CHAPTER 1

AIRCRAFT ABANDONMENT

CONTENTS

EJECTION SEAT MALFUNCTION

Introduction

1. The reasons for emergency escape from an aircraft are many and various but whatever the emergency, it should be possible to abandon an aircraft with a reasonable chance of success. JSP 318 states that all crew members are to be provided with parachutes, with the following exceptions:

a. When the aircraft's authorized exercise prevents the likelihood of successful escape by parachute.

b. In passenger-carrying aircraft and aircraft certified to BCARs performance Group A or its equivalent Service group.

The implication of the above is that abandonment is either impracticable or is not possible from a number of aircraft, and that it may only be possible from a number of others on specific flights.

2. Military aircraft operate in an extremely large flight envelope—speeds range from zero to well over 1000 kt, and operating heights from ground level to over 50 000 ft. Escape from aircraft operating in the lower speed range may be possible solely with a parachute, but assisted escape is necessary for those with a wide or high speed range. Escape systems are designed to aid occupants to get clear of an aircraft and into an environment from which a normal parachute descent is possible.

Conventional Escape

3. Up to about 200 kt, it is possible to escape unaided from an aircraft. At or above 200 kt it becomes extremely difficult and dangerous to escape unassisted. The situation is made worse at any speed if the aircraft is subjected to *g* forces, *eg* due to a spiral dive. The minimum height at which the escapee must be clear of the aircraft is 1000 ft agl. It follows that the decision to bale-out must be made at a greater height than this, depending on

aircraft type (*ie* difficulty of egress) and rate of descent. At the higher speeds, the slipstream across an exit makes it difficult for the crew member to escape and if he does, it is possible that he will contact a part of the aircraft. Deflectors are fitted to some aircraft; these protrude into the slipstream and allow the individual to clear the aircraft at higher speeds. In high level escapes from such aircraft the escapee may have several thousand feet to fall before his parachute is deployed by the barostat. In prolonged free fall the body tends to develop a flat spin about an axis more or less parallel to the line of fall. The acceleration at head level in this situation could cause serious damage, but the situation is avoidable by adopting the "free fall" position (*see* Chap 3 para 20).

4. **Swivel Seats.** The rear crew members positions in the Victor and Vulcan are fitted with swivel seats. These seats can be moved fore and aft and swivelled (except for the centre seat in the Vulcan) to face the exit door during normal or emergency operation. In addition, the seats are fitted with a pneumatic assister to force the occupant to his feet in high *g* conditions. Operation of the assister also releases the harness lap strap anchorages.

5. **Helicopter Escape.** Some current helicopters are not cleared for the carriage of parachutes, hence escape from them in flight is not possible. Most of the remainder are required to carry parachutes when operating above 3000 ft. Although helicopters generally fly at speeds below 200 kt, there are many problems associated with clearing the aircraft. Some of these are listed below:

a. Incompatability of AEA with exit path.

b. Inadequate size of escape hatch or door.

c. Failure of the helicopter to stay in a reasonably steady attitude after the cyclic stick has been released (*eg* Whirlwind).

d. Difficulty in avoiding parts of the airframe after exit.

Methods of Assisted Escape

6. The current means of assisted escape from fixed wing aircraft is the ejection seat. This has provided many aircrew with a lifesaving facility, but as airspeeds increase, the present open seats do not give adequate protection against the effects of wind blast. Escape modules have been developed in the USA (*see* Chap 4) but their future use looks doubtful due to weight, complexity and cost.

7. At present, assisted escape from helicopters is not provided. Even if the problems listed in para 5 could be overcome, survival without assisted escape is doubtful from less than 1000 ft. The most promising means of assisted escape is rocket extraction. This, and other possible methods, are explained in Chap 4.

Development of the Ejection Seat

8. Assisted escape development was begun in Germany in the late 1930s. The Germans first installed an ejection seat in fighter aircraft in 1944 and by the end of the war, 60 successful escapes had been made. Development in UK began in 1944 and the first live test ejection was carried out on 24 Jul 46.

9. The main features of the first British Martin-Baker production seats were as follows:

a. *The Face-Screen Firing Handle.* The face-screen firing handle was adopted for the following reasons:

(1) To protect the face from wind blast.

(2) To restrain the head.

(3) To provide a good ejection posture.

(4) To transmit a significant portion of the weight of the arms and shoulder girdle to the blind.

The disadvantages of the face-screen handle *ie* the time to locate, extract and pull the handle fully, and the impossibility of raising the arms at high *g* levels, led to the addition of the seat pan handle.

b. *The Dual-Cartridge Ejection Gun Providing Acceptable Rates of Acceleration.* To keep within the limits of human tolerance a dual-cartridge gun is used; the first cartridges, fired by the flame when uncovered by the moving piston, build up the pressure and accelerate the seat steadily to that required for safe ejection. In early seats the ejection velocity was something less than 18.3 m/s (60 f/s), but modern seats have an ejection velocity of about 24.4 m/s (80 f/s). In considering ejection accelerations the contents of the seat pan on which the occupant is sitting are significant, since they are interposed between the seat and the occupant and affect the characteristics of the transmitted accelerations.

c. *The Stabilizing Parachute Drogue Withdrawn by a Drogue Gun.* A drogue gun is used to deploy the stabilizing drogue parachute; the "bullet" extracting the drogue to ensure that it deploys well clear of the seat and associated air turbulence. Stabilization is necessary to stop the seat and its occupant tumbling during the descent which, if uncontrolled, produces severe acceleration loads at the extremities, which causes disorientation and possible injury. Stabilization is also required at man/seat separation to reduce the chance of entanglement between man, seat and parachute.

d. *An adjustable Seat Pan to Cater for Variations in Sitting Height.* A seat pan, adjustable vertically, is provided to cater for variations in the sitting heights of aircrew without altering the overall height of the seat.

e. *Integral Thigh Guards.* Thigh guards were provided to prevent any fouling of the legs with the cockpit structure during ejection and subsequently to minimize flailing whilst the subject was falling in the seat.

Note: The use of thigh guards without leg restraint cords resulted in some leg fractures due to flailing. All seats are now fitted with leg restraint cords.

10. Since those early days, Martin-Baker ejection seats have been developed to provide an entirely automatic escape facility, from ground level upwards, within specified speed limits. The user is required only to initiate the firing sequence, and thereafter all the required operations take place automatically. The firing mechanism first clears the ejection path and then operates the ejection seat. As the seat rises, the seat systems are activated by static rods, services are disconnected and emergency oxygen turned on. The feet swing back from the rudder pedals due to inertia at the beginning of the upward travel of the seat on its rails, and the legs are restrained close to the front of the seat pan by the automatic action of the leg restraining cords. This prevents fouling of the lower part of the legs on the instrument panel and leg flailing throughout the time that the occupant is exposed to high air blast while he remains in the seat during the subsequent descent.

11. The drogue gun fires about 0.5s after the seat rises; the drogue bullet pulls the duplex drogues from their housing. The drogues stabilize and slow down the seat sufficiently to ensure safe man/seat separation. This occurs 1.2 to 2.3s after ejection or as soon as it is safe (seat deceleration less than about 4*g*), or at a barometric height of 10 000 ft or 5000 m.

12. Modern ejection seats are fitted with rocket packs, which are used to sustain the ejection velocity provided by the cartridges in the ejection gun. The rocket is ignited as the seat leaves the aircraft. The advantages of rocket assistance are:

a. Reduced exit velocity—usually about 20 m/s (65 f/s).

b. Reduced acceleration, due to the reduced velocity, of about 11*g*, and reduced rate of application.

c. Increased trajectory, giving a zero-zero capability which is also beneficial in conditions of low altitude and high sink rate.

Pre-Ejection Considerations

13. Many aircrew have failed to survive emergencies which occur at an altitude sufficiently high for a successful escape to be made simply because the decision to eject was taken too late. In single or twin-seat aircraft the decision must be made above the minimum safe ejection altitude (MSEA). In multi-crewed aircraft there is the need to inform the crew members with or without ejection facilities so that they can take the appropriate emergency action. This will increase greatly the initial decision height.

14. **Minimum Safe Ejection Altitude.** It is generally accepted that ejection in straight and level flight at 230 kt and 9000 ft is the ideal. The rate of descent and aircraft attitude have an adverse effect on the MSEA, the rate of descent overriding the factor of aircraft attitude except when very close to the ground. In addition to computing the height lost or gained by an ejection seat, together with the height lost while the parachute develops, the following factors should be considered:

a. *Decision Time.* This is the time taken for aircrew to appreciate the emergency and to inform the other crew members. Acknowledgement of orders also affects decision time.

b. *Acting Time.* This is the time taken to react to the order to eject and to operate the ejection seat.

c. *Time for Equipment to Function.* Time taken from initiation until the seat clears the cockpit.

d. *Time for Full Operation of the Seat.* This is from seat initiation until the aircrew member is descending vertically on a fully deployed parachute.

Note: It is important that aircrew are aware of the fact that an ejection seat with a ground level capability may have a minimum safe ejection altitude of several thousand feet when escape is attempted in other than straight and level flight. The MSEA will be greatest in a high speed vertical dive. A reasonable approximation is to allow 10% of the rate of descent. Other minima for particular aircraft and situations may be published in Aircrew Manuals and appropriate orders.

Ejection Drill

15. Ideally, the position which the individual adopts to carry out his task in reasonable comfort should be that in which he can fire the seat without further adjustment, with a high probability of successful uninjured escape. In single-seat or training aircraft something approaching this state of affairs can exist, but the situation is not ideal where a crew member has to undo his restraining harness or even move from his seat in order to carry out his task.

16. The following actions are common to most seat installations. Pre-ejection actions peculiar to individual aircraft types will not be discussed in detail, but are to be found in the appropriate Aircrew Manual. Where speed of escape is paramount, use the seat pan handle. Grasp the handle firmly and pull it out to the full extent of the operating cable (25–120 mm (1–5 in)). The pulling action will tend to place the body in an acceptable ejection posture. No additional action need be taken before a premeditated ejection if the correct strapping in drills have been followed, but the following checks can be completed if time permits:

a. Ensure that the lumbar pad is located snugly in the small of the back and that the buttocks are forced against the rear of the seat pan.

b. Tighten the harness and anti-*g* strap, but do not overtighten shoulder harnesses.

c. Place the head against the headrest.

d. Operate the face-blind handle (if fitted).

17. The ease with which the blind can be drawn over the head and face will depend very much on the level of the top of the

protective helmet in relation to the handle of the blind. The seat position adopted for normal flying should not only permit satisfactory vision, but also a free extraction of the firing blind with the head against the seat rest. Aircrew should not normally consider seat lowering as part of the ejection sequence in order to be able to pull the blind over the head. Such an action not only wastes time, but may require the shoulder harness to be readjusted. On some types of seat with raising and lowering handles, positive engagement of the seat position lock is essential as seat damage may be produced by ejecting with an unlocked seat pan, with the possibility of the damage producing a seat malfunction or physical injury. It is important not to raise the face-blind handle too much during the initial pull because this can markedly increase the effort necessary to extract the blind from its housing, which, in the worst case, could prevent the seat from firing.

18. The higher the top of the protective helmet in relation to the firing handle, the more difficult it becomes to operate the firing blind. This action becomes even harder under negative *g* conditions. In trying to extract the blind upwards over the helmet, the head may be forced down so that the neck is flexed at the moment when the blind comes out of its stowage. The sudden withdrawal of the blind may result in further flexing of the neck. At this stage, one of two things will happen:

a. The seat will fire, with possible damage to the top of the spine due to marked neck flexion.

b. As a reaction to the sudden withdrawal of the blind, the forward pull might be relaxed before the sear has been extracted to allow the seat to fire.

19. In the situation described in para 18b, the blind is out of its stowage but the seat has not fired. The most effective way to ensure ejection initiation by the face blind is to pull the elbows well back to the hips, as this ensures that the hands come as low down as possible on the chest and that the face blind is pulled fully down to extract the firing sear. This action will ensure that the head is in a good position at the moment of ejection. The head should not be butted into the blind to fire the seat. In seat systems fitted with an interdictor mechanism removed by the cockpit canopy as it is jettisoned, it will be necessary to maintain the pull on the face blind or on the seat pan handle. In practice the time lapse between the two pulls, to jettison the canopy and to initiate ejection, is seldom noticed.

20. When using the seat pan handle, ejection initiation will not occur until the handle is pulled to the full limit of its travel and the pull maintained until the seat fires. This limit varies with seat type, but on most modern seats it is the lower end of the range given in para 16. As the seat pan handle is more easily accessible, the time taken to reach, extract and initiate ejection with it is perhaps 1–1.5s faster than with the face blind handle which, being out of sight above the head, must be located with both hands, extracted, lifted over the protective helmet and pulled down to effect ejection initiation. This saving of time is of vital importance in critical ejection conditions where ejection trajectory is becoming limited by aircraft attitude, height above the ground, rate of descent and effective forward speed. The face blind may be better when time is not critical and conditions allow a degree of control of the aircraft up to the time of ejection initiation. Hence the seat pan handle is, with the one exception above, the preferred method of initiating ejection, and it must be used in any aircraft after the cockpit canopy has been jettisoned either manually or by a prior ejection.

Posture During Ejection

21. The posture of the body is extremely important in determining whether the ejectee will escape uninjured and is directly related to the correct strapping in procedures. If the back is correctly positioned and supported during ejection by a correctly adjusted

restraint harness and lumbar pad, it can safely tolerate the accelerations imposed on it by the current 24.4 m/s (80 f/s) ejection guns. Poor posture could result in injury even with the lower velocity of rocket assisted seats; the acceleration of these is always less than 14*g*.

22. The back is at its strongest, and thus more able to withstand loads such as those caused by ejection, when it is in its normal position, *ie* straight when viewed from the front and slightly curved like an elongated 'S' when viewed from the side. In the normal position, the back can withstand accelerations of up to 30*g* at a rate of application of over 300*g*/s. If the back is bent or twisted, this figure can fall to 9–14*g* at rates considerably less than above. Poor posture may cause compression fractures of the back, but only very rarely produce spinal chord damage.

23. The nature of the seat pack through which the ejection accelerations are transmitted, the support afforded by the lumbar pad and the effectiveness of the restraining harness are of the utmost significance in seat ejection. The user can only adopt and maintain a posture as good as the equipment will allow. The items of equipment being considered are:

a. *Personal Survival Packs*. There are a variety of personal survival packs currently installed as items of aircraft equipment in the various types of ejection seats. The main characteristics of these packs are:

(1) *Comfort*. As well as ensuring good ejection characteristics, it is important that the personal survival pack is correctly contoured and therefore comfortable. In long range aircraft this factor is of great importance since the degree of comfort has a marked effect on the efficiency of the user. Moreover, from the ejection point of view, he is more likely to remain in the correct position on the seat if it is correctly shaped and comfortable. Comfort is improved by a limited slip quality of the top surface, since this permits small movements, when desired, to ease pressure points.

(2) *Shape*. The pack should be of such a shape that it is located firmly in the seat pan, but at the same time is capable of unhampered separation from the seat during the process of escape. Its top surface should be shaped so that it encourages the user to sit correctly in the best position towards the back of the pack. Some packs were improved by the addition of a shaped insert located under the top layers of the pack, which enables the individual to settle comfortably into the correct position. The survival equipment in most current ejection seats is contained in a rigid shaped box to achieve good positioning of the body in the seat and the policy is for more "shaped" packs to be used.

(3) *Contents*. The contents of the personal survival pack will range from the bulky rubber liferaft and its accessories to small hard objects. Unless they are contained in a rigid box, the packing of the objects in the container is particularly critical to ensure constant shape and ejection characteristics. A shaped insert will assist in maintaining the correct shape, but if the contents under it are not properly distributed it can tilt with dangerous effects on posture, hence the move to the shaped rigid box.

(4) *Characteristics During Ejection*. In providing an ideal pack there are many different and conflicting requirements. In seeking comfort, for example, care must be taken that the pack is not too soft. The degree of compliance must be kept within specified limits to prevent harmful peak accelerations, due to a series of compression and rebound effects being transmitted to the back during ejection. The pack must be such that its comfort is acceptable for normal flying and can be relied upon to react in a predicted manner during ejection.

b. *Lumbar Pads*. The purpose of the

lumbar pad is to fill the gap between the seat and the natural hollow in the small of the back. This will ensure comfort and good posture both in normal flight and during ejection. It is important that the pad is of a size and shape to fill the gap and can be located and retained in the correct position. If displaced, it can get into a position behind the hips and create a hazard during ejection (*see* para 16a).

c. *Restraining Harness*. Earlier marks of ejection seat have separate parachute and restraining harnesses; the later seats are now fitted with a combined harness system. It is important that the harness system is adjusted correctly to ensure the maintenance of good posture during the escape sequence. The location of the straps and harness fastening in the optimum position and the correct sequence of tensioning of the system will restrain and also maintain body position.

Post-Ejection Considerations

24. As the seat and occupant leave the aircraft they may be exposed to the following stresses:

a. *Wind Blast*. When the seat clears the aircraft, the occupant is exposed to the ram effect of the slip-stream. This is proportional to the IAS. At indicated speeds up to about 350 kt wind blast is not likely to cause injury. As speeds increase above 350 kt, there is an increasing likelihood of injury unless appropriate restraint is provided. The upper limit for the open seat appears to be about 650 kt.

b. *Sudden Deceleration*. On entering the slip-stream the seat and its occupant undergo a marked deceleration caused by the wind drag; the higher the IAS, the greater the deceleration effect. For a given IAS the maximum linear decelerations are not affected by altitude. As the ejection altitude is increased, however, the deceleration time is prolonged. This is because for a given IAS, increased altitude results in a greater kinetic energy (higher TAS) which takes longer to dissipate in the lower density. Ejection seats are provided with a stabilizing system so that this deceleration is linear, otherwise an unstable system would produce a variety of forces on the occupant of the seat. There are many factors which affect the drag characteristics of the man/seat complex, so that it is not possible to lay down a maximum IAS for safe ejection from the point of view of the deceleration effects. Assuming a maximum safe peak linear deceleration of 35*g*, it has been calculated that this might be experienced at an IAS between 600 and 700 kt.

c. *Tumbling and Spinning*. Unstable seats would tumble and spin and the high acceleration loads could cause serious injury to the occupant; seats are therefore stabilized by means of drogues. In most seats two drogues are used; a small one opening first, bringing the seat into alignment with the relative airflow and pulling out a second, larger, drogue. Most ejection seats are now fitted with a heavy drogue gun bullet which fully extracts both drogues and their lines and the large drogue may well inflate first. By using this method, stabilization is achieved early without fear of the main drogue being ruptured. A *g* stop is incorporated which prevents separation from the seat and deployment of the main parachute canopy until the acceleration loads have been reduced to an acceptable level. During stabilized free fall, spinning or swinging about a vertical axis can occur and this may induce sensations of tumbling and the impression that the drogues have not deployed.

d. *Effects of Environment at High Altitude*. If ejection occurs above the barometric level of the automatic system, a delayed drop to the set altitude occurs before man/seat separation and the deployment of the main parachute canopy. This allows the seat to descend, stabilized by drogues —*eg* from 50 000 ft to 10 000 ft in approximately 3.5 mins. The reasons for this delayed drop are:

(1) To prevent explosive opening of the main parachute canopy which is likely to cause severe tearing of the fabric and injury to the escapee.

(2) To keep the time spent at altitude to a minimum, as only a very limited quantity of emergency oxygen is carried and, in the worst case, the oxygen mask may have been lost due to the wind blast on ejection.

(3) To keep the time spent in the low temperature regions of the atmosphere to the minimum. (Note: a 5000 m (16400 ft) barometric capsule may be fitted to any aircraft flying over high land masses.)

e. *Parachute Opening Load*. The opening load of a parachute canopy depends on many factors. The design of the canopy and the length of its rigging or shroud lines, the method of opening, the altitude and speed through the air at the moment of opening, the size and design of the vent, the weight and porosity of the material, air density and humidity being but a few. The Irvin 24 canopy has been used for many years for most Service emergency escape systems because it is a simple, compact, quick opening and reliable canopy. The principal factors which affect the opening load of the Irvin 24 are terminal speed through the air at the moment of pack opening and the altitude at that moment. The drogue system is designed to decelerate the seat/man system down to a safe speed for parachute extraction and deployment. Release from the seat does not occur until both the load on the drogue system has reduced allowing the *g*-stop to release and altitude is lost so that the barostat allows the time delay in the automatic release mechanism to run for its set period. With rocket assistance and the need for earlier seat/man separation in low level ejections, the *g*-stop has been removed from most modern ejection systems, but the time delay has been slightly increased. The opening load of a parachute canopy is proportional to the TAS (V^2) and as the terminal velocity increases with altitude V^2 also increases. Thus, parachute opening loads are very much greater at higher altitudes, even at the minimum barometric altitude of 10000 ft. The opening jerk after seat man separation from a seat stabilized by the drogue system to 10000 ft is very often described as severe. Opening the parachute at higher altitudes, particularly after even a very short period of free fall, can be hazardous as the load may produce physical injury or exceed the designed loads of the parachute or harness system. Fortunately, parachutes tend to fail safe in that deployment damage relieves the excessive loading and still leaves sufficient canopy for a safe, and stable, descent. Manual separation from an ejection seat and manual parachute deployment above barometric altitude is therefore potentially hazardous. Fortunately, seat systems are very reliable, certainly far more reliable than the individual escapee who rarely has had previous experience.

EJECTION SEAT MALFUNCTION

Action in the Event of Failure to Fire

25. Failure of the seat to fire is a very rare occurrence. However, should it fail to fire at the first attempt, initial efforts should be directed towards obtaining a normal ejection. The firing handle should be pulled again harder, and the alternative handle (if fitted) can also be pulled. Jettison the cockpit canopy or, if unsuccessful, open the cockpit canopy using the normal aircraft system as the canopy jettison system may be the cause of the failure. If these actions are unsuccessful, the situation should be re-assessed and the original decision to abandon reconsidered, *ie* the actual emergency should be reviewed against the likelihood of a successful manual escape.

Hazards of a Manual Escape

26. The seat and the associated aircrew equipment have been designed specifically

for gun ejection and the manual override facility is provided to overcome the failure of the automatic separation which occurs once the seat is clear of the aircraft; it is not designed for escape from the cockpit. It is therefore difficult, if not impossible, to leave a failed ejection seat unless conditions are ideal. Moreover, the hazards of snagged straps and clothing *etc*, and of subsequent impact with parts of the airframe after leaving the cockpit, cannot be discounted. The only record of a successful manual escape is from a USN Crusader, flying level at 5000 ft at a speed of about 250 kt, but note the advice given in para 3.

Factors to be considered in a Manual Escape

27. A deliberate ejection is usually the alternative to:

a. A fatal impact with the ground.

b. Disintegration of the aircraft in the air.

c. A hazardous landing in unsuitable terrain.

d. Ditching.

e. Descent through low-based cloud over unknown territory, without radar or other assistance.

28. Clearly an attempt at manual escape is indicated in the case of 27a and b above, but time would be the deciding factor. The time taken to escape unassisted from the aircraft is variable because individual performance and impediments to escape are variable, but a realistic appraisal indicates a figure in a time scale 15–45 s. Manual escape therefore becomes a practical proposition mainly as an alternative to 27c, d and e.

29. In the case where subsequent survival on the ground or in water will depend on the escapee having his Personal Survival Pack, it should be borne in mind that in a manual escape the PSP may not be available and this too will affect the ultimate decision.

Manual Escape (Static or Swivel Seats)

30. The actual drill for escaping from the aircraft varies with aircraft type and the make and mark of the seat fitted. The appropriate drill is published in Aircrew Manuals; it should be borne in mind that it is not a normal listed emergency drill, but rather a suggested course of action. The following factors will have been considered when formulating the recommended procedure:

a. The difficulty in freeing the parachute from its housing.

b. The number and complexity of the attachments between the occupant and seat, all of which must be freed before attempting to escape.

c. The best method of actually getting out of the aircraft and the likelihood of snagging of the straps, or being struck by parts of the aircraft during and after the escape.

31. The inverted "fall-out" escape is unlikely to be successful because freeing the parachute pack from its housing requires considerable strength and agility, even under ideal conditions. High airspeed, *g* loading, or loss, or partial loss, of control will increase the hazards.

Summary

32. A modern ejection seat is a very efficient means of abandoning an aircraft. Provided that it is operated within its design parameters and the crew member does his utmost to maintain the correct posture, the chance of sustaining serious injury is slight. The manual override device is provided to cater for failure of the automatic sequencing of the seat—a very rare situation. The override is not designed for manual escape in the unlikely event of the seat failing to fire; the advice given in this Chapter is merely a suggested course of action.