (e.g. name or identification of a facility) and read the clearance back to ATC.

b. Transfer the route to the en route charts.

c. Enter new waypoints into the FMS.

d. Alter heading after cross-checking FMS with chart and by dead reckoning.

e. Mark appropriate facilities and RT frequencies.

f. Calculate new ETAs and safety altitudes.

Traffic Alert and Collision Avoidance System (TCAS)

87. Aircraft equipped with TCAS may receive warnings that demand action to prevent a potential mid-air collision. Within CAS, the crew should take the following actions:

a. In the event of a Traffic Advisory warning, the crew should commence a visual search for the potential threat. If the threat is not seen, ATC assistance should be requested to decide whether a change of flight path is required. If the threat is seen, and considered to be a collision risk, the pilot should manoeuvre, then resume previously cleared flight path, advising ATC of deviations from clearance.

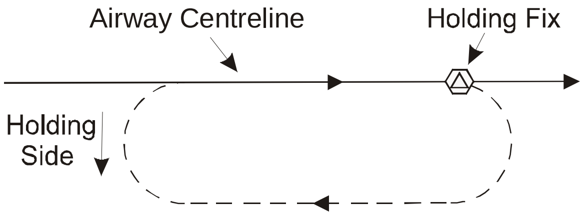
b. In the event of a Resolution Advisory indicating a risk of collision, the required manoeuvre should be initiated immediately, whilst the crew search visually for the threat. Once TCAS indicates that adequate separation has been achieved, or visual/ATC information shows that there is no longer a conflict, the aircraft should be promptly returned to its intended flight path and ATC informed.

88. TCAS operations are described in Volume 7, Chapter 16.

En Route Holding

89. ATC may instruct an aircraft, during transit, to hold at a nominated point (usually overhead a beacon or reporting point). The standard hold in such circumstance will be a right-hand hold, based on the inbound centreline of the airway (Fig 5).

8-30 Fig 4 En Route Holding Pattern (Standard ICAO - Turning Right at the Fix)



90. Wherever possible, 280 kt IAS should be used for holding procedures within airways route structures (see FIH for IAS requirements for holding patterns).

91. If ATC give an onward clearance time (OCT), the crew must adjust the hold pattern to overfly the holding fix at the OCT, before continuing the flight.

PLANNING FOR AIRWAYS FLIGHTS

92. There are many of the considerations which aircrew must take into account when planning an overseas airways flight. The advice given in the following paragraphs does not cover aircraft type-specific aspects and cannot cover all eventualities.

Aeronautical Documentation

93. Aeronautical documents (including the AIP) are described in Volume 9, Chapter 13, and must include the latest amendments. The following are pertinent to overseas and airways planning:

a. Flight Information Handbook (FIH).

b. En Route Supplements (ERS).

c. UK Military Aeronautical Planning Document (MAPD).

d. Terminal charts (TAP, SID and STAR). The Terminal Charts Catalogue lists current availability.

e. No 1 AIDU (RAF) Terminal Charts Specification & Legend.

f. En Route Charts (ERC).

g. Radio Communications Failure - National Procedures.

h. Topographical Charts. The MOD Aero-nautical Chart Catalogue (available in Flight Planning sections) provides information on world coverage of charts and Projected Map Displays.

94. No 1 AIDU maintains a comprehensive library of aeronautical information world-wide, and requests for information may be made direct to that unit.

Overseas Flight Planning

95. **Diplomatic Clearances**. Before a military or state-owned aircraft may fly though the sovereign airspace of another country, permission must be obtained from the government of that country for the

flight to proceed. The procedures for obtaining the Diplomatic Clearance to conduct the flight are contained in AP1158, Approval and Diplomatic Clearance for Flights to Destinations Abroad. It is the responsibility of the aircraft operating authority to obtain Diplomatic Clearance and this is usually done through the Station operations staff.

96. **Flight Notification Signal**. Captains should send a flight notification signal to request diplomatic clearance and give notice of flight details to units and ATC authorities concerned. This signal includes routeing, times and notification of requirements at landing destinations, e.g. fuel uplifts, accommodation needs, customs clearance etc.

97. **National Procedures**. National procedures are listed within the UK MAPD Vol 3, Pt 2 International Planning Information, Section 2-2.

Flight Preparation

98. **Destination**. Captains should check that:

a. Airfield facilities and services are sufficient for operation of aircraft type, e.g. field lengths, fuel etc.

b. Where an airfield operates a ‘prior permission required’ (PPR) system for approval to land, this has been obtained.

99. **Route Planning**. Aircrew should include the following within route planning:

a. If the flight is to be GAT, select suitable airways and/or RNAV routes (consult ATC preferred routes and Route Availability Document). For OAT flight, select TACAN or other military routes.

b. From the MAPD, determine national requirements for each country to be over flown, in respect of division of airspace, vertical separation, minimum navigation and communication equipment, Flight Plan requirements, ATC procedures and any supplementary route information.

c. Choose suitable SID and STAR procedures.

d. Select suitable Flight Levels by determining upper and lower limits of airways to be used and considering flight profile required.

e. Select suitable diversion (alternate) airfields for use en route and at destinations.

f. Prepare a radio log listing radio frequencies for airways control, ATCC sectors, airfield approach, weather broadcasts and emergency assistance.

g. Study taxi patterns at destinations. At airfields operating to all-weather standards, there may be distinct holding points for Cat 1 and Cat 2/3 operations. These holding points are marked on Aerodrome Charts.

h. Select suitable navigation aids.

i. Study airways structure adjacent to route, in anticipation of possible ATC re-routeings.

j. From topographical charts, identify suitable radar check points and features to assist with visual identification of destination and diversion airfields.

k. Prepare a communications failure plan covering all stages of flight from airborne to landing.

l. Identify altimeter setting regions and calculate safety altitudes.

m. Check route and forecast meteorology for any Aircraft Scheduled Performance restrictions, including terrain clearance in event of single-engine failure.

CHAPTER 31 – AIRFIELD DEPARTURE, ARRIVAL AND APPROACH PROCEDURES

Contents **Page**

Table of Figures

Tables

Introduction

1. Instrument procedures and standards have been developed to ensure the highest possible level of safety in flight operations. The main reference document for this annex is No 1 AIDU Terminal Charts, Specification and Legend which is available on the AIDU MilFlip web site. Other reference documents are detailed in paras 2, 4a, 4b, 6a and 6b. The latest editions of these reference documents are authoritative over the content of this annex.

Terminal Chart Standards

2. There are several design standards for Terminal Charts. The main standards that will affect UK aircrew are the ICAO Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS) and NATO Military Instrument Procedures and Standards (MIPS). NATO has expressed the aim to move towards ICAO standards for military flight operations, but ICAO PANS-OPS are not particularly adapted to the unique manoeuvring capability that many military aircraft have. As a result MIPS have been developed. The USA produces the United States Standard for Terminal Instrument Procedures (TERPS). Procedures are also produced under EU-OPS and are issued through the European Aviation Safety Agency (EASA). Individual nations may issue their own standards but where there are differences from PANS-OPS, nations are required by ICAO to publish the details.

3. Although there are several agencies producing instrument procedures, it must be understood that they are primarily designed to provide protection from obstacles by creating protected airspace around the aircraft track. Whichever standards are applied to the design of an instrument procedure, it is important that the procedure is flown as it is depicted on the appropriate chart to ensure that the aircraft does not exceed the boundaries of the protected airspace.

Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS)

4. **Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS)**. Instrument approach procedures for NATO military airfields were designed in accordance with Allied Publications Air Traffic Control (APATC) criteria. NATO nations have now adopted ICAO criteria for procedure design. These ICAO standards are published in two documents, Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS), volumes 1 and 2.

a. **PANS-OPS Vol 1, Flight Procedures**. Volume 1 is intended to provide aircrew with an insight into how instrument procedures are designed and how to adhere to them in flight.

b. **PANS-OPS Vol 2, Construction of Visual and Instrument Flight Procedures**. Volume 2 defines the criteria by which procedures are constructed.

5. **Exceptions to PANS-OPS**. None of the criteria set out in PANS-OPS are binding on an ICAO member but exceptions are published in national AIPs.

Military Instrument Procedures and Standards (MIPS)

6. **Military Instrument Procedures and Standards (MIPS)**. PANS-OPS do not cover all military flying, e.g. TACAN and High Performance Military Aircraft (HPMA) procedures are not catered for. As a result, additional criteria have been designed to meet NATO requirements which are termed Military Instrument Procedures and Standards (MIPS). As with PANS-OPS, the NATO criteria are not binding on ICAO member nations but they are required to publish exceptions in their national Military

AIP and also in the Allied Air Traffic Control Publication (AATCP-1). MIPS are described in two documents, which should be consulted to determine the differences:

a. **Allied Flight Procedures Publication (AFPP –1 (A))**. AFPP-1(A) is issued by STANAG 7199 and is intended to provide aircrew with an insight into how instrument procedures are designed and how to adhere to them in flight.

b. **Allied Air Traffic Control Publication (AATCP-1)**. AATCP-1 is issued by STANAG 3759 and defines the criteria by which procedures are constructed.

NATO military airfield instrument procedures designed employing either NATO AATCP-1 or ICAO (PANS-OPS) criteria are identified on the procedure charts as MIPS.

7. The procedures in PANS-OPS Vol I and AFPP-1(A) are intended to be strictly adhered to by flight crews in order to achieve and maintain the highest possible level of safety in flight operations. Flight crews will find pertinent and specific information/exceptions in national civil and military AIPs.

US Terminal Instrument Procedures (TERPS)

8. US Terminal Instrument Procedures (TERPS) philosophy for the construction of procedures differs from PANS-OPS in several areas which affect the way procedures are flown; e.g. turn radius, visual manoeuvring, ILS procedures and the missed approach. In PANS-OPS, aircraft category plays a significant role in affecting the final approach minima. Also, angles of bank and maximum speeds by aircraft category for holding, departures and the initial and intermediate segments of instrument approaches may differ from TERPS.

European Aviation Safety Agency (EASA) EU-OPS

9. Within the European Union (EU) only, EU-OPS have been developed based on the now superseded JAR-OPS. EU-OPS are issued through the European Aviation Safety Agency (EASA).

10. Some authorities issue airfield instrument charts based on EU-OPS criteria. These charts are clearly marked as being designed using EU-OPS criteria.

11. Aircraft Categories are based on the aircraft indicated airspeed at the threshold (V_{AT}) and the values reflect those of PANS-OPS.

12. Under EU-OPS an Instrument Approach (IA) may be commenced if the reported RVR/Visibility is less than the specified minima for landing. However, the IA shall not be continued beyond the Outer Marker (OM) or equivalent, or below 1000 ft above the aerodrome is no OM or equivalent exists. If after passing the OM/1000 ft point, the reported RVR/Visibility falls below the specified minimum, the IA may continue to DA/H or MDA/H and a landing completed if the required visual reference is established and maintained. The touchdown zone RVR is always controlling.

13. The No1 AIDU Terminal Charts Specification and Legend has an explanation of how EU-OPS calculates DA/H, RVR and other visibility criteria with regard to aircraft category and the type of approach. Readers should refer to the AIDU document.

Procedure Identification

14. The publisher of a procedure should identify what criteria a procedure is based on. On No1 AIDU charts, the design authority will be identified under the airfield name and also in the minima table. Some nations use special criteria in the design of procedures. Where these differ significantly from PANS-OPS, the procedure should be marked 'NATIONAL'. When planning to fly such procedures, pilots should consult the relevant national regulations.

Non-standard Procedures

15. The standards used to produce instrument charts are designed to ensure that safe flight operations for all users result from their application. There may be instances where non-standard procedures that deviate from these standards may be approved provided they are fully documented and an equivalent level of safety exists. The appropriate national authority is the approving authority for non-standard procedures. Military procedures that deviate from the standards may not achieve an equivalent level of safety. Where this occurs they shall be marked 'MILITARY USE ONLY' and also, when applicable, 'NON-STANDARD'.

General Considerations

16. Instrument procedures assume that all engines are operating. All procedures depict tracks, and pilots should maintain the track by adjusting the aircraft heading to counter wind effects. For all pilots, the adherence to the published speeds for their aircraft is vital to remain within protected airspace. It is particularly important for helicopters to maintain minimum speeds as they may be subject to high drift angles which could cause an excursion from protected airspace. Put simply, protected airspace is defined to ensure that aircraft remain at a safe distance, horizontally and vertically, from obstacles.

17. **Track**. Procedure charts depict the track the aircraft is to follow. The track is the projection on the earth's surface of the path of the aircraft, usually expressed in degrees from North specifying true or magnetic. Wind effects must be applied to the aircraft heading to maintain the track. Obstacle clearance is provided assuming the pilot will maintain the depicted track.

18. **Angle of Bank (AOB)**. Unless otherwise specified, the Angle of Bank (AOB) used for PANS-OPS is as follows:

a. Approach procedures are based on an average achieved AOB of 25º or the AOB giving a rate of turn of 3º/sec, whichever is less.

b. Departure and missed approach procedures are based on an average achieved AOB of 15º. MIPS procedures are generally the same but visual climb over airport (VCOA) departures are based on 23º AOB.

c. The AOB for HPMA is 30º for all segments.

d. TERPS procedures are generally based on an AOB of 25º but there are exceptions with regard to circling AOBs which depend upon aircraft category, see Paragraph 54.

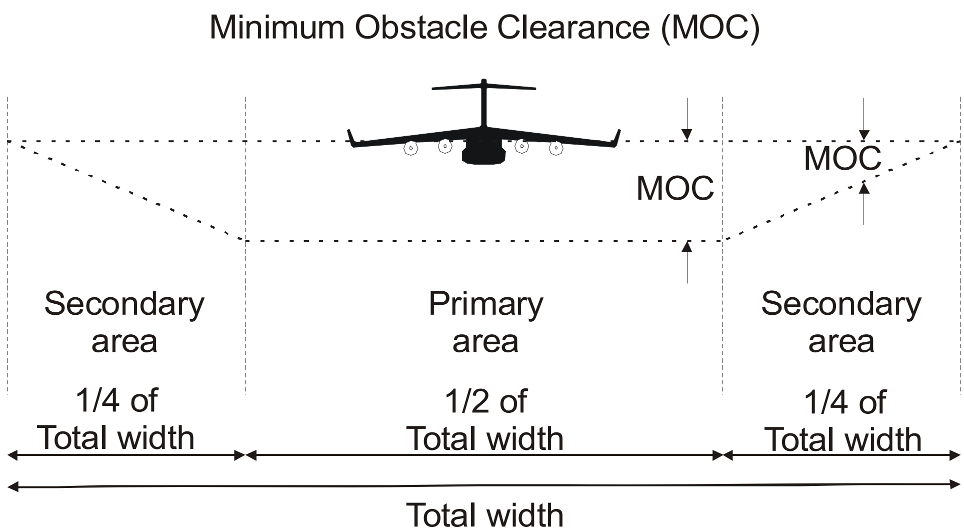
19. **Established on Course**. PANS-OPS defines 'established on course' as being within half full-scale deflection for a VOR/DME or ILS localizer and within ± 5º of the final bearing for an NDB. MIPS apply the same criteria as a VOR/DME for a TACAN procedure. Deviation from these tolerances may reduce the safety margin with regard to obstacle clearance.

20. **Obstacle Clearance**. Obstacle clearance is a primary safety consideration in the development of instrument procedures with defined criteria laid down in PANS-OPS Volume 2. Operationally, the obstacle clearance applied to each procedure is considered the minimum required for an acceptable level of safety. This implies that departing from a procedure will reduce the clearance to an unsafe level.

21. **Protected Airspace**. Where track guidance is provided in a procedure, the volume of protected air around the track is divided symmetrically about the track. The volume of air is divided into Primary and Secondary areas (Fig 1). The Primary area, centred on the track, provides Minimum Obstacle Clearance (MOC) for its whole width. In the Secondary area, which bounds the Primary area on each side, the MOC gradually reduces to zero as the distance from the track increases. The Primary area measures half the total width of the protected area, with one quarter of the protected area forming the Secondary areas either side. The width of the area is determined by the accuracy of the navigational facility that the procedure is based upon and will increase as the distance from the aid increases.

22. **TERPS Protected Airspace**. The protected airspace in TERPS procedures may be determined using different criteria but will follow the general principles of PANS-OPS to provide safe obstacle clearance. TERPS uses the term Required Obstacle Clearance (ROC) vice the PANS-OPS term MOC.

8-31 Fig 1 The Relationship of Minimum Obstacle Clearance in Area Cross Section



23 **Accuracy of Fixes**. Fixes and points used in procedures are normally based upon standard navigation systems. Accuracies will depend upon the tolerances of the ground based system, the airborne receiving system and the flight technical tolerance. The tolerances used in the production of procedure charts are summarized in Table 1.

Table 1 Summary of Fix Tolerances Used in the Production of PANS-OPS Procedure

Navigation Facility	Tolerance	
Terminal Area Surveillance Radar	± 0.8 nm (*1.5 km*)	Within 20 nm (*37 km*)
En-route Surveillance Radar	± 1.7 nm (*3.1 km*)	Within 40 nm (*74 km*)
DME	± 0.25 nm (*0.46 km*)	+ 1.5 % of distance to antenna
Overhead VOR [1]	or d = 0.033 h *d = 0.2 h*	d and h in nm *d and h in km*

[1] Based on a circular cone of ambiguity generated by a straight line passing through the facility and making an angle of 50º from the vertical.

24. **Flight Management Systems (FMS) and Area Navigation Equipment (RNAV)**. FMS and RNAV equipment may be used to fly conventional procedures provided that the procedure is monitored using the basic display normally associated with that procedure and the tolerances for flight using raw data on the basic display are complied with. Lead radials are for use by non-RNAV equipped aircraft and are not intended to restrict the use of turn anticipation by FMS.

Aircraft Categories

25. Aircraft performance has a direct effect on the airspace and visibility required for the various manoeuvres associated with instrument approach procedures and the most important factor is aircraft speed. It should be noted that the speed ranges specified by category may be different to the category speeds of procedures designed under other criteria. PANS-OPS aircraft categories are summarized in Table 2.

Table 2 Aircraft Categories

Aircraft Category	Velocity at Threshold V_{AT} (kt)	Speed Range for Initial Approach (kt)	Speed Range for Final Approach (kt)	Max Speed Circling (kt)	Max Speed for Missed Approach (kt)	
					Intermediate	Final
A	91	90 to 150 (110)*	70 to 100	100	100	110
B	91 to 120	120 to 180 (140)*	85 to 130	135	130	150
C	121 to 140	160 to 240	115 to 160	180	160	240
D	141 to 165	185 to 250	130 to 185	205	185	265
E	166 to 210	185 to 250	155 to 230	240	230	275
H	N/A	70 to 120**	60 to 90***	N/A	90	90
H($P_{IN}S$)	N/A	70 to 120	60 to 90	N/A	70 or 90	70 or 90

* Maximum speed for reversal and racetrack procedures.

** Maximum speed for reversal and racetrack procedures below 6000 ft is 100 kt and above 6000 ft is 110 kt.

*** Helicopter Point in Space ($P_{IN}S$) procedures.

26. The instrument approach chart (IAC) will specify the individual categories of aircraft for which the procedure is approved. Normally, procedures will be designed to provide protected airspace and obstacle clearance for aircraft up to and including category D. Where airspace requirements are critical procedures may be restricted to lower categories.

27. A procedure may specify a maximum IAS for a particular segment without reference to aircraft category. It is essential that pilots adhere to the approved limits to remain safely clear of obstacles.

British Military Aircraft Categories

28. The Manual of Military Air Traffic Management (MMATM) (Chapter 1) categorizes British military aircraft according to the normal approach speed at DH/MDH (DA/MDA) or V_{AT} + 15 kt, where V_{AT} is the target threshold speed. The speeds are the same as in column 2 of Table 2. Helicopters are Cat A. Aircraft captains have discretion to move aircraft into a higher or lower category when circumstances dictate a significantly higher or lower approach speed than normal.

High Performance Military Aircraft (HPMA)

29. **High Performance Military Aircraft (HPMA)**. An additional NATO performance category, HPMA, is designed for aircraft meeting the criteria given below and is identified in the procedure title as HPMA. HPMA shall be capable of flying an instrument procedure within the parameters given in the following sub-paras, while adhering to the segment speeds. Performance criteria may be specified that are higher than those given. Such restrictions will be specified, and it is the responsibility of the pilot in command to ensure that the aircraft can fly the actual procedure.

a. Departure: Minimum climb gradient - 8.75 % (5.0º).

b. Initial Approach Segment: Maximum rate of descent – 1000 ft/nm.

c. Bank Angle: Minimum 30º for all segments to be established within 5 sec.

d. Maximum ac dimensions for ILS – wing span 30 m and glide path antenna to wheel base maximum 6 m.

e. Height loss on precision approach transition to missed approach – Maximum 100 ft.

f. Missed Approach Climb Gradient – 6.0 % (3.43º), with a transition time from level flight to the required climb gradient of maximum 10 sec.

g. Aircraft Category: For aircraft performance requirements, all HPMA are contained within one aircraft category.

30. **HPMA Departures**. The Obstacle Identification Surface (OIS) is a sloping surface of 7.95% used by the procedure designer to identify obstacles in the departure area. The origin for straight departures is 16 ft above the Departure End of the Runway (DER). For unidirectional departures, several OISs are considered. HPMA procedures use a standard 8.75% (5º) Procedure Design Gradient (PDG). The PDG origin is the same as the OIS and if the OIS is penetrated, the PDG will be increased and the higher climb gradient published on the procedure. For low, close in obstacles requiring an increased climb gradient to 200 ft or less above the DER, the obstacle(s) will be identified on the procedure by position and height but no climb gradient will be published.

31. **HPMA Speeds**. When constructing the various procedures for HPMA operations, a range of speeds are used to determine the area of protected airspace. Speeds should be annotated on the appropriate chart and pilots should adhere to these (see also Table 3).

Table 3 HPMA Speeds (IAS) for Procedure Calculations in Knots

Aircraft Category	Range of speeds for holding, initial approach, reversal, racetrack, intermediate segment.	Range of final approach speeds.	Max speed visual manoeuvring (circling)	Max speed missed approach (1)	
				Intermediate	Final
HPMA	250/300	90/185	220	300	350

Note: (1) For missed approach, where operationally required to avoid obstacles, reduced speeds as low as 250 kt may be used, provided the maximum speed is clearly noted on the procedure.

32. **HPMA Missed Approach**. The minimum required missed approach climb gradient is 6% (3.4º). The procedure may specify a missed approach turn (more than 15º) when at least 164 ft obstacle clearance is obtained and can be maintained with a minimum climb gradient.

33. **HPMA Visual Manoeuvring (Circling)**. Visual manoeuvring radii are drawn around the runway threshold(s) and joined by tangents to the arcs. The radii depend upon the airfield elevation (3.55 nm at sea level and 3.65 nm at 1000 ft airfield elevation). The protected area is calculated using a maximum speed of 220 kt IAS an AOB of 30º and a wind of ±25 kt. The following criteria also apply to HPMA circling approaches:

MOC ft (m)	Lower limit for OCH above aerodrome elevation ft (m)	Minimum Visibility nm (km)
300 (90)	550 (165)	1.7 (3.2)

34. **Additional Military Criteria**.Additional military criteria are detailed in AATCP-1 NATO Supplement to ICAO Doc 8168-Ops/611 – Vol 2. Some differences are as follows:

a. **ILS/(M)MLS**. For CAT 1 precision approaches (ILS/(M)MLS), a required missed approach climb gradient in excess of 5% (2.86º) may be published at certain locations. These minima will be marked as 'NON-STANDARD' and will be approved by national authorities.

b. **TACAN Final Approach Track Alignment**. In PANS-OPS straight in approaches the maximum angle between the final approach track and the runway centreline is 30º for CAT A/B aircraft and 15º for other categories. MIPS straight in TACAN procedures may be offset up to 30º for all categories.

c. **TACAN Final Approach Centre Line Intercept Distance**. In PANS-OPS the final track must intercept the runway centre line a minimum of 1400 m before the runway threshold. MIPS straight in TACAN procedures may intercept the runway centre line at the runway threshold.

35. **Safe Altitude (100 nm)**. A Minimum Safe Altitude (MSA) should be established within 100 nm (185 km) radius from the Aerodrome Reference Point (ARP). It will provide at least 984 ft (300 m) of obstacle clearance in non-mountainous areas and 1968 ft (600 m) in mountainous areas. When published, the altitudes will be rounded to the next higher 100 ft or 50 m increments. TERPS MSA provides at least 1000 ft of obstacle clearance for emergency use within a specified distance, usually 25 nm, from the facility on which the procedure is based.

DEPARTURES

General

36. In order to ensure acceptable clearance above obstacles during the departure phase, instrument departure procedures may be published as specific routes to be followed or as omnidirectional departures together with procedure design gradients and details of significant obstacles. Departure procedures are in general dictated by the terrain surrounding the airfield, ATC requirements, the location of navigation aids and airspace restrictions. The procedures assume that pilots will not compensate for wind effects when being radar vectored. Pilots are expected to compensate for known or estimated wind effects when flying departure route which are expressed as tracks to be made good.

Runway End Crossing Height or Screen Height

37. For PANS-OPS and MIPS, the origin of the Obstacle Identification Surface (OIS) begins at 16 ft (5 m) above the Departure End of Runway (DER).

Climb Gradient

38. PANS-OPS obstacle clearance during departures is based on a 2.5% gradient obstacle clearance (152 ft/nm) and an increasing 0.8% obstacle clearance (48 ft/nm), This equates to a minimum climb gradient of 3.3% (200 ft/nm). Minimum climb gradients exceeding 3.3% will be specified to an altitude/height after which 3.3% will be used. Unless the procedure specifies otherwise, aircraft should climb on track until reaching 400 ft above the DER at a minimum rate of climb of 200 ft/nm (3.3%) and then continue to climb at the same gradient until reaching a safe en-route altitude.

Omnidirectional Departures

39. The PANS-OPS Omnidirectional Departure is similar to the TERPS Diverse Departure where track guidance is not provided. An omnidirectional departure may be published even though obstacles penetrate the 2.5% Obstacle Identification Surface (OIS). Where this occurs, departure restrictions will apply as detailed in para 42. Where obstacles do not permit the development of omnidirectional procedures it is necessary to fly a SID or to ensure that the ceiling and visibility permit visual avoidance of obstacles.

40. **Beginning of the Departure**. The departure begins at the DER. As the point of lift off will vary, the procedure assumes that a turn at 394 ft (120 m) above the elevation of the airfield is not initiated sooner than 1968 ft (600 m) from the beginning of the runway. Procedures are normally designed/optimized for turns at a point 1968 ft (600 m) from the beginning of the runway. Any variations will be notified on the chart.

41. **Procedure Design Gradient (PDG)**. Unless otherwise stated, departure procedures assume a 3.3% (helicopters 5%) PDG and a straight climb on the extended runway centreline until reaching 394 ft (120 m) (helicopters 295 ft (90 m)) above the aerodrome elevation. Normally, at least 295 ft (90 m) of obstacle clearance is provided before turns greater than 15º are specified.

42. **Departure Considerations.** Omnidirectional departures are designed with the following considerations:

a. **Standard Case**. Where obstacles penetrate the 2.5% OIS and 295 ft (90 m) of obstacle clearance prevails, a 3.3% climb to 394 ft (120 m) will satisfy obstacle clearance requirements for a turn in any direction

b. **Specified Turn Altitude**. Where obstacles preclude omnidirectional turns at 394 ft (120 m) the procedure will specify a 3.3% climb gradient to an altitude where a safe omnidirectional turn can be made.

c. **Specified Climb Gradient**. The procedure may specify a minimum climb gradient of greater than 3.3% to an altitude before turns are permitted.

d. **Sector Departure.** The procedure may identify sectors for which either a minimum turn altitude or a minimum climb gradient is specified, e.g. 'Climb in sector 180º - 270º to 2000 ft before commencing a turn'.

Standard Instrument Departures

43. PANS-OPS uses the term Standard Instrument Departure (SID) to refer to departures using track guidance. A SID is an approved procedure for departing safely from a runway and climbing into the en route or airways structure. Routeing for a SID will be designed to ensure that major obstructions, prohibited and restricted airspace are avoided. It is a departure procedure that is normally developed to accommodate as many aircraft categories as possible but a SID that is limited to specific aircraft categories will be annotated as such. The SID terminates at the first fix/facility/waypoint of the en-route phase following the departure procedure. All tracks, points, fixes and altitudes/heights required in the SID will be published.

44. **Types of SID**. There are two basic types of SID; Straight and Turning.

a. **Straight Departures**. A departure is considered straight if the track is aligned within 15º of the runway centreline. When obstacles exist which affect the departure route, climb gradients greater than 3.3% may be specified and the altitude/height to which it extends will be given. After that point the climb gradient of 3.3% resumes. Increased gradients to a height of 200 ft (60 m) or less caused by close in obstacles are not specified. Details of any such obstacles will be given.

b. **Turning Departures**. Where the departing route requires a turn of more than 15º, a turning departure may be specified using an average AOB of 15º. Straight flight is assumed until reaching an altitude/height of at least 394 ft (120 m) or 295 ft (90 m) for helicopters. Turns may be specified at an altitude/height, at a fix or overhead a facility. If an obstacle prohibits turns before the DER, or prior to reaching an altitude/height, an earliest turning point or a minimum turn altitude/height will be specified. After a turn, it may be necessary to fly a compass heading/track to intercept a specified radial/bearing and the procedure will specify the turning point, the track to be made good and the radial/bearing to be intercepted.

c. **Turning Departure Speeds**. Turning departures are designed with maximum speeds. If the designed speeds are below the standard maximums, they will be published by aircraft category or by a general note. Crews must comply with the published maximum speed to remain within protected airspace. If higher speeds are required for safe aircraft performance, ATC may approve the higher speed or offer an alternative SID. The maximum turning speeds, by aircraft category, are shown in Table 4 and are those of the final missed approach increased by 10%. Any deviation from the published speeds will be annotated on the departure chart.

Table 4 Turning Departure Maximum Speeds (IAS)

Aeroplane Category	Maximum Speed kt
A	225
B	305
C	490
D	540
E	560
H	165

Visual Climb Over Airport (VCOA)

45. Where an aircraft performance does not meet the specified climb gradient, a Visual Climb Over Airfield (VCOA) procedure may be specified. A Visual Climb Area (VCA) is constructed based on the Aerodrome Reference Point (ARP) as the centre of a circle.

a. An omnidirectional VCOA allows for a turn in any direction once a defined altitude is reached. A visual climb must be performed up to this altitude.

b. Where an omnidirectional VCOA is not feasible, a VCOA departure route, after the initial visual climb, may be constructed.

c. Obstacles inside the VCA are subject to see and avoid manoeuvres.

Obstacle Clearance

46. The MOC at the DER equals zero. From that point it increases by 0.8% of the horizontal distance in the direction of flight assuming a maximum turn of 15º. In the turn initiation area and turn area, a MOC of 295 ft (90 m) is provided. The MOC may be increased in mountainous terrain. Whenever a suitably located DME exists, additional height/distance information intended for obstacle clearance may be given. RNAV waypoint or other suitable fixes may be used to provide a means of monitoring climb performance.

Radar Vectors

47. Pilots should not accept radar vectors during departure unless:

a. They are above the minimum altitude(s)/height(s) required to maintain obstacle clearance in the event of engine failure. This relates to engine failure between V_1 and minimum sector altitude or the end of the contingency procedure as appropriate.

b. The departure route is non-critical with respect to obstacle clearance.

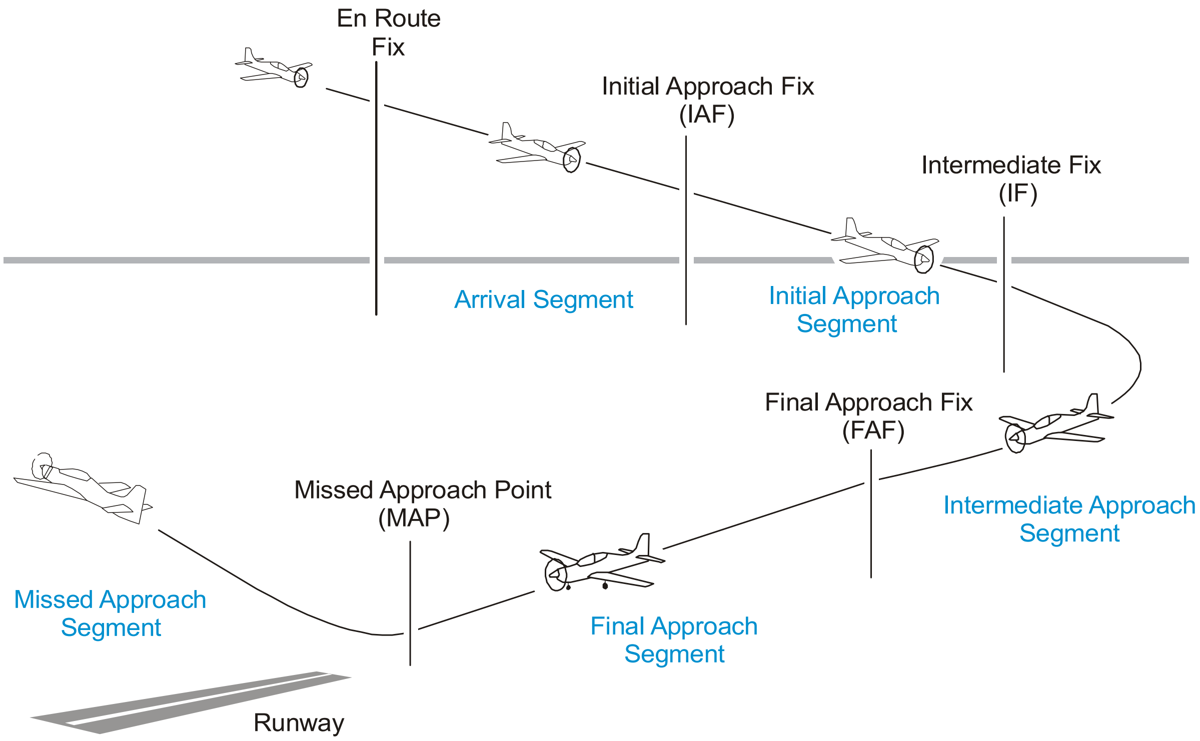
APPROACH AND ARRIVAL PROCEDURES

48. Approach and arrival procedures are in general dictated by the terrain surrounding the airfield, ATC requirements, the location of navigation aids and airspace restrictions. The type of operations contemplated and the aircraft to be accommodated will also be factors in the design of the procedures.

49. The procedures assume that pilots will not compensate for wind effects when being radar vectored. Pilots are expected to compensate for known or estimated wind effects when flying approach routes which are expressed as tracks to be made good.

50. An instrument approach may have five separate segments, arrival, initial, intermediate, final and missed approach (Fig 2). In addition, an area for circling the airfield under visual conditions is also considered.

8-31 Fig 2 The Segments of an Approach



Types of Approach

51. There are two types of approach, straight-in and circling.

a. **Straight-in Approach**. A straight-in approach is aligned with the runway centre line. In the case of non-precision approaches, a straight-in approach is considered acceptable if the angle between the final approach track and the runway centre line is 30º or less.

b. **Circling Approach**. Where terrain or other constraints cause the final approach track alignment or descent gradient to fall outside the criteria for a straight-in approach, a circling approach will be specified.

Circling Approach – Differences between PANS-OPS, MIPS and TERPS

52. PANS-OPS circling protected airspace is typically larger than MILS and TERPS and the obstacle clearance is higher. TERPS also relates AOB to aircraft category. The result is that to use a PANS-OPS circling AOB of 20º, and a higher max circling speed, on a TERPS procedure could cause an infringement of the safe limits. Knowledge of the AOB and maximum speed for the procedure in use is therefore essential.

Table 5 Difference Between PANS-OPS and TERPS

	TERPS		PANS-OPS	
Aircraft Category	Max Circ Speed (kt)	AOB	Max Circ Speed (kt)	AOB
A	90	25º	100	20º
B	120	25º	135	20º
C	140	20º	180	20º
D	165	20º	205	20º
E	210	22º	240	20º

53. PANS-OPS and MIPS procedures require the pilot to maintain visual contact with the runway environment throughout the entire circling manoeuvre. The runway environment means being visual with such features as the runway threshold, approach lighting aids or other features identifiable with the runway. TERPS circling procedures require the pilot to remain in visual contact with the airport environment, but they only allow descent below the circling MDA/MDH when the runway environment is in sight.

Obstacle Clearance Altitude/Height (OCA/H)

54. For each individual approach procedure and Obstacle Clearance Altitude/Height (OCA/H) is published on the chart. The OCA/H are defined as:

a. In a precision approach procedure, the lowest altitude (OCA) or alternatively the lowest height above the elevation of the relevant runway threshold (OCH), at which a missed approach must be initiated to ensure compliance with the appropriate obstacle clearance criteria.

b. In a non-precision approach procedure, the lowest altitude (OCA) or alternatively the lowest height above aerodrome elevation or the elevation of the relevant runway threshold, if the threshold elevation is more than 7 ft (2 m) below the aerodrome elevation (OCH), below which an aircraft cannot descend without infringing the appropriate obstacle clearance criteria.

c. In a visual (circling) procedure, the lowest altitude (OCA) or alternatively the lowest height above the aerodrome elevation (OCH) below which an aircraft cannot descend without infringing the appropriate obstacle clearance criteria.

55. In mountainous regions or where a Final Approach Fix (FAF) is incorporated into a non-precision approach procedure, and the length of the final approach is in excess of 6 nm (11 km), an additional margin may be applied to the MOC.

OCA/H Adjustment

56. Under certain circumstances, the OCA/H annotated on the procedure chart will have been adjusted from the standard.

a. **Remote Altimeter Setting**. When the altimeter setting is derived from a source other than the aerodrome, and more than 5 nm (9 km) from the threshold, the OCA/H shall be increased. Further adjustment is made in mountainous areas.

b. **Forecast Altimeter Setting**. Where the altimeter setting used in a procedure is based on a forecast value, the OCA/H will be increased. The chart will be annotated as such.

c. **Final Approach Track Intersection**. When the final approach track intersects the extended runway centre line between 5º and 30º the OCA/H is reduced.

d. **Final Approach Track Intersection Greater than 30º**. When the final approach track intersects the extended runway centre line at more than 30º, or the descent gradient exceeds 6.5%, the OCA/H for visual manoeuvring (circling) becomes the lower limit and is applied to the approach procedure.

Descent Minima

57. Descent minima are developed by adding a number of operational factors to OCA/H to produce, in the case of precision approaches, Decision Altitude (DA) or Decision Height (DH) and, in the case of non-precision approaches, Minimum Descent Altitude (MDA) or Minimum Descent Height (MDH).

Descent Gradient

58. In designing IAPs, adequate space is allowed for descent from the facility crossing altitude/height to the runway threshold for a straight-in approach or to OCA/H for circling approaches. This is achieved by establishing a maximum allowable descent gradient for each segment of the procedure. The minimum/optimum descent gradient/angle in the final approach of a procedure with a FAF is 5.2% / 3.0º (316 ft/nm (52 m/km)). Other gradients may be specified.

59. Gradients may be expressed in several forms, either as a Ratio of the rise (vertical height) to the run (horizontal distance), an angle (the Slope) or as a percentage (the Grade). Gradients in relation to aviation may be expressed in one or more of these measurements.

A Ratio will normally be expressed as ft/nm and can be calculated as:

$$\frac{\text{Vertical distance}}{\text{Horizontal Distance}} \qquad \begin{matrix}\text{(ft)}\\ \text{(nm)}\end{matrix}$$

The Ratio multiplied by 100 will give the Grade:

$$\frac{\text{Vertical distance}}{\text{Horizontal Distance}} \times 100 = \text{Grade (\%)}$$

Gradients in aviation are often expressed as a Grade. To calculate the ft/nm this equates to:

$$\text{Vertical distance} = \frac{\text{Grade (\%)}}{100} \times \text{Horizontal Distance}$$

Visualising the right angled triangle forming the gradient, there will be an angle between the horizontal plane and the slope. The Tangent of this angle multiplied by 100 will give the Grade. Thus:

$$\text{Tan } \alpha \times 100 = \text{Grade} \quad \text{(where } \alpha \text{ is the slope angle)}$$

From this it can be seen that:

$$\text{Slope (in }^{\circ}) = \text{Arctan } \frac{\text{Grade (\%)}}{100}$$

Example: Given a grade of 5.2%

$$\text{Vertical distance} = \frac{5.2}{100} \times 6076 \quad \text{(a)}$$

(a) 6076 ft = 1 nm

Thus: Vertical distance = 316 ft and the ratio will be 316 ft/nm

And:

$$\text{Slope (in }^{\circ}) \quad = \quad \text{Arctan } \frac{5.2}{100}$$

Thus: The Slope = 2.98°

Rounding the figures for gradients in the aviation context:

A Grade of 5.2% equates to a Slope of 3° and a Ratio of 300 ft/nm

Procedure Altitude/Height

60. In addition to minimum IFR altitudes established for each segment of the procedure, procedure altitudes/heights will also be provided. Procedure altitudes/heights will, in all cases, be at or above any minimum crossing altitude associated with the segment. Procedure altitude/height will be established taking into account the air traffic control needs for that phase of flight.

61. Procedure altitudes/heights are developed to place the aircraft at altitudes/heights that would normally be flown to intercept and fly an optimum 5.2 per cent (3° (300 ft/nm)) descent path angle in the final approach segment to a 50 ft (15 m) threshold crossing for non-precision approach procedures and procedures with vertical guidance. In no case will a procedure altitude/height be less than any OCA/H.

ARRIVAL SEGMENT

62. A standard instrument arrival (STAR) route permits transition from the en-route phase to the approach phase. The arrival route normally ends at the Initial Approach Fix (IAF). Omnidirectional or sector arrivals can be provided taking into account Minimum Sector Altitudes (MSA). Minimum sector altitudes or terminal arrival altitudes are established for each aerodrome and provide at least 1 000 ft obstacle clearance within 25 NM of the navigation aid, initial approach fix or intermediate fix associated with the approach procedure for that aerodrome. When terminal area radar is employed, the aircraft is vectored to a fix, or onto the intermediate or final approach track, at a point where the approach may be continued by the pilot by referring to the instrument approach chart.

INITIAL APPROACH SEGMENT

63. The initial approach segment begins at the IAF and ends at the Intermediate Fix (IF). Aircraft speed and configuration will depend on the distance from the aerodrome, and the descent required. Normally track guidance is provided along the initial approach segment to the IF, with a maximum angle of interception of 90° for a precision approach and 120° for a non-precision approach. The initial approach segment provides at least 1 000 ft of obstacle clearance in the primary area reducing laterally to zero at the outer edge of the secondary area.

64. Under PANS-OPS criteria, the optimum descent gradient is 4.0% (250 ft/nm)(Cat H 6.5% (400 ft/nm)). Where a higher descent gradient is necessary to avoid obstacles, the maximum permissible is 8.0% (500 ft/nm)(Cat H 10 %(600 ft/nm)). At locations where high altitude procedures provide an operational advantage for military operations (HPMA) the optimum descent gradient is 13.1% (800 ft/nm). The maximum permissible descent gradient is 16.4% (1000 ft/nm).

Reversal Procedure

65. Where no suitable IAF or IF is available to construct the instrument procedure in the form shown in Fig 2, a reversal procedure, racetrack or holding pattern is required. The reversal procedure may be in the form of a procedure or base turn. Entry is restricted to a specific direction or sector. In these cases, a specific pattern, normally a base turn or procedure turn, is prescribed. The direction and timing specified must be adhered to so as to remain within the protected airspace. There are three generally recognised manoeuvres related to the reversal procedure.

a. **45º/180º Procedure Turn**. The 45º/180º procedure turn (Fig 3) starts at the facility and consists of:

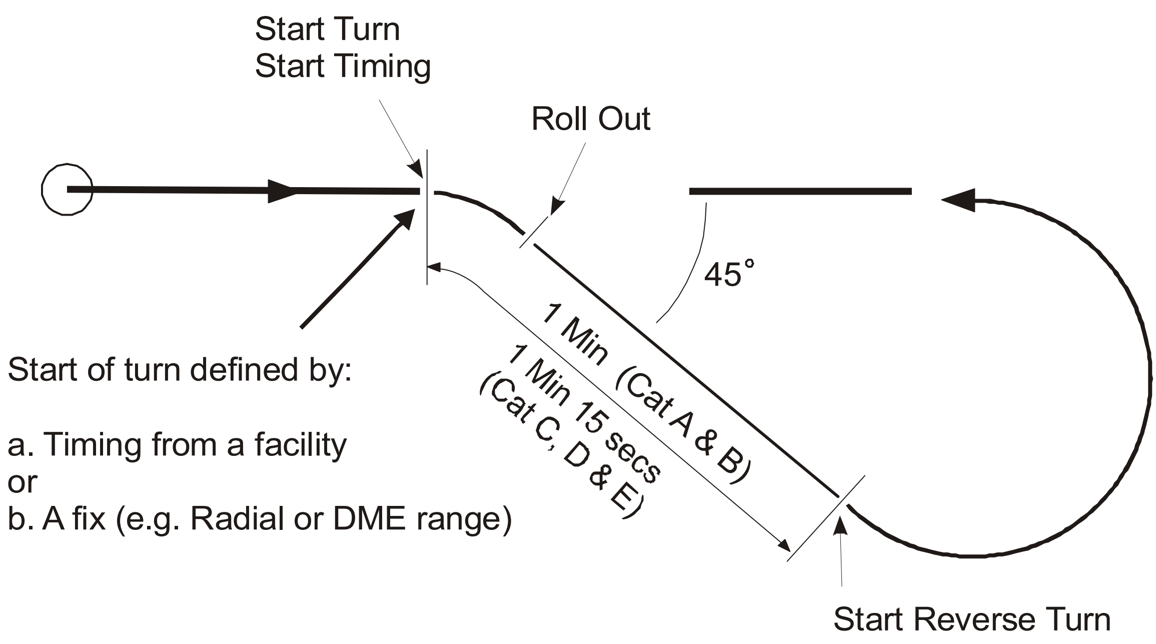
i. A straight leg with track guidance, either timed or limited by a radial or DME distance.

ii. A 45º turn.

iii. A timed straight leg, without track guidance, of 1 min for Cat A and B aircraft and 1 min 15 sec for Cat C, D and E aircraft, from the start of the turn.

iv. A 180º turn in the opposite direction to intercept the inbound track.

8-31 Fig 3 45º / 180º Procedure Turn



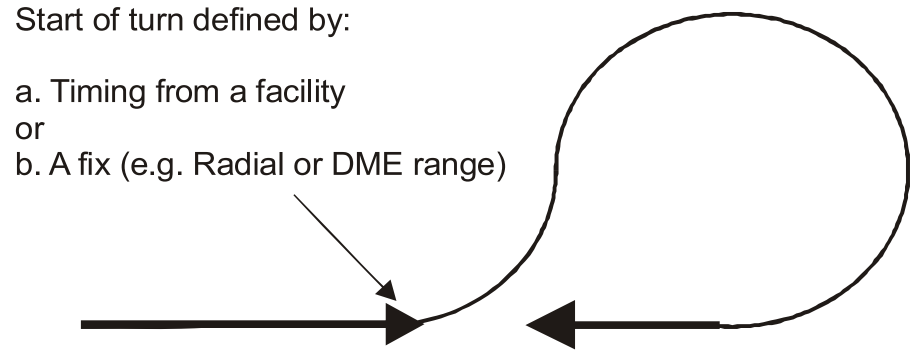
b. **80º/260º Procedure Turn**. The 80º/260º procedure turn (Fig 4) starts at the facility and consists of:

i. A straight leg with track guidance, either timed or limited by a radial or DME distance.

ii. An 80º turn.

iii. A 260º turn in the opposite direction to intercept the inbound track.

8-31 Fig 4 80º / 260º Procedure Turn

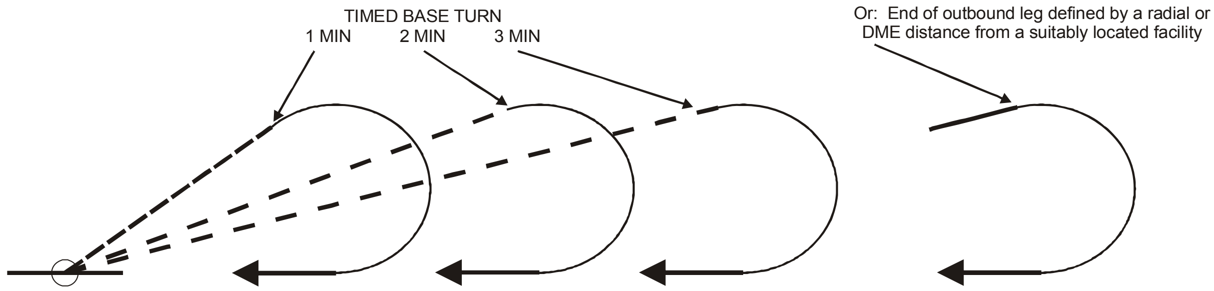


c. **A Base Turn**. A Base Turn (Fig 5) consisting of:

i. A specified outbound track and timing or DME distance from a facility. Followed by:

ii. A turn to intercept the inbound track.

8-31 Fig 5 A Base Turn



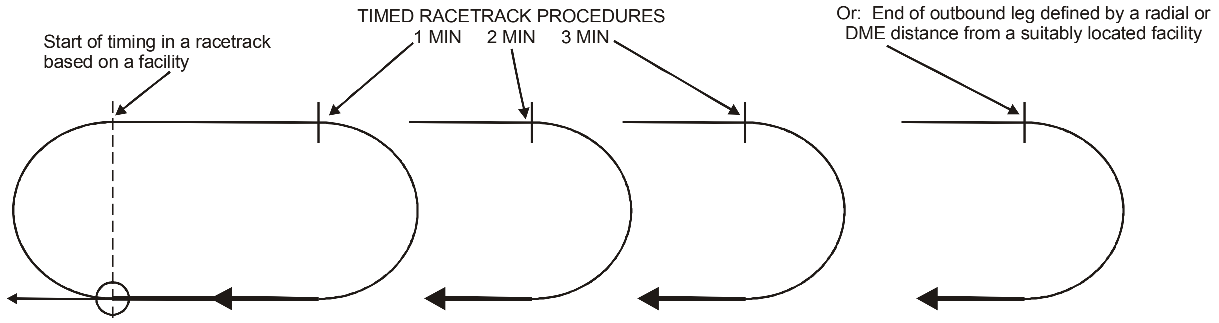
Racetrack Procedure

66. A racetrack procedure (Fig 6) is used where sufficient distance is not available in a straight segment to accommodate the required loss of altitude and when entry into a reversal procedure is not practical. It is not a holding procedure. The racetrack is used when aircraft arrive overhead a fix from various directions and consists of:

a. A turn from the inbound track through 180º from overhead the facility or fix onto the outbound track for 1, 2 or 3 minutes. Alternatively, the turn may be limited by a DME distance or radial rather than timing. Followed by:

b. A 180º turn in the same direction to return to the inbound track.

8-31 Fig 6 A Racetrack Procedure



67. **Entry into a Racetrack Procedure**. Aircraft entering (Fig 7) a racetrack procedure are expected to enter the procedure in a manner similar to that prescribed for a holding procedure entry (Fig 8) with the following considerations:

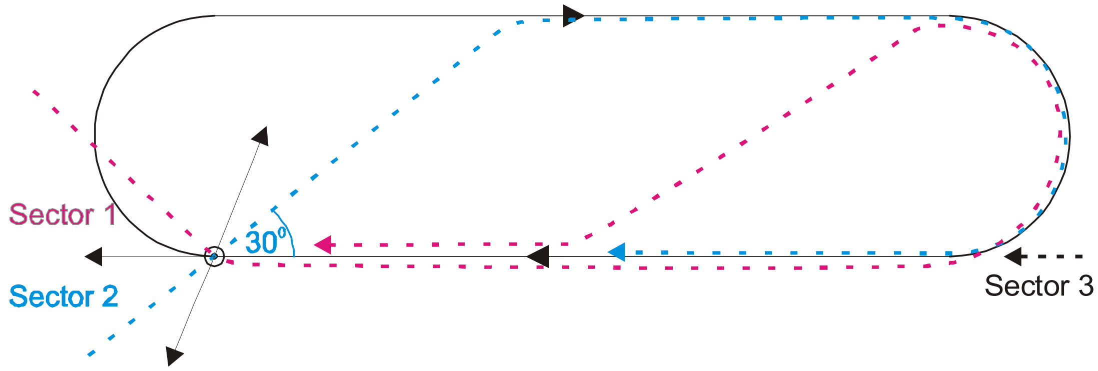
a. An offset entry from Sector 2 shall limit the time on the 30º offset track to 1 min 30 sec, after which the pilot is expected to turn to a heading parallel to the inbound track for the remainder of the outbound time. If the outbound time is only 1 min the time on the 30º offset track shall be 1 min also.

b. A Parallel entry shall not return directly to the facility without first intercepting the inbound track when proceeding to the final segment of the procedure.

c. All manoeuvring shall be done in so far as possible on the manoeuvring side of the inbound track.

Note: The procedures for entry are as above unless other restrictions are specified.

8-31 Fig 7 A Racetrack Entry Procedures



Hold Entry Procedures

68. Entry into the holding pattern shall be according to heading in relation to the three entry sectors (Fig 8) recognising a zone of flexibility of 5º either side of the sector boundaries.

69. **Sector 1 Procedure (Parallel Entry)**. On reaching the fix, the aircraft is turned onto the outbound heading for the appropriate time or DME limiting distance (if published). The aircraft is then turned onto the holding side to intercept the inbound track or return to the fix. On the second arrival over the holding fix the aircraft is turned to follow the holding pattern.

70. **Sector 2 Procedure (Offset Entry)**. On reaching the fix, the aircraft is turned onto a heading to make good a track making an angle of 30º from the reciprocal of the inbound track on the holding side.

a. The aircraft will fly outbound:

i. For the appropriate period of time, where timing is specified, or

ii. Until the limiting DME distance is reached (where specified), or

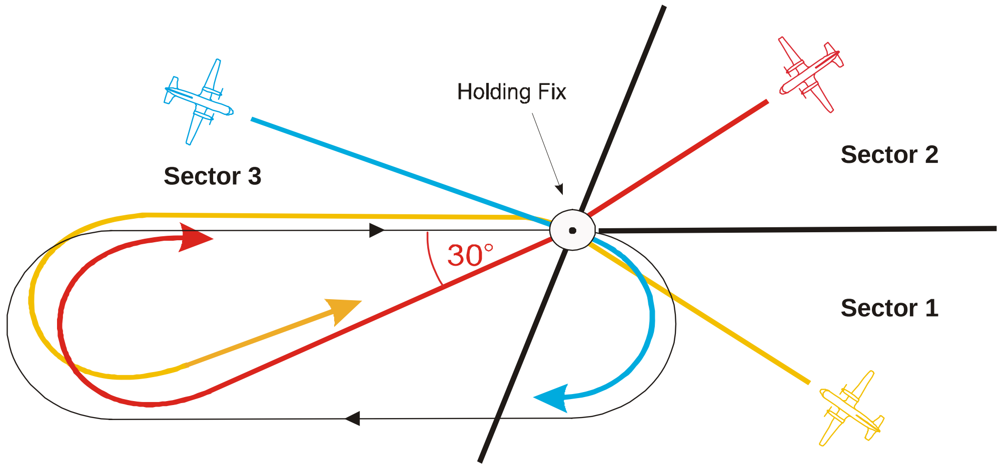
iii. Where a limiting radial is also specified, either until the limiting DME distance is reached or until the limiting radial is encountered, whichever occurs first.

b. The aircraft is turned to intercept the inbound holding track.

c. On the second arrival over the holding fix, the aircraft is turned to follow the holding pattern.

71. **Sector 3 Procedure (Direct Entry)**. Having reached the fix, the aircraft is turned to follow the holding pattern.

8-31 Fig 8 Entry to a Holding Procedure



72. **DME Arc Entry**. A DME arc entry procedure will only be specified when there is a specific operational difficulty which precludes the use of other entry procedures. On reaching the fix, the aircraft shall enter the holding pattern using either the Sector 1 or Sector 3 entry procedure.

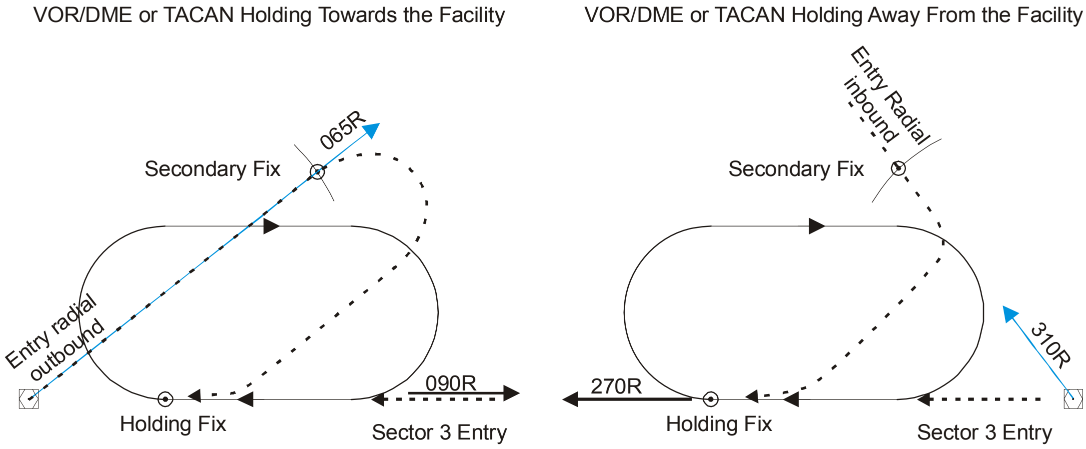
Cone of Ambiguity

73. There is an area directly above a directional beacon where the received signal will be lost. This area is known as the Cone of Ambiguity or Cone of Silence. VOR has a cone of ambiguity of 50º while a TACAN has one of 60º. Holding fixes therefore are not usually placed overhead the beacon, but low altitude holds may be overhead the beacon.

Special Entry Procedure for VOR/DME or TACAN Holding

74. Where an entry radial to a secondary fix of a VOR/DME or TACAN holding pattern is specified (Fig 9), Sector 1 and 2 entries are not authorised. The holding pattern is entered via the published radial or the Sector 3 procedure. On reaching the fix, the aircraft is turned to follow the holding pattern. Some British military airfields have exceptions to this and those procedures are clearly annotated on the appropriate chart.

8-31 Fig 9 VOR/DME and TACAN Holding



The arrival to the holding pattern may be along the axis of the inbound track, along a published track or by radar vectoring. The entry point may be via the holding fix or via the secondary fix.

75. PANS-OPS describes several other methods of entry to VOR/DME holding patterns. These are detailed on the appropriate chart. Further guidance can be found in the AIDU Terminal Charts Specification and Legend.

76. The outbound heading is flown for one minute if below FL 140 or one and a half minutes if above FL 140. The length of the outbound leg may be specified in terms of a DME distance instead.

Table 6 Holding Speeds

<table>
<tr><td colspan="3">Holding patterns are to be entered and flown at or below the following indicated airspeeds</td></tr>
<tr><td>Levels (Altitude or Flight Levels)</td><td>Normal Conditions</td><td>Turbulence Conditions</td></tr>
<tr><td>Up to 14000 ft</td><td>230 kt [1]
170 kt [3]</td><td>280 kt [2]
170 kt [3]</td></tr>
<tr><td>Above 14000 ft to 20000 ft inclusive

Above 20000 ft to 34000 ft inclusive</td><td>240 kt [4]

265 kt [4]</td><td>280 kt
Or
0.8 Mach
(whichever is less) [2]</td></tr>
<tr><td>Above 34000 ft</td><td>0.83 Mach</td><td>0.83 Mach</td></tr>
<tr><td colspan="3">1. When a holding speed in the initial segment of the approach procedure is higher, the holding speed may be increased.
2. These speeds may be used with prior ATC clearance.
3. For Cat A and B aircraft only.
4. Wherever possible, 280 kt should be used for holding procedures associated with airway route structures.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Helicopter Procedures</td></tr>
<tr><td>Maximum speed up to 6000 ft</td><td colspan="2">100 kt</td></tr>
<tr><td>Maximum speed above 6000 ft</td><td colspan="2">170 kt</td></tr>
<tr><td colspan="3">All turns are to be made at an AOB of 25° or rate of 3°/sec, whichever requires the lesser bank</td></tr>
</table>

Flight Procedures for Racetrack, Reversal and Holding Procedures

77. Unless otherwise specified, entry to a reversal procedure shall be from a track within ±30º of the outbound track of the reversal procedure. For Base Turns, where the ±30º direct entry sector does not include the reciprocal of the inbound track the entry sector is expanded to include it.

78. **Speeds**. Speeds may be specified in addition to, or instead of, aircraft category restrictions. To ensure the aircraft remains within the protected area speeds must not be exceeded.

79. **Bank Angle**. Procedures are based on an average bank angle of 25º, or the bank angle giving a rate of turn of 3º/sec, whichever is less.

80. **Descent.**Aircraft shall cross a fix or facility on the specified track, descending as necessary to the procedure altitude/height while adhering to altitude/height restrictions associated with that segment. If a further descent is specified after the inbound turn, it shall not be commenced until the aircraft is established on the inbound track. An aircraft is considered to be established when it is within half full scale deflection for the ILS and VOR, or, within ±5º of the required bearing for the NDB.

81. **Timing**. When a procedure is based upon a facility, the outbound timing starts from abeam the facility, or, on attaining the outbound heading, whichever comes later. When a procedure is based on a fix, the outbound timing starts from attaining the outbound heading. The turn onto the inbound track should be started:

a. Within the specified time (adjusted for wind), or

b. When reaching a specified DME distance, or

c. When a radial/bearing specifying a limiting distance has been reached.

Whichever occurs first.

82. **Wind Effect**. To achieve a stabilised approach, due allowance should be made in both heading and timing to compensate for the effects of wind. Any limiting DME distances always terminate the outbound leg.

a. **Drift**. As drift allowance cannot be applied during the turns, 3 times the drift (up to a maximum of 30º) is allowed on the outbound leg. One times the drift is applied on the inbound leg. The bank may be varied (up to 25º or rate 1, whichever is the lesser bank) during the final part of the inbound turn to roll out on the desired track. For TACAN holds, or holds longer than 4 minutes in total, 2 times the drift is applied when outbound.

b. **Timing**. It is necessary to know or estimate the head/tail wind component on the outbound leg in order to correct the timing. Allow 1 second (1.5 seconds if above FL 140) per 2 kt of wind component; this should be added to the standard time for a headwind, or subtracted for a tailwind. Note that timing action starts abeam the beacon.

83. **Descent Rates**. The specified timings and procedure altitudes are based on rates of descent (ROD) that do not exceed the following:

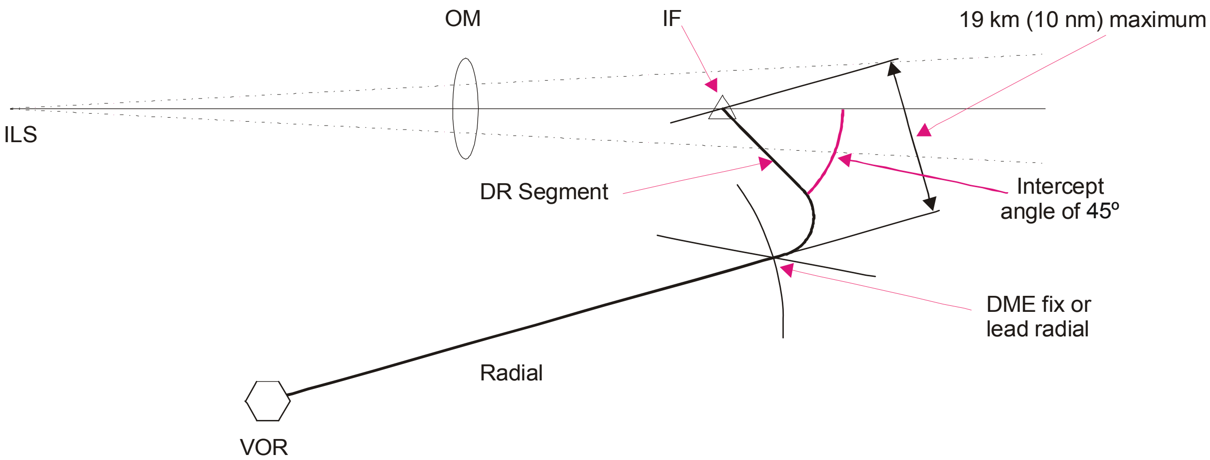
Table 7 Rates of Descent

Outbound Track	***Maximum ROD***	***Minimum ROD***
Category A/B	245 m/min (804 ft/min)	N/A
Category C/D/E/H	365 m/min (1197 ft/min)	N/A
Inbound Track	***Maximum ROD***	***Minimum ROD***
Category A/B	200 m/min (655 ft/min)	120 m/min (394 ft/min)
Category H	230 m/min (755 ft/min)	N/A
Category C/D/E	305 m/min (1000 ft/min)	180 m/min (590 ft/min)

84. **Shuttle**. There may be occasions where the required ROD between the end of the initial approach and the beginning of the final approach exceeds the values given above. In this case, a Shuttle may be prescribed, which is defined as a descent or climb conducted in a holding pattern.

85. **Dead Reckoning (DR) Segment**. An ILS procedure may include a dead reckoning (DR) segment from a fix to the localizer (Fig 10). The DR track will intercept the localizer at 45º and will not be more than 10 nm (19 km) in length. The point of interception is the beginning of the intermediate segment and will allow for proper glide path interception.

8-31 Fig 10 Dead Reckoning Segment



INTERMEDIATE APPROACH SEGMENT

General

86. During this segment the aircraft speed and configuration should be adjusted to prepare for the final approach. As such, the descent gradient is kept as shallow as possible. The obstacle clearance requirement reduces from 984 ft (300 m) to 492 ft (150 m) in the primary area, reducing laterally to zero at the outer edge of the secondary area. Where a final approach fix (FAF) is available, this segment begins when the aircraft is on the inbound track of the procedure turn, base turn or final inbound leg of the racetrack procedure. It ends at the FAF or final approach point (FAP) as applicable. Where no FAF is specified, the inbound track is the final approach segment.

FINAL APPROACH SEGMENT

General

87. The final approach segment is where alignment and descent for the landing are made. This may be to a runway for a straight in landing or to an aerodrome for a visual manoeuvre.

Approach Minima

88. **Approach Minima**. At the end of an instrument approach (with the exception of approved blind-landing systems approaches), the pilot must transfer from flight instruments to visual references for the landing. The required visual references are defined in the Manual of Military Air Traffic Management (Chapter 1). The minimum height for descent on instruments is pre-calculated and will be a Decision Height (DH)/Decision Altitude (DA) for a 'precision' approach, or a Minimum Descent Height (MDH)/Minimum Descent Altitude (MDA) for a 'non-precision' approach.

Determination of Decision Altitude (DA) or Decision Height (DH)

89. The DA/DH is calculated and depends upon several factors. These factors include aircraft category and performance, and the type of approach (e.g. ILS or MLS). The allowance made for these factors is applied to the OCA/H to determine the DA/DH. PANS-OPS references precision approaches to threshold elevation. MILS modifies this for PAR where TDZE is used as the datum. Thus for a runway served by an ILS CAT 1 and a PAR, both operating at system minima, the DH on both AIDU charts would be 200ft but the DA on each chart may differ if the TDZE is higher than the threshold elevation.

90. The rules for calculating DH/DA by British military pilots, as described in the MMATM (Chapter 23), detail additional allowances that may be applied to the basic procedure minima. The pilot instrument rating, any Command allowance and, where appropriate, an engine out allowance must be applied. Allowances specific to aircraft type must also be taken into account. They will be laid down in the Aircrew Manual/Pilot's Notes and may consist of Pressure Error Correction, Temperature Error Correction, Helicopter Type Allowance and Standby Pressure Instrument Allowance.

Calculation of DH/DA for Precision Approaches

91. The DH/DA for precision approaches for fixed-wing aircraft is calculated as follows:

a. With full power available, the procedure minimum is obtained and Master Green and Green rated pilots add this to any Command allowance to obtain their minimum. White and Amber rated pilots will further add any appropriate allowances to this minimum.

b. With one or more engines inoperative an appropriate engine-out allowance will be added to the DH/DA calculated at sub-paragraph a.

92. All AIDU procedures are for fixed-wing aircraft. All helicopters may operate down to 50 ft below the published minimum for fixed-wing Cat A aircraft as a baseline. Pilots will add any Command or rating allowance to this.

Calculation of MDH/MDA for Non-Precision Approaches

93. For fixed-wing Aircraft with full power available or with one or more engines inoperative, the procedure minimum for non-precision approaches will be calculated in accordance with the procedure detailed in Paragraph 91. Engine out allowance is not added directly to MDH/MDA but will be taken into account to avoid descending below this height/altitude. While a stepfix is employed in the final approach, any rating allowance is ignored in calculating the minimum height/altitude at the fix point.

94. The procedure minima for helicopters carrying out non-precision approaches will be calculated in accordance with the procedure detailed in Paragraph 92, excepting that the dispensation to subtract 50 ft from the minimum for category 'A' fixed-wing aircraft does not apply to non-precision approaches.

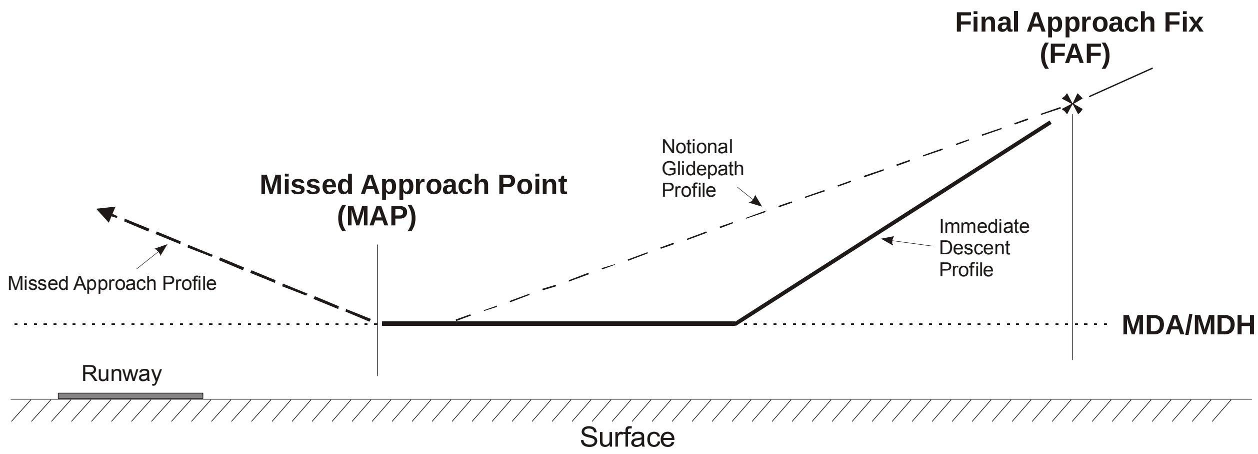
Types of Final Approach

95. The criteria for the final approach vary according to the type of approach. The different types of approach are:

a. **Precision Approaches**. A precision approach is an instrument approach using a facility which provides both azimuth and electronic glide-slope information. Precision Approach Radar (PAR), Instrument Landing System (ILS) and Microwave Landing System (MLS), when fully serviceable, are classed as precision approach aids. PAR procedures are not published in TAPs as they are passed by RT. On a precision approach, the aircraft is permitted to descend on the glidepath down to the declared DH/DA; the options at this point are either to continue the landing visually (if the required visual references are available), or to fly the Missed Approach procedure.

b. **Non-precision Approaches**. An instrument approach using a procedure which does not employ electronic glide-slope information is classed as a 'non-precision' approach. For such a procedure, the pilot will calculate an MDH/MDA. During the final approach segment, a descent to MDH/MDA is permitted from the Final Approach Fix (FAF), by flying either a notional glidepath profile or an immediate descent profile (see Fig 11). In the latter case, the maximum rate of descent allowed is 800 ft/nm (2,400 ft/min) in zero wind at 180 kt IAS. If an immediate descent profile is not permitted, it will be stated in the TAP. Descent below MDH/MDA is only permitted when the required visual references are obtained. Where the visual references are not available, the pilot must initiate the Missed Approach procedure no later than at the Missed Approach Point.

8-31 Fig 11 Descent Profiles - Non-precision Approach



Non-precision Approach - General

96. PANS-OPS references non-precision approaches to airfield elevation. Where the runway threshold is more than 7 ft below the reference elevation, the MDA/MDH calculation for a non-precision approach will be referenced to the runway threshold elevation instead and a note will be added to the chart.

97. The Missed Approach Point (MAPt) for a non-precision approach is defined either by a fix, a facility or by timing and is shown in plan and profile on the chart. When it is based on a facility or fix, timing shall not be used. AIDU non-precision charts show the timing from the FAF/FAP to the MAPt.

Continuous Descent Final Approaches

98. The Continuous Descent Final Approach (CDFA) is the standard profile view depicted on No 1 AIDU TAP charts for non-precision approaches.

99. Controlled flight into terrain (CFIT) is a major hazard in aviation, and evidence has shown that the majority of civilian CFIT accidents occur in the final approach segment of non-precision approaches (NPA). The elimination of level flight segments at MDH/A and any major changes in power/thrust or configuration close to the runway, both of which can destabilise approaches, have been seen as ways to reduce the operational risk of CFIT and runway excursions. EASA legislation in the civilian fixed-wing sector has mandated that all approaches are flown using the Stabilised Approach (SAp) technique. A SAp is flown in a controlled and appropriate manner in terms of configuration, energy and control of flight path from a pre-determined point or altitude/height down to a point 50 feet above the threshold or the point where the flare manoeuvre is initiated if higher. The CDFA technique was introduced to ensure a NPA can be flown as a SAp.

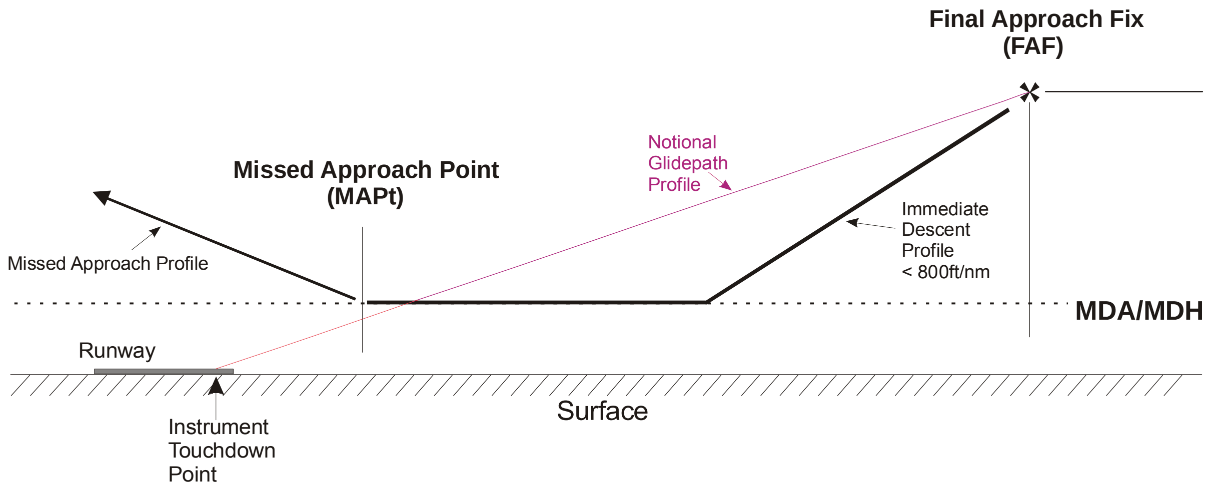
100. Without the glide-path information that is available on a precision approach, the traditional methods of flying a NPA are:

a. **Notional Glidepath**. A descent is started at or after the Final Approach Fix (FAF) to fly a vertical profile that approximates to that of a precision approach, such as the ILS. Use can be made of a table of heights against distance, a calculated rate of descent, or ATC advice to maintain the notional glidepath. During the approach, checks are required to ensure that the ac does not go below any step-down fixes specified in the procedure. At the bottom of the approach the ac should be levelled at or above the MDH/A and flown towards the Missed Approach Point (MAPt). (See Fig 12)

b. **Immediate Descent**. A descent is started at the FAF, using a maximum rate of 800 ft/nm, towards the approach minima or any intervening step-down height. The aircraft is then flown level until a lower height is allowed by the procedure, or the MAPt is reached. This technique is sometimes colloquially known as ‘dive and drive’. (See Fig 12)

101. When the required visual references are obtained, the approach to touchdown can then be continued visually. This is where the key problem with large commercial aircraft flying NPAs often manifests itself; whilst the MAPt is the last point on the NPA at which a go-around may be safely commenced, it is not always possible to continue with a visual approach to the runway from there. Indeed, there are examples where the MAPt is directly above the threshold or even considerably beyond it. In those cases it is unwise or impossible for an aeroplane to safely convert to a visual approach at the MAPt, although circling options may be available.

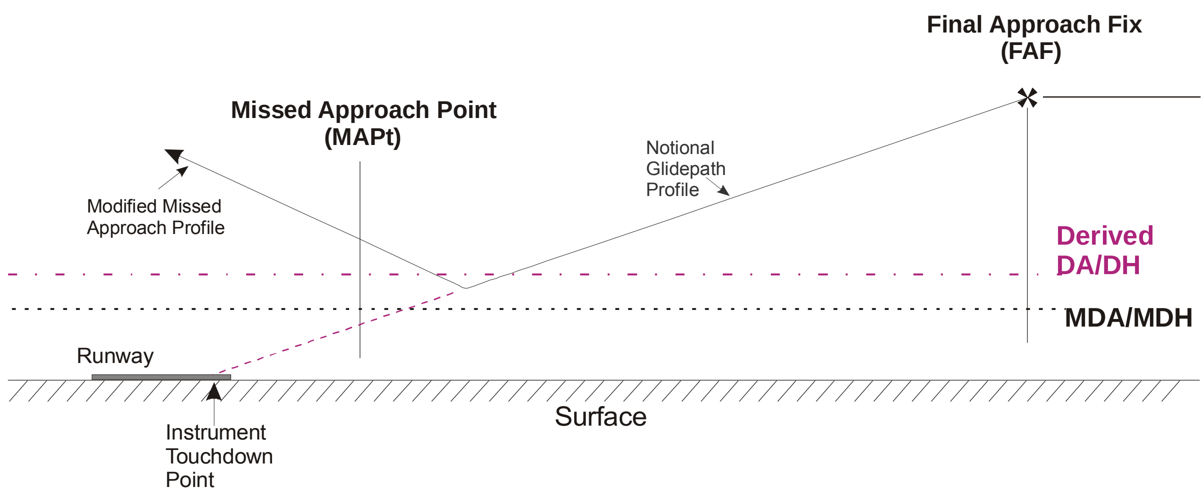
8-31 Fig 12 Descent Profiles – Non CDFA



CDFA Technique

102. The CDFA technique removes the potentially hazardous temptation to continue with an approach to touch-down from an inappropriate position. The final approach is flown with a notional glidepath that is calculated to give a continuous descent, without level offs, that respects all of the step-down fixes and will put the aircraft in a position to land safely. An allowance is added to the MDH/A to calculate a derived DH/A. A decision is made, approaching the derived DH/A, on whether the pilot has the required references to continue visually. If not, a go-around is commenced sufficiently early to ensure the aircraft does not descend below the approach minima. No attempt is made to level off at MDA/H and fly in towards the MAPt. In effect the CDFA NPA is flown like a precision approach with a DH/A, although it is important to remember it is still based on the underlying NPA procedure design and so there is no allowance for the aircraft to go below MDH/A whilst executing the go-around procedure. (See Fig 13).

8-31 Fig 13 Descent Profiles – CDFA



103. The height allowance required to carry out the initial go-around actions without descending below the MDH/A will vary according to aircraft type, and possibly vary further by configuration and serviceability. Type specific orders will specify the allowance to be added to the MDH/A to create a derived DH/A which is then used as the approach minima and passed to ATC if required.

104. When flying the approach to a derived DH, pilots should still be aware of the normal MAPt, and go-around if it is reached first. More usually the decision will be made before the original MAPt. In this case the aircraft should climb whilst continuing laterally towards the MAPt before commencing any turns, unless there is an overriding explicit ATC Clearance to turn earlier.

105. Aircrew may use other aids to assist in flying the NPA as a CDFA, for example a DME or RNAV derived distance against height table or ATC advisory heights on an SRA which can provide guidance to maintain a constant descent angle. These do not equate to the electronic glidepath information of a precision approach and as such they only offer guidance to the pilot and the limits of the underlying approach, such as step-fixes, should still be monitored and complied with.

Non-CDFA

106. There may be occasions when it is neither possible nor practical to fly a NPA as CDFA. If CDFA has been directed as the normal way of flying approaches regulations may permit the approach to be flown using one of the traditional techniques, although the problem of unstable approach segments will potentially be present (Fig 14a). The option to do this may be restricted to certain circumstances or airfields, or the discretion may be given to aircraft commanders. With the aircraft flying level at MDH/A regulations may direct an increase to the minimum required visibility in order to allow earlier acquisition of the visual references and a safe transition to the normal descent path (Fig 14b).

8-31 Fig 14 Non CDFA to Published MAPt & RVR and Non CDFA with Increased RVR

Fig 14a Non CDFA to Published MAPt & RVR

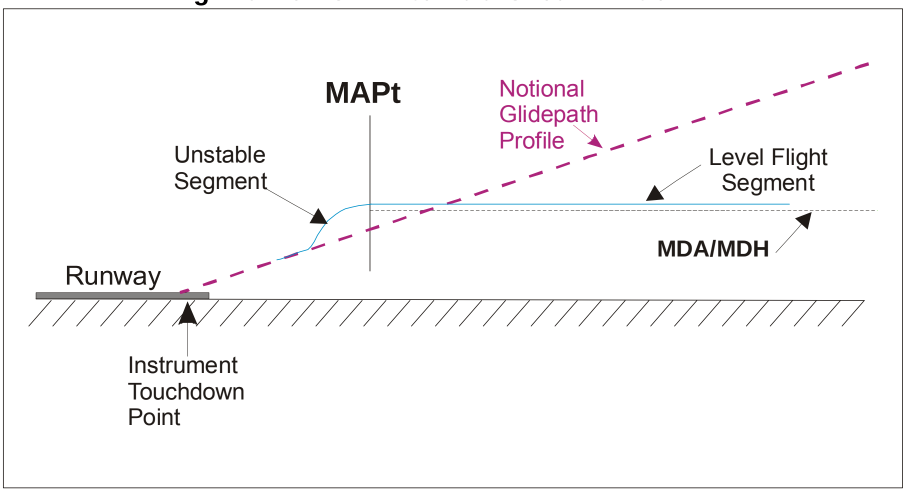
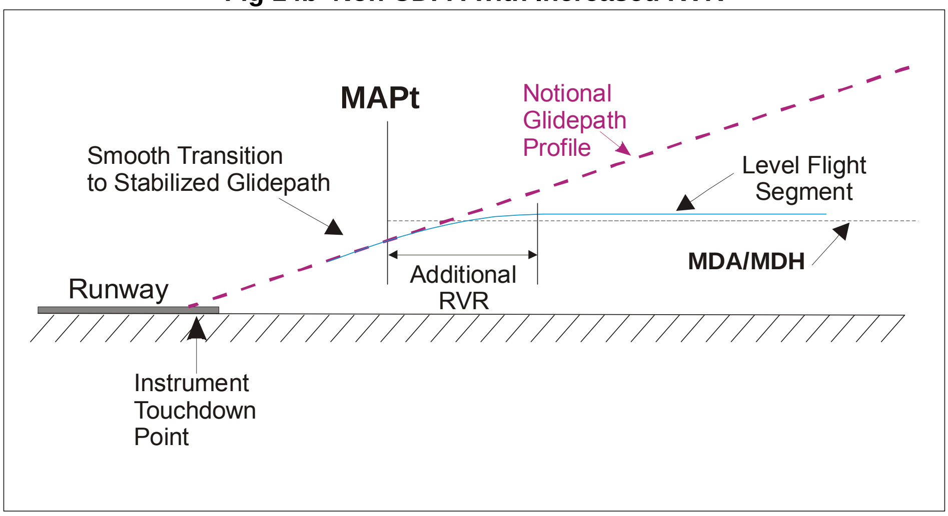


Fig 14b Non CDFA with Increased RVR



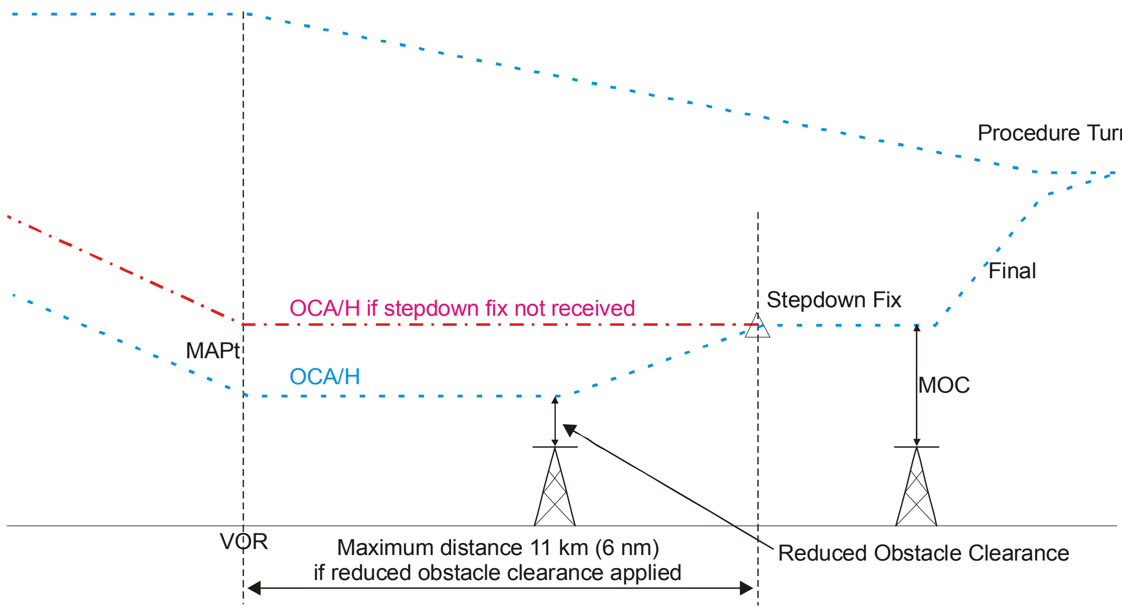
107. Some instrument TAPs present differing approach minima for CDFA and non-CDFA options. These only account for the additional visibility requirements, and importantly do not add to the original MDH/A as the vertical allowance depends on aircraft type and performance. Some TAPs have been modified to display a DH/A on the TAP. If regulations require an additional vertical increment for CDFA then this is added to the promulgated procedure minima for all NPA regardless of the publisher. Equally important for helicopter operators, who are normally allowed to subtract 50 ft from the published DH/A on precision approaches, is that this rule does not apply to NPA flown using CDFA techniques. In multi-crew aircraft the approach briefing should clearly state how the approach will be flown and the minima being used.

Non-precision Approach with a Final Approach Fix

108. **Non-precision Approach with a Final Approach Fix**. This segment begins at a facility or fix (FAF) and ends at the missed approach point (MAPt). The FAF is on the final approach track at a distance that permits selection of final approach configuration and descent to the appropriate MDA/H. A non-precision approach provides the optimum final descent gradient of 5.2% or 3º (ROD 318 ft/nm (52 m/km)). The FAF is crossed at the procedure altitude/height in descent but no lower than the minimum crossing altitude associated with the FAF under ISA conditions. Delaying the descent until the FAF will cause a ROD greater than 3º.

109. **Stepdown Fixes**. A stepdown fix may be incorporated into a non-precision approach procedure. In this case, two OCA/H values are published; a higher value applicable to the primary procedure and a lower value applicable only if the stepdown fix is positively identified during the approach. Normally only one stepdown fix is specified. In the case of a VOR/DME procedure, several DME fixes may be depicted, each with its own associated minimum crossing altitude.

8-31 Fig 15 Stepdown Fix



110. **Stepdown Fix with DME**. Where a stepdown procedure uses a suitable DME, the pilot shall not commence descent until established on the specified track. Once on the track, descent shall begin while maintaining the aircraft at or above the published DME height/distance requirements.

Non-precision Approach without a Final Approach Fix

111. There may be instances where an aerodrome is served by a single facility, on or near the aerodrome, and no other facility is suitable for a FAF. A procedure may be designed in this case where the facility is both the FAF and the MAPt. These procedures indicate a minimum altitude/height for a reversal procedure or racetrack and also an OCA/H for the final approach.

112. In the absence of a FAF, descent to MDA/H is made once the aircraft is established inbound within 5º of the final approach track. In these procedures, the final approach track cannot normally be aligned on the runway centre line. Whether OCA/H for straight-in approach limits are published or not depends on the angular difference between the track and the runway and position of the track with respect to the runway threshold.

Precision Approach

113. Precision Approach Radar (PAR). A PAR is a precision approach system. Failure of the azimuth and range information renders the entire PAR inoperative. When the glide slope information becomes inoperative the PAR may revert to a non-precision approach system and non-precision approach minima apply. The PAR procedure shall include instructions for the pilot in the event of a loss of communications with the controller.

114. **Final Approach Point (FAP)**. The final approach segment begins at the final approach point (FAP). This is a point in space on the final approach track where the intermediate approach altitude/height intercepts the nominal glide path/microwave landing system (MLS) elevation angle.

115. **Final Approach Length**. The intermediate approach altitude/height generally intercepts the glide path/MLS elevation angle at heights from 1 000 ft to 3 000 ft above runway elevation. In this case, for a 3° glide path, interception occurs between 3 NM and 10 NM from the threshold. The intermediate approach track or radar vector is designed to place the aircraft on the localizer or the MLS azimuth specified for the final approach track at an altitude/height that is below the nominal glide path/MLS elevation angle.

116. **Outer Marker/DME Fix**. The outer marker or equivalent DME fix is normally used to verify the glide path/MLS elevation angle/altimeter relationship. Prior to crossing the fix, descent may be made on the glide path/MLS elevation angle to the altitude/height of the published fix crossing but descent below the fix crossing altitude/height should not be made prior to crossing the fix.

117. **Altimeters**. It is assumed that the aircraft altimeter reading on crossing the fix is correlated with the published altitude, allowing for altitude error and altimeter tolerances. Pressure altimeters are calibrated to indicate true altitude under ISA conditions. Any deviation from ISA will therefore result in an erroneous reading on the altimeter. If the temperature is higher than ISA, then the true altitude will be higher than the figure indicated by the altimeter. Similarly, the true altitude will be lower when the temperature is lower than ISA. *The altimeter error may be significant in extremely cold temperatures*.

118. **Loss of Glide Path**. In the event of loss of glide path/MLS elevation angle guidance during the approach, the procedure becomes a non-precision approach. The OCA/H and associated procedure published for the glide path/MLS elevation angle inoperative case will then apply.

119. **Missed Approach Point (MAPt)**. The Missed Approach Point (MAPt) for a precision approach is defined either by the intersection of the glide path with the relevant DA/DH and therefore may not be depicted on the chart.

Protection on the Precision Segment

120. The width of the final approach protection area for a precision approach is much narrower than that for a non-precision approach. The protection area assumes the pilot does not deviate more than half scale deflection from the centreline once established on track. Thereafter the aircraft should adhere to the on-course, on-glide path/elevation angle position since a more than half course sector deflection, or a more than half course fly-up deflection combined with other allowable system tolerances, could place the aircraft in the vicinity of the edge or bottom of the protected airspace where loss of protection from obstacles can occur.

121. Operators must consider weight, altitude and temperature limitations and wind velocity when determining the DA/H for a missed approach, since the OCA/H might be based on an obstacle in the missed approach area and since advantage may be taken of variable missed approach climb performances.

MISSED APPROACH SEGMENT

122. During a Missed Approach Procedure (MAP) the pilot has to change the aircraft's configuration, attitude and altitude. The MAP is therefore designed to be simple and consists of three phases, initial, intermediate and final (Fig 16).

123. Only one MAP is established for each instrument approach procedure. It is designed to give protection from obstacles and has a defined start and end point. The MAP should be initiated not lower than DA/DH in precision approach procedures, or at a specified point in non-precision approach procedures not lower than the MDA/H.

124. The Missed Approach Point (MAPt) is the point in an instrument approach procedure at, or before, which the prescribed missed approach must be initiated in order to ensure that the minimum obstacle clearance is not infringed. A missed approach must be carried out if the MAPt is reached before visual reference is acquired in order to maintain protection from obstacles. If a turn is specified in the missed approach procedure, the turn shall not be initiated until the aircraft has passed the MAPt and is established in the climb. Pilots should be aware that the MAPt is not necessarily a point in space from which a safe landing can be made.

125. A pilot is expected to fly the MAP as published. If the MAP is initiated before the MAPt is reached, the pilot will normally proceed to the MAPt and then follow the MAP to remain within protected airspace. The pilot may fly over the MAPt at a height greater than that required by the procedure. A MAP may be modified under certain circumstances, but the details will be published on the chart.

126. **MAP Gradient**. The normal gradient for a MAP is 2.5% (150 ft/nm). A gradient of 2% (120 ft/nm) may be used if surveys have been done to assure obstacle clearance. Gradients of 3, 4 or 5% may be used for aircraft with the required climb performance. Gradients other than 2.5% will be published on the chart along with the OCA/H for this gradient. The OCA/H for the normal gradient will also be published.

127. **Special Circumstances**. A Gradient of 2.5% may not be practicable for certain aircraft operating at near maximum AUW and/or engine-out conditions. A special procedure may be established with a possible increase in DA/DH or MDA/H.

Initial Phase

128. The initial phase begins at the MAPt and ends at the Start Of the Climb (SOC). This is a short phase where the pilot is changing the aircraft configuration and attitude and is initiating the climb. No turns are specified in this phase.

Intermediate Phase

129. The intermediate phase starts at the SOC and ends at the first point where 164 ft (50 m) of obstacle clearance is obtained and can be maintained. The climb is continued, normally straight ahead, but the track may change by a maximum of 15º.

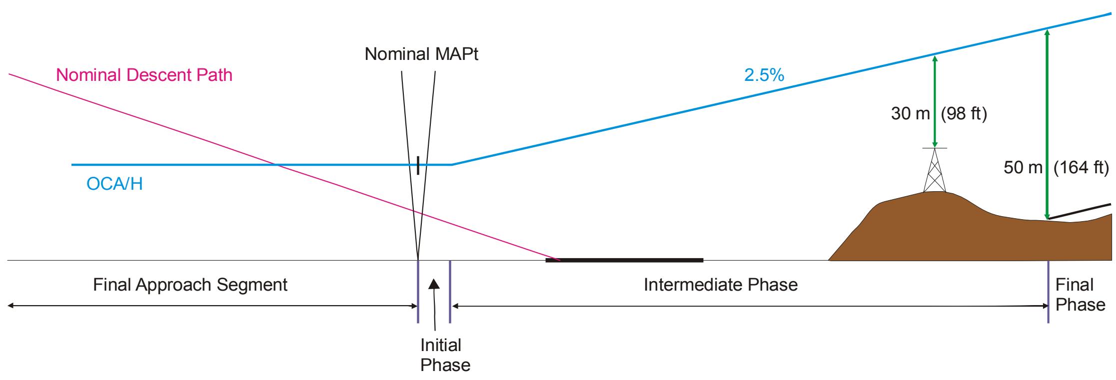
Final Phase

130. The final phase begins at the point where 164 ft (50 m) (for Cat H procedures, 131 ft (40 m)) of obstacle clearance is obtained and can be maintained. It extends to the point where a new approach, holding or a return to en-route flight is initiated.

Manoeuvres During the MAP

131. Turns during a MAP are only prescribed when necessary due to terrain or other factors. Speeds during the MAP are designed to ensure the aircraft remains within protected airspace. Pilots are expected to comply with instructions given on the chart without undue delay.

8-31 Fig 16 Missed Approach Phases



HELICOPTER PROCEDURES

132. There are several terms that are particular to helicopter procedures and are defined as follows:

a. **Height Above Landing** elevation (**HAL**).

b. **Height Above the Surface** (**HAS**) is the height of the MDA/DA above the highest terrain/surface within a 5200 ft radius of the MAPt in Point in Space procedures.

c. **Landing Area** refers to a portion of the heliport or airport runway used or intended to be used for helicopter landing and take-off.

d. **Landing Area Boundary** (**LAB**) is the beginning of the landing area of the heliport or runway.

e. **Point in Space Approach** is an instrument approach procedure to a point in space, identified as a missed approach point, which is more than 2600 ft from the landing area.

f. **Touchdown Zone** as used in helicopter procedures is identical to the landing area.

133. Helicopter only procedures shall bear an identification that includes the term 'COPTER', the type of facility providing the final approach course guidance and a numerical identification or the final approach course; e.g. COPTER VOR 090, COPTER NDB 270, COPTER PAR 327, COPTER ASR 327. If the procedure is designed for a runway, the runway identifier will be included, e.g. COPTER VOR RWY 30.

134. The criteria for helicopter procedures are based on airspeeds not exceeding 90 kt on the final approach and missed approach. For MIPS procedures, when a final approach speed of less than 90 kt is used, the maximum speed will be annotated on the approach plate.

135. **Point in Space Approach**. Where the centre of the landing area is more than 2600 ft from the MAPt, a point in space procedure may be developed. In such procedures, the point in space is the MAPt and, upon arrival at this point, helicopters shall proceed under VFR to the landing area or conduct the specified missed approach procedure.

136. **Descent Gradient**. The optimum descent gradient in all segments of helicopter approach procedures is 6.5% (400 ft/nm). However, to meet operational requirements, a gradient of as much as 13.1% (800 ft/nm) may be authorized. Gradients above 6.5% (400 ft/nm) shall be depicted on the approach chart.

Take-off and Landing Minima (Helicopters)

137. In the minima section of the procedure plate, the category is identified as 'H' followed by the abbreviated navaid and the final approach course heading, e.g. H-PAR 085 or H-PAR RWY 30 if the procedure is to a runway.

138. A decision height of 100 ft may be approved without approach lights (see also Table 8).

Visibility Minima

139. **Visibility Credit**. Where visibility credit for lighting facilities is allowed for fixed wing operations, the same type credit should be considered for helicopter operations. The approving authority will grant credit on an individual case basis. The minimum visibility required may be reduced by 0.4 km where approved approach light systems are operative. For precision approach procedures where RVR is approved and minima have been reduced to 0.4 km, RVR 400 m may also be authorized.

140. **Straight-in Minima**. The visibility minima for straight-in approaches are as follows:

a. **Non-precision Approaches**. (Landing area within 2600 ft of the MAPt). The minimum visibility required prior to applying credit for lights (see Para 124) is associated with the Height Above Landing elevation (HAL) as specified in Table 8.

Table 8 Effect of HAL on Visibility Minima

HAL (ft)	250-600	601-800	>800
Min Viz (km)	0.8	1.2	1.6

b. **Precision Approaches**. The minimum authorized visibility, prior to applying credit for lights, is 0.8 km (RVR 800 m).

141. **Take-off Minima**. Helicopter take-off minima will be in accordance with the appropriate national regulations.

Precision Approach Radar (PAR)

142. Navigational guidance for feeder routes, initial segments and intermediate segments may be provided by radar and/or other navigational facilities. The intermediate segment begins at the point where the initial approach course intercepts an extension of the final approach course and extends along the inbound final approach course to the point of interception of the glide slope. The minimum length of the intermediate segment is based on the angle if intersection between the initial approach and the intermediate course as follows:

Angle (degrees)	Minimum Length (nm)
30 and less	1.0
31-60	2.0
61-90	3.0
91-120	4.0

143. The final approach segment begins at the point of intercept of the glide path, the Final Approach Point (FAP). The final approach course shall be aligned to a landing area. The minimum distance from the FAP to the Ground Point of Intercept (GPI) is 2 nm.

144. For glide slope inoperative approaches, the Final Approach Fix (FAF) is on the final approach course within 5 nm of the landing threshold (but not less than the distance required by the descent gradient criteria). The FAF normally coincides with the FAP for PAR.

145. Glide slope angles greater than 6º shall not be established without the authorization of the approving authority.

146. The DH is adjusted wherever the glide slope angle exceeds 3.8º as follows:

GS Angle (deg)	3.00 to 3.80	3.81 to 5.70	Over 5.70
Minimum DH (ft)	100	150	200

Missed Approach Obstacle Clearance

147. No obstacle shall penetrate a 5% missed approach surface. The missed approach surface originates at the GPI elevation. When penetration of the 5% surface occurs, the DH may be raised by an amount equal to the maximum penetration of the surface or a higher climb gradient may be published. In this case the procedure will have two sets of DA/DH and associated minima, one standard and one for the higher climb gradient.

Human Factors and Departure, Arrival and Approach Procedures

There is little doubt that the most demanding flying and therefore the most potentially dangerous flying is when the aircraft is close to the ground. Rules, regulations and procedures are in place for good reasons and must be adhered to. Some procedures are complicated and can present potential for human error. Distraction, stress, weather, focussed attention and radio calls can degrade Situation Awareness and can be potentially fatal. Crew error in the approach phase of flight have resulted in numerous accidents. Think about minimising in-cockpit chat, adjust lighting for the conditions, remove possible distractions such as food and drink, plan and brief the approach early, rehearse the procedure during the transit if possible and if the cruise has been long and uninspiring consider a few minutes on 100% oxygen before top of descent.

NATO STANDARD

AFSP-2

AIRCRAFT MARSHALLING SIGNALS

Edition A Version 1

SEPTEMBER 2014

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED FLIGHT SAFETY PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

INTENTIONALLY BLANK

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

4 September 2014

1. The enclosed Allied Flight Safety Publication AFSP-2, Edition A, Version 1, AIRCRAFT MARSHALLING SIGNALS, which has been approved by the nations in the Military Committee Air Standardization Board, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 3117.

2 AFSP-2, Edition A, Version 1 is effective upon receipt.

3. No part of this publication may be reproduced, stored in a retrieval system, used commercially, adapted, or transmitted in any form or by any means, electronic, mechanical, photo-copying, recording or otherwise, without the prior permission of the publisher. With the exception of commercial sales, this does not apply to member nations and Partnership for Peace countries, or NATO commands and bodies.

4. This publication shall be handled in accordance with C-M(2002)60.

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

INTENTIONALLY BLANK

RESERVED FOR NATIONAL LETTER OF PROMULGATION

INTENTIONALLY BLANK

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

TABLE OF CONTENTS

INTENTIONALLY BLANK

CHAPTER 1 INTRODUCTION

1.1. AIM

1. The aim of this standard is to standardize aircraft marshalling signals and the distinctive garment to be worn by aircraft marshallers.

1.2. AGREEMENT

1. Participating nations agree that aircraft marshalling will be conducted as detailed herein. The signals described in Annexes A and B will be used, and marshallers will wear a distinctive garment (preferably of fluorescent international orange colour or yellow) except when operations dictate otherwise. Specialized signals or a complete list of the signals, which apply only to a particular aircraft or operational role are not included in this standard. They should continue to be included in the unit operating instructions and other specialized publications of the appropriate service.

1.3. GENERAL

1. The signals to an aircraft on the movement areas are designed for use by the marshallers facing the aircraft in the following position:

   a. For fixed wing aircraft, forward of the left wing tip within view of the pilot.

   b. For helicopters where the marshaller can best be seen by the pilot.

2. The signals described in Annexes A and B may be used by the pilot, as appropriate, in a similar way to that indicated.

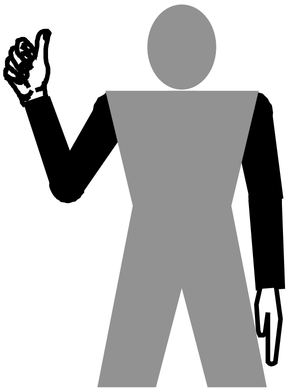
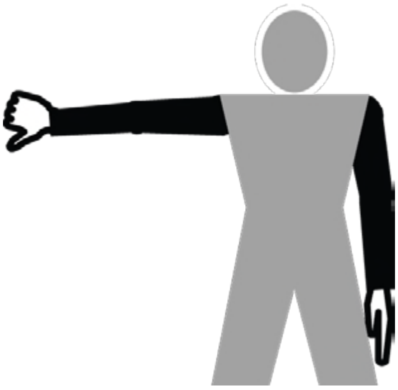
3. The night signals, except where noted, are the same as the day signals with wands pointing in the same direction as the thumbs. For night operations the wands will be used in pairs of the same colour and should not be too bright. During surface taxiing and parking the pilot will stop immediately when one or both of the marshaller's wands fail.

4. An effort was made to conform the NATO signals to the ICAO signals to the maximum extent possible. However, due to unique military operational considerations, some signals do not conform to ICAO signals. Additionally, some signals are unique to military operations and do not have an ICAO counterpart. Signals are compliant or non-compliant with ICAO as noted in Annexes. If there is no indication the signal is NATO only.

5. The signals located in Annex A are applicable for all aircraft. The signals located in Annex B are applicable to hovering aircraft.

INTENTIONALLY BLANK

ANNEX A - GENERAL MARSHALLING SIGNALS FOR ALL AIRCRAFT

DESCRIPTION	NATO SIGNAL
A-1 **<u>AFFIRMATIVE</u>** **<u>(I WILL COMPLY OR I UNDERSTAND)</u>** **DAY**: Hand raised, thumb up. **NIGHT**: For aircrew one flash. **ICAO COMPLIANT**	
A-2 **<u>NEGATIVE</u>** **<u>(NOT CLEAR OR I WILL NOT COMPLY)</u>** **DAY**: Hold right arm straight out parallel to the ground with hand displaying the "thumb down" with left hand remaining along body pointing down. **NIGHT**: For aircrew steady light. **ICAO COMPLIANT**	

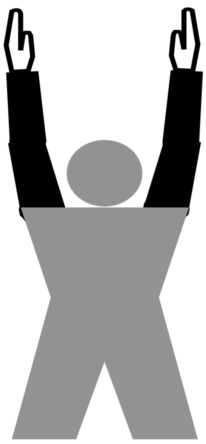
<table>
<tr><td>

A-3

THIS WAY

DAY: Arms above head in vertical position with palms facing inward.

ICAO COMPLIANT

</td><td></td></tr>
<tr><td>

A-4

PROCEED TO NEXT MARSHALLER

DAY: Right and left arm held vertically with hands pointing up, move and extend arms outward to sides of body and point with wands to direction of next signalman or taxi area.

ICAO COMPLIANT

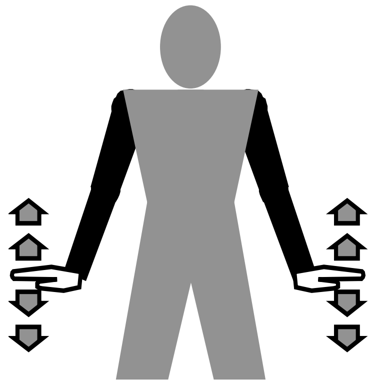
</td><td></td></tr>
<tr><td>

A-5

SLOW DOWN

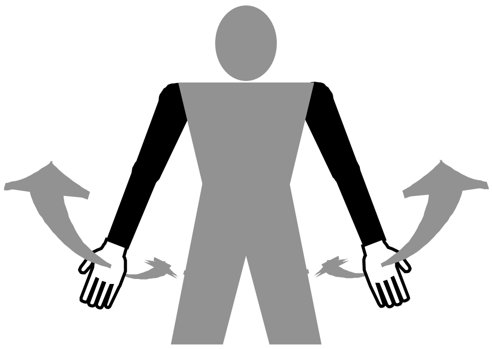
DAY: Arms down with palms toward ground, then moved up and down several times.

ICAO COMPLIANT

</td><td></td></tr>
</table>

A-6 **<u>TURN LEFT</u>** **DAY**: Hold both arms parallel to ground with hands extended sideways, left hand move repeatedly up and down. The rate of hand motion indicates to the pilot the rate of aircraft turn. **ICAO COMPLIANT**	
A-7 **<u>TURN RIGHT</u>** **DAY**: Hold both arms parallel to ground with hands extended sideways, right hand move repeatedly up and down. The rate of hand motion indicates to the pilot the rate of aircraft turn. **ICAO COMPLIANT**	
A-8 **<u>MOVE STRAIGHT AHEAD</u>** **DAY**: Extend both arms in front with palms up, move forearms up and down 90-degrees from chest height to head. **ICAO COMPLIANT**	

A-9 **<u>SET BRAKES</u>** **DAY**: Raise both arms above head with open palms forward, ensure visual contact with the flight crew then close both hands into a fist. Do not move until receipt of "thumbs up" from flight crew. **NIGHT**: Arms above head then wands crossed. **ICAO NON-COMPLIANT**	
A-9-A **<u>RELEASE BRAKES</u>** **DAY**: Raise both hands above shoulder height with closed fists facing the flight crew, ensure eye contact with the flight crew then open hand with palm forward. Do not move until receipt of "thumbs up" from flight crew. **NIGHT**: Crossed wands, then uncrossed. **ICAO NON-COMPLIANT**	

A-10 **<u>STOP</u>** **DAY**: Arms crossed above the head, palms facing forward. **ICAO COMPLIANT**	
A-10-A **<u>EMERGENCY STOP</u>** **DAY**: Same as A-10 but done rapidly and repeated until aircraft stops. **ICAO COMPLIANT**	
A-11 **<u>MOVE BACK</u>** **DAY**: Arms alongside body with palms facing forward, arms are swept forward and upward repeatedly to shoulder height. **ICAO NON-COMPLIANT**	

<table>
<tr><td>

A-12

<u>TURNS WHILE BACKING-TAIL TO LEFT</u>

DAY: Point right arm down and left arm brought from overhead, vertical position to horizontal forward position, repeating left arm movement.

ICAO COMPLIANT

</td><td></td></tr>
<tr><td>

A-13

<u>TURNS WHILE BACKING-TAIL TO RIGHT</u>

DAY: Point left arm down and right arm brought from overhead, vertical position to horizontal forward position, repeating right arm movement.

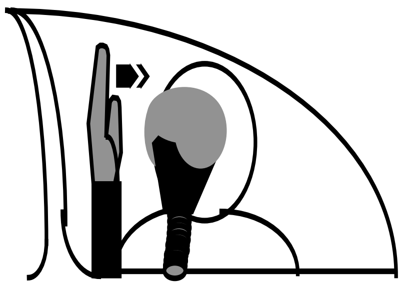
ICAO COMPLIANT

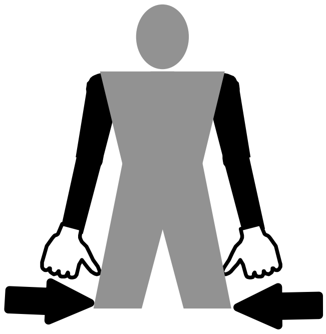
</td><td></td></tr>
<tr><td>

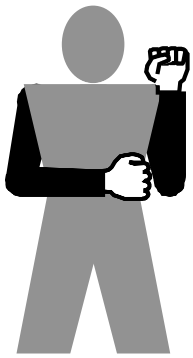
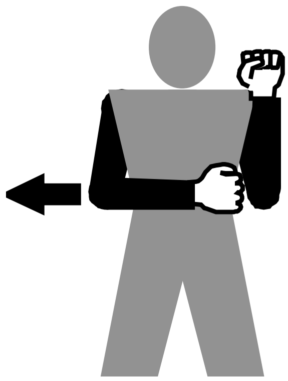
A-14

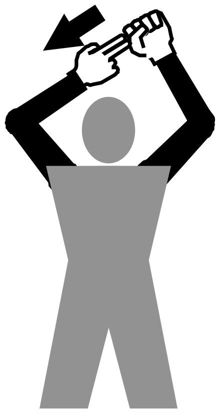
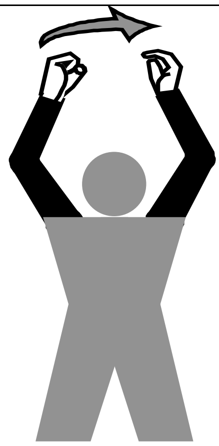
<u>REQUEST/CLEARANCE FOR PERSONNEL TO APPROACH AIRCRAFT</u>

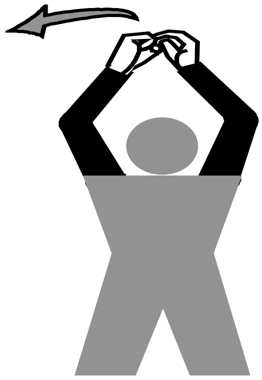
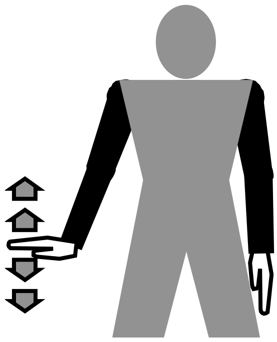
DAY: A beckoning motion with either hand at eye level.

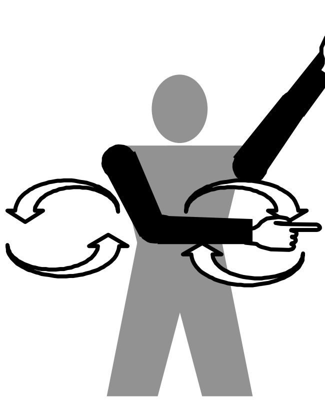
</td><td></td></tr>
</table>

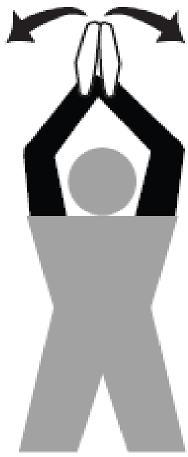
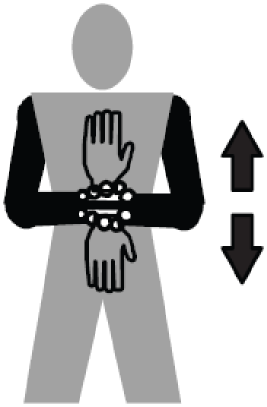
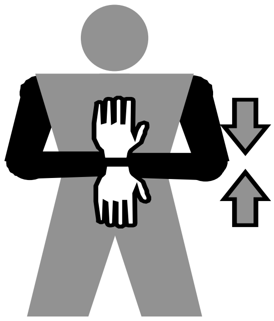
A-15 **<u>REQUEST BY MARSHALLER TO MOVE PERSONNEL TOWARD AIRCRAFT</u>** **DAY**: Either hand raised vertically above head, palm towards aircraft. The other hand held horizontally and indicating to pilot that personnel are standing-by to approach the aircraft.	
A-16 **<u>PERSONNEL APPROACH THE AIRCRAFT</u>** **DAY**: Either hand raised vertically overhead, palms towards aircraft. The other hand points to personnel standing-by and indicates where personnel are to proceed.	
A-17 **<u>INSERT CHOCKS</u>** **DAY**: Arms down, fists closed, thumbs extended inwards, swing arms from extended position inwards. **ICAO NON-COMPLIANT**	

A-18 **<u>REMOVE CHOCKS</u>** **DAY**: Arms down, fists closed, thumbs extended outwards, swing arms outwards. **ICAO NON-COMPLIANT**	
A-19 **<u>DOWN LOCKS / UNDERCARRIAGE PINS INSTALL</u>** **DAY**: Left arm bent vertically in front with fist clenched, right arm bent horizontally in front with fist clenched and held motionless at left elbow.	
A-20 **<u>DOWNLOCKS / UNDERCARRIAGE PINS REMOVE</u>** **DAY**: Left arm bent vertically in front with fist clenched, right arm bent horizontally in front with fist clenched and held motionless at left elbow. Right fist moves horizontally away from left elbow.	

A-21 **GROUND-ELECTRICAL POWER SUPPLY INSERT** **DAY**: Hands above head, left fist partially clenched, right hand moved in direction of left hand with first two fingers extended and inserted into circle made by fingers of the left hand. **ICAO NON-COMPLIANT**	
A-22 **GROUND-ELECTRICAL POWER SUPPLY DISCONNECT** **DAY**: Hands above head, left fist partially clenched, right hand moved away from left hand, withdrawing first two fingers from circle made by fingers of the left hand. **ICAO NON-COMPLIANT**	
A-23 **EXTERNAL AIR SUPPLY CONNECT** **DAY**: With hands above head, left hand cupped, right fist clenched and moved in direction of left hand and inserted into cup made by left hand.	

A-24 **<u>EXTERNAL AIR SUPPLY DISCONNECT</u>** **DAY**: Hands above head, left hand cupped, right fist moved away from left hand withdrawing fist from cup made by left hand.	
A-25 **<u>START ENGINE(S)</u>** **DAY**: Left hand overhead with appropriate number of fingers extended to indicate the number of the engine to be started, and circular motion of right hand at head level. **NIGHT**: Similar to the day signal except the wand in the left hand will be flashed to indicate the engine to be started. **ICAO COMPLIANT**	
A-26 **<u>SLOW DOWN ENGINES ON INDICATED SIDE</u>** **DAY**: Arms down, with either right or left arm moved up and down, palm facing down, indicating that left or right side engines respectively should be slowed down.	

ICAO COMPLIANT	
A-27 **CUT ENGINES** **DAY**: Either arm and hand level with shoulder, with hand moving across throat palm down. **ICAO COMPLIANT**	
A-28 **FIRE** **DAY**: Make rapid horizontal figure-of-eight motion at waist level with either hand, while other hand is pointing at source of fire. **ICAO NON-COMPLIANT**	
A-29 **TAILWHEEL LOCK** **DAY**: Wrists together overhead, hands opened to form a V, then close suddenly.	

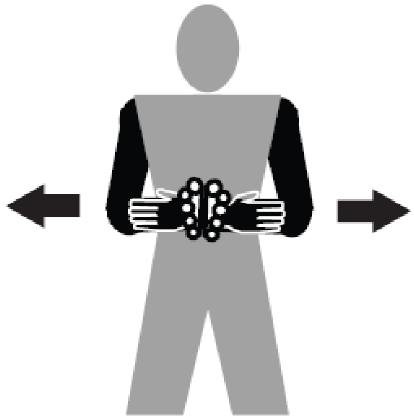
A-30 **TAILWHEEL UNLOCK** **DAY**: Hands overhead, palms together then hands opened from the wrist to form a V, wrists remaining together.	
A-31 **LOWER WING FLAPS** **DAY**: Hands in front, palms together horizontally then opened from the wrist crocodile-mouth fashion.	
A-32 **RAISE WING FLAPS** **DAY**: Hands in front, horizontally, with palms open from the wrists, then suddenly closed.	

<table>
<tr>
<td>

A-33

<u>OPEN AIR/SPEED BRAKES</u>

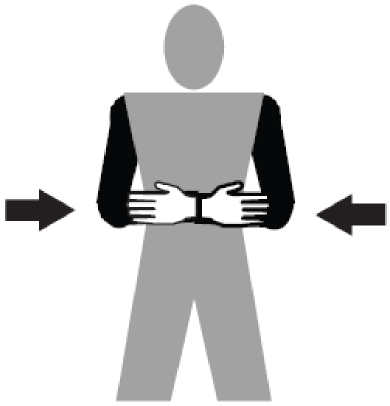
DAY: Hands in front at waist level with palms touching each other, open hands wide from the wrists junction.

</td>
<td></td>
</tr>
<tr>
<td>

A-34

<u>CLOSE AIR/SPEED BRAKES</u>

DAY: Hands open in front at waist level with wrists touching each other, close palms together.

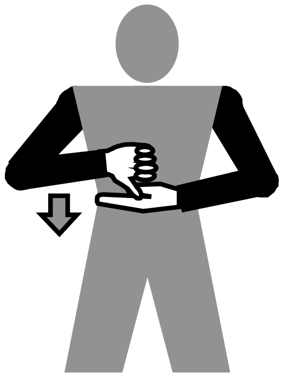
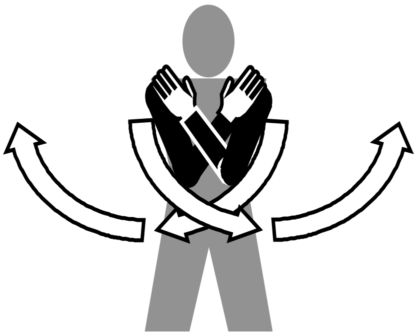
</td>
<td></td>
</tr>
<tr>
<td>

A-35

<u>TAILHOOK UP</u>

DAY: Right fist, thumb extended upward, raised suddenly to meet horizontal palm of left hand at chest level.

</td>
<td></td>
</tr>
</table>

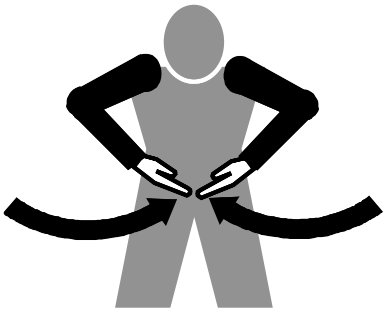
A-36 **TAILHOOK DOWN** **DAY**: Right fist, thumb extended downward, lowered suddenly to meet horizontal palm of left hand at waist level.	
A-37 **FOLD WINGS/HELICOPTER BLADES** **DAY**: Arms straight out at sides, then swept forward and hugged around shoulders.	
A-38 **SPREAD WINGS/HELICOPTER BLADES** **DAY**: Arms hugged around shoulders then swept straight out to the sides. Hold signal until wings/blades are locked, then give affirmative signal.	
A-39 **OPEN WEAPON BAY(S)DOOR(S)** **DAY**: Body bent forward at the waist, hands held with fingertips touching in front of the body and elbows bent at approximately 45 degrees, then arms swing downwards and outwards.	

<table>
<tr><td>

A-40

CLOSE WEAPON BAY(S) DOOR(S)

DAY: Body bent forward at the waist and arms extended horizontally, then arms swing down and in until finger tips touch in front of the body with elbows bent at approximately 45 degrees.

</td><td></td></tr>
<tr><td>

A-41

TAKE-OFF (FIXED WING AIRCRAFT)

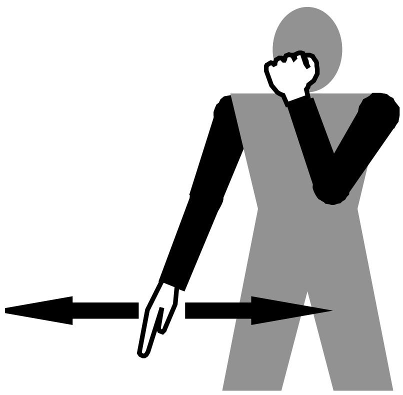
DAY: Marshall conceals left hand and makes circular motion of right hand above head in horizontal plane ending in a throwing motion of arm towards direction of take-off.

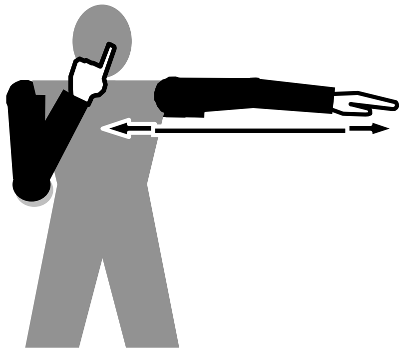
</td><td></td></tr>
<tr><td>

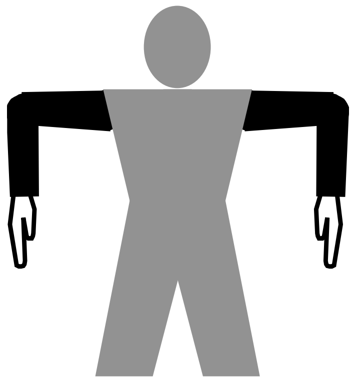
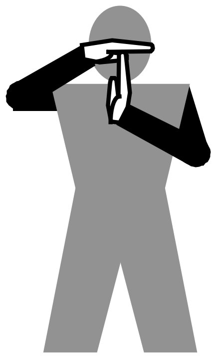
A-42

TILLER BAR/STEERING ARM IN PLACE

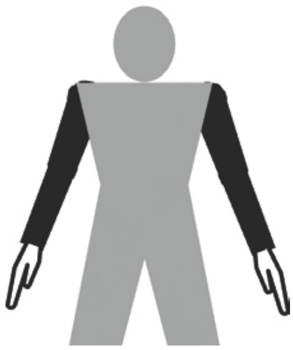
DAY: Hold nose with left hand, right hand moving horizontally at waist level. The affirmative signal immediately following signals means: SOMEONE IS TENDING BAR. A negative signal immediately following signals means: NO ONE IS TENDING BAR.

</td><td></td></tr>
</table>

A-43 **ENGAGE NOSEWHEEL STEERING** **DAY**: Point to nose with index finger while indicating direction of turn with other index finger.	
A-44 **DISENGAGE NOSEWHEEL STEERING** **DAY**: Point to nose with index finger, lateral wave with open palm of other hand at shoulder height.	
A-45 **ABANDON AIRCRAFT** **DAY**: Simulate unfastening seat belt and shoulder straps and throwing them up and off.	

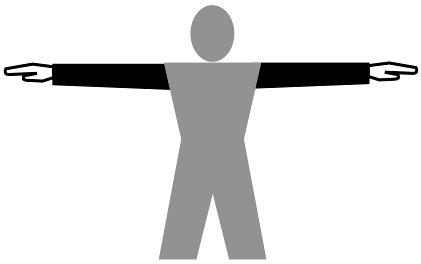
A-46 **<u>HOT BRAKES</u>** **DAY**: Arms extended with forearms perpendicular to the ground. Palms facing inward.	
A-47 **<u>VENTILATION</u>** **DAY**: Circular motions of right hand in horizontal plane, fist clenched, index finger stretched down, right arm extended, with forearm perpendicular to the ground.	
A-48 **<u>TELEBRIEF</u>** **DAY**: Make a "T" signal with hands at head level. **ICAO NON-COMPLIANT**	

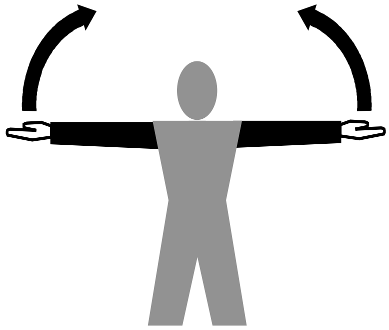
A-49 **<u>LASHINGS ON</u>** **DAY**: Hands in front at waist level, rotate in circular motion.	
A-49a **<u>LASHINGS OFF</u>** **DAY:** Hold left arm straight down along body. Bring right hand to left shoulder and sweep down to other hand. Repeat on the other side.	
A-50 **<u>FUEL SPILL</u>** **DAY**: Right hand is repeatedly drawn across the forehead with palm facing forward. Left hand points towards the fuel spill.	

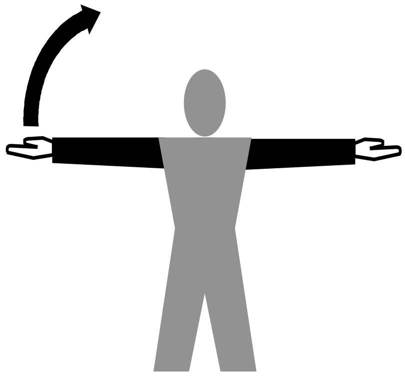
A-51 **WINGWALKER/GUIDE** **DAY**: Raise right hand above head level with fingers pointing up, move left hand up and down with palm facing down toward body. **ICAO COMPLIANT**	
A-52 **HOLD POSITION/STAND BY** **DAY**: Fully extend arms downwards at a 45-degree angle to sides with palms facing inwards. Hold position until aircraft is clear for next maneuver.	
A-53 **DISPATCH AIRCRAFT** **DAY**: Perform a standard salute with right hand to dispatch the aircraft. Maintain eye contact with flight crew until aircraft has begun to taxi. **ICAO COMPLIANT**	

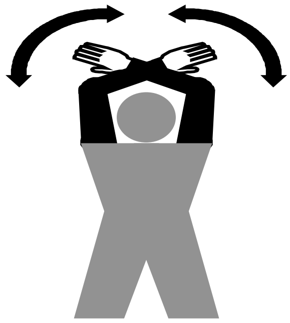
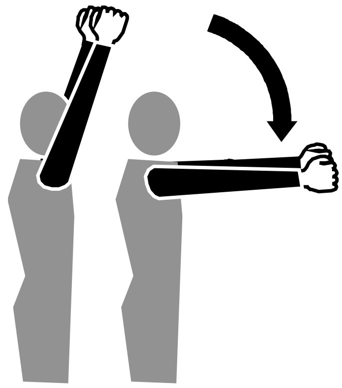
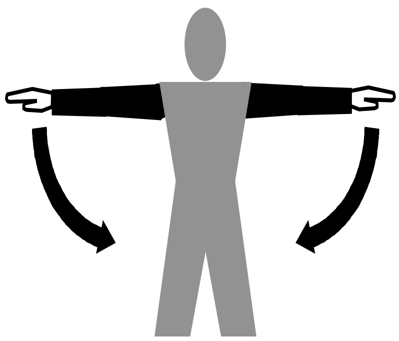
A-54 **DO NOT TOUCH CONTROLS** **DAY**: Extend right arm above head with a closed fist. Left arm remains steady at side along body. **ICAO COMPLIANT**	
A-55 **OPEN/CLOSE STAIRS** **DAY**: With right arm at side of body and left arm raised above head at a 45-degree angle, move right arm in a sweeping motion towards top left shoulder. **ICAO COMPLIANT**	

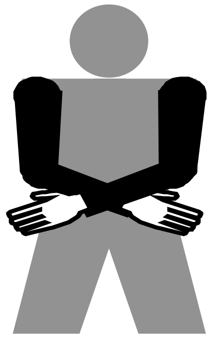
ANNEX B - SIGNALS FOR SPECIAL AIRCRAFT (HOVERING, VTOL AND AIR CUSHION VEHICLES)

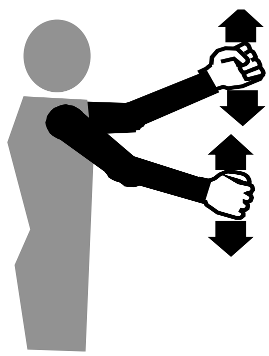
B-1 **<u>TAKE OFF</u>** **DAY**: Arms extended horizontally sideways beckoning upwards.	
B-2 **<u>HOVER</u>** **DAY**: Arms extended horizontally sideways, palms downwards. **ICAO COMPLIANT**	

B-3 **<u>MOVE UPWARDS</u>** **DAY**: Arms extended horizontally sideways beckoning upwards, with palms turned up. Speed of movement indicates rate of ascent. **ICAO COMPLIANT**	
B-4 **<u>MOVE TO LEFT</u>** **DAY**: Both arms extended horizontally, left arm is raised vertically in a repeating movement. **ICAO NON-COMPLIANT**	

B-5 **<u>MOVE TO RIGHT</u>** **DAY**: Both arms extended horizontally, right arm is raised vertically in a repeating movement. **ICAO NON-COMPLIANT**	
B-6 **<u>CLEAR</u>** **DAY**: Both arms extended on same side above shoulder level in direction clear to fly off.	
B-7 **<u>LOWER WHEELS</u>** **DAY**: When aircraft approaches with landing gear retracted, marshaller gives signal by side view of a cranking circular motion of the hands.	

B-8 **WAVE OFF** **DAY**: Waving of arms over the head.	
B-9 **LANDING DIRECTION** **DAY**: Marshaller stands with arms raised vertically above head and facing towards the point where the aircraft is to land. The arms are lowered repeatedly from a vertical to a horizontal position, stopping finally in the horizontal position. **ICAO NON-COMPLIANT**	
B-10 **MOVE DOWNWARDS** **DAY**: Arms extended horizontally sideways beckoning downwards with palms turned down. Speed of movement indicates rate of descent. **ICAO COMPLIANT**	

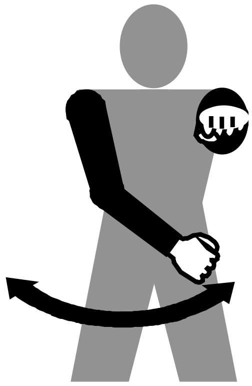
B-11 **<u>LAND</u>** **DAY**: Arms crossed and extended downwards in front of the body. **ICAO COMPLIANT**	
B-12 **<u>DROOP STOPS OUT</u>** **DAY**: When rotor starts to run down, marshaller stands with both hands raised above head, fists closed, thumbs pointing out.	
B-13 **<u>DROOP STOPS IN</u>** **DAY**: When droop stops go in, marshaller turns thumbs inwards.	

B-14 **<u>REMOVE BLADE TIE-DOWNS</u>** **DAY**: Left hand above head, right hand pointing to individual boots for removal.	
B-15 **<u>ENGAGE ROTOR(S)</u>** **DAY**: Circular motion in horizontal plane with right hand above head.	
B-16 **<u>HOOK UP LOAD</u>** **DAY**: Rope climbing motion with hands.	

B-17

RELEASE LOAD

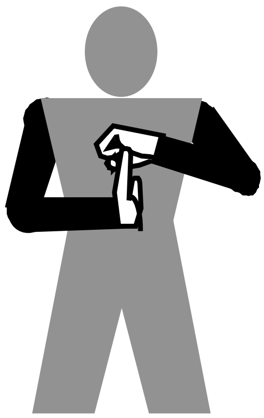
DAY: Left arm extended forward horizontally, fist clenched, right hand making vertical pendulous movement with first clenched.



B-18

TROUBLE WITH LOAD

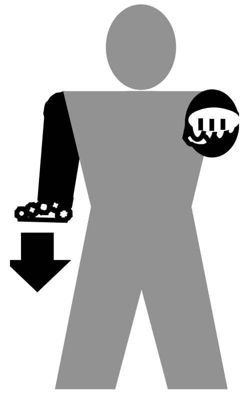
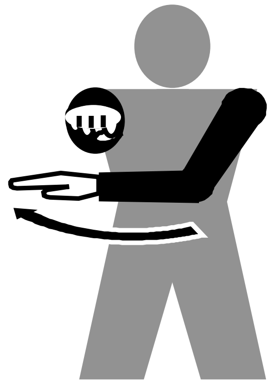
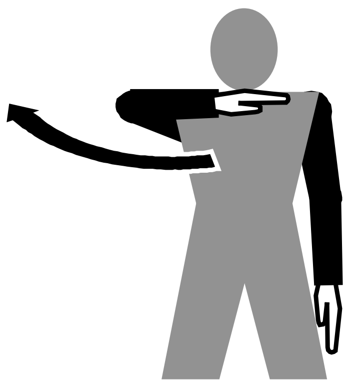
DAY: Bend left arm horizontally across chest with fist clenched, palm downwards; open right hand pointed up vertically to center of left fist.

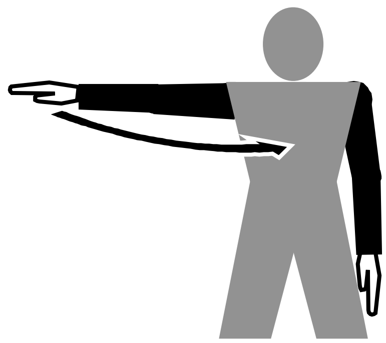
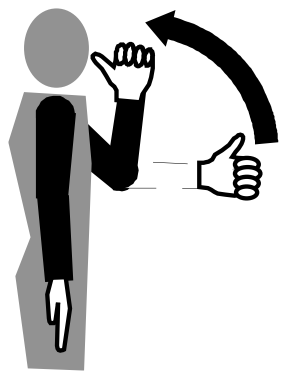


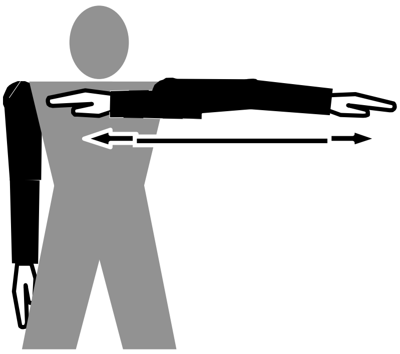
B-19

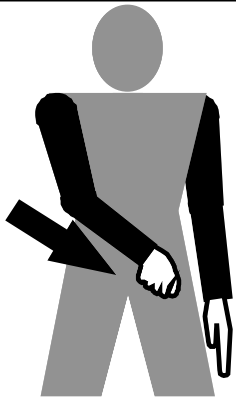
WINCH UP

DAY: Left arm horizontally stretched in front of body at shoulder height, fist clenched. Right arm, with palm turned upwards, making upward motion.

B-20 **WINCH DOWN** **DAY**: Left arm horizontally stretched in front of body, fist clenched. Right arm, with palm turned downwards making downward motion.	
B-21 **CUT CABLE** **DAY**: Right arm extended forward horizontally, fist clenched, left arm making horizontal slicing movements below the right fist, palm downward.	
B-22 **SPREAD PYLON** **DAY**: Bend elbow across chest, palm downward. Extend arm outward to horizontal position, keeping palm open and facing down.	

B-23 **<u>FOLD PYLON</u>** **DAY**: Extend right arm horizontally, palm downward. Bend arm across chest, keeping palm down.	
B-24 **<u>I DESIRE HIFR</u>** **DAY**: Helo crewmember brings thumb to mouth as if drinking from a glass.	
B-25 **<u>COMMENCE FUELLING</u>** **DAY**: Helo crewmember makes circular motion with right hand.	

B-26 **FUELLING COMPLETE** **DAY**: Helo crewmember/ground crew member makes vertical motion of hand.	
B-27 **CEASE FUELLING** **DAY**: Helo crewmember/ground crew member makes horizontal motion with palm of right hand across body at shoulder height.	
B-28 **HARPOON UP** **DAY**: Right hand moving up and across the body from left thigh (as if drawing a sword).	

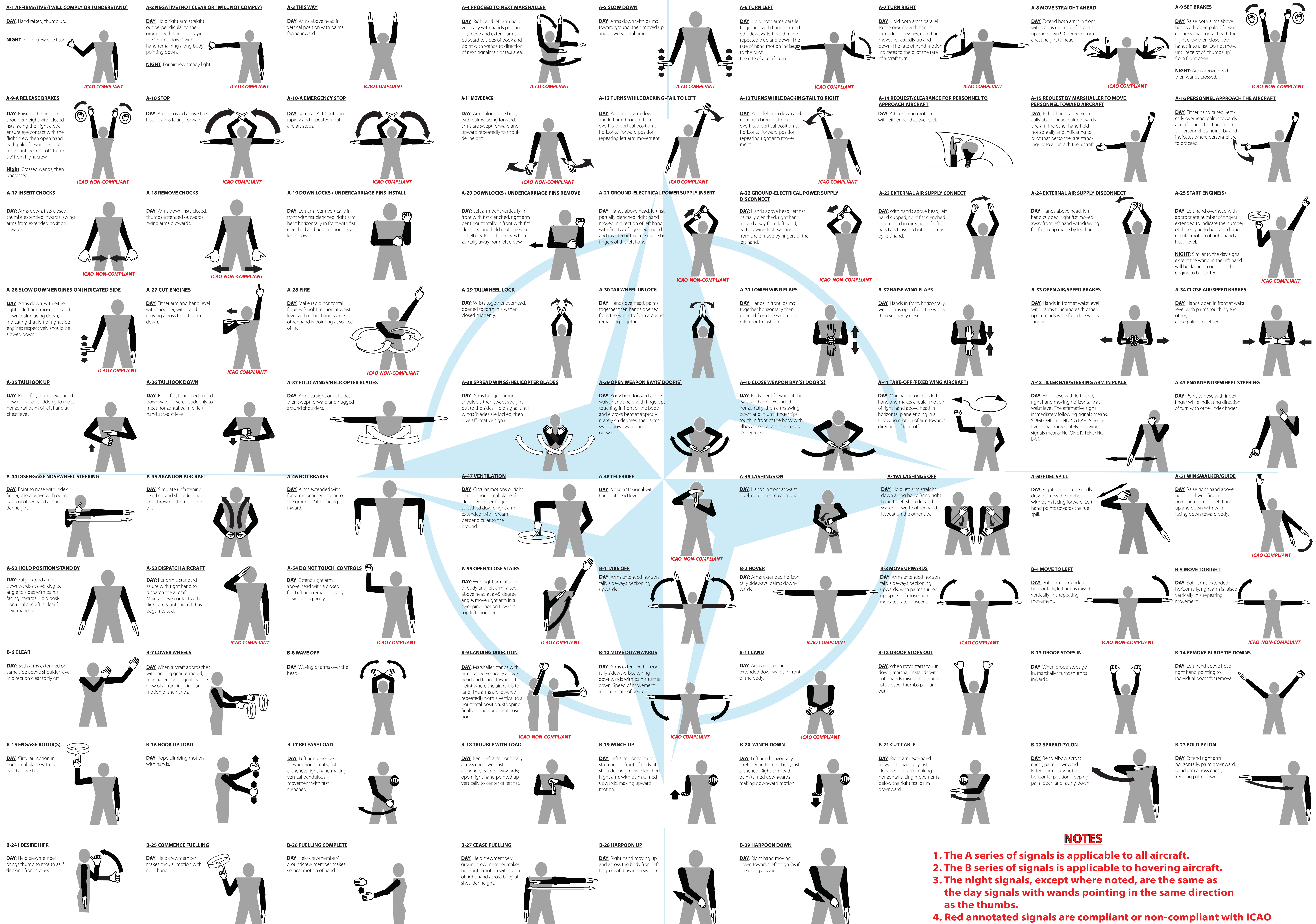
B-29 **<u>HARPOON DOWN</u>** **DAY**: Right hand moving down towards left thigh (as if sheathing a sword).	

INTENTIONALLY BLANK

SEE ATTACHED ZIP FILE

AFSP-2(A)(1)

AIRCRAFT MARSHALLING SIGNALS



Reference: NATO STAGNAG 3117 Edition 9/ AFSP-2 Edition A V1.0

AP3456
The Central Flying School (CFS) Manual of Flying

Version 9.0 – 2017

Volume 9 – Navigation

AP3456 is sponsored by the Commandant Central Flying School

Contents

CHAPTER 1 - THE EARTH, DISTANCE, AND DIRECTION

Contents **Page**

Table of Figures

THE EARTH

The Form of The Earth

1. For most navigational purposes the Earth is assumed to be a perfect sphere, although in reality it is not. For many centuries man has been concerned about the shape of the Earth; the early Greeks in their speculation and theorizing ranged from the flat disc to the sphere, and even cylindrical and rectangular Earths have been propounded.

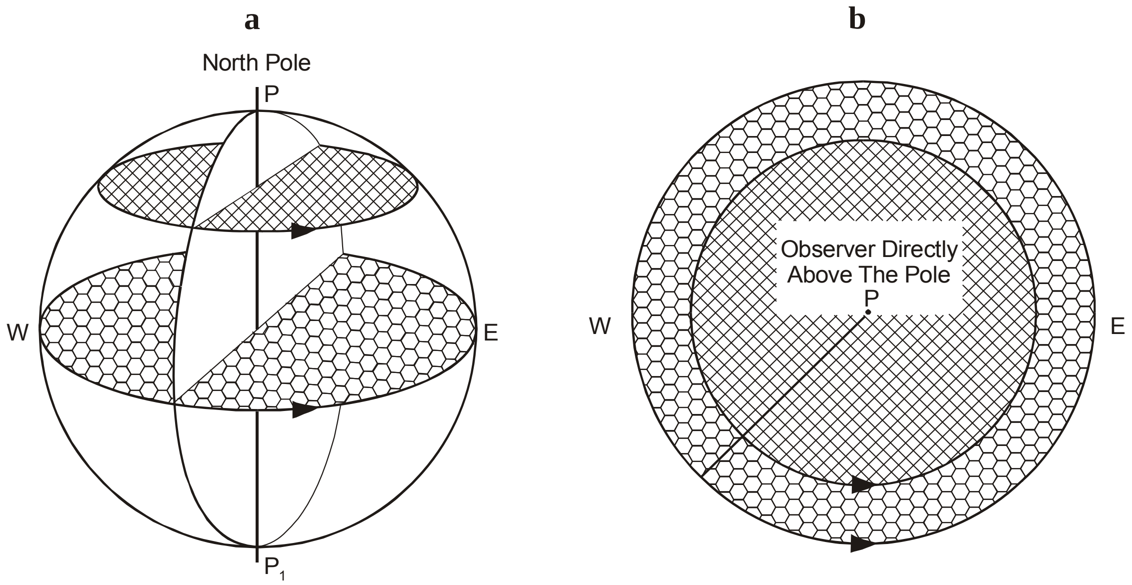
2. The basic shape of the Earth is almost spherical, being slightly flattened at the poles. This shape is more properly termed an oblate spheroid, which is the figure generated by the revolution of an ellipse about its minor axis. Because of this flattening, the Earth's polar diameter is approximately 27 statute miles shorter than its average equatorial diameter.

3. The ratio between this difference and the equatorial diameter is termed the compression of the Earth, and indicates the amount of flattening. This ratio is approximately 1/300 but geodetic information obtained from satellite measurements indicates that the Earth is very slightly 'pear-shaped', the greater mass being in the southern hemisphere.

4. **The Poles.** The extremities of the diameter about which the Earth rotates are called poles. In Fig 1a these are represented by P and P_1.

5. **East and West.** East is defined as the direction in which the Earth is rotating. This direction, anti-clockwise to an observer looking down on the pole P, is shown by the arrows in Figs 1a and b. West is the direction opposite to East.

9-1 Fig 1 Earth References



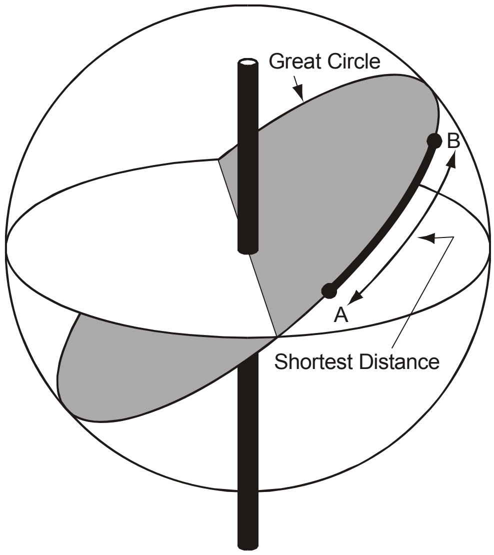
6. **North and South.** The two poles are distinguished arbitrarily; the North Pole (P in Fig 1a) is said to be the pole which lies to the left of an observer facing East. North is therefore that direction in which an observer would have to move in order to reach the North Pole; it is at right angles to the East-West direction. The other pole (P_1 in Fig 1a) is known as the South Pole. The directions East, West, North and South are known as the cardinal directions.

Lines Drawn on the Earth

7. The shortest distance between two points is the length of the straight line joining them. It is, however, impossible to draw a straight line on a spherical surface and so all lines drawn on the Earth are curved, some regularly and others irregularly. The regularly curved imaginary lines on the Earth which are of interest to the navigator are described below.

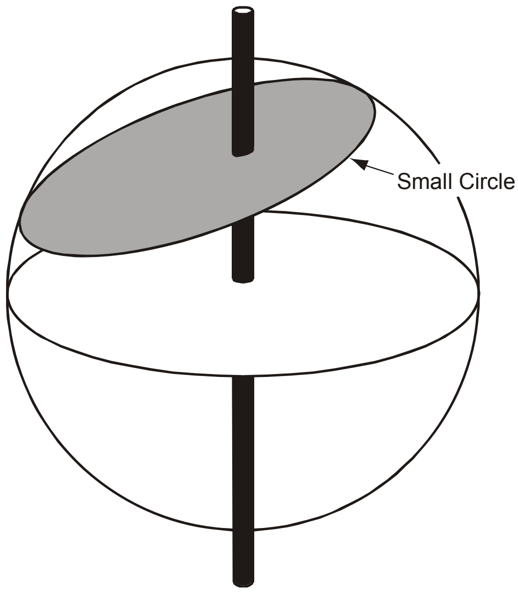
8. **Great Circle**. A great circle is a circle on the surface of a sphere whose centre and radius are those of the sphere itself. Because its plane passes through the centre of the sphere, the resulting section is the largest that can be obtained, hence the name great circle. Only one great circle may be drawn through two places on the surface of a sphere which are not diametrically opposed. The shortest distance between any two points on the surface of a sphere is the smaller arc of the great circle joining them (see Fig 2).

9-1 Fig 2 Great Circle



9. **Small Circle.** A small circle is a circle on the surface of a sphere whose centre and radius are not those of the sphere. All circles other than great circles on the surface of a sphere are small circles (see Fig 3).

9-1 Fig 3 Small Circle

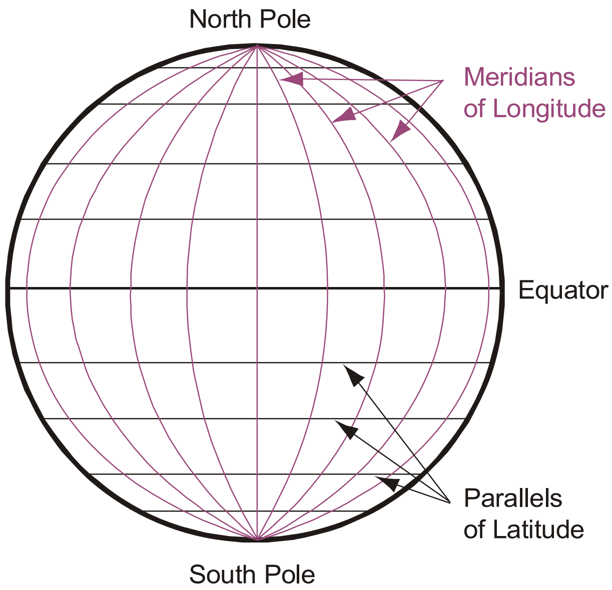


10. **The Equator**. The equator is the great circle whose plane is perpendicular to the axis of rotation of the Earth. Every point on the equator is therefore equidistant from both poles. The equator lies in an East-West direction and divides the Earth into northern and southern hemispheres.

11. **Meridians.** Meridians are semi-great circles joining the poles; every great circle joining the poles forms a meridian and its anti-meridian. All meridians indicate North-South directions.

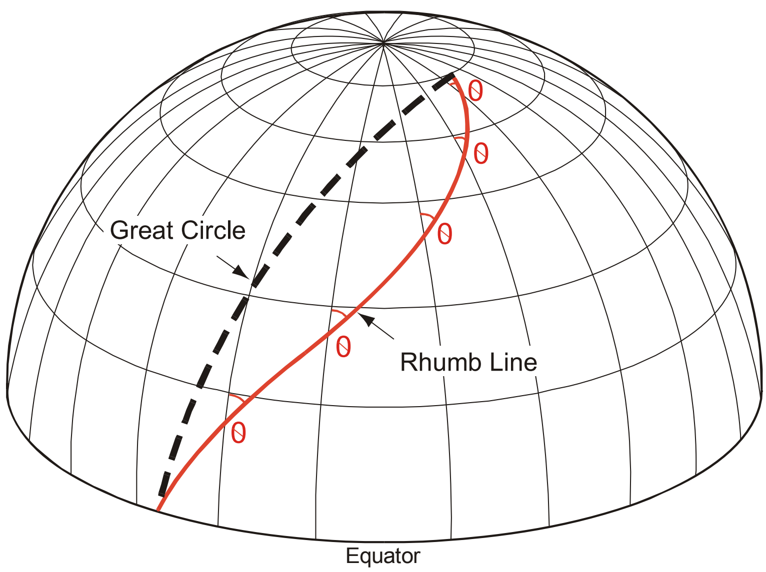
12. **Parallels of Latitude.** Parallels of latitude are small circles on the surface of the Earth whose planes are parallel to the plane of the equator. They therefore lie in an East-West direction (see Fig 4).

9-1 Fig 4 Equator, Meridians and Parallels



13. **Rhumb Line.** A rhumb line is a regularly curved line on the surface of the Earth cutting all meridians at the same angle. Only one such line may be drawn through any two points. Parallels of latitude are rhumb lines as are the meridians and the equator, though the latter two are special cases as they are the only examples of rhumb lines which are also great circles. Thus, when two places are situated elsewhere than on the equator or on the same meridian, the distance measured along the rhumb line joining them is not the shortest distance between them. However, the advantage of the rhumb line is that its direction is constant, therefore the rhumb line between two points may be followed more conveniently than the great circle joining them since the direction of the latter changes continuously with reference to the meridians. The saving in distance effected by flying a great circle rather than a rhumb line increases with latitude but it is appreciable only over great distances, consequently flights of less than 1,000 miles are usually made along the rhumb line. Rhumb lines are convex towards the equator (excepting parallels of latitude, the equator and meridians) and lie nearer the equator than the corresponding great circles (see Fig 5).

9-1 Fig 5 Rhumb Line



Earth Convergence

14. From Fig 5 it can be seen that the meridians are only parallel to one another where they cross the equator, elsewhere the angle of inclination between selected meridians increases towards the poles. This angle of inclination between selected meridians at a particular latitude is known variously as Earth convergence, true convergence, meridian convergence and convergency.

UNITS OF MEASUREMENT

Angular Measurement

15. The sexagesimal system of measuring angles is universally employed in navigation. In this system the angle subtended at the centre of a circle by an arc equal to the 360th part of the circumference is called a degree; each degree is subdivided into 60 minutes (') and each minute into 60 seconds ("). Thus the size of any angle may be expressed in terms of degrees, minutes and seconds.

16. In spherical calculations it is frequently convenient to express spherical distances (ie great circle distances) in terms of angular measurement rather than in linear units. This is possible because of a simple relationship between the radius, arc, and angle at the centre of a circle. Thus the length of the arc of a great circle on the Earth might be expressed as 10º 38'; this would convey little unless there were some ready means of converting angular units to linear units. This difficulty of converting from angular to linear units has been overcome by the definition of the standard unit of linear measurement on the Earth, the nautical mile.

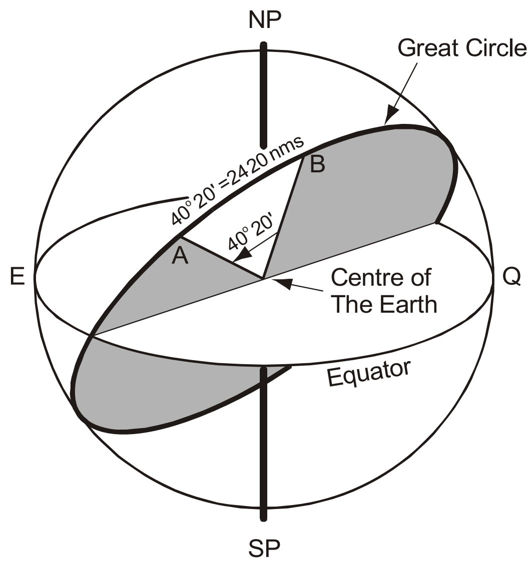
Measurement of Distance

17. Assuming the Earth to be a true sphere, a nautical mile is defined as the length of the arc of a great circle which subtends an angle of one minute at the centre of the Earth. Thus the number of nautical miles in the arc of any great circle equals the number of minutes subtended by that arc at the centre of the Earth. The conversion of an angular measurement of spherical distance to linear units requires only the reduction of the angle to minutes of arc; the number of minutes is equal to the spherical distance in nautical miles.

18. In Fig 6a, if AB, the arc of a great circle, subtends an angle at the Earth's centre of 40º 20', AB is said to be 40º 20' in length. Forty degrees 20 minutes is equivalent to 2,420 minutes of arc which is equal to a length of 2,420 nautical miles.

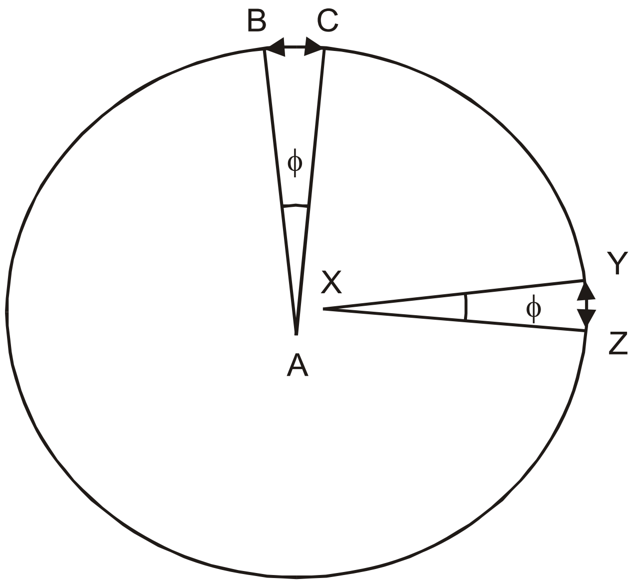
9-1 Fig 6 Angular Distance and the Nautical Mile

Fig 6a Angular Distance



19. Because of the Earth's uneven shape the actual length of the nautical mile is not constant, but varies with latitude from 6,046 feet at the equator to approximately 6,108 feet at the poles. A more accurate definition of the nautical mile than that given in para 17 is that it is the length of the arc on the Earth's surface that subtends an angle of one minute at its own centre of curvature. In Fig 6b the arc BC is on a comparatively flat part of the spheroid and the distance to the centre of curvature is relatively long (AB or AC); therefore an angle ϕ is subtended by a comparatively long arc BC. The arc YZ is at a comparatively curved part of the spheroid, the distance to the centre of curvature (XY or XZ) is shorter and the angle ϕ is subtended by a shorter arc length. However, for the purpose of navigation a fixed unit of measurement is helpful. Until 1 March 1971 this was the UK Standard Nautical Mile of 6,080 feet. Since that time the International Nautical Mile of 1,852 metres (6,076.1 feet) has been adopted as the standard unit of distance for air navigation.

Fig 6b Nautical Mile



20. The other mile unit in common use is the statute mile (so called because its length, 5,280 feet, is determined by law). The statute mile evolved from the Roman "milia passuum" (1,000 paces - approximately 4,860 feet). Unlike the nautical mile, the statute mile is not readily converted into angular measurement terms.

21. **Metric Units.** The SI unit of distance is the kilometre. One kilometre is the length of 1/10,000th part of the average distance between the equator and either pole; it is equivalent to 3,280 feet.

Speed

22. Speed is a rate of change of position. It is usually expressed in linear units per hour. As there are three main linear units, there are three expressions of speed:

a. Nautical miles per hour, stated as "knots" (kt).

b. Miles (ie statute miles) per hour (mph).

c. Kilometres per hour (km/hr).

DIRECTION

Direction on the Earth

23. In order to fly in a given direction it is necessary to be able to refer to a datum line or fixed direction whose orientation is known or can be determined. The most convenient datum is the meridian through the current position, since it is the North-South line. By convention, direction is measured clockwise from North to the nearest degree, i.e. from 000º to 360º. It is always expressed as a three-figure group; thus East, which is 90º from North, is written 090º, and West is 270º.

24. **True Direction**. Direction measured with reference to True North, the direction of the North geographic pole, is said to be the True direction. True direction has the following advantages:

a. It is a constant directional reference (ie True direction about a point does not change with time).

b. It is the basis of nearly all maps and charts.

c. It is the direct and continuous output from inertial systems.

However, magnetic direction continues to be used as an aircraft heading reference and as the basic direction reference in non-inertial systems.

25. **Magnetic Direction.** The Earth acts as though it is a huge magnet whose field is strong enough to influence the alignment of a freely suspended magnetic needle any where in the world. The poles of this hypothetical magnet are known as the North and South magnetic poles and, like those of any magnet, they can be considered to be connected by lines of magnetic force. Although the magnetic and geographic poles are by no means coincident (the respective North poles are separated by approximately 900 nm), the lines of force throughout the equatorial and temperate regions are roughly parallel to the Earth's meridians. A freely suspended magnetic needle will take up the direction indicated by the Earth's lines of force and thus assume a general North-South direction; the actual direction in which it points, assuming no other influences are acting upon it, is said to be Magnetic North. With such a datum available it is possible to measure magnetic direction. If, at any given point, the angular difference between the directions of Magnetic North and True North is known, then it is possible to convert Magnetic direction to True direction.

Variation

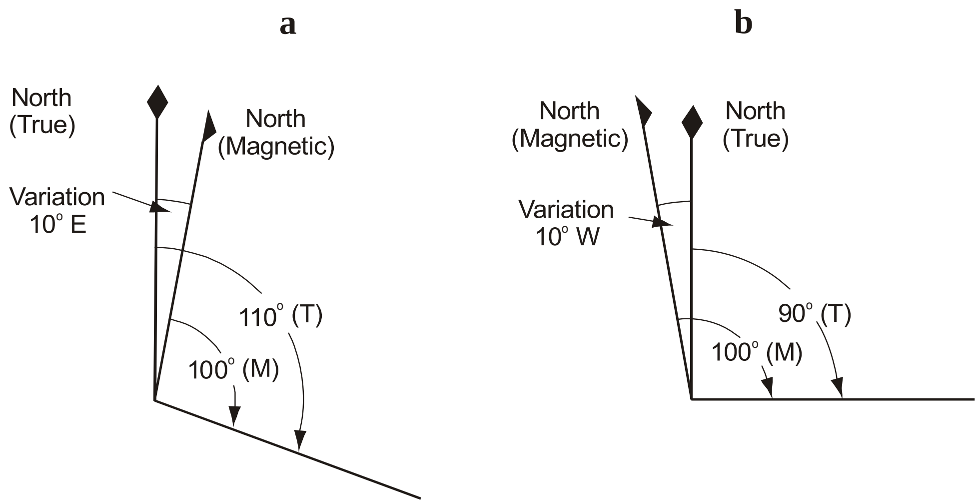
26. The angular difference between the direction of True North and Magnetic North at any given point, and therefore between all True directions and their corresponding Magnetic directions at that point, is called Variation. Variation is measured in degrees and is named East (+) or West (–) according to whether the North-seeking end of a freely-suspended magnetic needle, influenced only by the Earth's field, lies to the East or West of True North at any given point. The algebraic sign given to Variation indicates how it is to be applied to magnetic direction to convert it to True direction. At any point, therefore, the True direction can be determined by measuring Magnetic direction and then applying the local Variation (see Fig 7). A useful mnemonic is:

"Variation East, Magnetic least,
Variation West, Magnetic best."

9-1 Fig 7 Variation

In Fig 7a it can be seen that:		
Magnetic direction	=	100º (M)
Variation	=	10º E (+)
∴ True direction	=	110º (T)

In Fig 7b it can be seen that:		
Magnetic direction	=	100º (M)
Variation	=	10º W (–)
∴ True direction	=	090º (T)



Isogonals

27. Variation is not constant over the Earth's surface, but varies from place to place. This change is gradual and follows a more or less regular pattern. By means of a magnetic survey, the variation at numerous points is accurately measured and tabulated. From such a survey, it is possible to discover a number of points where variation has the same value. Lines joining these points of equal variation are known as isogonals, and these lines are printed on maps and charts.

28. The variation at any given point is not a fixed quantity, but is subject to gradual change with the passage of time because the magnetic axis of the Earth is constantly changing. This change, which is indicated in the margin of the chart, is not large but, in certain places, may amount to as much as one degree in five years. It is important, therefore, that charts indicate the date to which variation values apply, and also the annual change, so that the isogonal values may be updated.

Deviation

29. When a freely-suspended magnetic needle is influenced only by the Earth's magnetic field, the direction it assumes is known as Magnetic North. If such a needle is placed in an aircraft, it is subject to a number of additional magnetic fields created by various electrical circuits and magnetized pieces of metal within the aircraft; consequently its North-seeking end deviates from the direction of magnetic North and indicates a direction known as compass North.

30. The angular difference between the direction of Magnetic North and that of Compass North, and therefore all Magnetic directions and their corresponding Compass directions, is called Deviation. Deviation is measured in degrees and is named East (+) or West (–) according to whether the North-seeking end of a compass needle, under various disturbing influences, lies to the East or West of Magnetic North. The algebraic sign given to deviation indicates how it is to be applied to compass direction to convert it to Magnetic direction.

31. Deviation is not, as might be imagined, a constant value for a given compass; instead it varies with the heading of the aircraft. Nor is the deviation experienced by two different compasses likely to be the same under identical conditions (see Volume 5, Chapter 15). Thus, in order to convert the directions registered by a particular compass to Magnetic directions, a tabulation of the deviations of that compass, found on various headings, is required. Such a tabulation of the deviation, usually in the form of a card, must be provided and placed near the compass to which it applies. The method by which compass cards are produced (known as 'compass swinging') is covered in detail in Volume 5, Chapter 16.

32. The deviation of a compass will change as its position in the aircraft is changed. Deviation will also change, over a period of time, due to changing magnetic fields within the aircraft. Moreover, as the aircraft flies great distances over the Earth, changes occur in deviation because of the Earth's changing magnetic field. It is not sufficient, therefore, to prepare a deviation card and expect it to last indefinitely, the card must be renewed at frequent intervals in order that it may always record the deviation as accurately as possible. A useful mnemonic for the application of deviation is:

"Deviation East, compass least,
Deviation West, compass best."

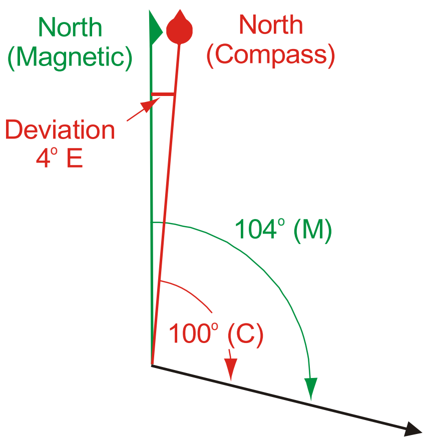
Figure 8 illustrates the two cases, Deviation East and Deviation West, for the following values:

9-1 Fig 8 Deviation

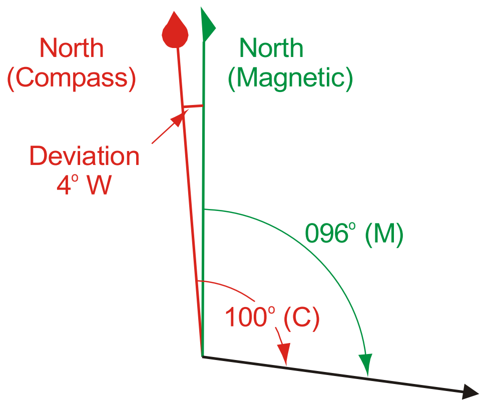
Fig 8a	
Compass direction	100° (C)
Deviation	4° E (+)
Magnetic direction	104° (M)

Fig 8b	
Compass direction	100° (C)
Deviation	4° W (–)
Magnetic direction	096° (M)

a Deviation East



b Deviation West

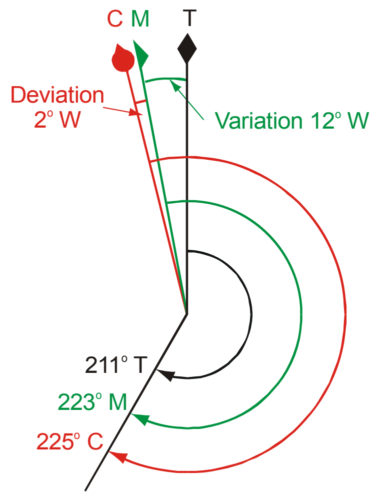


Derivation of True Direction

33. It is possible, therefore, to express a direction given with regard to a particular compass needle as True direction, provided that deviation and variation are known. To avoid the complications arising from the changing values of variation and deviation during flight, plotting is usually carried out using true directions. An example is shown in Fig 9:

9-1 Fig 9 Three Expressions for Direction

Compass direction	225º (C)
Deviation	2º W (–)
Magnetic direction	223º (M)
Variation	12º W (–)
True direction	211º (T)



CHAPTER 2 - POSITION

Contents **Page**

Table of Figures

Table

Introduction

1. Since air navigation is the process of directing an aircraft from one point to another, it is essential to be able to define these points as positions on the Earth's surface.

LATITUDE AND LONGITUDE

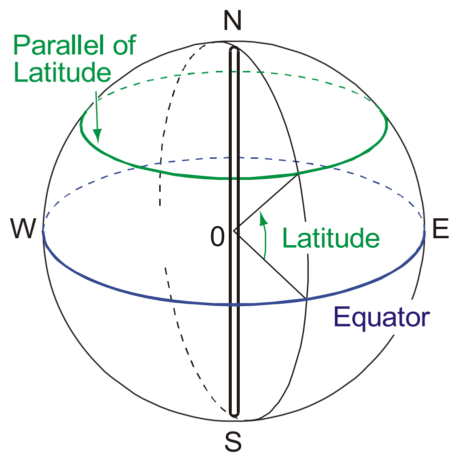
General

2. On the Earth, position is normally defined by a reference system known as latitude and longitude.

Latitude

3. Latitude is defined as the angular distance from the equator to a point, measured northward or southward along the meridian through that point. This quantity is expressed in degrees, minutes and seconds and is annotated N or S according to whether the point lies North or South of the equator (see Fig 1).

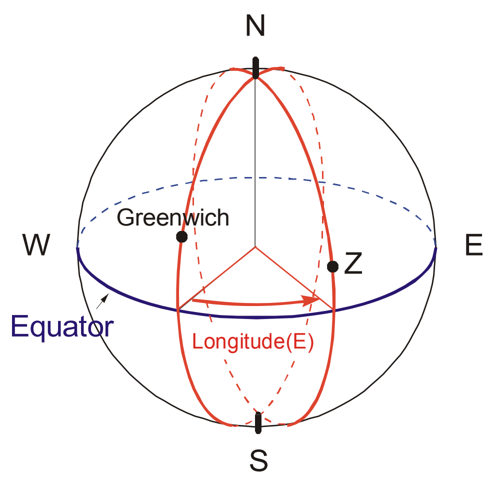
9-2 Fig 1 Latitude



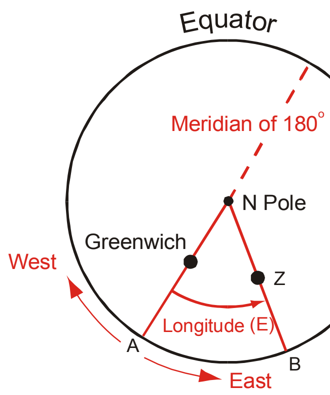
Longitude

4. The longitude of any point is the shorter angular distance along the equator between the meridian running through Greenwich (the Greenwich or Prime Meridian) and the meridian through the point (Fig 2). It is expressed in degrees minutes and seconds, and is annotated E or W according to whether the point lies to the East or West of the Greenwich Meridian. As the plane of the Greenwich Meridian bisects the Earth, longitude cannot be greater than 180º East or West (Fig 3).

9-2 Fig 2 Longitude



9-2 Fig 3 Extremes of Longitude



Recording Position

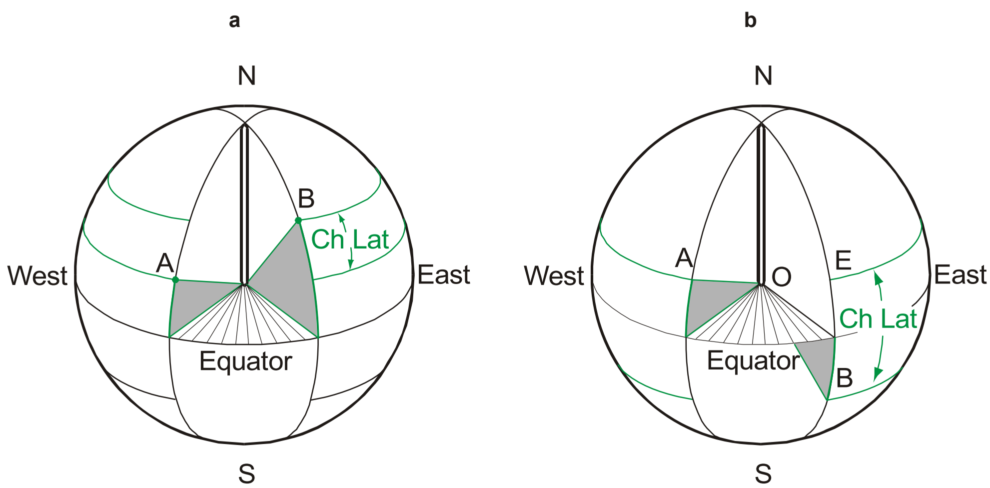
5. In air navigation, it is usually sufficient to express latitude and longitude in degrees and minutes only. By convention, the group of figures representing latitude is always written first and is followed by the figures expressing longitude. To avoid ambiguity, there are always two figures used to denote degrees of latitude, those below ten being preceded by the digit 0. Similarly, three figures are used to denote degrees of longitude, employing leading zeros as necessary. The letters N, S, E, and W are used to indicate the hemisphere. Thus the position of a point situated in latitude 53 degrees 21 minutes North and in longitude zero degrees 5 minutes East, is written: 53 21 N 000 05 E, the spaces being optional.

Change of Latitude

6. The change of latitude (ch lat) between two points is the arc of a meridian intercepted between their parallels of latitude. It is annotated N or S according to the direction of the change from the first point to the second. By convention, northerly latitudes are considered positive, while southerly latitudes are considered negative.

7. If the two points are on the same side of the equator, and thus have the same sign (as in Fig 4a), the ch lat is found by subtracting the lesser latitude, that of A, from the greater, that of B. If A and B are on opposite sides of the equator, and thus have the different signs (as in Fig 4b), the ch lat is equal to the sum of the latitudes of A and B. In Fig 4a the ch lat of point B from an observer at point A is annotated N, in Fig 4b the ch lat of point B from point A is annotated S.

9-2 Fig 4 Change of Latitude

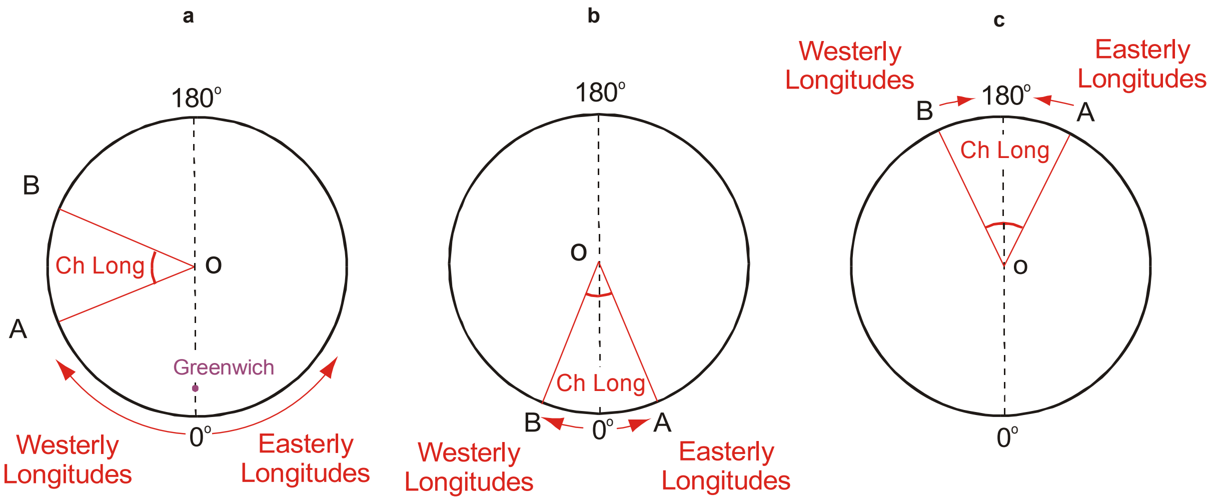


Change of Longitude

8. The change of longitude (ch long) between two points is the smaller arc of a parallel intercepted by the meridians through the two points. It is annotated E or W according to the direction of the change from the first point to the second. By convention, easterly longitudes are considered positive, while westerly longitudes are considered negative.

9. In Fig 5a, the points A and B are in the same hemisphere and so have the same sign. The change in longitude is the difference between them. The ch long from A to B is westerly, while the ch long from B to A is easterly. In Fig 5b, the points A and B are in different hemispheres and so have different signs. The change in longitude is the sum of their longitudes. The ch long from A to B is westerly, while the ch long from B to A is easterly. When considering the example in Fig 5c, it is vital to remember the definition of ch long given in para 8. Points A and B are in different hemispheres and so have different signs. By calculating their sum, the derived ch long would be a measurement of the larger arc of the parallel intercepted by the meridians through the two points. Thus, in this situation, ch long is derived by subtracting the sum of the longitudes of the points from 360°.

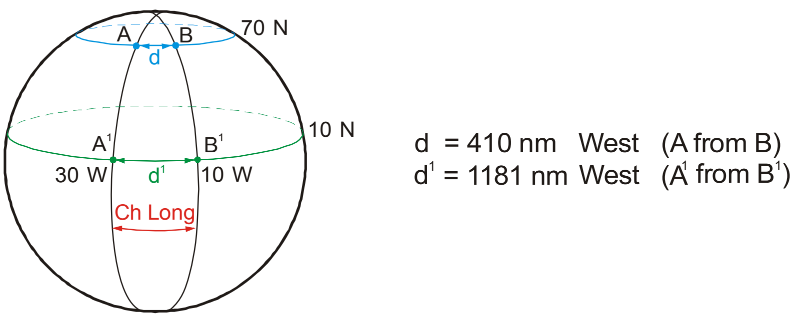
9-2 Fig 5 Change of Longitude



Departure

10. The distance between two given meridians, measured along a stated parallel and expressed in nautical miles, is called departure. In general terms, it is defined as the East-West component of the rhumb line distance between two points. The value of departure between two meridians varies with latitude, decreasing with increasing latitude (Fig 6); the change of longitude between these meridians remains the same, irrespective of the latitude.

9-2 Fig 6 Departure and Change of Longitude



11. The departure between any two points is a function of their latitudes and the change of longitude. The relationship is given by:

$$\text{Departure (nm)} = \text{ch long (mins)} \times \cos \text{(mean lat)}$$

$$\text{where mean lat} = \frac{\text{lat A} + \text{lat B}}{2}$$

Disadvantages of the Latitude and Longitude Reference System

12. The latitude and longitude method of reporting position suffers from certain disadvantages:

a. The possibility of confusion in areas close to the equator and the prime meridian.

b. The necessity of giving an 11 character group to obtain positional accuracy of 1 min e.g. 5136 N 00125 W.

c. One minute of latitude and one minute of longitude represent different distances on the earth, except at the equator, and the distance represented by one minute of longitude decreases with increasing latitude.

13. To overcome these disadvantages, military forces use reporting systems based on networks of lines (grids) which are a fixed distance apart and cut each other at right angles. Examples of these systems discussed in this chapter are:

a. The British National Grid System (covering Great Britain and the Isle of Man).

b. The Irish Grid (covering Northern Ireland and the Republic of Ireland).

c. The Universal Transverse Mercator Grid (UTM) (covering the latitudes between 80º S and 84º N).

d. The Universal Polar Stereographic Grid (covering the north and south polar regions).

e. The Geographic Reference System (GEOREF). Note that this system is based on graticule lines (latitude and longitude), and is not a true grid system.

THE BRITISH NATIONAL GRID SYSTEM

Description of the Grid

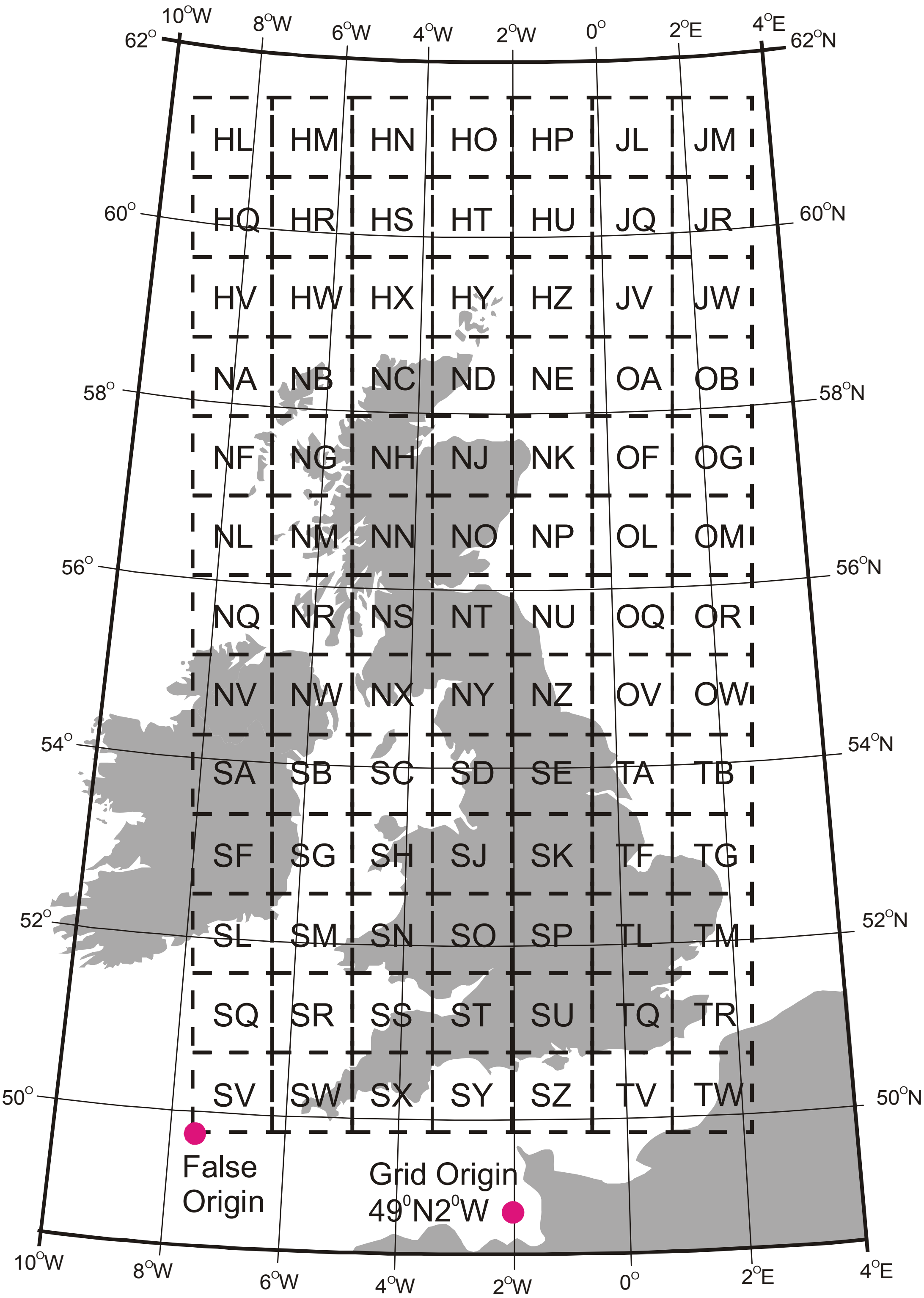
14. The British National Grid is the national grid for Great Britain and is a unique system for use by both civilian and military authorities. It is based on the Transverse Mercator projection with a central meridian at 2º W, to which all grid lines are parallel or perpendicular. The origin of the grid is at 49º N 2º W, with a false origin located 100 km north and 400 km west of the grid origin to ensure that all coordinates on the grid are positive (see Fig 7). British National Grid coordinates are given in terms of metres east and metres north of the false origin. Depending on the scale of the chart, the distance between grid lines shown on the chart is 10,000 metres, 1,000 metres or 100 metres. The distance between grid lines shown on the chart is termed the 'grid interval'.

The British National Grid Reference System

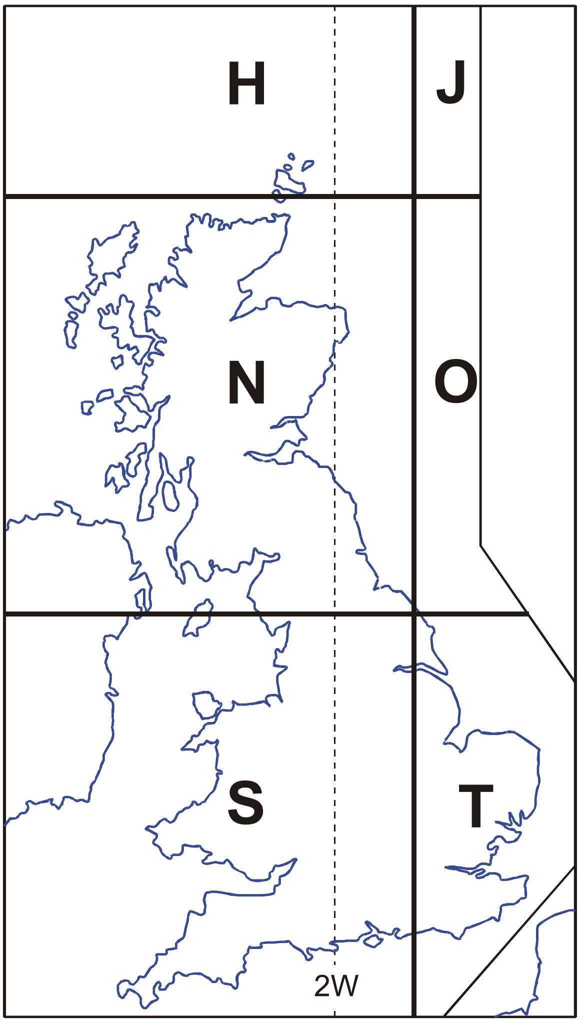
15. The British National Grid Reference System is the means by which national grid references are given using the British National Grid. The British National Grid is first divided into 500 km grid squares. Each 500 km square is assigned a letter, referred to as the 500 km 'square identification', as shown in Fig 8. Each 500 km square is subdivided into 100 km squares, each of which is assigned a 'square

identification' letter. The 100 km squares are lettered A to Z (omitting I), starting in the top left of the whole 500 km grid square, as shown in Fig 7. It can be seen from Fig 7, that by combining the square identification letters, each 100 km square has a unique identifier. The 100 km squares can be further sub-sub-divided into 10 km, 1 km, and 100 metre squares, depending on the scale of the chart in use (see para 14). Each grid square within the 100 km square is designated by the respective metric distances of its South-West corner from the West and South margins of the 100 km square. The user can extract these distances from the figures printed in the margins of the maps against the grid lines.

9-2 Fig 7 The National Grid showing the Grid Origin and False Origin



9-2 Fig 8 The 500 km Grid Squares of the British National Grid



16. A full grid reference consists of the two letters representing the square identifications, followed by a numerical element to identify a position within the square. The numerical part of a grid reference consists of an even number of digits in two equal groups. The first group represents the eastings and the second group the northings. Each group is made up as follows:

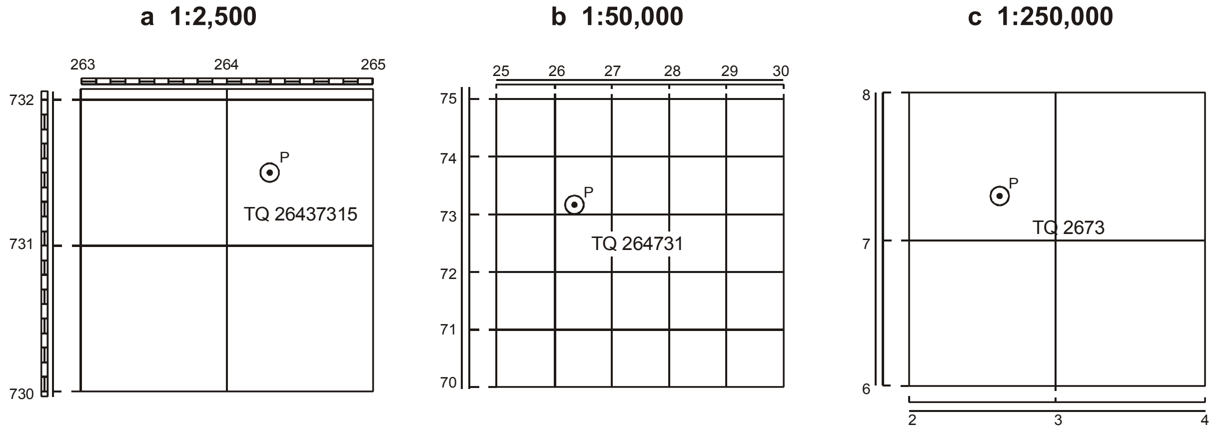
a. **Principal Digits**. Principal digits label the grid lines and are shown on the chart. For a chart with a 100 metre grid, each grid line has three principal digits (Fig 9a). For a 1,000 metre grid, each grid line has two principal digits (Fig 9b). For a 10,000 metre grid, each grid line has one principal digit (Fig 9c).

b. **Estimated Tenths**. A 'standard reference' obtained from a chart is a grid reference to a precision of one tenth of the grid interval of the chart. The grid square is divided into tenths, either by measurement or estimation, in an easterly and northerly direction and counted respectively from the left and south grid lines.

An eight figure reference identifies a point to a precision of 10 metres. A six figure reference identifies a point to a precision of 100 metres. A four figure reference identifies a point to a precision of 1,000 metres. This can be seen in Fig 9. In Fig 9a, the grid interval is 100 metres and so the estimated tenths gives a precision of 10 metres. Grid references always read right (eastings) first and then up (northings). A grid reference is written without any spaces.

17. Examples of standard grid references, appropriate to various scales, are illustrated in Fig 9.

9-2 Fig 9 Grid References on Various Scale Charts



THE IRISH GRID

Description of the Grid

18. The Irish Grid is shown on military maps and charts that cover Northern Ireland and the Republic of Ireland. It is based on the Transverse Mercator projection with a central meridian at 8º W to which all grid lines are parallel or perpendicular. The origin of the grid is 53º 30' N and 8º W, with a false origin 250 km south and 200 km west of the grid origin. Irish grid coordinates are given in terms of metres east and metres north of the false origin. Depending on the scale of the chart, the distance between grid lines shown is 10,000 metres, 1,000 metres or 100 metres. The distance between grid lines shown on the chart is termed the 'grid interval'.

The Irish Grid Reference System

19. The system for reporting grid references on the Irish Grid is almost identical to the British National Grid Reference System (para 16). The difference is that the whole of the island of Ireland falls within a single 500 km square which is designated by the letter 'I'. This letter is not used anywhere else, either in the reference system used with the Irish Grid, or in the British National Grid Reference System. As with the British National Grid Reference System, a full grid reference consists of two letters, the first identifying the 500 km square in which the point lies, and the second identifying the 100 km square in which the point lies. Grid letters are followed by the numerical part of the grid reference that identifies a position within a grid square.

THE UNIVERSAL TRANSVERSE MERCATOR GRID

Introduction

20. Any rectangular grid system must be based on a flat projection of the Earth's surface. However, because the Earth's surface is curved, any flat projection will become increasingly distorted as the area of projection is extended. Therefore, the area covered by one particular grid must not be extended beyond the limits at which its distortion becomes excessive.

Description of the Grid

21. The Universal Transverse Mercator (UTM) Grid is a world-wide grid extending from 80º S to 84º N. It is based on sixty separate grid zones, each one covering six degrees of longitude and each with its own projection. The UTM Grid is based on the Transverse Mercator Projection with each grid zone having a