2010

OFFSHORE HELICOPTER SAFETY REPORT

Michael Taber

This report details five key areas of interest as they relate to offshore helicopter travel safety. In order to contextualize the report, the first section identifies previous helicopter events (crashes and ditching) within the offshore oil and gas industry. This is followed by a discussion of additional operator requirements outlining the need for an integrative approach associated with operational requirements and human performance of helicopter underwater escape procedures. The third section of this report then addresses the current understanding of Helicopter Underwater Escape Training (HUET) standards in an effort to identify possible improvements to survivability. The fourth section focuses on personal protective equipment associated with helicopter transport over water in order to discuss standardization limits. The fifth section of this report details the need for a collaborative approach to the implementation and monitoring of helicopter safety initiatives. The sixth section of the report calls for an understanding of personal accountability with regard to helicopter travel safety and suggests that in order to achieve maximum survivability in the event of a ditching, all stakeholders share in the responsibility of risk mitigation. The final section offers a list of information related to influencing factors associated with helicopter ditching survivability. This list is divided into known and unknown information in an effort to offer some direction for future research.

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PREAMBLE

Transporting offshore personnel to installations located hundreds of kilometers off the North Atlantic coast represents some unique challenges. The considerable distance from shore, difficulty of personnel transfer, and variability of weather all play key roles in a decision of how best to safely transport individuals to these remote work sites. Not surprisingly, helicopters have been adopted as the primary means of moving individuals due mainly to their efficiency and have become are an elemental part of the offshore environment. As evidence of their popularity, approximately 900,000 flight hours are completed each year during normal personnel transport to offshore installations around the world (Hart, 2008). However, as the search for hydrocarbons moves further offshore, the need to address specific safety issues related to helicopter transportation increases. Therefore, the following report is intended to provide a review of existing information related to offshore helicopter transportation safety. Specifically, this report is designed to aid in developing future guidelines related to operational requirements for operators, helicopter safety training standards, personal protective equipment for passengers and pilots, worker and pilot participation in safety initiatives, and finally, personal accountability related to helicopter safety.

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LIST OF ABBREVIATIONS

AAIB	Australian Aviation Investigation Board
ALARP	As Low As Reasonably Practicable
ASRS	Aviation Safety reporting System
AWM	Airworthiness Manual
BCAR	British Civil Airworthiness Regulations
BP	British Petroleum
BST	Basic Survival Training
BST/R	Basic Survival Training/ Recurrent
CAA	Civil Aviation Authority
CAPP	Canadian Association of Petroleum Producers
CGSB	Canadian General Standards Board
CHC	Canadian Helicopter Corporation
C-NOPB	Canadian Nova Scotia Offshore Petroleum Board
C-NLOPB	Canadian Newfoundland and Labrador Offshore Petroleum Board
CSB	U.S. Chemical Safety and Hazards Investigation Board
EASA	European Aviation Safety Agency
EBS	Emergency Breathing System
ESTO	European Technical Standard Order
FAA	Federal Aviation Authority
FAR	Federal Airworthiness Regulations
HPTS	Helicopter Passenger Transportation Suit
HUEBA	Helicopter Underwater Emergency Breathing Apparatus
HUET	Helicopter Underwater Escape Training
ICAO	International Civil Aviation Organization
JAR	Joint Airworthiness Regulations
METS™	Modular Egress Training Simulator
MI	Marine Institute
NASA	National Aeronautics and Space Administration
NTSB	National Transportation Safety Board
OGP	Oil and Gas Producers
OLF	Norwegian Oil Industry Association
OPITO	Offshore Petroleum Industry Training Organization
PLB	Personal Locator Beacon
PPE	Personal Protective Equipment
QMS	Quality Management System
SMS	Safety Management System
SSTL	Survival System Training Limited
TC	Transport Canada
TSBC	Transportation Safety Board of Canada

1. INTRODUCTION

Based on combined reports from the National Transportation Safety Board, Civil Aviation Authority, and various other sources, the international offshore community experienced 60 helicopter ditchings/crashes between January 2000 and December 2009 (Table 1). Of the 60 events, 29 (48%) involved fatalities and resulted in the death of 152 of the 294 (52%) individuals onboard. The information in Table 1 has not been divided into classifications such as a ***ditching*** (controlled/semi-controlled intentional emergency landing on water) or a ***crash*** (uncontrolled flight into terrain/water); however, the number of fatalities represents a survival rate well below that suggested by previous studies (Table 2).

Table 1. World offshore helicopter ditchings for 2000 – 2009.

Date	Helicopter Type	Offshore Location	Number Onboard	Fatalities	Survival Rate (%)
29/04/00	Bell 206	Gulf of Mexico	2	0	100
07/09/00	Bell 206	Gulf of Mexico	1	0	100
26/12/00	Bell 206	Gulf of Mexico	1	1	0
08/01/01	Bell 206	Gulf of Mexico	3	0	100
04/05/01	Bell 206	Gulf of Mexico	1	0	100
04/08/01	Bell 206	Gulf of Mexico	2	0	100
05/08/01	Bell 206	Gulf of Mexico	3	0	100
26/09/01	Bell 206	Gulf of Mexico	3	0	100
18/10/01	Bell 206	Gulf of Mexico	5	5	0
01/12/01	Bell 407	Gulf of Mexico	1	0	100
29/12/01	Bell 407	Gulf of Mexico	1	1	0
08/01/02	Bell 206	Gulf of Mexico	1	0	100
23/03/02	Bell 206	Gulf of Mexico	1	1	0
08/04/02	AS 355	Gulf of Mexico	2	2	0
16/07/02	S 76	North Sea	11	11	0
25/07/02	Bell 206	Gulf of Mexico	2	0	100
01/09/02	Bell 206	Gulf of Mexico	4	0	100
09/01/03	AS 350	Gulf of Mexico	5	0	100
16/01/03	Bell 206	Gulf of Mexico	4	1	75
21/01/03	Bell 206	Gulf of Mexico	5	0	100
16/02/03	Bell 407	Gulf of Mexico	5	2	60
11/05/03	Bell 407	Gulf of Mexico	4	0	100
08/07/03	EC 120	Gulf of Mexico	3	0	100
11/08/03	Mi-172	India	27	27	0
13/08/03	Bell 206	Gulf of Mexico	5	3	40
12/09/03	Bell 206	Gulf of Mexico	4	0	100
10/10/03	Bell 206	Gulf of Mexico	3	3	0

Date	Helicopter Type	Offshore Location	Number Onboard	Fatalities	Survival Rate (%)
01/12/04	Bell 407	Gulf of Mexico	1	1	0
18/02/04	Bell 407	Gulf of Mexico	4	1	75
06/03/04	Bell 206	Gulf of Mexico	3	0	100
24/03/04	S 76	Gulf of Mexico	10	10	0
24/06/04	Bell 206	Gulf of Mexico	3	3	0
17/07/04	Bell 206	Gulf of Mexico	1	1	0
21/07/04	Bell 206	Gulf of Mexico	3	0	100
19/08/04	Bell 412	Gulf of Mexico	9	0	100
29/09/04	Bell 206	Gulf of Mexico	3	0	100
18/02/05	Bell 206	Gulf of Mexico	3	0	100
13/03/05	Bell 206	Gulf of Mexico	1	0	100
13/05/05	EC 120	Gulf of Mexico	2	0	100
18/06/05	AS332L	Indonesia	13	3	77
17/07/05	Bell 412	Mexico	2	2	0
18/08/05	Bell 206	Gulf of Mexico	2	2	0
06/09/05	S 76	Gulf of Mexico	12	0	100
06/10/05	Bell 206	Gulf of Mexico	3	3	0
19/03/06	Bell 222	Gulf of Mexico	2	0	100
05/05/06	EC 120	Gulf of Mexico	1	0	100
27/12/06	AS365N	North Sea	8	8	0
22/07/07	Bell 206	Gulf of Mexico	3	0	100
13/10/07	Mi-8T	Caspian Sea	6	6	0
15/12/07	Bell 407	Gulf of Mexico	2	0	100
29/12/07	Bell 206	Gulf of Mexico	5	1	80
09/04/08	Bell 206	Congo	1	1	0
04/09/08	Bell 212	Dubai	7	7	0
25/09/08	Bell 407	Australia	7	0	100
11/12/08	Bell 206	Gulf of Mexico	5	5	0
04/01/09	S 76	Gulf of Mexico	9	8	11
18/02/09	AS332L	North Sea	18	0	100
12/03/09	S 92	North Atlantic	18	17	6
01/04/09	AS332L	North Sea	16	16	0
01/11/09	Bell 206	Gulf of Mexico	2	0	100
Totals – Average			**294**	**152**	**48%**

Although not an exhaustive list, Table 2 shows past ditching study survivability results. The combined (day/night + trained/untrained) survival rate for the ditching studies does not appear to fluctuate dramatically from one time period to the next. Brooks, MacDonald, Donati, and Taber (2008) suggest that the average worldwide ditching survival rate is approximately 78%. With this in mind, it is noteworthy that the world offshore ditching survival rate shown in Table 1 is at least

24% less than that of previous reports. Based on the assertion that 85% of all aircraft crashes are survivable (Shanahan, 2004), the rate indicated in Table 1 is a full 36% below what should be considered an acceptable average. Further statistical analyses of these offshore cases would be beneficial in identifying survival factors related to external flotation, amount of warning, time of day, previous underwater escape training, and position of the helicopter when passengers and crew escaped.

Table 2. Reported helicopter ditching survivability rates.

Study Population	Author(s) – (Study Date)/ Time Period	Survival Rate
US Navy	Cunningham (1978)/1963-1975	91.5% (with training) 66% (without training)
Canadian military	Brooks (1988)/1952-1987	77%
Royal Navy	Vyrnwy-Jones & Turner (1988)/1972-1984	85%
US Navy	Brooks (1989a, b)/1978-1987	79% (daytime) 72% (night)
World (civilian) and US military	Chen, Muller, & Fogarty (1993)/1982-1989	82%
US Navy	Kinker, Loeslein, & O’Rourke (1996)/1985-1997	88% (daytime) 53% (night)
World civilian statistic	Clifford (1996)/1971-1992	62.5%
World (civilian and military)	Taber & McCabe (2006)/1993-2005	70% (daytime) 39% (night)
World (civilian and military)	Taber & McCabe (2007)/1971-2005	66%
Canadian registered helicopters	Brooks, MacDonald, Donati, & Taber (2008)/1979-2006	78%
Average Survival Rate (combined)		**72%**

Considerable attempts have been made to mitigate known risks associated with helicopter transportation over water; however, survivability rates remain lower than what should be expected and these events stand as a sobering reminder that a more critical understanding of how to manage helicopter emergency situations is needed. Specifically, a better understanding of Helicopter Underwater Escape Training (HUET) standards and how they might affect survival rates is essential to directing future research.

Based on the survival rates presented in Table 1, 2, and recent ditching information, the primary focus of this report is aimed at increasing the safety of offshore helicopter travel. In order to accomplish this goal, it is necessary to contextualize the key areas of interest by outlining previous helicopter ditching survivability research. Therefore, this first section addresses factors known to influence overall survival rate.

1.1 Survival Rates Based on Time of Day and Position in Water

To examine the effect of factors such as cause of event and time of day, Kinker, Loeslein, and Contarino (1998) reported that US Navy/Marine Corps daytime ditching survival rates were 88% while nighttime rates were only 53%. In a similar examination of world helicopter statistics, Taber and McCabe (2006) examined 151 helicopter ditchings that occurred from 1993 to 2005 and reported that one of the most significant contributing factors to survivability was the time at which the ditching occurred. They noted that if a ditching occurred between 18:00 and 23:59 (local times), survival rates were only 39%, whereas a ditching that occurred between 06:00 and 17:59 resulted in a survival rate of 70% (Taber & McCabe 2006). It was further identified that if the helicopter inverted immediately following impact (occupants had to escape while upside down underwater), survival rates were significantly lower than if the helicopter remained upright long enough for passengers and crew to evacuate. In a larger meta-analysis, Taber and McCabe (2007) examined over 500 ditching reports from various sources around the world. In this meta-analysis, it was noted that the overall survival rate was 66% and that the majority of the fatalities resulted when the helicopter rapidly inverted and sank (see also Chen, Muller, & Fogarty, 1993). Taber and McCabe (2007) further noted that 63% of the helicopters capsized and fill with water regardless of whether external flotation devices were installed and/or deployed.

1.2 Survival Rates Based on Amount of Warning

Research also shows that the amount of warning just prior to impact plays a considerable role in overall survival rates. Brooks et al. (2008) report that of the 46 ditchings investigated, 83% occurred with less than 15 seconds of warning. Of the ditchings that occurred with minimal warning time, the survival rate was 86% while those ditchings that afforded longer warning times showed a survival rate of 100%.

1.3 Survival Rates Based on Type of Injury

Although impact injuries are often assumed to be the single greatest contributor to fatalities in a ditching (Civil Aviation Authority, 1995), this is not borne out by results. For example, in a detailed examination of cause of death, Clifford (1996) reported that the majority (57% for civilian ditchings and 73% for British military ditchings) of fatalities were the result of drowning as opposed to impact injuries. Cunningham (1978) reported that 19% of the 196 ditching fatalities he investigated were the result of drowning. After examining the 46 Canadian registered ditchings between 1979 and 2006, Brooks et al. (2008) indicate that, when cause of death was reported, 63% of the fatalities were the result of drowning. The Transportation Safety Board of Canada (TSBC) (1994) also cites drowning as the primary cause of death in fixed wing ditchings that occurred between 1976 and 1990. In fact, the TSBC (1994) report clearly points out that, of the 168 fatalities examined, only 10% were as a result of impact injuries while 67% died of drowning while trapped inside the fuselage.

Limited data exists regarding the point at which drowning occurs post-impact. In the majority of cases, recovery of casualties takes place several hours or days after the initial occurrence, thus making it difficult to identify the exact time that water ingestion took place (during the impact and subsequent inversion or after breath-hold capabilities have been exceeded). Although the identification of ingestion time may at first appear to be irrelevant, detection of the precise moment is crucial to understanding whether a ditching is considered survivable. If, for instance, all of the passengers and crew drown as a result of impact forces causing unconsciousness, possible egress difficulties are less likely to be investigated. If however, the passengers and crew survived the impact and were unable to egress due to poor design of exits, suits, or aircraft interior configuration, identification of these difficulties is paramount to ensuring that risks are mitigated. Based on previous research and survivor testimony (personal communication Canadian military aircrew), egress difficulties typically relate to locating and functioning emergency exits, disorientation, lack of visual acuity, poor breath-hold ability in cold water, and aircraft attitude immediately after impact and have been implicated as the cause of low survival rates (Brooks, et al., 2008; TCSB, 2006).

1.4 Survival Rates Based on Previous Training

Taken together, these results indicate that if the impact forces are considered survivable, passengers and aircrew need to be trained how to escape from the helicopter fuselage when it is inverted and filled with water. This assertion is supported by the fact that survival rates are higher for those trained in helicopter underwater escape procedures (Brooks & Bohemier, 1997; Bohemier, Brooks, Morton, and Swain, 1998; Canadian Forces, 2008; Hytten, 1989; Ryack, Luria, & Smith, 1986). In addition, Cunningham (1978) reports that overall survival rates for those without underwater escape training was 66% while those who had training showed a survival rate of 91.5%. Past underwater escape training is not typically recorded during the ditching/crash investigation. For example, Brooks et al. (2008) indicate that only one of the 46 (2%) ditching reports examined states whether individuals had completed underwater escape training. In order to better understand the relationship between survival and training, it is important to record past training experience as well as identify the amount and quality of this training (see Section 3 below). Only then will it be possible to effectively explore correlations between training and survival.

2. NEED FOR ADDITIONAL OPERATOR REQUIREMENTS

This section of the report addresses the need for operators to ensure that an effort is made to reduce the risks associated with helicopter transport as low as reasonably practicable (ALARP). Although considerable effort has been made to ensure helicopter transportation is safe, specific investigation of the interrelatedness of multiple factors has yet to be explored. Therefore, a holistic examination of crashworthiness related to seat position, window locations and size, number of personnel required to utilize one exit, physical requirements needed to open a primary and secondary exit, placement of auxiliary equipment (i.e. fuel cell, liferaft, survival or first aid kit), and an understanding of how these factors affect one another is needed. Research and anecdotal results following emergencies have clearly shown that, without fully examining the practical requirements necessary to survive a helicopter ditching, it is difficult to predict the consequences of untested strategies used during egress (Taber & McCabe, 2009). For example, those who have never opened an exit underwater may believe that the functionality and forces required to open it will be similar to that in air. Preparation based on this false sense of the skill set requirements may reduce the likelihood of survival.

2.1 Interior Safety Component Crashworthiness Related to Underwater Escape

Although there is a requirement for military and civilian helicopters to be examined for crashworthiness, testing is primarily directed at fuselage and seat designs during impact on land and does not specifically address the underwater escape environment experienced by those egressing after an event has occurred (Jackson, Fasanella, & Lyle, 2006). This fact is borne out by the fact that manufacturers of civilian helicopters are not required to test the escapability of a particular interior seat configuration in case of a ditching/water impact. Manufacturers may decide to incorporate crashworthiness components used in military helicopter design; however, there is no requirement to do so. Therefore, it is important to consider the interior environment (i.e. in-rushing water, floating debris, floatation angle or sink rate, compression and displacement of seats, etc…) to ensure that post-impact egress it possible.

If crashworthy components are incorporated into a helicopter safety system, testing under realistic (high fidelity) underwater egress conditions should be carried out to ensure that there are no complications during escape. For example, the decision to install crashworthy seats in the passenger cabin of an offshore helicopter has obvious benefits for those that might be involved in an incident that places considerable impact forces on the occupants; clearly the individuals need to survive the impact before they can begin an escape. Benefits of crashworthy seats have been demonstrated in fixed wing aircraft (Cherry, Warren, & Chan, 2000) and it is implied that these benefits would be transferred to any aircraft that might need a seat to attenuate (compress or lower) during impact forces that exceed 20 Gs (G = acceleration/gravitational constant of 32.2 ft/sec^2 or 9.8 m/sec^2). In addition, crashworthy seats typically incorporate a four-point seat harness, thereby transferring the impact loads away from the occupant during the critical portion of the impact as well as reducing the strike envelope (area immediately surrounding the individual in which flailing may result in contact with objects and other personnel) during and immediately following impact (Shanahan, 2004).

Although crashworthy seats are likely to increase survivability during a crash, there is no straightforward answer to: "*What is considered a survivable ditching G force*?" This is mainly due to the fact that survivability calculations are based on specific constraints related to the impact forces associated with aircraft structural components (Ubels & Wiggenraad, 2002). Additionally, there is a difference with regard to occupant survivability depending on the direction and duration of impact force as well as the type of restraint, physiological condition of the individual (i.e. fitness level, age, sex), and any possible re-direction of the forces (i.e. the seat breaks free and the individual accelerates forward or sideways immediately after impact). Based on previous research, an average person would be expected to survive a minimum of approximately 20 Gs of positive deceleration force within a duration of between 0.005 and 0.5 seconds in a four point harness facing forward in a seat that remains in place during the impact (Shanahan, 2004; see also Desjardins, & Laananen, 1980).

Shanahan (2004) suggests that, based on the criteria that impact forces are within human tolerances and the immediate environment surrounding the individual is relatively intact, 85% of all aircraft crashes are considered survivable. However, these estimates are based on crashes that occur on land and there is no immediate danger of drowning. During human crash tolerance testing in the 1960s, Colonel John Stapp showed that a rear facing seat was far better than a forward facing one and that, under the right conditions, a person could withstand over 40 Gs.

(Stapps, & Taylor, 1964). More recently, however, data from Indy car racing has shown that several drivers have withstood impact forces in excess of 100 Gs (Society of Automotive Engineers, 1999, as cited by Shanahan, 2004) due to the use of crashworthy seats. Given the fact that 20 Gs is within the limits of human tolerance, the installation of crashworthy seats appears to be beneficial. However, examined from a post-event perspective, these same seats may inadvertently place significant restrictions on mobility in the event of a required escape if they are placed too closely together or positioned next to an obstruction such as an auxiliary fuel cell (Figure 1).

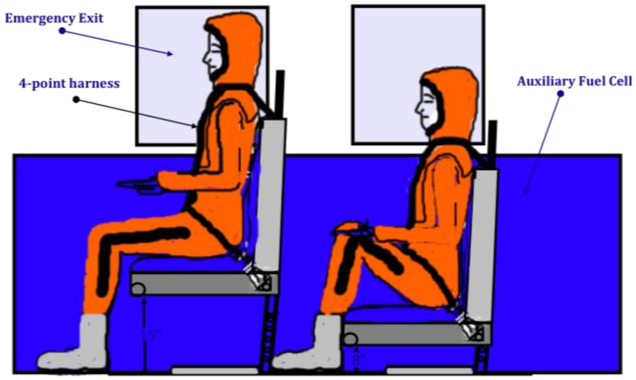

Figure 1. Crashworthy seat in full up (pre-impact) and compressed position (post-impact).

Based on the stroke distance of crashworthy seat installed in the S92, if the seat compresses to its full down position (from 15 inches to 8 inches - 380 mm to 203 mm), the individuals' knees and upper thighs will be rapidly forced into their chest and any seat harness release mechanism that was easily reached during the full up seat position may now be firmly buried in the person's lap (Figure 1). Additionally, if there is any possibility that individuals can roll their feet up under the seat prior to it collapsing, there exists the possibility that the full force of their body and chair, multiplied by the G-forces, will compress and injure the lower portion of the leg and ankle during impact. These problems are particularly more troublesome if the seats are located in such a position that the individual is unable to stretch their feet out in front of them (typical offshore configuration). Additionally, the lower position of the individual after the seat has compressed changes the physical distance between the seat pan (lower portion of seat) and the emergency exit, thus increasing the distance that an individual needs to reach out in order to locate an emergency exit. The average functional reach of American males in a seated position has been reported as 793.1 mm (31.2”) (Kozey, Reilly, & Brooks, 2005; Uppu, Aghazadeh, & Nabatilan, 2006; Sengupta & Das, 2000); therefore, any exit positioned beyond this distance cannot be reached if the shoulder harness lock has been engaged during the impact. If the exit is placed outside of the functional reach envelope, individuals may be required to disconnect their seat harness prior to opening an exit. The implications of disconnecting a seat harness to reach an emergency exit will be discussed in further detail in the next section, as it requires some thought regarding task analysis and skill performance.

With regard to distances between seats, the Civil Aviation Authority (CAA) Airworthiness Notice 64 regulates that the minimum required distance between the back cushion of one seat and the back of the seat in front of it is 660 mm (26”) (Quigley, Southall, Freer, Moody, & Porter, 2001). Quigley et al. (2001) point out however, that when the 95th percentile European male is considered, this measurement should be increased to a minimum of 711mm (28.2"), which increases knee clearance by 25mm (1"). These minima do not consider the fact that, when crashworthy seats are used, passengers are not able to place their feet under the seat in front of them as a barrier is placed around the base of the seat to prevent crushing injury during heavy impact forces. In addition, the minimum distance between the seats does not consider that the seat will move slightly forward on the compression rails in a crash which will further decrease the amount of space for the individual post-impact. Therefore, an analysis of crashworthy seat placement in offshore transport helicopters should be included during the design testing and certification process.

2.2 Window Location/Size and Human Factors of Underwater Escape

This section of the report explores the influence of emergency exit ergonomics (window locations and size), body size and number of personnel required to utilize one exit, physical requirements needed to open a primary and secondary exit, placement of auxiliary equipment (i.e. fuel cell, liferaft, survival or first aid kit) on the ability to successfully egress a capsized/flooded helicopter. Additionally, this section discusses the possible consequences associated with current interior helicopter configurations used to transport offshore personnel in Atlantic Canada.

2.2.1 Emergency Exit Ergonomics

After conducting underwater escape trials with 48 aircrew egressing through nine different emergency exits, Brooks, Bohemier, and Snelling (1994) concluded that the lack of standardized emergency exits and placement of release mechanisms presented considerable problems during testing of required egress tasks. Difficulties ranged from disorientation to inability to locate and function exit mechanisms. Based on these findings, as well as an identification of more than 23 exit types, Brooks and Bohemier (1997) concluded that the ergonomic confusion created by different exits needed to be addressed in order to enhance overall survival rates. Coleshaw (2006b) also points out that the different helicopters used for offshore transport in the North Sea have several different types of exits and door with different operating mechanisms. Operators of helicopters may assume that the aircraft manufacturer will test user interface with regard to survivability of the product even though there is no such requirement related to underwater escapability.

The Federal Aviation Authority (FAA) does regulate the number of emergency exits and states that there must be a minimum of 2 emergency exits (Type III or IV, listed below) located 1 per side for helicopters carrying more than 16 passengers (FAR 27.807). Emergency exits are defined by the FAA and CAA as follows (BCAR – Chapter G4-3; JAR/FAR 29.807):

- ***Type I*** – a rectangular opening of at least 610 mm wide by 1219 mm high (24" by 48"), with corner radii not greater than one third the width of the exit, in the passenger area in the side of the fuselage at floor level and as far away as practicable from areas that might become potential fire hazards in a crash.

- ***Type II*** – the same as Type I, except that the opening must be at least 508 mm wide by 1118 mm high (20" by 44") and, if located over a wing or sponson, a step up inside the rotorcraft of not more than 254 mm (10”) and a step down outside the rotorcraft of not more than 432 mm (17”) is permitted.

- ***Type III*** – a rectangular opening of at least 508 mm wide by 914 mm high (20" by 36") with a step up inside the rotorcraft of not more than 508 mm (20”) and, if located over a wing or sponson, a step down outside the rotorcraft of not more than 668 mm (27”).

- ***Type IV*** - a rectangular opening of at least 483 mm wide by 660 mm high (19" by 26"), with corner radii not greater than one third the width of the exit, in the side of the fuselage with a step-up inside the helicopter of not more than 737 mm (29") and, if located over a wing or sponson, a step down outside of the rotorcraft of not more than 914 mm (36”).

Johnson, Robertson, and Hall (1989) recommend that an emergency exits should be at least 22” (558 mm) square to accommodate the 95th percentile male US Army troop shoulder breadth during egress. Federal Airworthiness Regulations (FAR) suggest that an emergency exit should “admit a 483 by 660 mm (19" by 26") ellipse” (FAR 27.807). In an examination of a relevant workforce, Kozey, Brooks, Dewey, Brown, Howard, Drover, MacKinnon, and McCabe (2009) reported that the average (this includes the 5th, 50th, and 95th percentile) shoulder breadth of male offshore workers in Atlantic Canada was 20.3” (515 mm) in normal work clothes; however, this value increased to 21.7” (553 mm) when wearing an immersion suit. Quigley, Southall, Freer, Moody, and Potter (2001) reported that the average shoulder breadth (bideltiod measurement) of a United States dataset was 22.2” (563 mm) for the 95th percentile. Of particular relevance to this discussion, the CAA (Leaflet 11-18, 2006) reported that “Underwater escape through a rectangular aperture of 17” x 14” (432mm x 355mm) has been satisfactorily demonstrated by persons of a size believed to cover 95% of male persons wearing representative survival clothing and uninflated lifejackets” (Part 11, Leaflet 11-18, p. 1). Interestingly however, Reilly, Kozey and Brooks (2005) report that the 95th percentile offshore worker in Atlantic Canada has a crest breadth of 15.35” (390 mm) and a bi-acromial breadth of 17.5” (446 mm) without an immersion suit and these measurements increased to 16.46” (418 mm) and 19.13” (486 mm) respectively with a suit on. Therefore, an exit that measures 17” x 14” would not accommodate the 95th percentile worker even without an immersion suit. Furthermore, if a 95th percentile individual is seated next to someone of a similar size at a small exit (Figure 2) the possibility of successful underwater egress is greatly diminished.

Figure 2. AS332L (Super Puma) rear exit and seats.

In order to identify difficulties associated with helicopter emergency egress and size of personnel that may need to escape through smaller exits, Taber (2007) completed a functional task analysis of helicopter underwater escape skill sets needed to successfully egress a capsized/flooded AS332L (Super Puma) offshore helicopter configuration. In addition to finding that several of the emergency exits were positioned outside the functional reach of most offshore personnel (wearing a four-point seat harness), Taber (2007) reported that the aft most exits of the AS332L measured only 12” (305 mm) by 21” (533 mm) (Figure 3, panel A). Although these exits are not considered “*emergency exits*” they are positioned in the helicopter in such a manner that anyone sitting next to them would presumably try to utilize them as a primary escape route in the event of an emergency. Not surprisingly, participants requested to complete the task analysis while sitting side by side at these smaller exits raised concerns about the exit size and the ability to complete the underwater escape procedures (Taber, 2007). However, as the participants used in the task analysis were selected for their past training experience (safety divers and offshore survival instructors), no significant difficulties were recorded (Taber 2007).

Conversely, given the nature of a real-world ditching situation, with less qualified individuals (typical offshore worker), it is not difficult to imagine some of the complications that a smaller exit may pose for larger personnel (individuals requiring a large to extra large helicopter transportation suit). Based on the available anthropometric data regarding average shoulder breadth of the Atlantic offshore workers, it can be reasonably assumed that this small Super Puma window may represent a considerable egress challenge for half of those flying in the configuration currently used in Eastern Canada. As a comparison to this small Super Puma exit, the majority of exits installed in an S92 measures 17” (431.8 mm) by 20” (508 mm) and therefore represents a more reasonable egress solution for those seated next to them. Figure 3 shows an approximated representation of a 26” ellipse overlaid in both the small Super Puma (Panel A) and S92 passenger exit (Panel B).

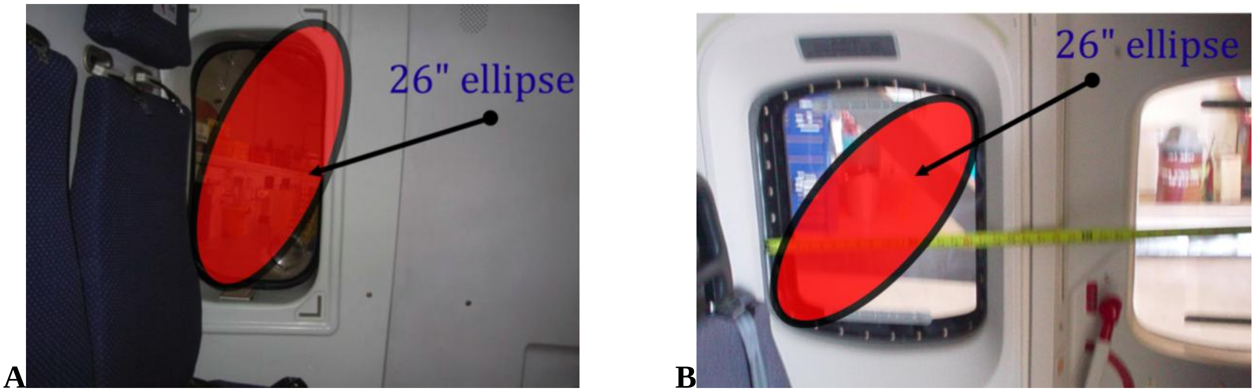

Figure 3. AS332L (Super Puma) rear cabin and S92 main cabin emergency exit with 26” ellipse overlay.

In order to better identify human factors issues during egress it is important to understand the position and functionality of an emergency exit as well as consider the size of the individuals that may need to utilize these escape routes under less than ideal conditions. It is also important to point out that any exit, regardless of whether it is designated an emergency exit or not, will be used by individuals attempting to escape a capsized and flooded cabin. With this in mind, the following sections address a combination of influencing factors in order to outline key aspects of underwater escape training.

2.2.2 Physical Requirements to Open Primary/Secondary Exit

In addition to recommending that emergency exits should be able to accommodate the 95th percentile troop in full combat gear, Johnson et al. (1989) suggest that an exit should take no longer than 5 seconds to open. FAA regulations (FAR 27.807) require emergency exits to:

- Open without interference from flotation devices whether stowed or deployed;
- Have simple and obvious methods of opening, from inside and from outside, which <u>do not require exceptional effort</u>;

- Be arranged and marked so as to be readily located and opened even in darkness (including from a capsized and submerged cabin), and;
- Be reasonably protected from jamming by fuselage deformation (underline added)

Although FAA regulations indicate that exceptional effort should not be required to open an emergency exit, there does not appear to be a standard that indicates what effort is acceptable. Swingle (1995) examined the force (in lbs.) required to operate 12 different emergency exits in 6 different helicopters for the U.S. Army and found that there were considerable differences in both the operation and functioning of the release handles. Swingle (1995) reports that “There is no specific standardized method to describe emergency egress procedures in U.S. Army helicopters” (p. 16) and indicates that forces range from “minimal” to “substantial” with specific values ranging between 10 to 45 pounds.

Without a clear guideline, the FAA regulations are open to interpretation and aircraft manufacturers are free to develop an exit that adheres to general requirements. As evidence of this problem, the CAA (1995), in a review of helicopter safety and survival following a ditching off the Cormorant Alpha platform in 1992, reported that concerns were raised over the lack of “standardization in the operation of emergency exits, which present a variety of different mechanisms, operated by tags and/or handles located in various positions relative to the exit and operating in different directions” (p. 23). From these reports, it was recommended that the CAA should monitor the situation “with the aim of defining one standard method of exit release which could be fitted to all aircraft” (p. 23). This recommendation has not been employed in any of the new aircraft designs and only adds to the number of operating instructions that must be recalled by passengers and crew. This becomes a particularly difficult situation for those flying in several different types of helicopter over a short period of time.

It should be noted however, that the majority of exits installed in the passenger cabin of offshore transport helicopters are of a push-out design and require minimal understanding of their operating system. This reduces the ergonomic confusion suggested by Brooks and Bohemier (1997). There do not appear to be any documented reports indicating the force that is required to jettison these push-out exits and without this information it is difficult to predict how many offshore personnel are capable of opening the exit while inverted underwater. If the forces required to open an exit exceed the physical capabilities of the individuals expected to use them, changes in design and training are required.

2.2.3 Placement of Auxiliary Equipment/Cargo

In order to explore the influence that auxiliary equipment has on underwater escape and survivability, this section continues the discussion surrounding the use of crashworthy seats. Given the fact that an individual will be in a lower position if a crashworthy seat has attenuated the impact forces, an obstruction such as an auxiliary fuel tank placed between the individual and an exit may impede egress. As previously indicated, the individual might not be able to physically reach the exit due to this lowered position and the additional distance required to reach around the obstruction only compounds the problem. This may be true regardless of whether the individual is attempting to use a primary (closest escape route) or secondary exit (across an aisle) as there are limited physical reference points on the outside of the fuel tank. Individuals that are suddenly plunged into a cold underwater environment and turned upside down would struggle to locate and jettison a primary exit even under ideal circumstances. Adding the additional effects of disorientation caused by the rapid attenuation of the crashworthy seat during impact may prove to be too difficult if an inexperienced individual is required to egress from this lower position without having experienced similar egress requirements during training.

Practical egress training may be able to mitigate these risks; however, a detailed analysis of the problems needs to clearly document what step by step instructions will be used to address any difficulties associated with equipment placement or use. If personnel are expected to use a secondary exit across the aisle and an auxiliary fuel tank has been positioned under the exits, reference points that can be reached from a full up and compressed position must be installed to ensure that individuals will be able to locate their way to the exit after releasing their seat harness. However, if the individuals are expected to climb over or move to the row of seats in front of them before egressing, performance of this skill set should be demonstrated during underwater escape training.

Figure 4. Crashworthy seat in full up positioned next to S92 auxiliary fuel tank.

Figure 4 clearly shows that if the crashworthy seat is lower as a result of heavy impact forces and the auxiliary fuel tank is positioned between the individual and the exit, individuals may not be able to reach the closest exit (lower windowsill for the S92 push-out exit is 914 mm – 36” above the floor) without disconnecting their seat harness. A combination of ditching factors such as rapid inversion of the helicopter immediately following impact, inrushing water, degradation of visual acuity, inherent buoyancy of an immersion suit, reduced tactile senses (due to cold water), and possible disorientation represents a less than ideal time to disconnect a seat harness. Wearing the seat harness represents one of the only physical cues to identify one’s position relative to the airframe during inversion underwater and should not be released until a known reference point has been obtained. Furthermore, the added time needed to properly reference one’s position prior to disconnecting the seat harness as well as the lack of mechanical advantage of having the harness in place, may be beyond the person’s breath-hold (Cheung, D’Eon, & Brooks, 2001) and physical capabilities needed to egress safely.

With regard to additional equipment placement, Norwegian Oil Industry Association (OLF) (2004) developed recommendations of offshore helicopter flights and suggests, “Cargo must not be placed in such a way that passengers do not have direct access to alternative escape ways (push-out windows). Passengers cannot be placed in a seat where the adjacent push-out window is blocked, or in a seat where cargo obstructs the free access to the nearest push-out window” (section 5.1.2). These recommendations, although meant for the placement of cargo, should be considered a minimum when planning seat configurations and passenger escape routes. For example, the current Super Puma (AS332L) used in Atlantic Canada has a seat configuration when carrying an external fuel tank that restricts the use of two push-out exits on the starboard side of the helicopter, thus requiring the forward facing passenger on the starboard side to egress across the aisle after waiting for someone else to escape (Figure 5).

Figure 5. AS332L forward passenger seat of auxiliary fuel tank. (*Note: the passenger must egress across the aisle*).

2.2.4 Interior Helicopter Seat Configurations

In their helicopter safety review, the CAA (1995) reported that the “seating configuration of some offshore helicopters has hitherto left much to be desired” and indicated that changes were underway to improve the situation (p. 22). In a study of underwater escape procedures, Survival Systems International (1993) identified that the Super Puma AS332L used to transport offshore personnel represented a considerable challenge for passengers in particular seats and recommended that the interior configuration be modified. However, Taber (2007) writes, “modifying the helicopter interior configuration to meet the needs of all passengers during an event such as a ditching can be considered an excellent first step,” but suggests that “it is also important to keep in mind that the passengers must be trained to escape from the modified configuration under simulated emergency conditions. Only then can it be reasonably predicted that an individual will be able to transfer the simulated tasks to a real-world event” (p. 2).

Quigley et al. (2001) strongly recommends that when considering the relationship between cabin seating configurations and evacuation of passengers, the 99th percentile population should be used as a guide to ensure that the space between seats will not impede movement of personnel. Inclusion of the larger personnel is important when considering the size of the exits needed during underwater escape; however, Taber (2007) clearly demonstrated that smaller individuals required more assistance from survival instructors and reported more difficulties than larger personnel when attempting to open a representative Super Puma push-out exit while inverted underwater. The difficulties in opening the exit were related to the ability to overcome buoyancy (inherent from the suit and trapped air) while forcing on the push-out exit (Taber, 2007). Therefore, consideration of both the largest and smallest passengers should be used when testing helicopter seating and window configurations.

In addition to the size of individuals, Taber and McCabe (2009) found that, while conducting a functional task analysis of HUET for Canadian military land force troops being transported to offshore vessel platforms in a new configuration of a Sea King (CH124), the further away individuals were from an exit during underwater escape on breath-hold, the more difficulties they experienced. During their analysis, Taber and McCabe (2009) found that troops egressing from seats 3, 4 and 12 (Figure 6) rated the breath-hold egress tasks as considerably more difficult than those trials where they were sitting closer to an emergency exit. The recommendations of this study were to ensure that troops were outfitted with Emergency Breathing Systems (EBS) and that the exit being blocked by seat 5 and 6 (Figure 6) should be moved to ensure access to an additional exit.

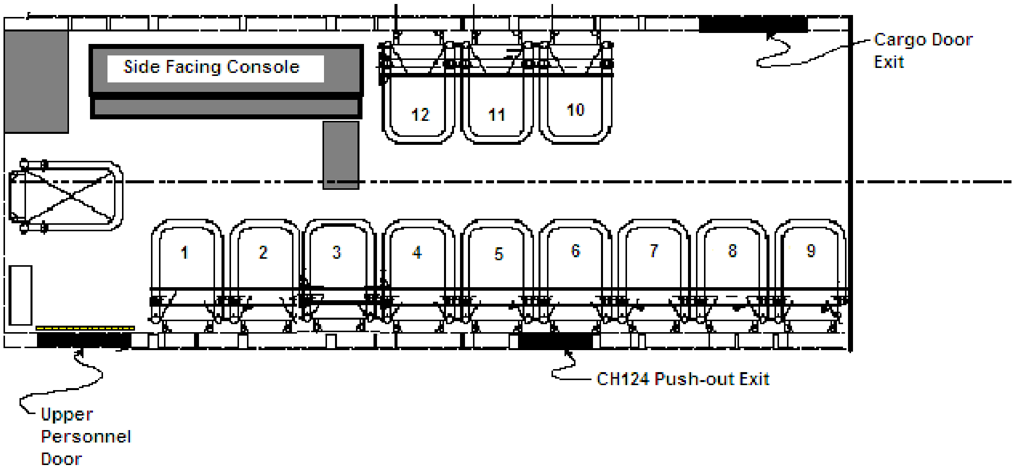

Figure 6. METS™ CH124 configuration for land force troop egress trials. (from Taber & McCabe, 2009 with permission).

At a minimum, each new seating configuration should be tested to ensure that egress is possible. This testing should use high physical fidelity (seat harnesses, exits and seats positioned in a configuration that closely resembles the actual helicopter interior) as well as a representative test population in an effort to identify snagging hazards, obstructions, and limitations of egress performance. Simulation fidelity and its influence on skill acquisition will be discussed in further detail in the Section 3.1.3; however, without a detailed level of testing that examines escapability, a new helicopter design may place the occupants in a non-survivable situation if the helicopter were to capsize and rapidly flood with water.

2.3 Interrelatedness of Egress Factors During Underwater Escape

After examining total underwater egress times from a fully loaded (18 passengers) Super Puma, Brooks, Muir, and Gibbs (2001) concluded that if an overall evacuation time for all personnel could not be completed within 20 seconds, "passengers should be provided with some form of air supply, or, after ditching, the helicopter should be modified so that it will stay afloat on its side and retain an air space in the cabin" (pg. 560). Cheung et al. (2001) also point out that when testing offshore workers' egress performance, 34% of the 228 participants breath-hold time (BHT) in water was less than the 28 seconds it took to evacuate under ideal conditions. Recent Canadian military ditchings have also indicated that an EBS aids in egress by affording additional time to deal with loose equipment, darkness, and disorientation (personal communication with ditching aircrew survivors, see also Brooks & Tipton, 2001, and Coleshaw, 2006a, b). Therefore, having EBS training combined with HUET courses is essential to mitigate a number of egress difficulties.

As further evidence for the need to consider the interrelatedness of multiple factors related to egress, Taber and McCabe (2009) clearly demonstrated that the placement of emergency exits and seating arrangements of the interior configuration significantly affected the performance of trained military troops. It was shown that when troops needed to wait for someone else to egress before attempting their own escape (i.e. not seating next to a window exit), overall escape time was significantly higher than the 20 second breath-hold egress threshold suggested by Brooks et al. (2000) (Taber & McCabe, 2009). Furthermore, it was reported that despite the fact that all personnel had successfully completed HUET requirements less than 60 minutes prior to testing, it was clearly shown that without the use of EBS, nearly half (48%) of the 12 troops involved in the breath-hold trial would have perished if they had been involved in a real-world helicopter ditching that rapidly capsized.

Given the paucity of available research and technical documentation on HUET requirements as they relate directly to operational requirements (i.e. the need for auxiliary fuel tanks, seat configuration, transport of miscellaneous equipment, need for night flights), future studies should focus on the integration of safety systems, human performance requirements, and the environments in which the specific skills must be completed. At a minimum, offshore operators should be encouraged to seek human factor/HUET expert advice regarding interior helicopter configuration changes and exit egress requirements that may impact survival rates. Operators should ensure that full-scale functional task analysis egress testing in a high fidelity simulator (discussed further in Section 3.1.3 below) is conducted prior to aircraft implementation in the offshore environment. Furthermore, HUET skill performance data should be collected during offshore training courses in order to establish a baseline of existing difficulties experienced by the offshore workforce. Such a database could then be used to inform both operators and manufacturers of where strategic interventions might increase survivability.

3. HELICOPTER UNDERWATER ESCAPE TRAINING (HUET) STANDARDS

This section of the report examines the existing Helicopter Underwater Escape Training (HUET) standards used to prepare offshore workers in Atlantic Canada for a possible ditching at sea. First, internationally recognized HUET standards are outlined to identify differences in training methodology. Second, specific egress skill sets performed by offshore trainees at the two Canadian Association of Petroleum Producers (CAPP) recognized HUET facilities in Canada are compared. Finally, a discussion concerning the fidelity of the training environment and focused research areas are detailed in order to answer the following questions:

- ➢ *How much HUET practice is needed to prepare an individual for a real-world ditching?*
- ➢ *How often do individuals need to refresh their HUET skill set?*
- ➢ *What level of training fidelity is needed to ensure transfer of task knowledge to a real-world situation?*

The final portion of this section is directed at answering these questions by proposing appropriate standards of offshore helicopter safety training needed to ensure that passenger risk is reduced to a level that is reasonably practicable.

3.1 Internationally Recognized HUET Standards of Training

Central to any investigation of human performance in extreme environments is the standard of training provided to individuals prior to an emergency. Despite HUET courses that have been provided to the offshore workforce for more than 25 years, no one international standard exists. Currently, there several different HUET standards used to prepare personnel for offshore helicopter travel. As one of the most widely used standards, Offshore Petroleum Industry Training Organization (OPITO) has 49 approved HUET providers in 26 countries (http://www.opito.com/international/training-providers.html). The majority of these OPITO providers are also certified to train individuals to the Norwegian Oil Industry Association (OLF) standards which require more HUET exercises from a submerged and inverted position. Other HUET providers conduct training similar to OPITO standards, yet disagree regarding the level of skill performance required to gain certification. In order to identify differences in current standards it is important to outline the certification requirements of several recognized HUET providers as well as the environments in which the training takes place. As OPITO issues certification to facilities around the world, HUET simulators must meet the following requirements to gain approval:

Helicopter Underwater Escape Trainers (HUETs), used for OPITO training must meet the following criteria:

- *That it can be lowered on to the surface of the water, and then subsequently lowered below the water.*
- *In an emergency it can be rapidly retrieved to the surface and if necessary to the side of the pool with the delegates still inside.*
- *That it has <u>realistic seatbelt/harness fastenings</u> and a system for releasing delegates in an emergency should the buckle fail to open.*
- *That the body of the HUET rotates with the seats i.e. not just the seats rotating within a fixed body.*
- *There is a means of stopping the rotation in an emergency (usually a brake).*
- *The <u>exits should be of a similar size to those found on the common commercial helicopters used in the offshore industry</u>.*
- *If the HUET is also used for the on-land evacuation exercise involving then <u>the exit operating mechanism should be similar to that on real helicopters</u>.*
- *The <u>exit(s) used to conduct an evacuation on the water surface should be similar in operation to a real helicopter</u>.*
- *The <u>HUET must be fitted with push out windows for operation by delegates</u>.*
- *That there is sufficient room within the HUET for an instructor/assessor as well as the (4 max) delegates (<u>http://www.opito.com/international/approvals-faq.html</u>) - italics and <u>underline</u> added).*

Additionally, the International Association of Oil & Gas Producers (OGP) (2008) indicate that "HUET facilities should have the emergency exit mechanisms representative of the aircraft flown in offshore or water borne operations" (pg. 55). These minimum standards required for HUET simulation are generally accepted; however, the definition of *<u>representative exits</u>*, *<u>seats</u>*, and *<u>harnesses</u>* is open to interpretation as are the number of underwater escape trials required to gain certification. If not part of the OPITO certification process, it is typically left to the HUET provider to identify what constitutes a representative environment for underwater escape training and Appendix A is offered as an example of the different types of training simulators. The 29 different simulators shown in Appendix A clearly identify that HUET simulators range from a basic box with short plastic seats and non-representative lap-belts to a scale model of an actual helicopter complete with flight controls, electronic console panels, interior bulkheads, crashworthy seats, and 5-point harnesses that are the exact make and model of those used in the actual helicopter.

Although OPITO certification is recognized in most offshore environments, the Canadian Nova Scotia Offshore Petroleum Board (CNSOPB) and the Canada Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), in accordance with CAPP (2008) guidelines, also recognize OLF HUET from Norway and certification from two HUET training providers located in Atlantic Canada. The CAPP (2008) requirements are similar to those outlined by OPITO in that offshore personnel are required to have HUET and simply state that “The isolated nature of offshore installations create safety and emergency preparedness training needs to a much greater degree than would apply to a similar industrial setting onshore,” therefore, mandatory personal safety courses such as a Basic Survival Training (BST) and subsequent recurrent training (BST/R) is required (pg. 409). Within these guidelines, the BST and other mandatory courses require HUET exercises including emergency breathing systems; however, no description of the actual skill set is outlined. Therefore, the following sections identify which HUET skills appear to be most beneficial to the process of transferring information gained during training to a real-world situation.

3.2 HUET Skill Requirements

The explicit purpose of HUET is to ensure that individuals both understand what to do (declarative knowledge) in the event that a helicopter ditching is about to take place as well as what tasks (procedural knowledge) needed to be performed to successfully escape after the initial impact with the water. The division of these two types of knowledge is crucial to the development of a HUET standard as it bears directly on the approach taken during the design and implementation of training as well as the operational approach used by helicopter manufacturers and offshore operators. If for instance, declarative knowledge (information in memory that relates to facts and experiences) is seen as the most important aspect of training for underwater escape, the need to demonstrate practical skills warrants less emphasis. If however, procedural knowledge (information in memory related to the performance of skills) is considered to be more important to preparation of the individual, the ability to declare what skills need to be performed is deemphasized.

Still others suggest that the only way to measure the level of skill acquisition is by examining the amount of retention displayed at some later date (Schmidt & Bjork, 1992). Simply training an individual to escape a generic underwater egress simulator does not necessarily guarantee that the person will be able to generalize that information to a different environment (i.e. different emergency exits, sitting in an aisle versus a window, or one row back from an exit). In fact, it could be argued that a person can be trained to escape a specific underwater egress simulator perfectly every time and still not be able to perform these skills in a more stressful unfamiliar environment such as a real helicopter in a ditching. Schmidt and Bjork (1992) suggest that if a generic environment has to be used, it is best to include effortful practice trials that may not be easy for the individuals to perform. That is, if a skill does not require the individual to allocate a considerable amount of attention to ensuring an acceptable level performance is achieved, it is unlikely that the skill will be recalled at a later date.

It is further suggested that random practice (varied performance of different skills) is better for retention (Schmidt & Bjork, 1992; see also Perez, Meira, & Tani, 2005). These findings have been also been supported by Stokes, Lai, Holtz, Rigsbee, & Cherrick (2008) who suggest that during early learning, high variability facilitates skill acquisition, retention, and transfer as well as improves an individual’s capability to adapt skill performance to changing conditions. By increasing the variability and difficulty during the learning process, there may also be an increase in the level of stress and anxiety experienced by the individual. Coleshaw (2006a) indicates however, that individuals having completed HUET, in which underwater exit removal was required, suggested that they had a higher level of confidence and that removal of the exits was not seen as a major problem during training. This higher level of confidence would presumably decrease the levels of stress associated with increased difficulty of required skill sets.

From the survival rates shown in Table 2 (above), it is clear that military personal are more likely to survive a helicopter ditching that their civilian counterparts (83% versus 70% respectively). It may be argued that military personal need to be trained to a higher standard due to the fact they are placed in a more hostile environment on a more regular basis. Although this may be true, training of basic HUET skill sets should not be reduced merely because the likelihood of using the skills is less. In fact, egressing from a capsized and flood helicopter that has 16 to 18 other people (offshore configuration) may be more difficult than one that has only 3 to 5 people trying to escape (typical military helicopter crew). Therefore, HUET course providers should consider the fact that performance of a skill set requires the same level of training regardless of whether it is in a military or civilian environment.

Clearly, a holistic approach is most beneficial to the offshore workforce as it allows for consideration of the different possible situations that might be faced during a ditching (i.e. controlled landing on the surface of the water versus uncontrolled impact in which the helicopter inverts immediately). Therefore, declarative and procedural knowledge aspects are discussed in order identify their inclusion in existing HUET course information.

3.2.1 Declarative HUET Knowledge

Declarative knowledge related to HUET includes an understanding of the difference between pre- and post-impact skill requirements. For example, emergency breathing systems incorporated into the standardized personal protective equipment should not be used prior to water impact as potentially serious injury may occur if an individual inserts the air delivery valve into their mouth before impact has occurred. Pre-impact information (usually delivered in a classroom setting) should address past ditching results to ensure that individuals understand the importance of performing specific skills that will increase survival. This information should be used to identify hazards (i.e. poor brace position during impact, consequences of releasing a seat harness too early, hazards of loose ends of seat harness) that are known to reduce survival rates. The declarative knowledge covered during the theory portion of a HUET course should be designed to increase the possibility that individuals are able to create a beneficial survival plan regardless of the helicopter configuration used for offshore travel. That is, HUET course theory should ensure that pre-flight preparations (safety briefing, stowage of loose articles, checking primary and secondary emergency exit operation, and mental rehearsal of escape plan) become automatic regardless of helicopter type used for transport. After completing HUET theory requirements, individuals should be able to quickly identify ditching related hazards within an interior configuration and make appropriate changes to a pre and post-ditching plan.

3.2.2 Procedural HUET Knowledge

Procedural HUET knowledge should include physical performance of the required skill set. This includes the proper brace position depending on the style of seat and harness, physical motor skills necessary to open an exit in air and inverted underwater, as well as the physical requirements to function all supplementary survival equipment (i.e. personal locator beacon, lifevest, survival mitts, strobe light, and splashguard). In order to identify differences in skill performance requirements used to obtain certification, Table 3 outlines the HUET course requirements from the two CAPP approved course providers. Table 3 clearly identifies that there are a number of task requirement differences even though certification is recognized by CAPP and other offshore operators as being the same.

Table 3. Comparison of Basic Survival HUET skill set requirements from MI and SSTL. (Note: These numbers represent the minimum sequences conducted at each training facility. Additional exercises are conducted if required to demonstrate competency).

HUET Skill Set Requirements	**Seat Position and Number of Sequences Performed**	
	Marine Institute (MI)	**Survival Systems Training Limited (SSTL)**
Classroom Theory	Approximately 4 hours	Approximately 4 hours
Surface Evacuation and liferaft operation	1	1
Surface Evacuation with partial upright immersions	1	
Controlled ditching to surface including exit jettison procedures and subsequent immersion (no inversion)	1	
Total Number of Underwater Escapes	3	4
Number of Different Emergency Exits Used	1	2
Number of 180° Inversions Required	2	4
Number of Times Exit is Jettisoned Underwater	0	2
Number of Escapes from an Aisle Seat Position	0	2

As an extension of the diversity of simulation environment fidelity, differences in training methodology begin to emerge when an examination of skill requirement is completed. At a basic level, OPITO HUET certification requires an individual to demonstrate the ability to egress from an inverted HUET simulator while breath-holding once during initial training and once during recurrent training (every 4 years). Marine Institute (MI) carries out similar HUET programs and requires 2 inversion egresses during basic training and 1 during recurrent course training (every 3 years). In contrast, Survival Systems Training Limited (SSTL) requires HUET course participants to complete at least 4 breath-hold escapes from an inverted simulator during both initial and subsequent certification (every 3 years). Based on the training schedule minimums, trainees attending an OPITO HUET program would need to complete at least 4 courses (equivalent to 12 years offshore – assuming a 4 year recurrent requirement) in order to gain the same experience as those completing one course at SSTL. Similarly, trainees attending an MI

HUET program would need to attend 1 basic and 3 recurrent courses (equivalent to 6 years offshore) before they would gain the same amount of inverted underwater egress experience as an individual attending one basic HUET course at SSTL.

Additionally, the discrepancy between which skills need to be demonstrated is of particular interest. Hart (2008) suggests, "training works best when the HUET trainer simulates the actual passenger environment as closely as possible. Ideally passengers practice rolling inverted, pushing out windows and evacuating as first and second out the exit" (http://hartaviation.com/content.php?region=200). This suggests that individuals demonstrate their ability to jettison an exit from an inverted position at both the window and aisle seat. However, despite overwhelming evidence that helicopters typically invert rapidly after water impact, some of the offshore HUET certified workforce might never have been required to successfully jettison an exit while inverted underwater because, until recently, OPITO certification did not require trainees to open an emergency exit while underwater. In fact, the most recent gap analysis conducted by OPITO (2009) indicates that, although assessment during HUET skill performance requires that "*push out windows are to be fitted for the capsize exercise, competence in the operation of these should be assessed during the partial submersion exercise*" (pg 9). This statement suggests that although the push-out exits are installed during the HUET exercises that involve a 180° inversion of the simulator, trainees are not required to demonstrate their competency of exit removal skills from this position. Given the fact that "more than 120,000 people across 30 countries are trained to OPITO standards every year", a considerable number of individuals may not have the skill set required to perform one of the most basic tasks necessary to survive an underwater escape (http://www.opito.com/international/about-us/news.html). Additionally, MI does not require an individual to demonstrate the ability to jettison an exit while inverted underwater on a breath-hold. Therefore, although SSTL and MI trainees receive identical HUET certification, the level of inverted exit experience is vastly different.

The opportunity to perform an exit removal underwater from an inverted position has been reported to improve confidence in skill performance (Coleshaw 2006b) and capability to perform the skill after a delay period (Kozey, McCabe, & Jenkins, 2006). In one of the first examinations of skill performance based on retention of HUET skills, Mills and Muir (1999) documented

HUET skill performance of OPITO certified personnel who had completed training 6 months, 12 months, 18 months, 2 years, 3 years, and 4 years prior to testing. It was found that over a third of the individuals failed to meet the minimum performance criteria that "required trainees to demonstrate the ability, underwater in an inverted HUET, to release a representative seat restraint and escape exit mechanism, and effect an escape unaided" (Mills & Muir, 1999, section 3). It was noted, however, that the training environment was not the same for all of the participants and it was suggested that future studies should examine HUET performance of individuals having similar experience from the same training environment (Mills & Muir, 1999). It was also noted that the test individuals were considered to be a self-selected group that did not have an aversion to completing the HUET skill requirements. As all of the tested individuals were volunteers, it could be argued that a more representative offshore population might include a number of individuals who are extremely anxious about completing the required HUET skill set and performance levels may decrease.

In order to address the differences in HUET skill performance from a similar course population and training environment, Taber (2005) collected underwater escape performance from BST and BST/R personnel attending survival training courses at SSTL over a period of 11 months. The 277 course trainees were informed that HUET instructors would record if assistance was provided during the first two underwater inverted egress trials required for certification. Only one of the two HUET trials required the removal of an exit in an inverted position. It was noted that BST trainees were more likely to require assistance during their first training exercise (no window during inversion) than those attending a BST/R program (Taber, 2005). These results were not found to be surprising given the fact that the majority of individuals attending the BST were completing the HUET skill set for the first time and did not really know what to expect. Of greater interest was the performance of individuals who had completed HUET training prior to the collection of the test data. Taber (2005) reported that BST/R trainees required more assistance and committed greater numbers of procedural errors during their second escape trial (jettison exit underwater) than the BST group. Similar to the results reported Mills and Muir (1999), it was noted that 34.7% of those completing the BST/R required some form of assistance despite having gained HUET certification 3 years earlier (Table 4) (Taber, 2005).

Table 4. HUET performance and assistance required for BST and BST/R trainees. (from Taber 2005 with permission).

Assistance Provided	Courses			
	BST		BST/R	
	No. of individuals	No. of exercises	No. of individuals	No. of exercises
A (no assistance)	114 (74.5%)	554 (90.5%)	81 (65.3%)	434 (87.5%)
B (mild to moderate assistance)	28 (18.3%)	39 (6.3%)	39 (31.5%)	57 (11.5%)
C (emergency assistance)	11 (7.2%)	19 (3.1%)	4 (3.2%)	5 (1%)
Total	**153**	**612**	**124**	**496**

In order to examine the training environment associated with HUET experience, it is important to further consider the combined influence of both practice and simulator fidelity. Therefore, the next section addressed the level of physical fidelity associated with the HUET environment provided to the Atlantic Canadian offshore workforce. The differences in fidelity are then discussed in order to identify the implications of training in generic environments.

3.2.3 Fidelity of the Training Environment

Clearly, the procedural knowledge gained from the Canadian CAPP approved HUET providers are different, as is the environment in which the skill acquisition takes place. For example, MI uses a retrofit dunker manufactured by McLean and Gibson International during the mid to late 80s (Flight International, 1984) (Figure 7). The interior cabin contains low-back seats that are fitted with over-center lap belt seat harnesses. The MI dunker can be fitted with two types of emergency exits (push-out and mechanical); however, these are not used while in an inverted position.

Figure 7. Retrofit McLean and Gibson International dunker located at MI in Newfoundland (Panel A). Interior of the dunker during simulated impact (Panel B). *Note: images retrieved from http://www.mi.mun.ca/.*

Survival Systems Training Limited (SSTL), on the other hand, uses a Modular Egress Training Simulator (METS™) manufactured by Survival Systems Limited (Figure 8). The METS™ can be configured to resemble numerous helicopters currently used for offshore and military operations (http://www.survivalsystemsgroup.com/index.html?pg=25). More than 140 different exits have been manufactured for the METS™ and the interior of the cabin can be configured to the exact specification of the helicopter being used for flight operations. SSTL has a complete simulation of an S61N, AS332L (Super Puma), and S92, which includes high-back seats that are fitted with four-point seat harnesses. Additionally, the S92 configuration is equipped with crashworthy seats manufactured to the specifications outlined by the helicopter manufacturer.

Figure 8. METS™ model 40 showing 4 different exit types (Panel A). Interior of METS™ showing high-back crashworthy seats fully compressed and 4-point harnesses (Panel B).

Figure 9 further shows the fidelity of the METS™ as it relates specifically to an S92. Panel A shows the forward port emergency exit and push-out window in the actual helicopter. Panel B shows the interior configuration of the METS™ to identify the level of physical fidelity available for offshore workforce HUET courses. This level of physical fidelity allows for identification of skill deficiencies during training as well as clearly defined guidelines of both instructional delivery methods and offshore operator configuration approval.

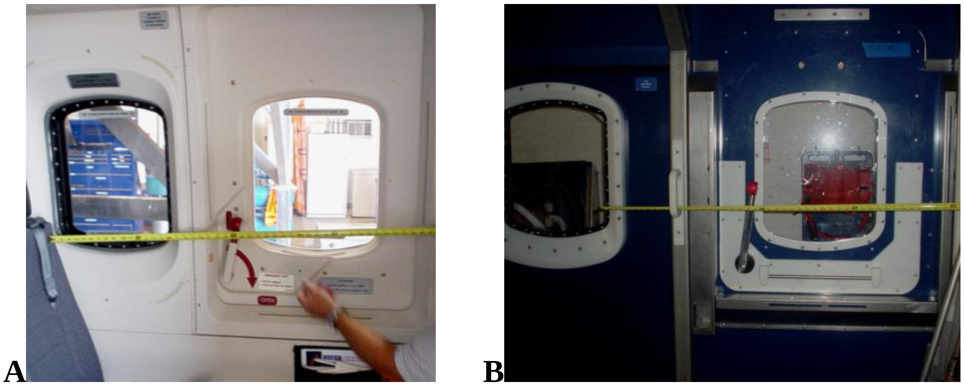

Figure 9. S92 helicopter interior (Panel A) and METS™ simulation (Panel B).

Research conducted by Coleshaw (2006b), Kozey et al. (2006), Mills and Muir (1999), and Taber and McCabe (2007, 2008, 2009) suggest that physical fidelity is necessary during HUET skill acquisition and indicate that it is a fundamental requirement to ensure the transfer of procedural knowledge. Additional, Kozey et al. (2006) demonstrated that the fidelity (requirement of exit functioning while inverted underwater) of HUET training provided to individuals has a significant impact on their ability to perform skills that may be necessary in a real world ditching. Specifically, it was shown that individuals having received more practice (4 versus 1 or 0 trials) opening an exit while inverted underwater performed better than those who had limited or no practical experience six months prior to a testing session. Kozey et al. (2006), therefore, concluded that "The results clearly demonstrate that the success rate from a single METS egress 6 months post training is greatest for individuals who receive trials with the greatest physical fidelity and extensive practice" (pg. 110).

As a further example of physical fidelity importance, every federal aviation administration (i.e. CAA, EASA, FAA, TC) requires pilots of large passenger aircraft to successfully complete *type specific* flight simulation once every 12 months (see CAR 2009-2, standard 723.98 for air taxi-helicopters). It would be unimaginable for an airline pilot to be tested on a small Beaver or Cessna type aircraft and be expected to perform emergency duties on an Airbus A320 or Boeing 767. Without having the experience of performing a skill set in an environment that closely matches that which would be experienced in a real-world situation, it is difficult to predict performance in the real situation. This is precisely why military and emergency response training is conducted under realistic conditions.

3.3 Research Identifying HUET Skill Proficiency

Before identifying specific HUET research related to skill proficiency, it is important to briefly outline skill acquisition. Stothart and Nicholos (2001) report “In order to learn and use a skill, or information, a learner needs to understand how it occurs and when to apply the skill. These only come with practice and experience; as the learner becomes an expert, they can apply their understanding to other situations, while also evaluating its appropriateness” (pg. 9). Research has shown that learning a skill typically shows a steep increase during the first few attempts and then begins to plateau as experience is gained and eventually performance becomes automatic (Schmidt & Lee, 2005). Generally speaking, performance curves typically follow what is referred to as the *power law of practice*, in which the more times a skill is practiced, the better the performance of that skill becomes until such a point that no further improvements are detectable (Schmidt & Lee, 2005). Performance of the skill can later be influenced by level of arousal and environmental conditions; however, the acquisition of the skill requires that it be deliberately practiced until it becomes automatic (Feltovich, Prietula, & Ericsson, 2006).

3.3.1 HUET Proficiency Requirements

Clearly then, HUET skills that will be needed during a real-world ditching should be practiced as often as possible if they are to be performed an expert level. Hart (2008) writes “The operation of emergency exits, doors, seat belts and survival equipment should be standardised between aircraft to the extent possible if more than one type is being flown on a contract, and the training should be such that operation of this equipment is second nature to passengers. In a ditching situation events happen quickly and well taught survival lessons can make a critical difference” (http://hartaviation.com/content.php?region=200, see also Hart, 2004). Benham, Redman, and Haywood (1995) also suggest that “more realistic training” would benefit those trying to escape and survive from a ditched helicopter (pg. 11). These statements are reiterated by Kozey et al. (2006), Mills and Muir (1999), and Taber, (2005), who found similar levels of HUET skill retention and suggest that a longitudinal study should be conducted to ensure the current training schedule ensures optimal survival rates if a ditching occurs. Learning research indicates that one of the best ways to increase retention of a procedural skill is by overlearning the task during initial acquisition (Driskell, Willis, & Copper, 1992). In other words, the task is practiced beyond the point that it is mastered. However, most civilian HUET course standards only require trainees to perform one errorless underwater inverted egress and do not request individuals to provide further evidence of their procedural knowledge. Therefore, it is difficult to identify whether the HUET skills will be integrated into long-term memory and be recalled during an emergency.

3.3.2 Proposed HUET Proficiency Requirements

Based on the research and anecdotal evidence related to ditching survival rates presented to this point, a HUET standard that requires individuals to perform *one* underwater egress with an exit installed every 3 to 4 years is not sufficient to ensure that the skill will be recalled in the event of a real emergency. Although the offshore workforce may be *current* under the existing guidelines, they are not necessarily *proficient*. Kozey et al. (2006) clearly showed that nearly 20% of the individuals, given only one egress training trial in which they had to remove the exit while in an inverted and submerged position, could not perform the task six months later. It was further shown that 46% of those who had not had the same opportunity to jettison an exit underwater failed in their attempt to egress (Kozey et al., 2006). This suggests that nearly half of the individuals completing a HUET course that does not require the removal of an exit inverted underwater would not survive a ditching that resulted in a rapid capsizing, just six months after gaining certification. These results closely match the survival rates cited by previous research (Table 2 above) and suggest that training may play as great a role in survival as structural crashworthiness factors.

With this in mind, it is proposed that in addition to the standard protocol for offshore operational requirements (i.e. weather limitations, helideck and refueling standard procedures, flight following), HUET course providers and offshore operators should:

1. Identify what HUET skills are required to egress from the existing helicopter interior cabin configurations (i.e. do current AS332L and S92 configurations influence overall survival rates and if so can they be mitigated through training or repositioning of seats and auxiliary equipment such as fuel tanks).
2. Ensure that representative exits (same overall dimensions, operating mechanisms and forces required to open them) be positioned in representative locations (same distance from seats and height from floor) for those type of helicopters being used in offshore

operations be installed and used for training within the HUET simulator.

3. Ensure that representative seats (i.e. high-back, crashworthy, forward/rear facing, bench style) similar to those used in offshore helicopter operations be installed for training within the HUET simulator.
4. Identify the level of initial HUET proficiency that will not degrade to a point that becomes problematic within the time to recurrent training.

Despite considerable effort to mitigate risks associated with a helicopter ditching/crash, changes to survival rates have not been realized and until underwater escape skill performance is fully understood, it is difficult to identify interventions that may aid in survival. For example, the addition of mandatory external flotation systems does not appear to have a significant affect on overall survival rates due primarily to the fact that floats may not have been deployed as a result of minimal warning or may be damaged during impact; therefore, do not aid in keeping the helicopter upright on the surface (Taber & McCabe, 2007, see also CAA, 2005). Moreover, supplying EBS to passengers without training in the realistic conditions expected during a ditching may not by itself be the answer to increasing survival rates. Changing one aspect of a complex system rarely ameliorates all difficulties as was pointed out in the most recent ditching report of the Search and Rescue (SAR) Cormorant helicopter (Canadian Forces FSIR, 2008b). In their report, it was noted that all crew members survived the initial impact forces; however, several personnel did not use the EBS that was available due to an inability to find it on their vest and the speed with which they made their escape. It was also reported that two of the crew members in the cabin of the helicopter were able to use EBS, but were unable to escape due to disorientation, debris, loose equipment, and blocked exits, before depleting the supplementary air (Canadian Forces FSIR, 2008b). Based on the findings from the ditching report, it is apparent that a holistic approach, which includes a detailed investigation of human factors, environmental conditions, and available technology, is needed before specific answers that address survival rates should be expected.

4. PERSONAL PROTECTIVE EQUIPMENT ASSOCIATED WITH HELICOPTER TRANSPORT OVER WATER

As outlined in the pervious sections, helicopter transport over water (particularly cold water) requires an understanding of the interrelated aspects of several components. Of particular importance is the integration of personal protective equipment (PPE) with regard to the overall survivability of passengers and crew during and immediately following a ditching/crash. Therefore, the following sections address the current PPE requirements and standards as well as suggest a guideline for system safety integration.

4.1 Helicopter Passenger Transportation Suit (HPTS) Requirements

Although the benefits of wearing personal protective equipment (PPE) to prevent cold water related injury is well documented, Transport Canada's operating manual (OM) does not require the use of an immersion suit within 15 nautical miles (nm) of shore (TSBC, 2006). In addition, Moorman (2005) writes "in Canada, there is not a regulatory requirement that helicopter pilots wear immersion suits during offshore operations" (http://www.aviationtoday.com/rw/commercial/offshore/1541.html). However, due to the harsh North Atlantic environmental conditions present during most of the year, thermal protective equipment has been mandated for all personnel if the potential of accidental immersion exists. For example, Transport Canada (TC) indicates that "no person shall operate the helicopter over water having a temperature of less than 10°C unless:"

- a helicopter passenger transportation suit system is provided for the use of each person on board; and
- the pilot-in-command directs each person on board to wear the helicopter passenger transportation suit system (CAR 602.63).

The regulation further states, "Every person who has been directed to wear a helicopter passenger transportation suit system…. shall wear that suit system."

Helicopter Passenger Transportation Suits (HPTS) can be approved for use in two distinct variations. An integrated HPTS incorporates the functionality of a lifejacket (FAA, Technical Standing Order-C13f) and does not need a separate lifejacket to be worn over the suit, whereas a basic HPTS requires the use of an additional lifejacket. This distinction is important in that an integrated HPTS does not require the user to don additional equipment that has been separately manufactured and may not integrate particularly well. This reduces the need to ensure the lifejacket is fitted for the individual and there are less compatibility issues with regard to inflation toggles, connection straps, and zippers.

HPTS suits are required to meet current Transport Canada Airworthiness Manual (AWM 551.407) and Canadian General Standards Board (CAN/CGSB-65.17-99) requirements which requires the integration of head and hand coverings and must meet specific requirements for performance tests such as a jumping into water, righting (turning a person from a face down to a face up position), underwater escape, swimming ability, freeboard, flotation position, and field of vision. At a fundamental level the HPTS must meet the following CAN/CGSB-65.17-99 standards:

4.1.1 Performance Requirements

- ***Maximum Escape Buoyancy*** - shall not be more than 175 N (17.85 kg/39.35 lbs).
- ***Minimum Flotation Buoyancy*** – shall not be less than 156 N (16.83 kg/37.10 lbs).
- ***Donning Time*** – must be able to don the suit system completely within 2 min. However, the "Life Preserving Helicopter Passenger Transportation Suit System" is exempt from the requirement as the suit is donned by all passengers prior to departure (Transport Canada 2006, SCA 2006-07).
- ***Floating Characteristics*** - suit system shall provide a stable floating position, with a face plane angle between 30º and 80º to the horizontal, in which the subject is face-up with the mouth and nose at least 120 mm above the surface of the water.
- ***Righting*** - suit system shall turn the wearer from a face-down position to a face-up position within 5 seconds or allow the wearer without assistance to turn himself or herself from a face-down position to a face-up position within 5 seconds. If a suit system has auxiliary buoyancy, the suit system shall be designed to meet these requirements when the auxiliary means of buoyancy is used as well as when it is not used.
- ***Thermal Protection*** - must not be less than $0.116°C{\cdot}m^2{\cdot}W^{-1}$ (0.75 immersed Clo). Using this test method, the hands shall have a minimum thermal Protection value of $0.6\ K{\cdot}m^2{\cdot}W^{-1}$ (0.5 immersed Clo). When testing humans – the suit system shall provide thermal protection such that the average body core (rectal) temperature of persons wearing the suit system for 6 hours in calm circulating water that is between 0 and 2°C shall not drop

more than 2°C and the finger, toe or buttock temperature of the wearers shall never drop below 5% and never below 8°C for more than 15 minutes for an entire immersion.

- ***Suit Sizing*** – sizes shall be classified by the maximum girth and height of the intended wearer. This standard also allows for suits to be sized to individual wearers.

- ***Survival Aids Attached to outside of Suit*** - allow for easy use, are visually and physically accessible and operable, not attain a position that either degrades the function of the fittings or reduces the wearer's ability to escape or survive.

  - ***Buddy Line***
  - ***Personal Locator Light***
  - ***Personal Whistle***
  - ***Splashguard***

4.1.2 Interpretation of the HPTS Standards

For clarification, the unit of thermal protection described in the standard refers to "1 clo for the insulation of a clothing system that maintained a sitting–resting average man comfortable in a normally ventilated room (0.1 m/s air velocity) at the air temperature of 21ºC and relative humidity less than 50%" (Gagge, Burton, & Bazett, 1941 as cited by Huang, & Xu, 2006, p. 318). The requirement of .75 Clo for passenger survival suits does not include thermal insulation gained from personal clothing. However, in an effort to approximate typical offshore workforce attire, the CGSB requires that HPTS thermal protection testing is completed in "A long-sleeved cotton shirt, denim trousers, underwear (briefs) and medium-weight dress socks for wear by the subject and by the manikin during the testing procedures" (CAN/CGSB-65.17-99). As there is no specific C-NLOPB guideline on required clothing for helicopter flights, passengers are permitted to wear a wide range of clothing under the suit while traveling offshore. The personal decision of what to wear under the suit is presumably based on environmental conditions such as the ambient air temperature. As there is no specific standard for required clothing, this issue will be addressed in further detail in Section 6.3.2 (below).

As with several of the previous sections, maximum allowable buoyancy does not appear to have an internationally recognized standard. For example, Brooks (2008) indicates that, after extensive underwater escape buoyancy testing, "a decision was made to establish a standard maximum of 42 pounds (175 Newtons) of added inherent buoyancy. A compromise had to be made in order to achieve the required 0.75 immersed Clo of thermal insulation. This could not be practically done if the inherent buoyancy was less than 175 N. Subsequent tests in the helicopter underwater escape trainers worldwide have shown that this appears to be a reasonable compromise – but ideally, in the concept for new suits the less inherent buoyancy the better" (RTO-AG-HFM-152, pg. 9C – 9). Interestingly, however, after investigating the post crash conditions experienced by crewmembers of a Search and Rescue Cormorant, the Canadian Forces (2008b) indicate that a maximum allowable buoyancy for thermal protective suits is 35lbs. Additionally, the European Aviation Safety Agency - Technical Standard Order (2006) identifies that the "the trapped buoyancy due to the suit and recommended clothing, with the suit fully vented, shall be no more than 150N (33.7lbs)" (ESTO-2C502, Section 9.1).

Similar to many of the components discussed thus far, maximum allowable water ingress does not have one recognized standard. For example, CGSB water ingress standards for the testing of HPTS requires a jump into water of not less than 3 meters and a swim test in calm water (CAN/CGSB-65.17-99), after which the combined ingress in grams from the jump and swim of not less than 60 minutes are used to calculate total accumulations of water. The CAN/CGSB-65.17-99 does not specify a maximum allowable limit for water ingress, whereas the CAA (1991) regulation indicates that the maximum allowable water ingress value shall not exceed 200g after a jump and swim test of not less than 30 minutes. The differences in swim time suggest that the CGSB are more stringent that those required by CAA regulations.

In order to examine the effects of water ingress on thermal protection, Tipton and Balmi (1995) collected rectal and skin temperatures from participants wearing immersion suits that had 0, 200, 500, and 1000ml of water ingress over a period of 70 minutes in water temperature of 5°C. Results of their study indicated that 200ml (200g) of water ingress at the torso should be the maximum allowable limit (Tipton & Balmi, 1995). These water ingress tests are designed to ensure proper fitting of the immersion so that water seeping in through face, neck, or wrist seals does not compromise the individual's chances of survival while waiting for rescue. However, recent reports have questioned the water ingress tests, suggesting that the jump and swim requirements lack ecological validity. Specifically, in a Transportation Safety Board of Canada (2004) occurrence report, investigators indicate, "because the swim test [CGSB]- an integral part of the standard - must be conducted in controlled facilities, the test has never been validated against realistic conditions" (p.15). In an examination of HPTS water ingress conducted by the CORD Group Limited (2009), it was recommended that, in addition to the current jump and swim test, there should be a requirement for testing to be completed after underwater egress from an inverted position with a window, as well as liferaft boarding with wind and waves. These suggested changes further highlight the need for international standardization for testing the HPTS.

4.2 Aircrew Immersion Suit Requirements

In a review of cold water survival needs, Brooks (Transport Canada, 2003) indicates that, while offshore passengers should wear a "Group II - .75 immersed Clo" immersion suit, aircrew should be thermally protected by a suit ranging from .25 to .75 Clo – "Group I" (pg. 65). This recognition of integrated hazards (i.e. hot environment in cockpit and cold water) is important to ensure that the effect of heat stress does not compromise flight safety. The thermal conditions experienced by the pilots is influenced by what is known as a "greenhouse effect" created by the sun streaming in through the cockpit windows. In the Transport Canada (2003) report, Brooks identifies a number of aircrew immersions that meet the .25 Clo rating. However, similar to the passenger immersion suit requirements, there is no specific standard or guideline that suggests the options for pilot clothing requirements to be worn under the immersion suit.

4.2.1 Thermal Loading and Heat Stress for Aircrew

Prolonged exposure to high ambient temperatures are generally linked to reduced cognitive functioning (Cheung, 2010; Pilcher, Nadler, & Busch, 2002) and decreases in working memory and information retention (Hocking, Silberstein, Man Lau, Stough, & Roberts, 2001). Ducharme (2006) indicates that, at ambient temperatures above 18°C, aircrew dressed in thermal protective clothing "will likely be affected by heat stress during flight operations" (p. 439). As evidence of thermal loading affecting performance, reported increases in core and skin temperature have been found to significantly increase the number of incorrect reactions individuals make when tested on an aircrew related vigilance task (Færevik and Reinertsen, 2003). The relationship between cognitive impairment and heat has also been supported by reports of decreased mental arousal and perceived increases in exertion during exercise-heat stress (Castellani, Young, Kain, Rouse, & Sawka, 1999; Nybo & Nielsen, 2001). However, Hancock, Ross, and Szalma (2007) purport that performance effects are linked to a complex interaction of duration and intensity of the heat stressor. Therefore, it is important to consider the amount of solar loading of aircrew when addressing thermal protective garments. As a guideline to protect against the harmful effects of thermal loading, the U.S. Military Standard Operating Procedures for Overwater Operations (n.d.) has suggested that immersion suits need to be worn during overwater operations if the water temperature is below 60 degrees Fahrenheit (15ºC); however, “when the water temperature is between 61 and 70 degrees Fahrenheit [15-20ºC], the unit commander or his designated representative may waive the wearing of the immersion suit. When the water temperature is above 71 degrees Fahrenheit, the wearing of the immersion suit is at the discretion of the individual pilot” (http://www.globalsecurity.org/military/library/policy/army/fm/1-564/AE.HTM).

4.2.2 Aircrew Immersion Suit Standards

Similar to those standards set out for passenger immersion suits, aircrew constant wear suits must meet specific performance and design standards. However, minor differences in suit design allowances are found and the CAA (1991) indicates that:

> The design of the immersion suit shall allow tailoring to fit the individual wearer or, where suits are not individually tailored, the size range must be fully satisfactory for all wearers whose significant body dimensions range from the 5th percentile female to the 95th percentile male and adequate for most of the 5% at each extreme. The significant body dimensions to be taken into account shall include at least the following:
>
> Total Height: from ground to top of head
> Sitting height: neck seam to crotch seam
> Inner leg: crotch seam to normal length of trouser
> Sleeve length: shoulder seam over elbow to cuff (arm bent at 90º) (Specification 19 – Section 3.6).

In addition to thermal protection and fitting, specifications related to the colour of the aircrew suit differ from that of the passengers. For example, in a safety recommendation from the Australian Aviation Investigation Bureau (AAIB) (2008), it is recommended “that the European Aviation Safety Agency (EASA) investigate methods to increase the conspicuity of immersion suits worn by the flight crew, in order to improve the location of incapacitated survivors of a helicopter ditching. The yellow immersion suits worn by the passengers were noticeably more conspicuous in the dark than the blue immersion suits worn by the pilots when illuminated by a helicopter’s searchlight” (Safety Recommendation 2008-036 AAIB). And the CAA suggests, “the choice of suit colour may vary to minimise the risk of the suit reflecting on surfaces within the flight deck” (p. 4).

As there is no standard requirement outlined by the TC, CAA, or FAA regarding clothing to be worn under the constant wear suits for aircrew, a guideline of thermal comfort zone with respect to protection in both hot and cold conditions should be developed. A discussion of suggested clothing is outline in Section 6.3.2 (below).

4.3 Additional Survival Equipment

Although specific standards exist for the design and testing of HPTS and aircrew constant wear immersion suits, there is no specific regulation that mandates the inclusion of additional or supplementary survival equipment. Additional equipment is typically included as standard issue at the request of offshore operators to aid in post-event survival and rescue. For example, OLF (n.d.) standards require that the immersion suits are fitted with a pocket for a personal locator beacon (PLB) and must have an integrated breathing system that "provides more time for underwater evacuation than what is possible when that time is limited to each individual's capacity to hold his/her breath. The breathing system must be compatible with the survival suit and must not reduce the suit's efficiency. The breathing system shall be automatically activated when submerged" (section 4). This statement regarding integration is repeated by CAA (1991) in that "any attached equipment shall not compromise the basic survival function of the immersion suit by causing puncturing, fretting or distortion of the material, or changes in its mechanical properties" (Specification No. 19, section 3.4). Operators in Atlantic Canada also require PLBs and more recently emergency breathing systems.

The addition of supplementary equipment is often not integrated into the original design of the immersion suit system; therefore, not always integrated in such a way that ensures it will not snag during underwater egress. Taber (2007) and Taber and McCabe (2009) indicated that snags identified during underwater egress task analysis trials in an AS332L and Sea King configuration were not apparent during dry testing in the actual helicopter and recommend that a full wet snag test analysis be carried out prior to implementation of new equipment or configuration change. As an example of this application of snag testing, Mills (2003) suggests that new military uniforms for the U.S. Army will be designed to decrease the amount of weight that each person is carrying as well as reduce what is termed "the Christmas tree effect" (http://usmilitary.about.com/cs/genweapons/a/futureuniforms.htm). The Christmas tree effect refers to the additional equipment being hung on individuals with little regard for how the items may impact safety. Currently, the offshore workforce wears a strobe light, emergency breathing system, and personal locator beacon in addition to an approved immersion suit which incorporates at least one pull toggle for vest inflation, a buddy line, whistle, thermal protective mitts (usually stored in a pocket), splash guard, and nose clip. Without ensuring that all of these items work together as one integrated system that will not create snag hazards during egress, it is difficult to predict how one single item or the combination of items might affect survival rates. Therefore, a full underwater egress task analysis should be carried out in each of the existing helicopter interior configurations to ensure that snagging of equipment does not impede escape procedures.

5. COLLABORATIVE APPROACH TO THE IMPLEMENTATION AND MONITORING OF HELICOPTER SAFETY INITIATIVES.

This section of the report addresses aspects of helicopter safety initiatives and how they are implemented within the offshore safety culture. In order to address the implementation and monitoring of these initiatives this section discusses safety management systems, safety climate, and safety culture. The last portion of this section identifies possible additions to the current process of dissemination of safety initiative information.

5.1 Safety Management System (SMS)

McDonald, Corrigan, Daly, and Cromie (2000) suggested that, in order to examine organizational safety, it is important to consider the influence of a safety management system, safety climate, and safety culture. By addressing the various factors of the overarching macro-environment within a particular organization that influence safety, it is possible to identify specific interventions that will aid in mitigating risk. As an example of the importance of risk mitigation, Transport Canada requires all aviation operators to have a Safety Management System (SMS) in place (CAR 107, T51-15/107-2008E-R). An SMS has been described as "an explicit, comprehensive and proactive process for managing risks that integrates operations and technical systems with financial and human resource management" and "provides for goal setting, planning, and measuring performance" (Transport Canada, 2008, section 3.2). The International Civil Aviation Organization (ICAO) also requires an SMS process to be in place for all aviation operators as of 2010.

The basic requirement of incident reporting and dissemination of information related to helicopter safety initiatives and activities is well documented and both Cougar Helicopters and CHC Helicopter Corporation (CHC) currently have extensive SMS procedures in place. Similar to the aviation safety reporting system (ASRS) developed by the National Aeronautics and Space Administration (NASA) in order to increase aviation safety (http://asrs.arc.nasa.gov/), CHC has a "Confidential and Anonymous Concern Hotline" where individuals can use a secure web form, email, or voicemail to report their concerns regarding operational issues related to financial or safety and quality procedures (https://www.openboard.info/chc/index.cfm). The importance of having a system like the ASRS cannot be overstated and this type of system has been cited as being one of the main reasons that the commercial airline industry has been able to reduce the number of reportable events and fatal accidents (Helmreich, 2000). In an effort to improve patient safety to reduce health care errors, a similar technique is being employed in medicine (Sexton**,** Thomas**,** & Helmreich**,** 2010). By creating an environment in which personnel not only feel comfortable discussing safety issues, but also one in which it is expected, the offshore work force and helicopter crews can work toward increased safety.

5.2 Safety Climate

Safety climate differs from a safety management system in that it is sensitive to the changes that occur within the organizational environment. Mearns, Whitaker, and Flin (2003) suggest that safety climate is "a manifestation of safety culture in the behaviour and expressed attitude of employees" (p. 642, see also Cox, & Flin, 1998). For example, the explicit identification of growing concerns about maintenance practices or safety operations typically increases after a major event has taken place and the climate of the environment shifts from a level of general dissatisfaction that remains unspoken to one of formal action involving written complains. For example, the shift from internal to external exposure of safety concerns can be seen immediately after the British Petroleum (BP) Texas oil refinery disaster in March of 2005. When reporting details of the event, the U.S. Chemical Safety and Hazards Investigation Board (CSB) (2007) cited issues related to poor communication among operators, malfunctioning instrumentation, poor computerized control displays, ineffective supervision, insufficient staff, operator fatigue, and inadequate training. It was further noted that the lack of response to previous incidents (considered to be of a serious nature) at the refinery might have created an environment in which the safety management system did not appear to be supported by BP's upper management. The apparent lack of support from upper management as well as inability to learn from past incidents, perhaps due to the complexity of the reporting system, undoubtedly influenced decisions made by key individuals prior to and during the event. The formal identification of safety concerns does not necessarily indicate that the safety culture or SMS of the organization is deficient, they do however identify that a change in observable workforce behaviour is reactive to recent events and, as Reason (1997) points out, they are often "shortlived" (pg. 192).

5.3 Safety Culture

Finally, safety culture has been defined as “the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour, that determine the commitment to, and the style and proficiency of, an organization’s health and safety management” (Transport Canada, 2008, section 3.5.2). Taken together, SMS, climate, and culture represent the collective aspects of the offshore workforce, the pilots that transport them to their destinations, the organizational structure in which they work, the environmental factors of their geographical location, and the technology of the equipment used to keep the system operating in an effective, efficient, and safe manner. Reason (1997) suggests “an ideal safety culture is the engine that continues to propel the system towards the goal of maximum safety health, regardless of the leadership’s personality or current commercial concerns” (pg.195). Therefore, it is the responsibility of all personnel within the system to ensure that safety initiatives are maintained and updated as issues arise. In other words, if a risk is not identified through a formal reporting system that is recognized and valued by all members of an organization, it is difficult to develop a strategy of mitigation.

5.4 Possible Additions to Safety Initiative Process

The global offshore helicopter safety culture will undoubtedly change with respect to current events and a collaborative effort from industry workforce members, organizational management, offshore operators, applied research and development, and governmental institutions will be needed to ensure all aspects are addressed. At a basic level, safety concerns related to offshore helicopter travel should have a clear mechanism of reporting such as the ASRS or a quarterly safety survey. However, this mechanism must have a definitive purpose with regard to implementation of future safety initiatives. For instance, if anonymous reporting or survey results identify that workers are concerned about safety implications of a particular passenger seat or a configuration within the helicopter, there needs to be a process by which workers can see the efforts being put forth by operators to rectify the issue; otherwise, the system will not be considered a viable option for voicing concerns. The managerial commitment to this process must be seen as a clear sign of safety over productivity (Mearns et al., 2003). Furthermore, all members of a safety system need to consider the consequences of particular initiatives in a proactive manner rather than waiting for an event to occur.

6. PERSONAL ACCOUNTABILITY WITH REGARD TO HELICOPTER TRAVEL SAFETY

As part of an overarching safety management system, personal accountability plays a critical role in identifying where rules and procedures are lacking. In sections 2 through 5 of this report, it was identified that several regulations and guidelines exist with regard to HUET course requirements, crashworthiness, emergency exit size and design, personal protective equipment, and the monitoring of helicopter safety initiatives. Additionally, benefits of these rules and regulations were discussed; this section of the report identifies some of the difficulties faced by operators and offshore helicopter transport suppliers when addressing personal accountability.

6.1 Operating within the Boundaries of System Safety Limits

A main component of identifying limits to personal accountability stems from the ability of a safety system to tolerate violations such as operating outside established safety boundaries (Busby & Bennett, 2008). Organizational safety research has clearly shown that individuals often work outside safety boundaries set by industry and equipment manufacturers due to a lack of system feedback and understanding of the consequences resulting from these minor violations (Vincente, 2003; Rasmussen, 1997). The fact that there are no negative consequences for operating outside these limits provides positive reinforcement that the system can tolerate small deviations. Operations conducted outside the prescribed limits slowly become normalized and the system is incrementally pushed further until a catastrophic event occurs. Reason (1997) suggests that it is difficult to maintain a level of vigilance that assumes everyday "will be a bad day," which might explain why individuals let their guard down (intentionally or not) when considering the consequences of violating safety protocols (pg. 37).

With regard to helicopter safety and personal accountability, it is important that individuals can readily identify these invisible safety boundaries (Vincente, 2003) in order to develop an understanding of how their actions may circumvent the defences implemented by organizational safety standards. Unfortunately, minor safety violations that do not result in a negative outcome are then used as a new benchmark by which limits are slowly adjusted. Only after an event has occurred is it obvious that systems had been pushed well beyond the original design. Issues such as moving a helicopter passenger seat to a particular position or placement of auxiliary equipment without considering the consequences as they relate to underwater egress may initially be addressed as a safety concern when they are first implemented, but slowly become the norm as each uneventful flight occurs. It is only after an undesirable event has occurred that these changes are again identified as a concern in which safety has been compromised and holes in the safety management system are identified.

Busby and Bennett (2008) suggest that, simply by identify a risk, there is an obligation to mitigate the associated hazards. However, sections 2, 3, and 4 of this report clearly identify that information regarding personal accountability and helicopter safety is limited to the “shall be,” “shall meet,” or “shall not” prescriptive regulations. And although the risks associated with thermal protection, heat stress, and thermal loading are known, the current rules and regulations do not set guidelines that indicate what clothing should be worn under an immersion suit, nor are there detailed lists of what clothing is appropriate given a specific set of environmental conditions, physical fitness level, sex, or age. Offshore personnel are therefore left to make a decision based on instructions given to them at a basic level and it is assumed that there is an understanding of the hazards associated with offshore helicopter travel. However, there does not appear to be a mechanism in place that allows for further development of this understanding. Personal accountability requires that individuals take the time and initiative to explore available information in order to develop a clear guideline by which to judge the behaviour of their own actions as well as those of others. If there are no suggested guidelines available, individuals often look to those who have the most experience even if there is no indication that they have a superior understanding of the hazards.

6.2 Quality Management System and Safety Culture

Turnusbekova, Broekhuis, Emans, and Molleman (2007) report that a critical first step in the development of a Quality Management System (QMS) is the clarity of standards and expectations. Without this fundamental level of agreement, it is difficult to establish an acceptable level of accountability. For example, the BST and recurrent training provided in both of the CAPP approved HUET organizations clearly outline the benefits of wearing thermal protective clothing next-to-skin; however, when newly trained offshore employees arrive at the heliport for their first offshore helicopter flight, they are not required to follow any of the suggestions pointed out during their training (anecdotal evidence). This first trip is the beginning of their indoctrination into the offshore helicopter safety system. Conflicting signs of standardization such as the requirement of next-to-skin thermal protection makes it difficult for the new employee to transfer the knowledge gained on a safety course to the real world.

Similar to the points made in Section 5 of this report, Rao (2007) suggests that organizational safety culture is based on norms, networks, and trust that need to be considered when analyzing occupational risk assessments. Likewise, personal accountability relies on the social support of others (Turnusbekova et al., 2007). If, for instance, one's peers continually arrive at the heliport in a pair of shorts, a T-shirt, sandals, and socks, social desirability theories (Adams, Matthews, Ebbeling, Moore, Cunningham, Fulton, & Herbert, 2005) would suggest that conforming to the group norms and expectations is the best course of action, even if it is known that these actions are contrary to previous experience (i.e. HUET instruction). Reason, Parker, and Lawton (1998) suggest that, for organizations that operate within hazardous environments, it is important that there is a "requirement to limit human actions to pathways that are not only efficient and productive, but also safe" (pg. 289). Reason et al. (1998) further argue that organizational safety is measured by the absence of incidents, thereby making it difficult to identify the true state of the organizational safety. Therefore, a lack of incidents in which wearing minimal thermal protection or an immersion suit that is too large in size results in fatalities could be construed by a new employee as a valid reason for not properly preparing for an offshore flight.

6.3 Personal Accountability of Offshore Workforce for Pre-flight Preparation

6.3.1 Hydration and Pre-flight Diet

In order to reduce the gap between basic helicopter safety training and pre-flight briefings, the following information suggests some of the preliminary preparation that should be taken before take-off. One of the fundamental factors of thermal regulation is hydration. Research has shown that dehydration and poor caloric intake are considered aggravating factors of hypothermia (Armstrong, 2005; Nagpal, & Sharma, 2004). It has also been reported that dehydration affects cognitive performance in hot environments similar to those found inside the helicopter (Cian, Barraud, Melin, Raphel, 2001; Sharma, Sridharian, Pichan, & Panwar, 1986; Gopinathan, Pichan, & Sharma, 1988). Therefore, it is recommended that individuals have a good meal and are well hydrated prior to an offshore flight. As a simplified way of subjectively judging hydration levels, Young, Sawka, Epstein, Decristofano, & Pandolf (1987) suggest that an estimate can be made on a scale from 1 (not at all thirsty) to 9 (very thirsty) and that a score between 3 (somewhat thirsty) and 5 (moderately thirsty) indicates mild levels of dehydration. Avoiding caffeine is also advisable as this is a diuretic and can reduce hydration levels (see also Armstrong, 2005). Being well hydrated is an important part of pre-flight preparation in that it accomplishes two goals. First, it ensures that thermal performance deficits will be minimized. Second, and more importantly, it begins the psychological preparation for the offshore flight.

6.3.2 Clothing

Although thermal protection of offshore personnel is considered during the development, design, and implementation of helicopter passenger transportation suits, it is advisable to take into account the benefits of additional thermal protection next-to-skin. The microclimate between the skin and first layer of clothing may affect performance and comfort during routine flights as well as those of accidental immersion. Sweat that accumulates between this layer of clothing and the individual’s skin may influence the sense of comfort as well as reduce the effectiveness of the body’s attempt to thermal regulate when wearing the impermeable layer of the immersion suit. For example, Yoo and Baker (2005) reported that 100% cotton was rated as being stiffer, had a higher level of clamminess, and retained a greater amount of moisture (i.e. sweat) than other heat resistant protective workwear. Golden and Tipton (2002) suggest that multiple layers of clothing are more effective than one single thick layer in maintaining thermal properties. Havenith (1999) also reports that wearing clothing that retains sweat close to the skin’s surface increases the likelihood of excessive cooling if the person is placed in a cold environment (i.e. sudden cold water immersion). Given that research clearly shows that some materials are ineffective for thermal regulation, it is advisable for individuals to wear clothing that is designed to wick sweat away from the surface of the skin. It is also advisable to wear clothing in layers with respect to the environmental conditions. For example, wearing one or two layers of thin wick-away clothing (long sleeve and full length pants) during summer months and three to four layers during colder winter months may increase the chances of survival after a ditching.

Wearing the extra thermal protection may increase thermal loading and the chance of heat strain, particularly during warmer months of the year; however, with proper hydration these effects are outweighed by the benefits that would be gained in the case of accidental cold water immersion. Windle, Hampton, Hardcastle, and Tipton (1994) clearly demonstrated that passive heating similar to that experienced while wearing an immersion suit during an offshore helicopter flight had no effect on short or long term survival in cold water. Furthermore, in an ongoing study of heat stress related to the performance of HUET skill set, Taber, Dies, and Cheung noted that, even after 90 minutes of exposure to 34°C, there were no decrements in task performance. Therefore, although the sensation of being hot and uncomfortable due to increased skin temperature may be perceived as a hazard in the event of a helicopter ditching, none have been reported.

6.3.3 Physical and Psychological Preparation

The physical and psychologically preparation as well as the pre-flight video briefing is designed primarily to start the process of identifying what skills are needed if a worst case scenario arises. Without considering the possibility of a ditching, it may be difficult to shift one's mental schema from that of a routine flight offshore to an emergency response mode in under 15 seconds (Brooks et al. 2008). It has been demonstrated that practice of a discrete motor skill is beneficial for physical preparation of future task performance (Schmidt, 2003). Therefore, it is advisable to mentally and physically rehearse the steps that would be needed to survive a possible ditching.

Physical preparation could be completed immediately following a pre-flight video briefing if a full-scale simulation of the helicopter interior were located at the heliport. Although not inverted and submerged underwater, practicing the actual steps that might be required during a ditching prior to boarding the helicopter might refresh aspects of the procedure critical to survival while providing the physical reinforcement needed to ensure that steps are carried out correctly. Furthermore, if all passengers were required to physically perform the required procedures prior to boarding the helicopter, any difficulties associated with suit sizing or equipment placement could be addressed prior to the flight.

As no such simulation is available at the heliport, offshore personnel, while watching the pre-flight video and then once inside the helicopter, should perform the following steps:

- Once seated in the helicopter, check primary and secondary escape routes to confirm exit jettison procedures (i.e. pull tab and push at corner, or rotate handle and push, etc…).
- Check that loose items are stored securely after use (i.e. book or magazine, safety card, ear defenders, water bottles, etc…) to ensure that these items will not cause impact injury or impede egress,
- Ensure that the seat harness is securely fastened and loose ends of the strap are tucked away (seat harness should first be made tight at the waist and then shoulders to ensure that the release mechanism remains on the pelvis and not mid-abdominal region).
- Ensure all supplementary survival equipment (i.e. strobe light, personal locating beacon, EBS hose and cylinder, EBS demand valve, whistle, buddy line, vest inflation toggle, splash guard pull tabs, etc…) is secured in such a manner that they are easily accessible and will not impede egress.
- Ensure proper brace position can be obtained prior to take-off.
- Ensure physical reference point can be located with seat harness fully secured and locked.
- Physically perform the movements that would be necessary to egress underwater (minus jettisoning the exit) which includes:
    - Brace position
    - Simulate deployment of emergency breathing system including clearing procedures
    - Physically locate reference point
    - Simulate window jettison
    - Simulate relocation of exterior reference point by holding the interior edge of window frame
    - Release seat harness
    - Simulate egress by moving head and body in the direction of escape
    - Repeat steps for secondary exit

This preparation is not to suggest that the every flight will result in an emergency. Nor is this suggested preparation intended to raise anxiety and stress about flying. It is intended as a proactive state of readiness whereby individuals understand the possibilities of risk and more importantly, the actions necessary to mitigate some of those risks. Being proactive as opposed to reactive to a potential threat is far more desirable position when safety is concerned.

7.0 Conclusions

Based on the information presented in this report, offshore helicopter travel in Canada is at or above safety levels in other regions around the world. There appears to be a well organized process of identifying hazards and risks as well as a clearly defined mechanism to mitigate risks. Supplementary survival equipment such as state of the art personal locater beacons, emergency breathing systems, and strobe lights are well above the standards set by Transport Canada, Civil Aviation and Federal Aviation Authorities. Moreover, thermal protective transportation suits meet and exceed Canadian General Standards Board requirements.

With this in mind, the final section of the report is designed to consolidate known and unknown aspects of helicopter safety in an effort to draw attention to the gaps in the collective understanding of offshore helicopter safety. By identifying the gaps in knowledge, future research may be better focused on improving factors that influence overall survival rates as well as routine flights. Furthermore, the following list helps to identify the interactive nature of the multiple factors associated with offshore helicopter travel.

CURRENT KNOWLEDGE REGARDING OFFSHORE HELICOPTER SAFETY

- Overall reported survival rate for helicopter ditching is approximately 72%.
- Approximately 85% of all aircraft accidents are considered survivable.
- Little warning is given prior to ditching.
- Majority of helicopters invert shortly after impact.
- Majority of ditching fatalities are from drowning.
- HUET improves survival rate.
- EBS improves survival rate.
- Practice with realistic exits improves HUET performance.
- There are several types of emergency exit designs and no regulation to ensure conformity of function.
- There are differences in what HUET skills are required.
- There are significant differences in HUET skill refresher schedules.
- Current testing guidelines for HPTS need to reflect a more realistic environment.
- Next-to-skin clothing material affects thermal regulatory properties of the overall HPTS system.
- Pre-warming before cold water immersion does not affect short or long term survival.
- There is no federal regulation regarding the required placement of helicopter supplementary survival suit equipment.
- Current SMS helicopter safety initiatives are available.
- Hydration and caloric intake (diet) influences cognitive performance and thermal regulation.
- Personal accountability plays a role in pre-flight preparations.

REQUIRED KNOWLEDGE REGARDING OFFSHORE HELICOPTER SAFETY

- What are the optimal HUET skills that should be demonstrated to gain certification?
- How many times should an individual demonstrate exit removal proficiency underwater?
- How often should HUET be refreshed?
- Should HUET be conducted in more realistic environmental conditions?
- Should crashworthy seats be incorporated into HUET performance requirements?
- What is the minimum force required to jettison an S92, AS332L, or S61N push-out window underwater?
- What are the egress implications of having an auxiliary fuel cell installed inside an offshore helicopter?
- Will individuals have difficulty finding a seat harness release mechanism if a crashworthy seat is lowered during impact?
- What clothing should be worn under the HPTS by passengers and crew to aid in thermal regulation?
- What tests should be performed to ensure an HPTS or constant wear immersion is properly fitted?

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Appendix A

Helicopter Underwater Escape Training Simulators

(*note: images were gathered from Google™ image search engine*)