DEFENCE RESEARCH AGENCY
FARNBOROUGH
HAMPSHIRE
GU14 6TD

An interim report on the developments of safe underwater escape from helicopters

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J A Benham
P J Redman
P Haywood

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Executive Summary

This working paper is the advisory report for Package 26f, RO4, assignment 4XX, the customer for which is DDOR5 (Air). Its purpose is to review the global developments that have taken place which contribute to safe underwater escape from helicopters. These include improving crashworthiness; keeping the aircraft afloat; providing training and escape aids for aircrew and passengers; improving the location, release and exit through emergency hatches; and awaiting subsequent rescue. Information has been obtained from accident data, experimental research and training experiences.

Safe underwater escape begins on the ground by ensuring that helicopter aircrew regularly obtain the appropriate survival training. Additionally all passengers should be given comprehensive pre-flight briefings. It is then important to ensure that the occupants survive an impact with water in an adequate physical condition in order to make good their escape. This can be achieved by introducing crashworthy airframes and seats, improving occupant restraint systems and investigating the optimum brace position for individual seats.

Having survived the ditching the next immediate requirement is for the helicopter to remain upright and on the surface for sufficient time for the occupants to evacuate safely. If it does invert or sink, then the occupants should be provided with a simple means of escape, aided by underwater escape lighting, breathing devices, easily operated escape hatches and a minimum risk of clothing or equipment snagging. Additionally, they should be fully educated in the complications caused by inrushing water, disorientation, cold water immersion and inherent buoyancy of clothing.

This report summarises the developments for safe underwater escape and identifies areas of concern. Recommendations are made for future human factors work to improve the chances of survival for aircrew involved in helicopter ditchings.

1 Introduction

1.1 General

1.1.1 There have been extensive studies conducted to investigate the factors relating to escape and survival from helicopters ditching in water[1,2,3,4,5]. These studies, and others, have resulted in a better understanding of helicopter crashworthiness and survivability. Many areas for improvements have been identified which should result in improved helicopter safety. However, much of the work conducted to date has been done in the United States (US), where changes to helicopter design have already been implemented and documented as a Military-Standard (Mil-Stan 1290).

1.2 Brief Review of Accident Data

1.2.1 Impacts with water account for 27% of UK military helicopter accidents[6]. Between 1971-83 there were 4 RAF helicopter ditchings[7] and between 1972-84 there were 57 RN ditchings representing 47% of RN helicopter accidents[8].

1.2.2 The most significant cause of helicopter accidents is mechanical failure[6,9]. Since many military helicopters routinely operate at low level, the occupants may have little or no warning before impact. In 9 out of 10 Canadian Sea King ditchings, during the period 1952-1987, warning time was less than 15 seconds[1].

1.2.3 Occupants may survive the impact only to perish as a result of their inability to make a safe exit. During the period 1972-84, 61% of all RN helicopter fatalities occurred subsequent to survivable impacts[8]. Of these a significant number were due directly to drowning or drowning as a result of minor injury. Injury and death are not inevitable consequences of an aircraft crash and up to 90% of crashes are survivable. It is therefore clear that improvements in helicopter crash survival should be actively pursued[10].

1.2.5 A major complication of helicopter accidents over water is the frequent failure of the aircraft to remain afloat and upright post impact. The inherent instability of helicopters, the ineffectiveness of current flotation systems and the prevailing meteorological conditions dramatically increases the tendency for inversion. In the period 1972-88 only 21% of UK military helicopters remained afloat and upright following an accident and in 50% of these inversion was immediate (<15s)[9].

1.2.6 Once inverted, even if the occupants are uninjured, escape can be hindered by inrushing water, disorientation, darkness, harness release, buoyancy, snagging, locating and reaching the escape exit, operating the exit mechanism, and finally egressing. In a study carried out by Rice and Greear[11], 50% of survivors reported that inrushing water, often coupled with disorientation and the inability to reach or open escape hatches, was the main problem in escaping from the aircraft. Brooks[1] stated that the US Navy Safety Center reported 14 cases of difficulty releasing the restraint system in the period 1983-85, and a further 31 cases in which crew were hampered by equipment. In the same period 33 cases were reported in which personnel had difficulty or found it impossible to open the escape hatch. The lack of standardisation in the operation of emergency exits (the Sea King alone has four different mechanisms) may be partly responsible for this difficulty and is the subject of study by the British Helicopter Advisory Board (BHAB). The operation and jettison of the emergency exit may extend the escape time by 20-35%[12]. If breathing aids are not available for the occupants then they must rely totally on a breath hold, which in water of 5-10°C, even if they are wearing an immersion suit, can be limited to approximately 19 seconds[13,14,15,16].

1.2.7 Survival begins with the appropriate training, so that pilots and aircrew are able to react instinctively to an emergency in order to execute a successful escape. Ryack et al[17] reported findings from the US Naval Safety Centre, showing that of personnel involved in ditchings who had received dunker training only 8% died compared to 20% of the untrained personnel.

1.3 Aims

1.3.1 This report reviews the developments that have taken place which contribute to safe underwater escape from helicopters. These include improving crashworthiness; keeping the aircraft afloat; providing training and escape aids for the aircrew and passengers; improving the location, release and exit through emergency hatches; and awaiting subsequent rescue.

2 Developments

2.1 Training

2.1.1 There is some evidence that survival training can reduce the number of deaths following a helicopter ditching[17]. Furthermore, many survivors have readily acknowledged that their survival had been due entirely to their training[5,18], some having been so conditioned by it that there was no conscious memory of egress or the operation of their survival equipment[19].

2.1.2 It is becoming accepted that the more realistic training is, the more beneficial it will be in a real situation. In response to this, helicopter underwater escape training is now developing to include the use of dunkers fitted with real restraint harnesses and realistic jettisonable doors, and the use by the trainees of operational equipment (including PSP) and survival aids. Within 18 months it is intended that realistic training modules will be available for the full RN inventory of helicopters.

2.1.3 Developments have been made in attempting to understand the psychological affects of stress during an emergency situation. For example, in the accident involving Sea King ZE 419[19,4] the first pilot (P1) demonstrated the confusion which can occur. He repeatedly attempted to open the sliding window rather than jettison the door and explained "it was a more natural place to go for". A Sea King pilot will open the sliding window for ventilation hundreds of times, but will only operate the window jettison mechanism once every 6 months or possibly not at all. In the absence of any other regular drill, the repetitive action of opening the window subconsciously trains the person to react in the way the P1 did. A similar event occurred in the ditching of Gazelle HT3 ZB628 South of Genoa Italy on 9 September 1993, where the Captain opened the starboard front door normally by using the standard door release mechanism, instead of jettisoning the whole door.

2.1.4 Repetitive training is likely to help an occupant to escape from an inverted helicopter by teaching him to react instinctively and it is important for aircrew to undertake regular dunker training. Although the optimum frequency is unclear, all RN aircrew and those RAF aircrew who regularly fly over water have refresher training every 2 years. Furthermore, the RN are investigating the requirement for aircrew to practise underwater escape from an inverted chair every 6 months. In contrast RAF aircrew who do not regularly fly over water have recently had their refresher training reduced to once every 3 years. The AAC, however, only undertake initial dunker training and do not subsequently receive any refresher training, unless they regularly fly over water. A dunker feedback report for Sea King aircrew[4] showed that 64% of trainees felt that the training frequency was about right, while 31% felt that it was not frequent enough. No-one felt that it was too frequent.

2.1.5 It has been found that abandon aircraft drills vary enormously from mere discussions to physically exiting the aircraft and it was noted that many rear seat crew had not exited an aircraft or knocked out a window during these drills[20].

2.1.6 There is one military dunker training establishment in the UK (RNAS Yeovilton), which RN personnel must attend. RAF and AAC personnel may use either this, or one of the many civilian offshore survival centres. These establishments each have different training guidelines and facilities, and some may not have the military clothing and equipment required for realistic survival training. A minimum standard of training should be defined in order that all military personnel, regardless of where they attend, are adequately prepared for survival.

2.2 Pre-flight Briefing

2.2.1 Braithwaite[21] highlighted the fact that there was inadequate briefing to AAC passengers on safety procedures and there is evidence that some passengers are likely to have suffered injury because of this. In contrast, civilian survivors from the Cormorant Alpha accident who were interviewed by the RHOSS group[5] considered that their briefings were thorough and useful. These briefings include the use of videos and consist of full pre-flight instructions before leaving for their tour of duty, plus short briefings before each shuttle flight.

2.3 Pre-Ditching

2.3.1 Provided that there is an adequate period of warning in advance of a ditching several actions may be taken by the crew, one of which is to jettison doors. Indeed, the Flight Reference Cards (FRCs) (AP101C-0801-14) for RAF Puma instruct aircrew to 'lock open doors and windows' for a power-off ditching. The main advantage of this is that any airframe distortion occurring on impact will not subsequently prevent the exits being jettisoned and is also one less thing for the occupants to do in order to successfully escape. However, there may be insufficient time, or an individual may fail, to return to his seat subsequent to jettisoning or opening doors, in which case he will be unrestrained during impact and more liable to injury (Puma HC1 XW215 on 24 June 1991). Furthermore, Wessex FRCs (AP101C-0102-14A) include a check to open hatches when leaving the coastline.

2.4 Impact Survivability

2.4.1 During ditching the principal factors affecting immediate survival will be the ability of the helicopter to remain substantially intact, the design of the occupant restraint systems and adoption of the optimum brace position.

2.4.2 Crew seats of some helicopters have been made stronger so that they remain intact and attached to the cockpit structure during impact. This increased strength assists survival because it provides better restraint, but there is little energy absorption, particularly in vertical impacts. Crashworthy seats, fitted with telescoping struts, have been developed and would help to prevent high impact forces being transmitted to the occupants during accidents. Inflatable seats are also available which are designed to deflate in a controlled manner during impact, and have the advantage that they could provide additional buoyancy for the sinking helicopter.

2.4.3 The forces of impact can also be reduced by efficient restraint systems which prevent secondary impact of the crew with objects in the helicopter. Pilots and other cockpit crew are usually well restrained by five point harnesses attached to strong seats, but rear crew are not, having only lap straps or a despatcher's harness attached to weak seats.

2.4.4 The brace position for helicopter passengers has been a matter of some concern and is complicated by the existence of a number of types of restraint and various seat orientations relative to the aircraft axis. Braithwaite[21] reported that AAC aircrew have a variable perception of the correct crash position to be adopted, either by themselves or their passengers. Brooks[1] has carried out much work into the optimum brace positions, but before advice can be given, each different seat and its position, harness and headrest must be considered separately.

2.4.5 An inflatable body and head restraint system (IBAHRS) has been developed to enhance the effectiveness of conventional restraint systems[22]. It consists of a pair of inflatable bags attached to the inside of the restraint system shoulder harness. The bags inflate rapidly pinning the torso to the seat and reducing the head excursion envelope. Depending upon the seat and equipment configuration, a cabin bag may also be used, which is mounted within interior structures. The IBAHRS configuration simplifies the retrofit of air bags into existing aircraft by requiring only an exchange of shoulder harnesses and installation of an airframe mounted crash sensor.

2.4.6 Another development to reduce the risk of crew incapacitation on impact has been to lessen the chances of contact with structures inside the helicopter. This can be as simple as covering surfaces with energy absorbing foams, curving the edges of panels, and recessing or shielding knobs and switches.

2.5 Helicopter Flotation and Stability

2.5.1 On ditching the immediate requirement is that the aircraft should float upright on the water for sufficient time to allow occupants to evacuate. Unfortunately, even if the sea is very calm this rarely happens due, in part, to failure of the helicopter flotation system. At present it is usually mounted on the undercarriage or lower areas of the helicopter, where it is susceptible damage. If it operates successfully, it may allow the cabin of the aircraft to remain dry, but it is thought to contribute to the overall instability. Alternatively, it has been suggested that the flotation gear should be mounted higher on the hull, thereby increasing stability and also reducing possible damage from impact.

2.5.2 Generally, the operation of the flotation gear requires first that the system is armed so that when contact with salt water is made it inflates automatically. It was designed to be salt water sensitive to prevent accidental inflation in wet weather conditions. This led to failure of the system in the accident involving Wessex XR524 in Llynpaddern lake because, although armed, the inflation system did not operate as the lake was fresh water. As a result of this accident a manual inflation button has been fitted.

2.6 Cold Water Immersion Responses

2.6.1 Much work has been carried out into cold water immersion responses providing some insight into the physiological mechanisms of cold shock. It is triggered by sudden cooling of the nerve endings of the superficial layers of the skin, therefore subcutaneous fat (which has been shown to be beneficial in protecting against hypothermia[23]) is not necessarily of any assistance in preventing this response. The best protection is provided by an effectively fitting dry suit worn over insulating undergarments, but even then, in very cold water (<10°C), a substantial response may be seen. Experiments have shown that the mean breath hold time of 18 subjects reduced from 43 seconds in air to 19.2 seconds in 10°C water. This figure reduced further to 9.5 seconds for subjects wearing normal clothing[13]. Paradoxically, some survivors[24] have clearly stated that they were not aware of the cold water until after they had escaped from the aircraft.

2.7 Disorientation

2.7.1 Only those who have experienced disorientation in a helicopter underwater trainer understand the problem and how to deal with it. Even experienced professional divers are surprised at the profound disorientation experienced when they first attempt the dunker. Ryack et al[25] noted that, in spite of their underwater experience, 16 of 24 divers testing escape hatch illumination became seriously disoriented and needed assistance. How to cope with disorientation cannot be taught in a classroom, it must be practically demonstrated underwater.

2.7.2 The effects of disorientation are further compounded by inrushing water; cold water immersion; darkness; early release of harness before water and aircraft movement has ceased; and direction changes during escape, for example attempting escape through the primary exit, finding it blocked and turning around to locate and escape through the secondary exit.

2.8 Underwater Visibility

2.8.1 Many people will not open their eyes underwater, and it has been presumed[1] that a significant number of fatalities have occurred simply because the survivors were too frightened to open their eyes and were therefore unable to make the appropriate escape response.

2.8.2 Even if the survivor does open his eyes, he still faces loss of visual acuity. Allan and Ward in the UK[26] and Brooks in Canada independently observed that underwater vision during simulated escape is greatly aided by wearing goggles.

2.8.3 Data on turbidity has been collected by Allan et al[27] and Buxton and Sowood[28]. They found that sea water turbidity varies considerably but that attenuation coefficients of about 4/m are not unusual in estuaries and harbours and may be higher in rough sea conditions. It should also be noted that debris, fuel and bubbles might well make the water entering a ditched helicopter even more turbid.

2.9 Underwater Escape Lighting

2.9.1 Attempts to specify the required performance of escape lighting have been made, notably by the USN and NATO. The UK have relied on functional specifications - that is, to specify the distance and angle over which the lights must be visible to the unaided eye under specified conditions of ambient lighting, water turbidity, and dark adaptation.

2.9.2 At present Beta lights are used within UK military helicopters to provide visual identification of emergency escape doors and windows. However, previous reports[1,29,30,31,32,33] have shown that they are totally ineffective in aiding escape from a submerged helicopter due to their low light output.

2.9.3 In civilian helicopters Exis lights are used as emergency escape markers. They are significantly brighter underwater than Beta lights. As an alternative electroluminescent (EL) lights are being developed as underwater escape lighting. The EL strips are very thin and flexible; are capable of being moulded round handles and guide bars or contoured along irregular surfaces or bulkheads; and are resistant to extreme temperatures and vibration.

2.9.4 Luria et al[34,35,36] studied the configuration of hatch lighting, which included flashing lights, shapes of lights, viewing angle and printed signs. They showed quite conclusively that flashing xenon lights around hatches were confusing and should not be used. The best configuration was found to be one in which the top and both sides of the hatch were illuminated, in an inverted U pattern. They found that short wide panels were more visible than long narrow panels of the same total area, and that it was not feasible to use printed instructions underwater.

2.9.5 Work by Allan et al[37] suggested that the visibility of emergency escape lights over distances greater than approximately 1.5m cannot be safely relied upon under adverse conditions. This resulted in the design of an escape route guidance system[38], to lead the survivor from his seat to the escape exit. It consists of an illuminated bar containing Exis lights which strobe towards the exits.

2.9.6 It should be noted, however, that most survivors of civilian accidents claim not to have seen the Exis lights, although it is by no means certain whether this was due to the failure of the lights to illuminate, turbidity of the water, or the reluctance of the survivors to open their eyes when submerged in cold salt water.

2.10 Inherent Buoyancy

2.10.1 Brooks and Potter[39] demonstrated that inherent buoyancy of clothing in excess of 137N was likely to hazard underwater escape for inexperienced individuals. Brooks[1] later showed that a suitable upper limit for the inherent buoyancy of Aircrew Equipment Assemblies (AEA) during simulated helicopter escapes was 146N.

2.10.2 Assessments have shown that Sea King AEA[40] does not exceed 146N. It should be noted, however, that when the PSP BA Mk 1 was added to the AEA the total inherent buoyancy increased in two of the nine subjects to the relatively high levels of 157N and 166N.

2.10.3 During work carried out independently in the UK and Canada, it was observed that many subjects found difficulty in manoeuvring underwater, and it is generally accepted that ease of escape is at least partly associated with the ability to achieve this. In addition to showing the way, guide bars are a considerable help in overcoming the difficulty of mobility due to buoyancy, as they provide the occupant with a solid object with which to pull themselves around. Historically, the RN Wessex was fitted with a guide bar but present military in-service helicopters are not. However it is proposed to fit one in the mission booth of the Merlin. Hand holds near exit jettison mechanisms would also provide the occupant with a purchase so that he is not recoiled back into the cabin when applying forces to the exit..

2.11 Escape Hatches

2.11.1 There is a serious lack of standardisation in the operation of emergency exits, different types of aircraft employ different mechanisms, and in some instances too many separate operations are required[19]. This is the subject of study by both the British Helicopter Advisory Board (BHAB) and also Brooks, and the results of each should be noted. In the period 1983-85, the US Navy reported 33 cases in which personnel had difficulty or found it impossible to open the escape hatch[1].

2.11.2 Evaluation of helicopter escape hatch jettison mechanisms have shown that all jettison levers throughout a helicopter should be the same shape, size and located in the same position[41]. They should be illuminated to aid final location, and for those severely disoriented, levers at the top and bottom are required on all exits; this would be particularly helpful for those flying in the left-hand seat where several instances of interference with the collective have been reported. It was also noted that it was common for levers to be moved in the wrong direction, when the system could be design to operate both ways; that people had not realised that the window had been jettisoned because the mechanisms were attached to the fuselage and not the window itself; and that extraordinary mental effort was required to conduct any manual task underwater more than 25 cm away from the finger tips.

2.11.3 It has been shown that even large subjects can escape through hatches measuring 17x14 inches[26]. Some current regulations specify minimum sizes for escape hatches which are unnecessarily large and benefits might well accrue from the provision of a greater number of smaller hatches, therefore enabling more exits to be placed nearer to passengers seats which is also a factor in successful escape[12].

2.12 Underwater Breathing Aids

2.12.1 It has been suggested that 40-60 seconds is the time needed to escape from a submerged helicopter[42]. However, because of the gasp reflex a persons ability to breath hold when immersed in cold water is severely limited[13]. In 5°C water breath holding is limited to 10-20 seconds, with the shorter periods characteristic of those not wearing immersion protective clothing. This has led to the development and introduction into service of the short term air supply system (STASS) which has already been instrumental in assisting underwater escape

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2.12.2 STASS contain approximately 50 litres (NTP) of compressed air which can be expected to last about 2 minutes underwater in warm conditions, but can be exhausted in only 40 seconds by a hyperventilating subject immersed in cold water[16]. Additionally, during training at RNAS Yeovilton, inexperienced and anxious students have been observed to exhaust the system in 14 seconds in water as warm as 29°C. Because the use of compressed air devices requires training to reduce the risks of pulmonary barotrauma, these breathing devices are only available to certain aircrew and regular flying RN passengers.

2.12.3 Rebreathers have been developed as an alternative to STASS. Experimental evidence suggests that in cold water rebreathing might enable a victim to gain as much as an extra 60 seconds to make his escape[43]. They have the advantage that if used with a single breath there is no risk of pulmonary damage. Their use is claimed to require little training making them potentially suitable for casual passengers and requests have been made by FONA to investigate this[44,45,46]. Indeed, the Directorate of Naval Operations (DNO) has stated that all occupants should be offered equal survival opportunities, and indicated that although STASS training is available for regular passengers and crew an alternative, such as a rebreather, should be considered for casual passengers[47].

2.12.4 Rebreathers in service with the US coast guard are initially filled with oxygen and exercise tests in cold water show them to be usable for up to 2 minutes. However, because the system contains more than a lung full of air, pulmonary barotrauma is still a potential complication.

2.12.5 Other ideas, so far only in the research stages, are: to use a closed circuit rebreathing bag containing potassium superoxide (KO_2) to both generate oxygen and absorb carbon dioxide (the most successful device was capable of supporting the breathing of a resting subject for 18 minutes[48]); and to use a continuous flow system, with air or oxygen being introduced from a small integral cylinder.

2.13 Snagging Problems

2.13.1 Among aircrew, the main snagging concern is their seat mounted personal survival pack (PSP). Indeed, the anxiety of this hindering or preventing escape is so high that it is common practice to choose not to connect to it when strapping into the aircraft. Three specific accidents have been highlighted where the crew failed to connect to their PSP (Lynx accident which occurred on 4 January, 1984; Puma HC1 XW215 on 24 June, 1991; Sea King ZE 419 on 6 November, 1993).

2.13.2 Occurrences of PSPs snagging have been reported by survivors in several accidents (for example Sea King ZE 419 on 6 November, 1993; Sea King ZA 194; Wessex HC MK 5C XS 518). However, many of these snagging reports were due to the occupant exiting through openings or windows not intended for escape.

2.13.3 Experimentally it has been shown that PSP snagging while exiting through a window can occur, especially when exiting face down[31,49] and it is now recognised that the correct fitting of the PSP (i.e. no gap between it and the buttocks) is essential to reduce snagging problems[50].

2.13.4 Dunker training at RNAS Yeovilton has been developed to include aircrew escapes with PSPs attached. A feedback report is being conducted of all aircrew undertaking Sea King simulated escapes, to investigate whether this training is increasing aircrew confidence in their ability to escape with PSPs[4]. Of the 105 Sea King aircrew who have completed the enhanced helicopter underwater escape training 38 admitted to not connecting to their PSP during flight. Of these 38, 17 stated, that following training, they were now confident to connect to their PSPs. Only 3 aircrew stated that they still lacked the confidence. Unfortunately 18 made no comment.

2.14 Sea Survival - Post Escape Problems

2.14.1 Immediate immersion protection for a survivor depends upon the lifejacket and immersion coverall. However, there is evidence to suggest that military lifejackets are deficient with regard to self-righting and flotation when worn with an immersion coverall[51,52]. If victims can board a liferaft survival times are approximately doubled[53], particularly if the immersion coverall or lifejacket has been damaged.

2.14.2 Passengers in the rear of helicopters are generally not provided with a PSP and so must use the MS 10 multiseat liferaft. These are generally stowed within the cabin and are virtually impossible to deploy from an inverted submerged helicopter[1]. In an attempt to address this problem an emergency escape door, incorporating an integral liferaft, has been developed and put into service in the Sikorsky S-61 helicopter. The RAF also developed an improved liferaft stowage system for the Sea King helicopter; which was very close to production before lack of funding caused the project to be put on hold.

2.14.3 The problem of sea sickness in a survival situation is recognised, but the severity of the problem is not. Bohemier[54] has observed that training exercises at sea can very quickly cause a survivor to behave in such a way that, if left alone, he would probably die.

2.15 Rescue

2.15.1 Although the immediate problems of post-rescue collapse have been addressed, by rescuing survivors where possible in a horizontal position, problems still exist in rewarming individuals, especially when their return to hospital or place of safety is extended due to protracted searches for other missing personnel (Sea King ZE 419).

3 Conclusions

3.1 Many aircrew initially survive helicopter ditchings only to perish subsequently as a result of their inability to make a successful escape. Factors identified as contributing towards this are:

a. The lack of crashworthy helicopter airframes and seats.

b. The lack of improved flotation systems to maintain the helicopter in an upright position above water.

c. The continued use of Beta lights as underwater escape lighting.

d. Disorientation caused by inversion and sudden immersion in cold water.

e. The serious lack of standardisation in the operation of emergency exits.

3.2 To improve the chances of escape and survival from a ditched helicopter much research has been undertaken. This has resulted in the following developments to improve underwater escape:

a. More realistic training.

b. The development of crashworthy seats.

c. The padding of structures within the occupants flail envelope.

d. The development of inflatable body and head restraint systems (IBAHRS).

e. The collection of sea water turbidity data.

f. The functional specification of underwater lighting.

g. The development of improved underwater escape lighting (e.g. Exis and electroluminescent lights).

h. The determination of the best configuration of escape lighting around hatches.

i. The development of illuminated guide bars to aid escape.

j. The determination of the minimum size for escape hatches.

k. A better understanding of cold water immersion responses in man.

l. The introduction of STASS.

m. The development of alternative underwater breathing aids.

n. The introduction of a manual inflation system for Wessex flotation gear.

3.3 Of particular concern was the observation that many aircrew fail to connect to their PSP because of their belief that it constitutes a serious snagging hazard during underwater escape from a helicopter.

4 Recommendations

4.1 As a result of this review numerous areas requiring attention or further development have been identified and are listed in full in Annex A.

4.2 It is recommended that future Human Factors work under this assignment should consider:

a. An assessment of all UK military helicopter escape jettison systems to investigate the problems associated with operating and jettisoning escape hatches underwater. This would involve assessing the systems in-situ, reviewing literature and carrying out underwater escape experiments. The work is of a long-term nature, but with initial objectives to be achieved within a 3 year time scale.

b. The continued development of novel breathing aids and the assessment of alternative STASS, with the aim of providing a device of substantial duration which could be used safely by individuals with a minimum of training. To aid this development further work is required to investigate the cold water immersion responses in man. The work is of a long-term nature, but with initial objectives to be achieved within a 1 year time scale.

c. An assessment of the occurrences and reasons for PSP snagging (both seat and back mounted versions) reported following ditchings. Findings may result in the requirement to evaluate the snagging problems caused by carrying the PSP during simulated underwater escape through representative escape hatches. It is envisaged that the initial work would be carried out within a 1-2 year time scale and the remaining work be conducted within a 3 year time scale, depending on the initial conclusions.

d. The introduction of survivor interviews by human factors experts specialising in underwater escape. This work is of a continuous nature.

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6 Annex A. Areas requiring attention or further development

a. The requirement for abandon aircraft drills should be enforced.

b. A minimum standard for helicopter underwater escape training should be defined so that aircrew attending civilian offshore survival centres receive adequate training.

c. Passenger briefings should be improved by introducing a similar system to that used by civilian operators.

d. The advantages of jettisoning or opening doors before ditching should be investigated.

e. An investigation for fitting crashworthy seats into all helicopters should be conducted.

f. Improved restraint systems should be fitted for rear crew and passengers.

g. Optimum brace positions should be identified for individual helicopter occupants.

h. Further work into inflatable body and head restraint system (IBAHRS) should be conducted.

j. Improved flotation systems for ditched helicopters should be investigated.

k. Investigation into cold water immersion responses in man should be continued.

l. Methods to improve underwater visual acuity should be investigated.

m. Beta lights should be replaced with a more suitable underwater lighting system.

n. An investigation for fitting an escape route guidance system into existing helicopters should be conducted.

o. Hand holds should be provided near exit jettison mechanisms.

p. Extensive work should be conducted into the jettison of escape hatches for all UK military helicopters.

q. Work into alternative underwater breathing aids should be continued.

r. Providing an alternative underwater breathing aid (eg rebreathers) for casual passengers should be considered.

s. The occurrence of PSP snagging during underwater escape should be investigated.

t. Investigations should be conducted to improve the flotation characteristics of lifejackets when worn with immersion coveralls.

u. Steps should be taken to reduce the risk of damaging immersion coveralls from protruding objects during escape.

v. Research into improving deployment of multiseat liferafts from helicopters should be resumed.

w. Investigate potential for immediate rewarming of casualties on-route to hospital.

x. Survivors should be interviewed by human factors experts specialising in underwater escape so that experiences and information can be used to aid further developments.

y. Helicopter modifications should be assessed for their influence on underwater escape.