Assessment of Hazards Associated With Pilots Wearing Helmets While Flying in the C-NL Offshore Area

Produced by

The Hazard Assessment Team

of

The C-NLOPB Offshore Helicopter Safety Inquiry Implementation Team

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Recommendation 15 in the Offshore Helicopter Safety Inquiry (OHSI) states: “It is recommended that the wearing of pilot helmets be made compulsory.” After extensively researching issues related to helmet wear, the OHSI Implementation Team recommended that a hazard assessment (HA) be conducted to identify, and as necessary address any hazards associated with helmet wear.

The objective of the HA was to recommend a strategy to address Recommendation 15. To do this, the Hazard Assessment Team (HAT) had to identify the hazards, existing defences and residual risks. The HAT also sought to identify potential system safety deficiencies (SSDs) related to the utilization of helmets by pilots. With this information, the HAT would suggest appropriate mitigation to maintain risks at a level as low as reasonably practicable (ALARP).

The HA was carried out by a panel of subject matter experts. The HAT was led by a human factors expert and an expert in safety-risk management, and included two pilots from Cougar Helicopters, an Operator worker representative, an Operator Logistics representative, and a Safety Officer from the C-NLOPB.

The HAT identified six hazards associated with pilots not wearing helmets while flying, and five additional hazards related to pilots wearing helmets. The risks associated with these hazards ranged from extremely low to moderate in significance.

As a result of its assessment, the HAT concluded that helmets should be made compulsory for all aircrew operating First Response helicopters. To ensure effective helmet functionality in the event of an accident, and to minimize the negative Human Factors effects associated with helmet wear, conditional to this recommendation is that a helmet maintenance program be established for all aircrew who wear helmets in the C-NL Offshore Area. As a minimum, this program must include routine maintenance, proper fitting, and helmet support.

The HAT also concluded that helmet use should remain non-mandatory for line operations flights in the C-NL Offshore Area, and that aircrew should be educated on both the pros and cons of helmet use. This recommendation was based on the fact that helmet wear by pilots does not significantly benefit passenger safety. The HAT determined that the instances in which a helmet will provide additional protection to pilots – an uncontrolled ditch or unsuccessful landing – are also situations in which a pilot will not be expected to influence the outcome, due to the expected failure of the airframe and flight controls.

In their assessment the HAT examined the BST programs, which teach survival as an individual responsibility. Appropriately, the current training does not teach individual survival as being contingent on the leadership of one crewmember over another. Successful survival from an underwater escape scenario, in practice, depends on an individual’s ability to react to the situation in seconds with no reliance on others for direction.

As a result of its assessment, the HAT also challenged the current practice guidance to pilots, which states that pilots should choose either a white or yellow helmet. White helmets can be difficult to see in a frothy sea. The HAT felt that pilots should choose either yellow or Dayglo-orange (also known as Blaze Orange or Safety Orange) helmets, as these colours aid visibility and would assist any SAR effort.

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AC	Aircraft Captain
AGL	Above Ground Level
ALARP	As low as reasonably practicable
ATC	Air Traffic Control
ATIS	Automated Terminal Information System
BST	Basic Survival Training
CAR	Canadian Aviation Regulation
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
DRDC	Defence Research and Development Canada
EGPWS	Enhanced Ground Proximity Warning System
FLIR	Forward Looking Infrared
FOD	Foreign Object Debris
ft.	foot (feet)
GPS	Global Positioning Satellite
HA	Hazard Assessment
HAT	Hazard Assessment Team
HF	Human Factors
HFDM	Helicopter Flight Data Monitoring
HLO	Helicopter Landing Officer
HO	Hoist Operator
HUMS	Helicopter Health and Usage Monitoring System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
JRCC	Joint Rescue Coordination Centre
LO	Line Operations
LRS	Lead Rescue Specialist
NDB/ARA	Non-Directional Beacon / Airborne Radar Approach
NVG	Night Vision Goggles
OHSI	Offshore Helicopter Safety Inquiry
PA	Public Address
PETE	Person Equipment Task Environment
PF	Pilot Flying
PIC	Pilot In Command
PIREPS	Pilot Reports
PNF	Pilot Not Flying
PSF	Performance Shaping Factors
RA	Risk Assessment
RADALT	Radar Altimeter
RAM	Risk Assessment Matrix
RS	Rescue Specialist
SAR	Search and Rescue
SIGMETS	Significant Meteorological Information
SOP	Standard Operating Procedure
TC	Transport Canada
TCAS	Terrain Collision Avoidance System
VFR	Visual Flight Rules

1. INTRODUCTION

1.1 Background

Recommendation 15 in the Offshore Helicopter Safety Inquiry (OHSI) states: “It is recommended that the wearing of pilot helmets be made compulsory.”

From the OHSI Implementation Team’s Advising Document to the C-NLOPB on Recommendation 15:

> The Board accepted in principle the OHSI’s recommendation for compulsory wearing of helmets by pilots in early December and a letter was sent to the Operators on December 13, 2010 stating that unless there were compelling arguments to the contrary, compulsory wearing of helmets should begin immediately. This initial position by the Board was modified in a second letter after the OHSI Implementation Team was formed and it was decided that a more thorough review of the recommendation was needed.

During their research, the OHSI Implementation Team identified several potential unintended consequences that could arise should the C-NLOPB mandate that pilots wear helmets. Some pilots are concerned with the potential for helmets to become mandatory. Most pilots find helmets uncomfortable[1]. Some feel that because Transport Canada (TC) has chosen not to regulate helmet use that it should remain an individual choice based on preference.[2] Others, particularly older pilots or those with existing medical conditions, are concerned that they may suffer pain from wearing helmets and be forced to stop flying in the C-NL Offshore Industry.

After extensively researching the benefits and issues related to helmet wear, the OHSI Implementation Team recommended that a hazard assessment (HA) be conducted to identify, and as necessary address any hazards associated with helmet wear.

1.2 Objective and Scope

The objective of the HA was to recommend a strategy to address Recommendation 15. To do this, the HAT had to identify the hazards, existing defences and residual risks associated with wearing and not wearing helmets. The HAT also sought to identify potential system safety deficiencies (SSDs) related to the utilization of helmets by pilots. With this information, the HAT was able to suggest appropriate mitigation to maintain risks at a level as low as reasonably practicable (ALARP).

The HA assessed the wearing of helmets while flying S-92A helicopters offshore from the St. John’s airport. The HA examined normal and abnormal operations (such as ditching, immersion and egress, bird strike, etc.), including both typical passenger flights and search and rescue (SAR) flights. The main focus of the HA was on how helmet wearing could affect:

- Vision;
- Hearing;
- Ability to process information; and
- Physical movement.

[1] This discomfort can be mitigated somewhat with proper-fitting helmets.

[2] TC does actively encourage the use of helmets, and there is some evidence in TC publications that indicates that the organization would prefer to make helmets mandatory, although no evidence was found that this desire is based on a risk assessment. Some of the reasons given for not making helmets mandatory include the fact that the mandate given to the organization by the federal government is to streamline regulations, and the fact that current regulatory development requires extensive consultation before such a regulation could be implemented.

The assessment also examined the potential operational effects of implementing mandatory helmets in the C-NL Offshore Industry.

1.3 Method

The analysis methodology used to complete the HA is called the Person – Equipment – Task – Environment (PETE) process. The PETE process focuses on human factors aspects related to the introduction of change(s) to systems. It combines a Human Factors framework with traditional System Safety techniques. The procedure enables the identification of hazards that are rooted in human and organizational factors.

A team of experts was formed to complete the HA. The team was led by a human factors expert and an expert in safety-risk management, and included two pilots from Cougar Helicopters, an Operator worker representative, an Operator Logistics representative, and a Safety Officer from the C-NLOPB. A list of team members and their affiliations is included in Appendix A. The team convened in March 2011 at Defence Research and Development Canada (DRDC) Toronto, the foremost research establishment in Canada for development of helicopter life support systems, to gather the best advice and data available with regard to helmet safety. The team reconvened in St. John’s for four days between August 1 and 5, 2011. The team’s work was completed in Ottawa from September 7 to 9, 2011.

The process began by describing the system being analysed. This involved identifying the tasks involved in a typical passenger flight (also referred to as Line Operations [LO]), as well as those for a typical SAR mission. Once all of the tasks were listed, the Hazard Assessment Team (hereafter referred to as the HAT or Team) described the interactions amongst the people; equipment; tasks; and environment associated with each task (see Figure 1.1). In the Figure, P1 refers to the person being assessed for HF effects, and P2 refers to other people within the system with whom P1 can be expected to interact.

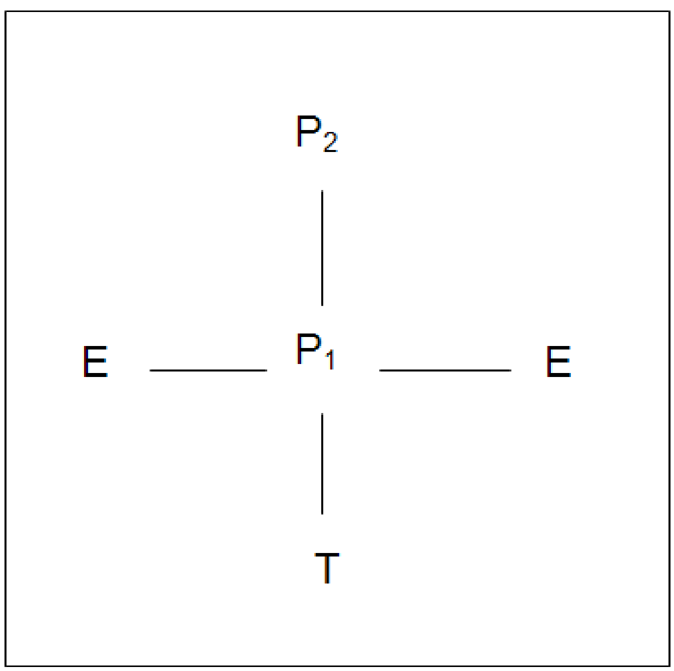

Figure 1.1 - PETE Model

Next, the Team identified any aspects of the system that could be negatively affected by the introduction of helmets, and any associated hazards. Then the Team assessed the effectiveness of existing defences to address the identified hazards. After identifying the importance of and exposure to each hazard, the Team determined the urgency with which additional mitigation should be implemented, and identified the likelihood and severity of the risks associated with each hazard. Finally, the Team suggested additional mitigation that could be put in place to ensure risks are managed to ALARP.

The analysis was finalised by integrating the information gleaned during the Team meetings to develop a draft report. This report was then provided to the Team members for technical verification and comment. Following this review, the report was prepared in its final form.

1.4 Risk Assessment Definitions and Categories

The HAT used the following terms to complete their assessment.

Hazard	A condition or circumstance that can lead to a loss of life or loss of an aircraft.
Risk	The consequence of a hazard, measured in terms of severity and likelihood.
Mitigation	Measures taken to eradicate a hazard, or to reduce the probability and / or the severity of a risk.
System Safety Deficiency	The circumstances that permit hazards of a like nature to exist.

The categories outlined in Tables 1.1 and 1.2 were employed in Section 3 to assess the risks resulting from each hazard.

Table 1.1 - Risk Severity

Category	Definition	Description
A	Catastrophic	Destruction of aircraft and / or multiple loss of life
B	Major	Major damage, single fatality, or major personal injury to one or more persons, or a major reduction in operational effectiveness.
C	Moderate	Moderate damage or moderate immediate / long-term personal injury to one or more persons, or a moderate reduction in operational effectiveness.
D	Minor	Minor damage or minor immediate / long – term personal injury, or a minor reduction in operational effectiveness.
E	Minimal	Inconvenience

Table 1.2 - Risk Likelihood[3]

Level	Definition	Description
I	Occasional	Expected to occur, but not often
II	Seldom	Expected to occur infrequently
III	Remote	Slight chance that it might occur
IV	Improbable	Not likely to occur
V	Extremely Improbable	Occurrence is almost inconceivable

1.5 Key Assumptions and Limitations

The HA was completed using several assumptions, and with some limitations on available information. These assumptions and limitations are outlined below.

The Team acknowledged that there is concern amongst a significant number of experienced pilots who believe that wearing helmets has led, to and will lead to, musculoskeletal injury in the long-term. In their view, this injury is expected to occur due to degradation of the spinal discs in the neck. The Team heard anecdotal evidence from some aircrew regarding this concern, but could not find any conclusive evidence to directly support the anecdotal statements. However, DRDC has extensive data showing a direct correlation between neck and back injury and the wearing of Helmets with night vision goggles (NVGs). Interestingly, many of the pilots who complain of neck and back discomfort while wearing helmets are ex-military pilots who have extensive flying experience with NVG equipment. To ensure an adequate assessment of the aviation safety-risks related to long-term neck injury due to helmet wear, the HAT assumed that wearing helmets could potentially increase the chance of neck injury in the long-term[4].

An area of concern identified by the HAT related to the reduction in peripheral vision resulting from wearing a helmet. To mitigate this problem, the natural response by pilots is to turn their head from side to side, or up and down, more frequently. The HAT assumed that Cougar pilots have a normal range of motion in their necks, and that this range of motion is not unduly altered when a helmet is worn[5].

Evidence presented by DRDC showed that the effectiveness of a helmet in enhancing a pilot's survival depends on several things. If a helmet is poorly fitted, it will provide less than optimal impact resistance. A poorly fitted helmet will also lead to greater discomfort and distraction. When assessing the effects of helmet wear, the HAT assumed that pilots in the C-NL Offshore Area wear properly fitting helmets. If helmet wear were to become compulsory, the HAT felt that steps would be required to ensure that this assumption would hold true in practice.

[3] All of the likelihood ratings are near the "infrequent" end of the frequency spectrum because aviation has earned an enviable record for safety due to the training, regulations and multiple layers of defence combine to reduce the likelihood of serious events occurring. By using finer ratings at this end of the spectrum, the expert panel was able to more precisely identify the likelihood of risks occurring, so that mitigation can be effectively targeted.
[4] If helmet wear were to become compulsory, the HAT felt that this topic would require additional study to verify this assumption.
[5] This could not be verified that the time of this writing. Standard medicals do not cover range of neck motion, nor are there lower limits on neck rotation required for pilots.

The HAT assumed that the only helmets that would be worn by pilots in the C-NL Offshore Industry are those presently recommended by Cougar in their risk assessment. This includes the following models: Gentex SPH5, HGU 56 or HGU 54; Gallet LH-250; and ALPHA Eagle 900 or 200.

Proponents of helmet wear frequently cite the risks associated with helicopter crashes as a reason to wear helmets. This point of view is supported by helicopter accident statistics, which have been used to suggest that up to 84% of aircrew fatal head injuries could be prevented by wearing helmets, and that occupants in helicopters not wearing helmets are up to six times as likely to sustain head injuries[6]. The HAT felt that these statistics could be misleading if applied to the specific conditions encountered in LO flights in the C-NL Offshore Area without further analysis, because these statistics are skewed by the fact that the vast majority of helicopter flights, and therefore also accidents, occur when helicopters are used for low-level aerial work in areas with treacherous terrain (such as heli-logging, aerial construction or aerial surveying). There are enough differences between these types of operation and the passenger operations in the C-NL Offshore Area to make direct comparison very difficult.

To address this concern and enable the risks arising from pilots not wearing helmets during LO flights in the C-NL Offshore Area to be properly evaluated, the HAT identified three separate types of event which were then assessed separately:

1. Controlled Ditching – involves the pilot landing the helicopter on the water, either under power (for instance, in the event that there are indications that the main gearbox is about to overheat) or in auto-rotation (in the event that both engines fail in cruise). The HAT determined that in a controlled ditching, the mitigation in place makes it unlikely that the pilots will hit their head or have debris hit their head[7]. In a controlled ditching, the aircraft remains intact – either upright or inverted, and leaves passengers and crew the opportunity to successfully egress per their training. The HAT determined that the risks associated with these scenarios are ALARP without further mitigation.

2. Crash – involves an uncontrolled impact with the ocean or land. The HAT determined that in the event of such an event during a typical line-flight in the C-NL Offshore Industry[8], the airframe is likely to be severely compromised upon impact, and no presently-available mitigation will effectively protect the passengers or pilots – all will be expected to perish. Mitigation for this event must take the form of avoiding failures or incidents that could lead to a crash[9]. The HAT determined that the risks associated with this event are ALARP without further mitigation.

3. Unsuccessful Ditching – is an incident in which a helicopter impacts the water while the pilot attempts a controlled ditching. This could occur due to additional mechanical failures, or due to challenging sea and / or wind conditions encountered during the ditching process. This event is characterised by the airframe being damaged by the impact forces, but not to the extent that everyone on-board is expected to perish.

The HAT determined that it was necessary to analyse the risks associated with the third event - Unsuccessful Ditching – and a similar event on land – Unsuccessful Hard-Landing.

6 Cougar Helicopters, *Aircrew Helmet Risk Assessment*, February 28, 2011.
7 Mitigation against head injury in controlled ditching includes: pilot simulator training, five-point harnesses which hold pilots firmly in place, a cockpit design in which it is very difficult for a pilot's head to contact any hard surfaces when harnessed in, and an airframe design which will withstand the forces exerted upon it during a controlled ditching (preventing objects from coming free and hitting the pilots).
8 Line operations in the C-NL Offshore Industry are conducted at high-speed and relatively high altitude.
9 In the C-NL Offshore Area, this includes: routine maintenance, daily aircraft inspections, aircrew walk-arounds, pilot training, the fact that helicopters are equipped with Traffic Collision Avoidance System (TCAS), etc..

Due to the fact that all LO flights in the C-NL Offshore Area presently take place in daylight, for the purposes of the HA, the HAT assumed that all flights take place in daylight[10]. This assumption will influence the likelihood that a ditching will be a controlled ditching.

The vast majority of flight time to and from the offshore installations takes place over water. Because the amount of time spent over land is so small, when assessing the likelihood and severity of risks associated with an unsuccessful hard landing, it was assumed that this landing would take place at an approved landing site, either at the St. John's International Airport, on one of the offshore installations, or at the alternate landing site, because pilots would normally choose to land at one of these locations rather than risk a landing on unknown terrain.

1.6 Report Use and Format

The intent of this report is to form advice on Recommendation 15 for the C-NLOPB Board. Following a decision by the Board regarding Recommendation 15, the Report will be used in the development of any activities related to helmet wear programs.

Section 2 of the report explains the details of the system that was assessed.

Section 3 contains the results of the risk assessment.

Section 4 describes the mitigation that could be applied to reduce the aviation safety-risks, if so desired.

Section 5 provides conclusions regarding the longer-term forecast safety-risks related to helicopter transportation in the C-NL Offshore Industry.

[10] The specific hazards and risks introduced when flying at night are being assessed and addressed through a separate risk assessment.

2. DESCRIPTION OF THE SYSTEM UNDER REVIEW

2.1 Introduction

The Team began their analysis by identifying the phases of flight during which pilots can be expected to wear helmets. The Team then generated a task list associated with each phase of flight and the interactions that can be expected to occur related to each task. The purpose of this list was to assist in identifying any hazards and risks related to helmet wear (see Appendix C).

2.2 Typical Passenger Flight

The HAT identified ten phases in a typical passenger flight to the offshore during which pilots could be expected to wear helmets:

1. Preflight briefing/inspection;
2. Taxi;
3. Takeoff & Departure;
4. Climb;
5. Cruise;
6. Descent;
7. Approach;
8. Landing & Arrival;
9. Deck Time (on an offshore installation); and
10. Post Flight (in St John's).

Phases one through nine apply to flights from St. John's International Airport to the offshore. Phases three through eight, and phase ten, apply to return trips from an offshore installation to St. John's.

Individual tasks are discussed at greater length as required in later sections of the report.

The helicopter used to transport personnel to the offshore is the Sikorsky S-92A. Brought into service in 2004, the S-92A is classed as a heavy helicopter and is a modern, twin engine design. It is capable of transporting a total of 21 people, including both passengers and aircrew. The S-92As that Cougar uses for line operations are equipped with glass cockpits, anti-icing, GPS, Blue-Sky GPS based tracking, auto-pilot, Traffic Collision Avoidance System (TCAS), and Enhanced Ground Proximity Warning System (EGPWS), among other safety systems. All passenger flights are governed by Canadian Aviation Regulations (CAR) 704, and take place under Instrument Flight Rules (IFR).

Cougar employs pilots with varying levels of experience. Many Cougar pilots have military flying experience. The average Cougar pilot flies 375 hours per year, is 39 years old, and has 19 years of flying experience[11].

All of Cougar's flights take place with two pilots. Before flight, the pilots decide amongst themselves who will sit in the right and left seats. This determines the role each will play during the flight[12], and these roles remain constant through all ten phases of a given flight. The pilot in the left seat is the pilot not flying (PNF). The PNF is responsible for "managing" the flight: carrying out calculations necessary for flight (fuel load, centre of gravity, etc.), talking on the radio (to offshore installations, Air Traffic Control (ATC), Cougar Dispatch, etc.), and completing paperwork. The PNF also applies the checklists associated with each flight, using Challenge and Response[13]. The pilot in the right seat is

[11] The maximum flown by a single pilot in 2010 was 525 hours, and the minimum flown was 225 hours.
[12] Many factors influence this decision, including the experience level of each crew member.
[13] For example, if an item on the approach checklist calls for landing lights to be switched on, the PNF will call out "Landing lights on?" over the intercom, and the PF will turn on the lights and reply "On".

the pilot flying (PF), who is responsible for flying the aircraft. All decisions are made as a “crew”, with the Aircraft Captain (AC) – also known as the Pilot in Command (PIC) - having the final word in any decision regarding safety. In the event that two qualified ACs are paired on a given flight, the pilot who signs for the aircraft is considered the PIC.

The environment for a typical offshore flight begins on a ramp at Cougar’s hangar. The ramp is often crowded with people, other aircraft (both rotary and fixed-wing) and the tractors (known as tugs) used to tow aircraft and equipment. The flight departs the ramp and taxis to the runway for take-off. The taxiway and runways are frequently covered in rain or snow, and in these conditions the helicopter’s downwash[14] can blow the snow or water into the air, often reducing pilots’ visibility. After take-off, the majority of the flight takes place over the ocean. Flying conditions over the North Atlantic are some of the harshest on earth, with high winds, wind-shear, icing, rain, fog, and turbulence. Cougar flies Non-Directional Beacon / Airborne Radar Approach (NDB/ARA) approaches at the Offshore Installation and Instrument Landing System (ILS) approaches for St John’s.

The environment inside the S-92A is characterised by relatively high background noise (~90 dB in flight), and relatively high levels of vibration. Pilots address the noise level through the use of ear defenders, which can have either active or non-active sound deadening. The temperature inside the S-92A can be quite high. To reduce this effect, all but one of Cougar’s S-92As has air-conditioning[15].

2.3 Typical Search and Rescue Flight

Search and Rescue (SAR) flights include all of the phases of flight involved in a routine passenger transportation flight. They also include the following additional phases:

11. Search (typically low level, 1500 ft. above ground level [AGL] and below); and
12. Hover/Rescue.

While the roles of the PF and PNF are the same for the 10 phases of flight shared with routine passenger flights, there are some additional duties and flight regimes specific to SAR flights. In addition to the PF and PNF, SAR flights are manned by three additional crewmembers: a Lead Rescue Specialist (LRS), a Rescue Specialist (RS) and a Hoist Operator (HO). The PF is responsible for interacting with the HO, who in turn coordinates the activities of the rescue specialists. During SAR flights, the PNF is responsible for communicating with all external agencies, which now includes the Joint Rescue Coordination Centre (JRCC), local hospitals, ocean-going vessels, top cover, and other SAR assets in addition to those involved in line operations.

While every SAR crew-member participates in a SAR flight, overall responsibility for safety and effectiveness rests with the PIC. At any time during a mission, the AC, in conjunction with the entire crew, can halt a mission or sequence. The AC is responsible for initiating all sequences during the rescue phases of a flight, and is responsible for any decisions that could affect the safety and conduct of the mission (for example, whether to continue a mission in the event of bad weather, etc.).

SAR flights are undertaken using an S-92A similar to those used for LO flights but modified for the SAR role. All passenger seats are removed. A sliding door with a lower rescue door is installed, as is a dual rescue hoist, a forward left side bubble window for the Forward Looking Infrared (FLIR) station, and a Night Sun searchlight, among others.

SAR flights are exposed to the same environmental conditions as routine passenger flights. However, because SAR flights generally take place under visual flight rules (VFR) during the search and hover/rescue phases[16], they are also exposed to additional threats, such as tall trees, power lines and poles, whips on ships or installations, and other tall objects. During a typical SAR flight (whether

[14] Downwash is the air pushed downwards by the helicopter’s main rotor.
[15] As of this writing, there is a plan to install air-conditioning in the final remaining helicopter.
[16] The hover/rescue phase is conducted under VFR whether it takes place during daylight or in darkness.

training or operational), the helicopter is exposed to much longer loiter times in flight regimes and the aircraft is flown in “envelopes” requiring faster reaction times (to emergencies). As such, the consequences of human error are higher during SAR flights.

The environment inside a SAR helicopter is also noisier level than in a helicopter used for LO flights. When hovering with the doors open, the noise levels reach up to approximately 96 dBA. The duration of exposure to this noise can range from 10 minutes to 1.5 hours at a time. With the doors open, the crew is also exposed to loud “buffeting” created by the main rotor vortices.

2.4 Abnormal Operations

For the purpose of this report, the term Abnormal Operations is used to describe tasks associated with addressing predictable problems or failures that could be encountered in helicopter flight. These include such problems as bird strikes, equipment failure (mechanical, electrical, software, radio, etc.), ditching, fire/smoke in cockpit, equipment fire/smoke outside cockpit, etc.

When discussing these circumstances, the two pilots on the Team quickly identified that helmets would not negatively impact the tasks needed to address them. Indeed, the HAT was provided with anecdotal evidence that many pilots feel more comfortable working through abnormal situations and subsequent decision making while wearing helmets. This was felt to be related to the fact that helmets isolate pilots from noise and distraction, allowing them to focus more intensely on problem-solving activities associated with abnormal operations[17]. Therefore, the specific phases involved in each type of Abnormal Operation were not discussed in detail.

The Team explored Abnormal Operations in greater detail when considering the consequences of pilots not wearing helmets. These details are included in Section 3.3.

[17] It was also noted that wearing headsets can have a similar isolating effect.

3. ASSESSMENT OF RISKS

3.1 Introduction

Human Factors (HF), a field which finds its origins in World War II as a means to improve aircraft safety, is the science which tries to optimize the interface between people and the equipment they use, the tasks they perform, and the physical and organizational environment in which they work. HF takes into account physical, physiological, psychological and psychosocial components of human interactions with their environment.

To achieve optimum system performance, component design and operational procedures must take into account HF. Any change to the system has the potential to degrade that performance; hence the HF associated with any change should be assessed prior to implementation. Therefore, it is important to understand the hazards and risks associated with both wearing and not wearing helmets, so that a balanced decision can be made regarding their use.

The HAT determined that while the presence of helmets will shape the environment in which pilots operate, the hazards associated with wearing helmets will not, on their own, significantly increase the risk of helicopter accidents. Instead, they may be exacerbating factors that, when combined with other hazards, could result in loss of aircraft or injury to people.

Cougar's risk assessment identified several risks related to pilots not wearing helmets by examining the likely consequences to pilots involved in several scenarios. The results of this assessment are summarized in Section 3.2.

Section 3.3 outlines the results of the HAT's work to assess the risks associated with aircrew not wearing helmets.

Section 3.4 outlines the results of the work the HAT conducted to identify the hazards and risks associated with the human factors of aircrew helmet wear.

3.2 Summary of Cougar's Risk Assessment Results

Cougar Helicopters completed a risk assessment (RA) in February of 2011. The purpose of the RA was "to identify potential hazards and evaluate risks associated with wearing and not wearing a helmet." The RA "strictly focused on the post incident survival and egress properties directly relating to helmet usage."

The risk assessment looked at six scenarios, which are recreated below:

1. Aircraft experiences a controlled / uncontrolled ditching resulting in multiple forces and impact / injury to pilot's head.
2. Aircraft experiences a significant hard landing / deceleration event / crash on ground, resulting in impact forces and injury to pilot's head.
3. Aircraft experiences an un-commanded / unrecoverable rollover on ground which results in helicopter resting on its side resulting in multiple forces and impact of pilot's head.
4. Severe turbulence causes significant impact of pilot's head to cockpit interior / frame / instrument panel, incapacitation and possible loss of control of aircraft.
5. Bird-strike in flight causing head / face injury resulting in incapacitation and possible loss of aircraft control.

6. Sudden, significant acceleration (wind-shear) causing unsecured headset to depart pilot's head during flight.

The report concluded that Cougar's safety department would have "no objection to the customer request in developing and implementing a policy for compulsory helmet use by aircrew." The risk assessment also provided guidance on the models of helmet deemed appropriate (see Section 1.5 of this report for a list of recommended helmets).

3.3 Performance Shaping Factors Induced by Not Wearing Helmets

Using the task lists generated for typical LO flights[18] and the list of expected Abnormal Operations discussed in Section 2, the HAT identified Performance Shaping Factors (PSFs) – negative Human Factors effects – associated with not wearing a helmet while conducting each task. The Team identified six PSFs in total. The following sections describe the hazards that the HAT identified and analysed in relation to the six PSFs.

3.3.1 Bird Enters Cockpit Through Windshield

Bird-strikes are a relatively common occurrence for aircraft, and the threat changes depending upon the type of aircraft being flown. For instance, fixed-wing aircraft can be expected to hit birds at high speed, and the forward surfaces (and engines) of the aircraft are designed to withstand these impacts. Because helicopters fly at lower speeds than most fixed wing planes, they are not designed to the same standard for impact resistance. Additionally, the fact that a high percentage of a helicopter's frontal area is covered with a glass windshield means that the threat of birds actually entering the cockpit is higher for helicopters.

An avifauna study completed in late-2007 of the St. John's International Airport (YYT) and the surrounding area identified a number of migratory waterfowl in the vicinity of the airport. The study classified two species, the Herring Gull and the Great Black-backed Gull – birds that can weigh between 1 and 1.8 kg, and which flock in large numbers, as a 'severe' risk to helicopter operations at YYT. The Glaucous and Ring-billed Gulls, along with several types of large shorebirds, were classified as 'high' risk[19].

A large influx of gulls to the Robin Hood Bay landfill, located east-north-east of the airport, usually occurs with the onset of colder weather in the fall, and again during the spring. The majority of these gulls – in some years numbering from 26,000 to 30,000 – fly daily between the landfill and a night roost on Little Bell Island, southwest of the airport in Conception Bay. The flight Paths the birds fly often intersect the approach and departure paths of runways 02/20 and 16/34. A number of initiatives have been taken or are underway at the Robin Hood Bay Landfill to make the site less attractive to gulls. However, their effectiveness in reducing the presence of gulls is still being studied.

Despite these factors, which increase bird movement near the flight-paths leading offshore, there have been only three reported bird-strikes involving Cougar Helicopters' operation in the last 10 years, and in each instance the consequences were relatively minor[20].

Several forms of mitigation exist to reduce the likelihood of bird-strikes, including:

- Flight paths that direct helicopters to fly above typical migration routes;

[18] Due to the substantially different operating conditions of SAR flights, the HAT felt that helmets are appropriate for SAR flights, and the use of helmets for these operations was not assessed.
[19] LGL, Table 16, p. 59.
[20] For example, in one instance, a bird is suspected to have struck a main-rotor blade. The pilot immediately landed at the nearest oil platform to inspect for damage, and found none.

- Wildlife control programs at the YYT and on the offshore installations;
- Pilot Reports (PIREPS) and Automated Terminal Information System (ATIS) reports, which allow pilots to inform one another of meteorological conditions and other hazards, such as birds, that they experience during flight; and
- Daytime-only flight, increasing the likelihood that pilots will identify birds, thereby enabling them to take evasive action if necessary.

These forms of mitigation are not always appropriate or effective and do not guarantee that bird strikes will not occur. Should a bird-strike occur, the following mitigation helps to reduce the significance of the impact:

- The S-92 windshield is certified to withstand a bird-strike involving a 1kg bird at cruise speed and can be expected to withstand strikes involving larger birds at slower speeds;
- The fact that all S-92s fly with a two pilot crew provides redundancy in the event that one pilot becomes unable to fly due to a bird strike; and
- The design of the S-92 (with composite main rotor, etc.) makes it resistant to damage from bird strikes.

The HAT identified several gaps in the existing mitigation. Firstly, many of the birds flying in the C-NL Offshore Area are larger than the 1 kg used for certification tests on the S-92, and there is the potential that these birds will be encountered when the helicopter is at cruise speed. ATIS reports are numerous, which causes a degree of complacency amongst pilots: they must determine which information, out of a vast selection, is important, and frequently they do not have the time to complete this kind of assessment. As discussed, there are factors which attract large numbers of birds to the area over which Cougar's helicopters fly, which reduces the effectiveness of wildlife control programs. Finally, if a bird does enter the cockpit, both pilots are likely to be distracted, and this will reduce their ability to concentrate on flying the helicopter, whether they are both injured or not.

If a bird was to penetrate a helicopter's windscreen mid-flight, it could lead to several risks for a pilot not wearing a helmet[21]:

1. Debris caused by the bird strike hits the pilot in the eye, leading to one or both pilots losing their vision due to eye damage. *(Severity: C, Likelihood: I)*
2. Large debris caused by the bird strike hits the pilot in the head, rendering that pilot unable to function effectively, thus making it impossible for him/her to continue flying. *(Severity: C, Likelihood: III)*
3. Large debris caused by the bird strike hits the pilot in the head, incapacitating him/her, forcing the pilot to ditch. *(Severity: B, Likelihood: IV)*

Note: The severity and likelihood ratings listed above reflect the situation once a bird has entered the cockpit through the windshield. The actual likelihood of a bird entering the windshield is low (Likelihood: III).

The HAT determined that pilots wearing helmets (with visors down) would provide adequate mitigation to reduce the likelihood and severity of injury as a result of bird strikes. To achieve this, a formal helmet protocol could be developed, including the requirement to fly with visors down.

[21] A fourth risk - Dual engine failure (throttle quadrant struck by bird) – was identified but not analyzed, as it is not related to human factors and thus falls outside the scope of this risk assessment.

Currently, many pilots who wear helmets fly with their visors up, as the visors become scratched and reduce visibility from normal wear. A helmet maintenance protocol to ensure that visors remained scratch-free would be required to address this reduction in visibility due to scratching.

3.3.2 Severe Turbulence

Turbulence, a meteorological phenomenon involving the chaotic movement of air, is encountered routinely during helicopter flights in the C-NL Offshore Area. In most cases, turbulence will cause an aircraft to shake, and in some cases will cause a sudden increase or decrease in altitude. In the most extreme circumstances, turbulence has been a contributing factor in aircraft accidents[22]. It is theoretically possible for turbulence to shake an aircraft so violently that pilots inside the helicopter could hit their heads on the hard surfaces in the cockpit.

Several forms of mitigation exist to reduce the likelihood of pilots hitting their heads as a result of extreme helicopter movements:

- Pilots flying the S-92A wear self-locking five-point harnesses which hold them firmly in their seats, preventing them from moving far enough to hit their heads on cockpit surfaces;
- The cockpit design of the S-92A ensures that there are no protruding objects on which a pilot could strike his/her head when wearing a five-point harness;
- Weather forecasting and weather radar alert pilots to potential areas of extreme turbulence so that they can adjust their flight paths to avoid them;
- Significant Meteorological Information reports (SIGMETS) and PIREPS inform pilots of significant turbulence experienced by other pilots in the area so that they can adjust their flight paths;
- Cougar standard operating procedures (SOPs) include turbulent penetration speeds which, if applied, reduce the effect of turbulence on the helicopter and reduce the likelihood of extreme motions; and
- Local knowledge helps pilots to recognize meteorological conditions likely to cause significant turbulence so they can adjust their flight paths to avoid it.

There are some weaknesses in the existing mitigation. Self-locking five-point harnesses may not lock in turbulence, meaning that pilots would not be held as securely in their seats. Weather forecasting is never 100% accurate, meaning that areas of severe turbulence may go unidentified and unreported. Finally, local knowledge is very pilot-dependent, and pilots who are less experienced or new to the area will not have the same advantage as those more experienced in the conditions in the C-NL Offshore Area.

The risk to a pilot not wearing a helmet during turbulence is that the pilot hits his/her head on the interior of the cockpit, causing him/her to become incapacitated. *(Severity: E, Likelihood: V)*

The HAT felt that due to the strong existing mitigation, their experience with turbulence and their knowledge of the design of the S-92A's cockpit, this risk requires no further mitigation to achieve ALARP.

[22] Accidents are most commonly associated with turbulence called "Wing Tip Vortices" or "Wake Vortices", which can occur in the wake of large fixed wing aircraft during take-off and landing. These vortices have been known to cause small aircraft flying behind the large aircraft to lose control, and at low altitude this can lead to accidents. Helicopters flying in the C-NL Offshore Area are not exposed to this type of turbulence.

3.3.3 Vision Impairment Due to Sunlight

One of the challenges associated with flying helicopters, which have large windscreens, is that sunlight can be blinding. This hazard is particularly noticeable in the C-NL Offshore Area when pilots fly the return trip from the offshore to St. John's late in the day, when the sun is low over the horizon. Unmitigated, the bright sunlight can make it exceedingly difficult for pilots to see their instruments, which is a significant hazard when flying IFR.

This is not a new problem for pilots, and several forms of mitigation exist to reduce the impact sunlight has on pilots' ability to see, including:

- All pilots carry high-quality sunglasses with them when they fly, and put them on when they encounter bright sunlight; and
- The windscreen on the S-92A is tinted to reduce the glare caused by the sun.

The HAT identified some weaknesses with these forms of mitigation. Sunglasses could be forgotten or broken during flight. To minimize the impact on visibility during low-light conditions, the windscreen of the S-92A is not sufficiently tinted to be considered a replacement for sunglasses in conditions of direct sunlight.

The risks associated with sunlight for a pilot not wearing a helmet are:

1. Pilots are blinded by sunlight and unable to see approaching aircraft, leading to a mid-air collision. *(Severity: A, Likelihood: V)*
2. Pilots are blinded by sunlight and unable to see approaching birds, leading to a bird-strike. *(Severity: C, Likelihood: V)*

After thorough discussion, the HAT determined that the risks associated with blindness due to sunlight are mitigated to ALARP by existing mitigation. If pilots desire additional protection from these risks, the HAT suggested that they could:

- Wear baseball caps to shield their eyes from the sun;
- Wear helmets with tinted visors; or
- Install removable portable solar-screens on the upper portions of the S-92A's windshield when they fly.

3.3.4 Head Injury Resulting from Rollover During Take-off or Landing

Helicopters are susceptible to two forms of rollover: static rollover and dynamic rollover. Static rollover, which occurs when the helicopter's blades are stationary, is the same type of rollover that can happen to any tall object, and is related to the height of the helicopter's center of gravity and the width (and strength) of the helicopter's supports (be they skids, floats, or wheels)[23]. Static rollover occurs when a critical rollover angle is exceeded. This could happen due to a helicopter being parked on inclined terrain, or due to heavy wind. Because it occurs when the helicopter is stationary, static rollover is unlikely to cause injury to pilots or passengers, and will not be discussed further.

Dynamic rollover is a more significant hazard to the safety of pilots and passengers in the C-NL Offshore Industry, as it occurs when a helicopter is flying or in the process of taking off. Dynamic rollover happens when the helicopter rolls beyond its critical rollover angle, at which time the thrust

[23] A wider stance for the helicopter's supports and a lower center of gravity reduce the tendency for helicopter to suffer from static rollover.

from the main rotor acts to continue the roll, causing the helicopter to roll onto its side. Normally, dynamic rollover starts when a helicopter begins to pivot about a fixed point (due to a landing wheel being stuck on takeoff or due to inappropriate take-off technique). A pilot can recover from a dynamic roll if the roll is corrected before the critical rollover angle is reached.

Several forms of mitigation exist to prevent dynamic rollovers from occurring. These include:

- Pilot experience and SOPs for taking off and landing;
- Simulator training on how to identify and correct a dynamic roll before it leads to an accident;
- Runway and helipad maintenance to reduce the likelihood of helicopter landing gear becoming stuck in snow or ice; and
- Two-pilot crews for S-92A helicopters, providing some redundancy in the event that one pilot does not identify and act to correct a dynamic roll.

In the event that a dynamic rollover does occur, the following mitigation reduces the significance of the consequences:

- All pilots wear five-point harnesses to hold them securely in their seats and prevent them from coming into contact with the interior surfaces of the cockpit/cabin; and
- The airframe design of the S-92A ensures a degree of crash-worthiness to protect the passengers and crew in the event of a dynamic rollover.

The HAT identified one weakness with the aforementioned mitigation, which is that neither five point harnesses nor crash-worthy design will provide complete protection for pilots or passengers from debris created by the spinning main rotor blades contacting the ground.

The risk to a pilot not wearing a helmet during a dynamic rollover is that the pilot becomes injured due to debris from the main rotor blades contacting the ground. *(Severity: B, Likelihood: IV)*

Due to the robustness of existing mitigation, the HAT determined that the risks associated with dynamic rollover are ALARP and do not require any additional mitigation. If pilots desire additional protection from the risk associated with dynamic rollover, the HAT felt that helmets would provide additional protection from debris.

3.3.5 Head Injury as a Result of Unsuccessful Ditching[24]

As described in Section 1.5, the HAT defined an unsuccessful ditching as an incident in which a helicopter impacts the water while the pilot attempts a controlled ditching. The HAT expected that this event would occur with low forward speed and relatively low rate of descent, such that the airframe would be damaged by the impact forces, but would not fail completely. In the event of airframe damage, the HAT expected that components of the cockpit (or cabin) could move inwards, increasing the likelihood that the pilots' heads could come into contact with the interior of the cockpit.

An unsuccessful ditching could occur due to additional mechanical failure(s) which occur during the ditching process (for example, tail rotor drive-failure caused by the main gearbox overheating). It could also be precipitated by challenging sea and/or wind conditions encountered during the ditching process.

Several forms of mitigation exist to prevent pilots having to initiate a ditching. These include:

[24] Defined as: *Damage to aircraft; Fuselage does not remain intact.*

- SOPs and robust pilot simulator training, which help to ensure that pilots identify emergent mechanical problems and take action before a ditching is required;

- Daily inspections of the aircraft by both aircraft mechanics and aircrew to ensure system integrity;

- Routine maintenance of mechanical systems to help ensure reliability;

- The Helicopter Health and Usage Monitoring System (HUMS), which identifies mechanical problems so that they can be addressed before they lead to failure; and

- Helicopter Flight Data Monitoring (HFDM), which monitors flight paths to ensure that critical system parameters are not exceeded, and to specify additional inspection and maintenance if critical system parameters are exceeded.

In the event that a pilot is forced to initiate a ditching, several forms of mitigation safeguard against it becoming an uncontrolled ditching. These include:

- SOPs and simulator training, which help pilots to identify mechanical problems early so that they can carry out a ditching before further mechanical failure[25], and to ensure that the ditching goes as smoothly as possible; and

- Weather restrictions, which help to ensure that the sea-state, wind and visibility pilots might encounter during a ditching are within acceptable limits.

There are some weaknesses with the above forms of mitigation. Because an S-92 has never been ditched, flight simulator training for ditching is not expected to be completely accurate, since it is based on calculations and assumptions. Weather forecasting is also imperfect: there is no data for the sea-state or visibility conditions along the majority of the route flown by Cougar's helicopters, and weather in the C-NL Offshore Area is very changeable.

The HAT determined that the risks to a pilot not wearing a helmet during an unsuccessful ditching are:

1. Rapid collapse of the cockpit, leading to death due to head injury, or from drowning due to unconsciousness caused by a head injury. (Severity: A, Likelihood: I)

2. Rapid collapse of the cockpit, leading to a serious head injury, compromising survivability. (Severity: B, Likelihood: I)

3. Rapid collapse of the cockpit, leading to a loss in ability to function due to head injury. (Severity: D, Likelihood: I)

Note: The severity and likelihood ratings data above reflect the situation given a helicopter has been involved in an unsuccessful ditching event. The actual likelihood of a helicopter being involved in an unsuccessful ditching is very low (Likelihood: IV)

The HAT determined that the risks associated with uncontrolled ditching could be further mitigated by pilots wearing helmets. The HAT noted that helmets would not provide mitigation under all circumstances, such as an instance in which a part of a pilot's body other than the head was struck by a rapidly collapsing cockpit.

[25] Such as the new flight path instituted by Cougar following the crash of Cougar Flight 491 which ensures that in the event of total loss of main gearbox oil, a helicopter can be brought to the surface of the ocean within 7 minutes, four minutes before it is expected that the main gearbox will overheat and fail.

In the long term, the HAT felt that new technological advancements, such as changes in airframe crash-worthiness or the introduction of air-bags for pilots, should be considered by the Operators working in the C-NL Offshore Area as means to improve the resistance of airframes to collapse and increase survivability in the event of unsuccessful ditchings.

3.3.6 Head Injury as a Result of a Hard Landing[26]

An unsuccessful hard landing is similar to an unsuccessful ditching, except that it happens on land or on a helideck offshore instead of over water. Because of its similarity to unsuccessful ditching, the mitigation that exists to prevent a pilot entering into a situation in which a hard landing is likely are the same as those that protect against having to initiate a ditching over water.

When conducting a landing on land or on a helideck, there are some additional forms of mitigation that increase the likelihood of a landing being successful. These include:

- Lights on the helipad and runway which provide pilots with additional visual cues to assist them to complete their landing;
- Instrument approaches and ATC to guide pilots towards safe landing areas;
- Weather reports, which are expected to be very accurate;
- Pilot experience and training; and
- Runway and helipad maintenance programs, which ensure that hazards on the landing surfaces are minimised.

In the event of an unsuccessful hard landing, the mitigation to reduce the severity of the consequences is the same as the mitigation in the event of an unsuccessful ditching, with the addition of:

- Trained emergency response personnel to remove and treat injured pilots from the wreckage quickly;
- Crew training for emergency response following an accident; and
- First aid conducted by trained personnel on the aircraft.

The risks in the event of an unsuccessful hard landing, and their severities and likelihoods, were assessed by the HAT to be the same as those for unsuccessful ditching. However, the likelihood of a landing hard enough for the fuselage to fail was assessed to be lower than that in the scenario of an unsuccessful ditching[27], due to the additional mitigation in place. *(Likelihood: V)*

The HAT determined that additional mitigation to protect against the risks of unsuccessful landings are the same as the additional mitigation to mitigate the risks of unsuccessful ditching.

3.4 Performance Shaping Factors Induced by Helmet Wearing

Using the task lists generated for LO and SAR helicopter flights discussed in Section 2, the HAT identified Performance Shaping Factors (PSFs) – negative Human Factors effects associated with wearing a helmet while conducting each task. The Team identified five PSFs in total.

[26] Defined as: *Damage to aircraft; Fuselage does not remain intact.*
[27] See *Note* in Section 3.3.5.

From these PSFs, the following five hazards were identified and analysed[28].

3.4.1 Reduction in Peripheral Vision

The helmets designed for use in helicopters, and recommended in Cougar's risk assessment, reduce pilots' peripheral vision. In an informal test conducted by the HAT on a single pilot wearing a Gallet LH-250 helmet (Figure 2.1), it was estimated that pilots could lose up to ~20^{o} of peripheral vision. Humans rely entirely on their peripheral vision to detect motion[29]. Thus, a reduction in peripheral vision could be critical for pilots in certain circumstances.

Figure 2.1 – Gallet LH-250 Helmet

During typical passenger flights, pilots rely on their peripheral vision most heavily during critical phases of flight: taxi, takeoff, approach, and landing. SAR pilots add to this list the search and hover/rescue phases. In these circumstances, pilots must identify objects in the environment that could pose a hazard to the aircraft to take appropriate actions. During taxi, this includes other aircraft or vehicles that could collide with the helicopter, and foreign object debris (FOD). During takeoff, approach, landing, and hover/rescue, pilots watch for FOD, birds, towers, radio whips, etc. With a reduction in peripheral vision, it may take longer for pilots to identify and react to these threats, or they may fail entirely to identify them.

The significance of this issue is reduced by the following defences:

[28] A sixth PSF was considered briefly: the helmet could make it more difficult for pilots to manoeuvre themselves to egress in the event of an accident. However, this PSF was discounted because of the far more significant advantages provided by wearing a helmet in the event of a ditching or accident, and the fact that the helmet will also provide bump protection during the escape. A crushed or damaged cockpit in which the door area collapses or changes shape could aggravate this situation, but the fact that the pilot is more likely to be conscious will increase the chances of dealing with the situation effectively. Pilots who currently wear helmets prepare for this scenario by training in the HUET with their helmets on.

[29] The human eye is made up of several components. Two of the most important for vision are called Rods and Cones. Cones are most dense near the center of the Fovea, and provide the greatest image clarity and contrast when we look at something straight ahead. Rods are least dense near the center of the fovea, but are much more dense than Cones around the majority of the eye. Because they are spread over a larger percentage of the eye, Rods are able to identify moving objects, because the object will be seen sequentially by several adjacent rods.

- S-92As are flown by two-person crews (LO) or five-person crews (SAR), which reduces the visual area each person is responsible for, thus increasing the likelihood that dangers will be identified;

- Pilots will naturally turn their heads more to compensate for the reduction in peripheral vision;

- S-92As are equipped with modern “glass cockpits”, meaning that all alarm indications are projected on large screens directly in front of the pilots, reducing their reliance on peripheral vision to see trouble lights;

- Cougar SOPs ensure that pilots make thorough visual checks/scans of their environment during critical phases of flight;

- ATC monitors the airspace around the St. John’s International airport and informs pilots of items of concern;

- TCAS, EGPWS, and Radar Altimeter (RADALT) systems provide pilots with information or warnings related to the helicopter’s proximity to the ground, reducing their reliance on visual cues;

- FLIR improves the chances that hazards will be identified when flying at night (SAR only);

- The HLO (Helicopter Landing Officer) on offshore installations assists the pilots by communicating information regarding environmental hazards to pilots; and

- Marshallers provide pilots with directions and information to ensure that environmental hazards do not cause accidents.

The HAT identified one gap in these defences, which is that pilots may not be aware of the fact that their peripheral vision has been reduced, which could lead to them overestimating their ability to identify threats in their environment.

With these defences in place, the risks associated with a reduction in peripheral vision include:

1. Pilots not seeing other vehicles on the taxiway / runway / ramp, leading to a collision. (Severity: A, Likelihood: V)

2. Aircrew walking on the ramp may not notice and avoid equipment moving on the ramp, resulting in their being struck. (Severity: B, Likelihood: V)

3. Pilots not detecting environmental hazards during critical phases of flight, leading to collision with one or more hazards. (Severity: A, Likelihood: V)

4. Pilots not detecting and manoeuvring to avoid FOD, resulting in uncontrolled flight into terrain. (Severity: A, Likelihood: V)

5. Aircrew receiving personal injury due to collisions with objects in confined spaces on an offshore installation. (Severity: D, Likelihood: IV)

The HAT assessed the risks of environmental hazards going unnoticed (risks 1, 3 and 4) to be ALARP given existing mitigation. Due to the low likelihood and consequences of risk 5, no further mitigation was deemed to be necessary.

The likelihood of pilots being struck by equipment on the ramp could be reduced by updating the training (initial and refresher) for personnel working on the ramp to include awareness of the fact that aircrew walking on the ramp with helmets cannot see as well due to the reduction in peripheral vision, and so will be less likely to notice approaching equipment.

3.4.2 Impaired Ability to Hear Sounds Originating Outside the Helmet

Helmets designed for use in helicopters have sound deadening properties which reduce the wearer's ability to hear sounds originating outside the helmet. This improves the wearer's ability to hear speech or warning signals through the radio headset, and also protects the wearer from noise encountered during normal operations (particularly SAR operations where the rescue-door is open). The reduction in the wearer's ability to hear external sounds could have unintended consequences that introduce risk.

Passengers travelling by helicopter in the C-NL Offshore Industry are taught to step forward and communicate with the pilots if they have any safety or health concerns during the flight. Whether a pilot wears a David Clark headset (Figure 2.2) or a helmet, they will be unable to hear the passenger's concern. With a headset, the pilot addresses this issue by sliding one cup of the headset off of his or her ear. If the pilot is wearing a helmet, he or she must completely remove the helmet to speak with the passenger. This means that the Pilot is no longer connected to the helicopter's radio system, and thus cannot hear communications from the other pilot, ATC, etc.[30]. There is also the possibility that the pilot could drop the helmet once it is removed, and the helmet could possibly restrict the use of the helicopter's controls, or contact instruments or switches.

Figure 2.2 – Typical David Clark Headset

[30] The consequences could be more severe if the pilot speaking with the passenger is the PNF, as is normally the case, since the PNF is responsible for interacting with ATC and other external groups over the radio.

A second concern arises for pilots walking to and from the aircraft on the ramp. When coupled with the reduction in peripheral vision discussed in Section 3.4.1, the reduction in the ability to hear environmental sounds reduces the wearer's situational awareness, and increases the chance that they may unknowingly walk into harm's way. The risks associated with this loss of situational awareness are more likely to be realized in the winter, when ice on the ramp reduces the ability of equipment to manoeuvre to avoid striking obstacles or personnel.

Several defences are presently in place to mitigate these concerns. Mitigation for hazards related to communications includes:

- Cougar SOPs, which direct pilots to formally hand off radio communications if needed, and ensure that pilots minimize distractions during critical phases of flight (meaning they will not speak to passengers at these times);

- Pilots have access to a public address (PA) system with which they can interact with passengers without removing their helmets[31];

- Passengers receive instruction in communication protocol during pre-flight videos, reducing the likelihood that they will attempt to contact pilots during critical phases of flight[32]; and

- Pilots conduct visual checks of passengers to verify that there are no issues developing.

Defences to keep pilots safe while walking on the ramp include:

- Ramp personnel training in equipment operation, which must be completed prior to operating equipment on the ramp to ensure that they are aware of the hazards and risks involved;

- Pilots will naturally rely more on their other senses (i.e., turning your head more frequently and relying on vision) to maintain situational awareness while on the ramp; and

- Aircrew experience/airmanship – pilots are taught during their initial training to always make eye contact with personnel operating equipment on the ramp, whether the equipment is a tug or an aircraft, prior to walking near the equipment.

The HAT identified a gap in these defences, which is that ramp personnel may not be aware of the reduction in hearing resulting from pilots wearing helmets. Without this awareness, they may rely on aircrew hearing them coming and stepping out of harm's way.

The following risks related to loss of hearing were identified:

1. A pilot misses critical communication between crew during an emergency situation when helmet is off. *(Severity: E, Likelihood: V)*

2. After removing the helmet to speak to a passenger, the helmet falls and strikes a critical switch or other control. *(Severity: D, Likelihood: IV)*

3. After removing the helmet to speak to a passenger, the helmet falls and jams the cyclic, leading to momentary loss of directional control. *(Severity: D, Likelihood: IV)*

4. Aircrew are struck by a ground vehicle while walking to or from the aircraft. *(Severity: C, Likelihood: IV)*

[31] This is a one-way system that does not enable passengers to speak to pilots.
[32] The HAT knew of only one instance where a passenger had tried to communicate with a pilot during a critical phase of flight. In this instance, the pilot instructed the passenger to return to their seat.

The likelihood of the risks associated with pilot-passenger communication being realized could be further reduced by adding a two-way communication device for passengers to speak with pilots through the aircraft's intercom system. For example, each passenger aircraft could be equipped with a single David Clark headset in the passenger compartment.

The likelihood of pilots being struck by equipment on the ramp could be reduced by updating the training (both initial and refresher) for personnel working on the ramp, to include awareness of the fact that aircrew walking on the ramp with helmets on cannot hear as well, and so will be less likely to notice approaching equipment.

3.4.3 Reduced Clearance Between Head and Overhead Controls

People are used to the size of their head, and use this awareness to avoid hitting their head when manoeuvring in tight spaces. People rely on many sensory cues to help them with this – visual cues, hair, scalp nerve endings, etc. A helicopter helmet effectively increases the size of a pilot's head in every dimension, which means that people must familiarise themselves with this change. Additionally, the helmet dulls or blocks sensory inputs that would normally be used to gain information on physical position, orientation, etc. This change could affect a pilot's movement in several circumstances.

It is expected that pilots will bump their heads more often when wearing helmets. Pilots with experience wearing helmets explained that this often happens when they are getting into the helicopter. This can result in switches on the overhead panel being accidentally manipulated or even broken. The consequences of this bumping will be most severe when the helicopter is running, as it is during Phase 9 – Deck Time, on an installation[33].

Pilots who have never worn a helmet in a helicopter are expected to bump into things most frequently. As their experience wearing helmets increases, pilots will adapt – they will become used to the size of the helmet – and they will bump their helmet less frequently.

Several barriers are presently in place to reduce the chances of switches being accidentally manipulated or broken, and also to reduce the chances that an accidental manipulation goes uncorrected. Barriers include:

- A cockpit design in which pilots, once seated, have adequate head clearance and are securely located in order to, among other things, avoid inadvertently manipulating switches;

- The use of checklists for all phases of flight to ensure that systems are in the proper configuration for each phase;

- SOPs: when running on deck, one pilot remains seated in the helicopter at all times. To prevent accidental manipulation of the flight controls, this pilot covers sensitive switches whenever the other pilot is moving around the cockpit;

- A cockpit design which includes robust overhead switches, reducing the chance of breakage[34]; and

- Pilots are generally aware of the hazards related to moving around the cockpit, with or without helmets.

The risk associated with the helmet's impact on a pilot's freedom of movement in the cockpit was determined to be inadvertent operation of an overhead switch when an Aircraft Maintenance Engineer is near the Auxiliary Power Unit exhaust, resulting in a minor burn. *(Severity: E, Likelihood: V)*

[33] When landing offshore, it is typical for one pilot to disembark from the helicopter, meaning that they then must re-enter the helicopter while it is running.
[34] No circumstances in which a switch was broken were identified during the analysis.

The HAT determined that the defences in place adequately mitigate this risk. The checklists used during each phase of flight help to ensure that essential systems are in the correct configuration for the given phase.

3.4.4 Heat Stress Due to Helmet Wear

Due mainly to the number and size of the windows in the S-92A, the cockpit and passenger compartment are subject to high thermal loads on sunny days. Pilots flying the S-92A offshore wear dry suits over their flight suits to protect them in the event that the helicopter crashes or is forced to ditch at sea. With their bodies insulated, pilots' heads become a key avenue for shedding excess heat. By covering the majority of the head, helmets reduce the surface area available for shedding excess heat while in flight.

Under these conditions, pilots' core temperatures could increase. The body's natural responses to heat stress include physical responses (such as sweating, which reduces comfort and increases distraction[35]) and mental responses (heat-stress induced fatigue, which increases complacency and the likelihood of critical information not being acted upon. Information that is attended to is not processed as effectively). These effects in turn could lead to an increase in cognitive difficulties, such as an increase in the number of errors made, or an increase in the time required for problem solving. It could also result in a shift in workload (normally balanced 50:50 between pilots) to the pilot not suffering from heat stress, increasing the workload pressure on this pilot, while simultaneously reducing the other pilot's ability to verify that the work is being done correctly.

The environmental conditions encountered in the C-NL Offshore Area (typically cool, often overcast) provide a natural defence against these problems, although there are warm sunny days during which pilots could be exposed to the hazard.

Several defences exist to reduce the likelihood and severity of these factors:

- The majority of S-92As flown for the C-NL Offshore Industry are equipped with air conditioning[36];
- All S-92As are equipped with vents that circulate the air within the helicopter;
- All S-92A passenger flights are flown by a two-man crew, providing redundancy in the event that one pilot suffers from heat stress;
- The use of checklists reduces the chance that a critical task will be missed, even if one or both of the pilots suffers from heat stress; and
- Cougar SOPs ensure that critical items become routine, and that pilots memorize critical steps, helping to ensure that these steps do not get missed.

There are gaps in these defences. One of the S-92As currently in use is not equipped with air conditioning[37]. Ironically, this aircraft is one of the most frequently used, due to the fact that it is lighter that the others (no air conditioning system) and thus has a greater payload capacity. The Operators and Cougar have received several complaints from passengers regarding the temperature aboard this aircraft[38].

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[35] Poorly fitting helmets can also lead to "hot spots", localized areas of excessive heat. This can be addressed by wearing helmets that fit properly (see assumptions in Section 1.3.2).
[36] At the time of writing, there is a plan to outfit the final airframe with air-conditioning, meaning that all airframes used in the C-NL Offshore Industry will be equipped with air-conditioning.
[37] At the time of writing, there is a plan to install air-conditioning in this aircraft.
[38] The clothing worn by passengers aboard the S-92As provides greater insulation than the clothing worn by pilots.

A concern with all of the helicopters equipped with air-conditioning is the frequency with which the air-conditioning is inoperable. For aircraft with broken air-conditioning, the ventilation system normally available to provide circulating air to the cabin is intentionally disabled per Sikorsky maintenance instructions[39], which eliminates another defence against heat-induced issues.

While a two-man crew is one defence against the effects of heat stress, it is reasonable to expect that when both pilots are exposed to high ambient temperatures, each could simultaneously suffer from heat stress.

The risks associated with heat-stress are:

1. Failure to detect a developing situation (mechanical, instrument, system configuration error, navigational error, fuel starving, etc.) brought about by the body's normal responses to heat stress, leading to loss the aircraft. *(Severity: A, Likelihood: IV)*

2. A reduction in situational awareness, brought about by the body's normal responses to heat stress. *(Severity: E, Likelihood: IV)*

The HAT determined that the risks associated with heat stress warrant additional mitigation. The HAT supports the recent move to retrofit air-conditioning to airframe SCH, the only airframe currently without air-conditioning. The HAT also felt that improvements in the availability rates of air-conditioning systems would be desirable. This could be achieved by updating spare-parts scaling, updating preventive maintenance schedules, etc.

Finally, the HAT noted that there are several options currently on the market to provide individual cooling, called personal cooling life support systems. Typically, these systems involve circulating cool liquid in a suit worn against a person's skin under their normal clothing. The HAT felt that such personal life support systems should be explored for use by pilots who suffer from overheating and discomfort while flying.

3.4.5 Helmet Weight Related Spinal Health Issues

One of the most controversial issues related to the introduction of mandatory helmets for aircrew has been the concern that wearing helmets could result in neck pain and potentially long term neck injury for some pilots.

Long-term neck injury would most likely result from disc injury. This disc injury will occur if the rate of disc degradation is greater than the rate of disc regeneration. The rate of regeneration is likely to be affected by several factors, which could include the person's genetics, their overall health, whether the person has existing neck-injuries or a history of neck injury, and the person's age.

As stated in Section 1.5, there is presently no evidence that wearing helmets will result in neck injury. However, there are pilots presently working for Cougar who suffer from neck pain as a result of previous employment with the Armed Forces, during which they were required to fly while wearing helmets equipped with NVGs. During a visit to DRDC in Toronto in March of 2011, DRDC scientists presented members of the HAT with conclusive evidence that wearing helmets with NVGs resulted in neck injury in some wearers[40]. The scientists hypothesised that several elements contributed to these injuries, including the weight of the helmets and NVGs, and helicopter vibrations, among others.

[39] The circuit breaker is for the ventilation system is "pulled and clipped".
[40] This research is not currently available to the public.

NVGs, particularly the older models worn by pilots in the 1970s and 1980s, add several pounds to the front and rear of a helmet[41]. This weight compresses the disks in the neck. For the helmet to be balanced, its centre of gravity must be near the centre of the helmet when viewed from above. This means that the vertical force applied by the helmet to the head is not in line with the neck on some wearers, instead being slightly forward of the vertebrae. In these cases, to support the head, the neck muscles must pull downwards on the back of the head to counteract the moment created by the helmet[42]. This results in even more force being applied to the vertebrae in the wearer's spine.

Coupled with these factors, NVGs greatly reduce the wearer's field of vision. When not wearing NVGs, a person's normal field of view "is almost 190 degrees - but that is cut down to 40 degrees" when wearing NVGs[43]. The result for NVG wearers is that they must turn their head from side to side to increase the number of visual cues available to them. This rotation, coupled with the weight of the NVGs, tends to increase the stress and wear of neck discs.

Because modern helmets weigh significantly less than the combination of older style helmets and NVGs, they are not expected to have identical effects. Nevertheless, because they amount to an additional weight on a pilot's head, there is the potential that over long periods of use, helmets could lead to similar neck pain and injury. The exacerbating factor of helicopter vibrations is also still present for pilots wearing helmets in modern helicopters like the S-92A. Older pilots, those with previous neck injuries and those with existing musculoskeletal neck injuries, are expected to be the most likely to experience helmet-induced neck pain or neck injury.

Because helmets are not yet mandatory, there are no formal defences in place to protect against this hazard or the resulting risks. However, several informal defences exist naturally in the structure of the current helicopter transportation system. The defences against helmet-induced neck injury include:

- Modern helmet designs are relatively light-weight, weighing between 2.2 and 3.5 lbs (approximately). By comparison, a David Clark H10-13.4 headset weighs 16.5 oz. (just over 1 lb.) without a cord;
- Pilot exposure to the hazard is limited by work schedules. Pilots flying with Cougar average 375 flying hours per year; and
- Pilots remove their helmets shortly after each flight, meaning that they are normally not worn for more than ~3.5 hours at a time.

The defences against the aviation safety risks resulting from a pilot succumbing to a neck injury (i.e., being unable to fulfil their duties) while flying include:

- Aviation medical checks, which pilots receive twice per year to verify their health, meaning that they will not fly if their physical capabilities preclude the safe operation of a helicopter;
- The daily risk assessment matrix (RAM) filled out by pilots provides an opportunity for pilots to self-identify physical ailments that could preclude their ability to fly safely;
- CARs and the Cougar Operations Manual preclude flying when medically unfit, meaning that pilots have a legal obligation to report any ailment that could preclude their ability to fly safely; and
- S-92As are operated with a two person crew, which provides redundancy in the event that one pilot becomes unable to fulfil their duties in flight.

[41] The NVG goggles hang off the front of the helmet, making the helmet imbalanced. To counteract this, the batteries for the NVGs are mounted on the rear of the helmet. In addition to the batteries, some models of NVG required the addition of small lead weights to help properly balance the helmet.
[42] A moment is an engineering term describing a force that is applied to the end of a lever-arm, causing it to want to rotate. This force must be resisted to hold an object to which a moment is applied in equilibrium.
[43] Night Vision Goggles, Article, http://www.globalsecurity.org/military/systems/ground/nvg.htm, accessed August 29, 2011.

While not a defence, the fact that NVGs are not currently used in the C-NL Offshore Area removes one of the risk factors identified in DRDC's research on neck pain.

There are some weaknesses with the existing defences. There are incentives (self-esteem, financial, etc.) that could cause pilots to down-play pain that they feel, which could delay necessary treatment in the event that an injury exists, and could lead to worsening symptoms. The current aviation medical does not test neck movement, and some aspects of the examination rely on pilots self-identifying whether they feel fit to fly.

The risks associated with spinal health issues brought on by wearing helmets include:

1. Individual pilots' flying careers end prematurely or be restricted due to injuries resulting from wearing a helmet. *(Severity: C, Likelihood: Unknown[44])*

2. Pilots' ability to function in the cockpit (due to difficulty concentrating or to difficulty performing neck rotation) is reduced, resulting in an increase in errors. *(Severity: E, Likelihood: V)*

3. Several senior pilots leave the C-NL Offshore Area due to mandatory helmet requirements, resulting in a reduction of experience in the local operating environment. *(Severity: C, Likelihood: III)*

Risks one and two, related to a reduction in pilots' ability to function in the cockpit with the potential for career implications, could be partially mitigated with the introduction of a health and wellness program. Such programs have been implemented for offshore workers with good results[45]. They could also be addressed by including exemptions for older more experienced crew who are more likely to experience helmet-induced neck pain.

The risk of more senior pilots leaving the C-NL Offshore Area could be mitigated with a thorough education program, to assist people to make balanced choices regarding whether to remain working in the area in the event that helmet wear became mandatory. The HAT felt that any education program should present the facts; positive and negative, related to helmet wear.

To determine whether there is a link between long term helmet wear and spinal health, a program could be established to identify whether neck injuries can result from, or be exacerbated by helmet wear in helicopters. This effort could include an epidemiological study of pilots who do and do not wear helmets. If a link is made, plans for suitable compensation or alternate work programs for aircrew could be implemented.

These discussions are carried farther in Section 4, Mitigation Strategies.

3.5 Summary

The HAT determined that the risks associated with not wearing helmets range from very low to moderate significance.

The HAT determined that the risks associated with wearing helmets range from very low to moderate significance. Those rated to be of moderate significance are based on the assumption that helmet wear can potentially lead to neck injuries. This assumption requires substantiation.

[44] The reason the likelihood of this risk is unknown is that it is unknown: whether helmets will cause neck injury; how many pilots might suffer neck injury.
[45] At least one Operator claims a reduction in lost time incidents since the introduction of the program.

4.1 Introduction

Before recommending mitigation for the hazards and risks identified in the HA, or recommending an approach to address Recommendation 15, several items must be considered. Section 4.2 addresses concerns associated with helmet wear, and the possible implications if helmet wear were to be made mandatory. Section 4.3 discusses possible future changes to the system that could influence the results of this assessment. Section 4.4 outlines the HAT's decision process when developing its recommendation regarding OHSI Recommendation 15.

4.2 Perceived Unintended Consequences of Wearing Helmets

The HAT identified several potential unintended consequences that could arise should the C-NLOPB mandate that pilots wear helmets.

Some pilots are concerned with the potential for helmets to become mandatory. Most pilots find helmets uncomfortable[46]. Some feel that because Transport Canada (TC) has chosen not to regulate helmet use that it should remain an individual choice based on preference[47]. Others, particularly older pilots or those with existing medical conditions, are concerned that they may suffer pain from wearing helmets and be forced to stop flying in the C-NL Offshore Industry.

Several people have suggested that, while they agree that helmets can reduce the severity of injuries received during significant incidents, such as unsuccessful ditchings, the likelihood of these accidents is so low that helmets do not need to be worn[48]. Other pilots have argued that because all personnel working in the C-NL Offshore Area are trained in helicopter ditching escape and survival, that it is not of consequence whether pilots remain conscious following a ditching or accident.

Due to these concerns, it is possible that if helmets are made mandatory, experienced pilots may choose to leave the C-NL Offshore[49], and it may become difficult to entice experienced pilots from other jurisdictions to work in the C-NL Offshore. Others may choose to obtain physicians' notes exempting them from wearing helmets.

4.3 Future Changes

To ensure that the recommendations arising from the HA remain relevant for the foreseeable future, it is important to consider potential future changes to the helicopter transportation system.

[46] This discomfort can be mitigated somewhat with proper-fitting helmets.

[47] TC does actively encourage the use of helmets, and there is some evidence in TC publications that indicates that the organization would prefer to make helmets mandatory, although no evidence was found that this desire is based on a risk assessment. Some of the reasons given for not making helmets mandatory include the fact that the mandate given to the organization by the federal government is to streamline regulations, and the fact that current regulatory development requires extensive consultation before such a regulation could be implemented.

[48] Due to the fact that the majority of LO flights take place in a level-cruise, some pilots liken flying a modern, large twin-engine helicopter in the C-NL Offshore Area to flying a Dash-8, and hence helmets should not be required. This argument suggests a lack of understanding of the risks involved with flying helicopters offshore. The two systems are sufficiently different to make comparison very difficult. Even if a comparison is attempted, the numbers suggest that pilots are exposed to greater risk flying an S-92A offshore than flying a Dash-8. Although S-92A accidents are rare, the hazards faced by S-92A pilots are significantly different than those faced by commercial airline pilots. Looking only at accident numbers, since its introduction in 1984, the world's 1098 Dash 8 (and Dash-8 derived) aircraft have been involved in five major accidents, four of which resulted in fatalities. Since its introduction in 2004, the world's 129 Sikorsky S-92As have been involved in two major accidents, with one, Flight 491, resulting in fatalities.

[49] See section 3.4.5.

There is the potential that NVGs will be introduced in the future for SAR operations (and possibly, although less likely, for line operations). NVGs would have a significant impact on current SOPs, and would require an assessment of risk prior to their introduction. Due to the fact that data related to musculoskeletal injuries arising from NVG use exists, this risk assessment should include the identification of hazards, risks, and mitigations to address musculoskeletal injuries resulting from NVG use.

Currently, helicopters are designed with helmet use in mind. Many helicopter models suitable for use in the C-NL Offshore Industry, like the S-92A and Cormorant, are derived from military aircraft or as a minimum have military equivalents, where helmet use has always been mandatory. This is likely to remain the case for the foreseeable future. As such, the hazards associated with helmet wear in other helicopter models are likely to be similar to those identified in this assessment. However, any change in helicopter should be accompanied by an assessment of risk to ensure that any additional hazards are identified and, as necessary, mitigated.

4.4 Addressing OHSI Recommendation Number 15

The ultimate role of the HAT, after having assessed the hazards and risks associated with both wearing and not wearing helmets, was to make a recommendation to assist the C-NLOPB to address OHSI Recommendation 15.

The HAT determined that the ultimate objective when selecting the best option should be:

> *To select the best regulatory approach regarding helmet utilization by pilots in the C-NL Offshore Area.*

This objective was chosen because the HAT wanted to minimize bias during its decision process, and reduce any influence from the Commissioner’s recommendation, the C-NLOPB’s activities related to helmets, etc.

Due to the unique operating environment in which SAR operations take place (low level, VFR, over challenging terrain and with long loiter times), the HAT felt that helmets should be mandatory for all aircrew on SAR missions. It is standard practice for Cougar’s SAR aircrew to wear helmets.

One of the reasons given to support mandatory helmet wear has been to benefit passengers in the event of an accident. The HAT concluded through its assessment that pilots wearing helmets will not significantly benefit passenger safety. As discussed in Section 1.5, the HAT felt that pilots will benefit most from helmets during an unsuccessful ditching in which the fuselage fails. In this type of accident, the helmet protects the pilot, but the pilot will no longer be expected to influence the outcome of the event (due to the system failures that are likely to occur in the event of a fuselage failure).

In their analysis, the HAT examined the BST programs, which teach survival as an individual responsibility. The current training, for a number of reasons, does not teach individual survival as being contingent on the leadership of one crewmember over another. Successful survival from an underwater escape scenario, in practice, depends upon an individual’s ability to react to the situation in seconds with no reliance on others for direction. Therefore, in these cases, whether a pilot is wearing helmet or not has minimal bearing on the survivability of the passengers.

The Team explored several options in an effort to address the concerns outlined in Section 4.2. Many of these concerns could be partially addressed through an education program similar to that discussed in Section 3.3.5. Pilots should be given all available information related to the hazards of working in the area, including those related to helmets, so that they can make balanced decisions.

Further, should the Board mandate helmet wear, the requirement could be written to provide a grandfather clause for existing pilots, or to allow pilots to obtain exemptions for pre-specified reasons.

Finally, a date could be chosen for a time (for example, 1-3 years in the future) after which helmets would be made mandatory. This would afford pilots wishing to find alternative employment ample time to do so, and would increase the likelihood that some older pilots who do not feel comfortable with helmet wear would choose to retire before the requirement came into effect.

The Team also considered the possibility that additional, new helicopter operators could eventually operate in the C-NL Offshore Area. These operators could work in the Area on either short-term contracts or on a long term basis. The Team felt that a complex regulation which mandates helmets but allows for exemptions could be more difficult to apply to new operators wishing to work in the area, particularly those planning to work for only a short period.

Recognizing that there were both pros and cons associated with each available options, the Team chose what they believe is the best possible recommendation, and then identified additional mitigation to address the risks associated with the C-NLOPB pursuing that option.

The Team's recommended option, and mitigation strategy, is discussed in Section 5.

5. CONCLUSION & RECOMMENDATIONS

5.1 Recommendations Related to Helmet Use

The HAT recommends that Helmets be made compulsory for all aircrew operating First Response helicopters. To ensure effective helmet functionality in the event of an accident, and to minimize the negative Human Factors effects associated with helmet wear, conditional to this recommendation is that a Helmet maintenance program be established for all aircrew who must wear helmets, as well as for aircrew who elect to wear helmets for LO flights in the C-NL Offshore Area. As a minimum, this program must include routine maintenance and proper fitting.

The HAT recommends that helmet use remain non-mandatory for LO flights in the C-NL Offshore Area, and that aircrew be educated on both the pros and cons of helmet use.

The HAT makes this recommendation based on the fact that helmet wear by pilots does not significantly benefit passenger safety. The HAT determined that the instances in which a helmet will provide additional protection to pilots – an uncontrolled ditch or unsuccessful landing – are also situations in which a pilot will not be expected to influence the outcome, due to the expected failure of the airframe and flight controls.

In their assessment the HAT examined the BST programs, which teach survival as an individual responsibility. Appropriately, the current training does not teach individual survival as being contingent on the leadership of one crewmember over another. Successful survival from an underwater escape scenario, in practice, depends on an individual's ability to react to the situation in seconds with no reliance on others for direction.

5.2 Additional Recommendations Arising from the Risk Assessment

One recommendation stemming from Cougar's Helmet Risk Assessment and the Wells commission was that helmets should be White or Yellow. The HAT challenged this recommendation, due to the fact that white helmets can be difficult to see in a frothy sea. The HAT felt that Yellow or Dayglo-orange (also known as Blaze Orange or Safety Orange) would be the most appropriate helmet colours to aid visibility and assist any SAR effort.

It is recommended that Cougar update its guidance to aircrew so that in future, helmets are purchased in either yellow or Dayglo orange.

APPENDIX A: HAZARD ASSESSMENT TEAM MEMBERS

TEAM LEADS

Panel Lead	Remi Joly, Human Factors Specialist
Deputy Panel Lead	Tom Moir, SMS Aviation Safety Inc.

TEAM MEMBERS

Ryan Brown	Safety Officer, Canada-Newfoundland and Labrador Offshore Petroleum Board
Ronnie Moores	SAR Pilot, Cougar Helicopters
Evan Sturge	Pilot, Cougar Helicopters[50]
John Whelan	Radio Operator, Hibernia Management and Development Company Ltd.
Jeremy Whittle	Emergency Preparedness, Husky Energy

OBSERVERS

Matthew Hawco	OHSI Implementation Coordinator, Canada-Newfoundland and Labrador Offshore Petroleum Board
Peter McKeage	Aviation Advisor, Canada-Newfoundland and Labrador Offshore Petroleum Board

[50] Participated in the second panel meeting from September 7-9 only.

APPENDIX B: LIST OF REFERENCES

Cougar Helicopters, *Aircrew Helmet Risk Assessment*, February 28, 2011.

APPENDIX C: RISK ASSESSMENT TABLES - PILOT WEARING HELMET

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 1: Helmet Design reduces peripheral vision</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• Two-man crew (LO) / five man crew (SAR)
• Turning head more
• Standard Operating Procedures (SOPs)
• Air Traffic Control (ATC)
• TCAS (Terrain Collision Avoidance System)
• Enhanced Ground Proximity Warning System (EGPWS)
• Forward Looking Infrared (FLIR)
• Radar Altimeter (RADALT)
• HLO (Helicopter Landing Officer)
• Marshallers</td><td colspan="3">Lack of awareness of the hazard amongst Pilots</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Low</td><td colspan="2">Low (Moderate during critical phases of flight)</td><td colspan="2">Immediate (if helmet wear made mandatory, less urgency for existing users who have already adapted)</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Collision due to runway incursion
R2: Personnel struck on tarmac
R3: Pilot does not detect obstacles in critical phases of flight, leading to aircraft/helideck collision
R4: Personal injury due to walking in confined space on installation</td><td colspan="3">R1: A.V.
R2: B.V.
R3: A.V.
R4: D.IV.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">Awareness program (e.g., PowerPoint for pilots)</td><td colspan="3">Appropriate / Effectiveness will be limited (information may need to be included in recurrent training to be sustainable)</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">Put PowerPoint in mandatory online training
Include in Crew Resource Management (CRM) training
It is common in high traffic environments to have pedestrian awareness training, stressing, for example eye contact between people before walking in front of hazardous equipment.</td></tr>
</table>

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 2: Noise attenuation of helmets reduces ability to detect/hear external sounds</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• Situational awareness (other senses)
• Crew experience/airmanship
• PA system
• Communication protocol for passengers (pre-flight videos)
• Pilot visual checks of passengers
• SOPs for pilot communication</td><td colspan="3">Ground crew’s lack of awareness
… Inability to have a <u>two-way</u> conversation with passengers in flight, without removing helmet</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Low</td><td colspan="2">Low</td><td colspan="2">Near Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Missing critical communication between crew in an emergency situation when helmet is off
R2: Helmet is removed and becomes drop hazard
R3: Helmet is removed and jams cyclic
R4: Aircrew struck by ground vehicle (higher exposure in winter)</td><td colspan="3">R1: E.V.
R2: D.IV.
R3: D.IV.
R4: C.IV.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">1. Add to ground crew awareness training
2. Appropriate two-way communication device for passengers (e.g., David Clarke headset)</td><td colspan="3">1. Yes
2. Yes; very effective (mid-term?)</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">1. Mitigation is relatively straightforward and easy to implement.
2. May take a while. Would increase level of comfort among passengers.</td></tr>
</table>

<table>
<tr><th colspan="4">Hazard</th></tr>
<tr><td colspan="4">HZ 3: Helmet thickness (visors included) reduces clearance between head and overhead consoles</td></tr>
<tr><th colspan="2">Existing Defences</th><th colspan="2">Defence Deficiency</th></tr>
<tr><td colspan="2">Cockpit design, once seated (5-point harness, adjustable seat, etc. give adequate clearance in flight)
Checklists
SOPs
Robust overhead switches
General awareness of hazard</td><td colspan="2">New helmet users will experience a period of adjustment</td></tr>
<tr><th>Importance</th><th colspan="2">Exposure</th><th>Urgency</th></tr>
<tr><td>Low</td><td colspan="2">Low</td><td>Long-Term</td></tr>
<tr><th colspan="2">Risks</th><th colspan="2">Likelihood / Severity</th></tr>
<tr><td colspan="2">R1: Inadvertent APU start-up when an engineer is near the APU exhaust, (potential for minor burn)</td><td colspan="2">R1: E.V.</td></tr>
<tr><th colspan="2">Potential Mitigation Strategies</th><th colspan="2">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="2">Known hazard, evaluated and deemed to be ALARP without further mitigation.</td><td colspan="2">Existing mitigation is expected to be effective.</td></tr>
<tr><th colspan="4">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="4">Monitor using existing processes (hazard and event reporting program)</td></tr>
</table>

Hazard

HZ 4: Additional thermal insulation of the helmet could impact pilot’s ability to concentrate/process information.

<table>
<tr><th>Existing Defences</th><th>Defence Deficiency</th></tr>
<tr><td>

- Air conditioning (A/C)
- Vent (ambient/internal)
- Two man crew (catching correcting each other)
- Checklists
- SOPs

</td><td>

- One helicopter has no A/C
- To date, A/C has been relatively unreliable in the S-92A, and in the event of aircraft A/C unserviceability, aircraft can still be flown under rules of minimum equipment list
- Vent doesn’t work when A/C N/S (breakers removed to prevent electrical fire)

</td></tr>
</table>

<table>
<tr><th>Importance</th><th>Exposure</th><th>Urgency</th></tr>
<tr><td>Low</td><td>Moderate for the year
High in the summer

35% (up to 45 flights) of flights per month from June – Sep.

Note: this will change once SCH gets air conditioning. Will drop to 10 – 15% for broken A/C.</td><td>Short Term</td></tr>
</table>

<table>
<tr><th>Risks</th><th>Likelihood / Severity</th></tr>
<tr><td>R1: Heat stress causing degradation in performance (reduction of situational awareness); inattention, information processing.

R2: Failure to detect a developing situation (mechanical, instrument, system configuration error, navigational error, fuel starving, etc.) on return trip facing into the sun at the end of a shift, leading to loss the aircraft.</td><td>R1: E.IV.

R2: A.IV.</td></tr>
</table>

<table>
<tr><th>Potential Mitigation Strategies</th><th>Appropriateness / Effectiveness</th></tr>
<tr><td>

- Retrofit A/C in SCH
- Improvement to A/C serviceability (spares parts, improved PM, etc.).
- Explore personal cooling life support systems (e.g., DRDC) for body or head (helmets, underwear, etc.).

</td><td>This mitigation would be effective. Existing air conditioning is not reliable (frequent compressor failures summer 2011).</td></tr>
</table>

Recommendations Regarding Mitigation

Measure difference in temperature in SCH with and without air conditioning.

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 5: Weight of helmet may possibly cause musculoskeletal damage.</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">Helmet design/weight (e.g., not using NVGs currently)
Limited exposure (4-500 hours per year maximum)
Remove helmet as soon as possible
Aviation medical
Daily RAM
CARs (responsible to be fit for work)
Cougar ops manual (chapter 4)
Two person crew</td><td colspan="3">No substantial data to confirm that helmets without NVGs contribute to musculoskeletal damage
Aviation medical doesn’t examine neck in detail (self-reported)
Pilots may not self-report pain or injuries.</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">High</td><td colspan="2">Very High</td><td colspan="2">Near Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Career implications of wearing a helmet
R2: Impact ability to concentrate or perform neck rotation
R3: Some senior pilots leave C-NL offshore, resulting in a reduction of experience in the local operating environment</td><td colspan="3">R1: C. Unknown Likelihood.
R2: E.V.
R3: C.III.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">Possible exemptions for experienced crew
Health/wellness programme(s)
Education on benefits and risks associated with helmet use</td><td colspan="3">Exemptions may not be a sustainable solution.
It may be difficult to apply these forms of mitigation to short-term operators or pilots</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">Get volunteers for periodic monitoring of neck condition (professional epidemiological study)</td></tr>
</table>

APPENDIX D: RISK ASSESSMENT TABLES - PILOT NOT WEARING HELMET

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 1: Bird enters cockpit through windshield.</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• Windshield (and its bird strike capability. E.g., S-92 certified for 1kg bird)
• Pilot Reports (PIREPS)
• Air Traffic Information System (ATIS) reports
• Wildlife control at airport
• Two pilot crew
• Daytime-only flight</td><td colspan="3">• There are birds heavier than weight windshield is certified for; No throttle quadrant guards
• Complacency (many ATIS reports)
• Landfills near airport attract birds
• Non-struck pilot can be startled</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Very High</td><td colspan="2">Low</td><td colspan="2">Near Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Loss of vision (temporary blindness/eye damage)
R2: Loss in ability to think (head injury)
R3: Dual engine failure (throttle quadrant struck by bird)
R4: A forced ditching due to pilot incapacitation</td><td colspan="3">R1: I.C.
R2: III.C.
R3: (Out of scope)
R4: IV.B.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">Wearing helmet</td><td colspan="3">Effective only with visor down</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">Proper helmet protocol should be developed (including visors down). This would necessitate the development of helmet maintenance protocol, since the reason visors are currently not always worn is that they are normally scratched or otherwise reduce a pilot’s vision.</td></tr>
</table>

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 2: Severe turbulence</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• Weather forecasting
• Significant Meteorological Information reports (SIGMETS)
• PIREPS
• Weather radar
• Pilots’ use of 5-point harness
• SOPs (turbulent penetration speeds)
• Local knowledge</td><td colspan="3">• Weather forecasting is only ~80% accurate
• Five point harness won’t necessarily lock in turbulence
• Pilot knowledge is pilot dependent</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Low</td><td colspan="2">Low</td><td colspan="2">Long Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Head injury/incapacitation</td><td colspan="3">R1: V.E.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">Risks considered by HAT to be ALARP.</td><td colspan="3">Existing mitigation is expected to be effective.</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">No further mitigation necessary.</td></tr>
</table>

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 3: Vision impairment due to sunlight</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• Sunglasses
• Tinted windscreen</td><td colspan="3">• Sunglasses could be forgotten, broken or dropped</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Low</td><td colspan="2">Low</td><td colspan="2">Long Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Collision with another aircraft.
R2: Collision with flying bird.</td><td colspan="3">R1: V.A.
R2: V.C.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">Risks considered by HAT to be ALARP with existing mitigation in place. Additional mitigation could include:
1. Portable solar screen
2. Ball-cap</td><td colspan="3">Existing mitigation is expected to effective.</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">No additional mitigation necessary.</td></tr>
</table>

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 4: Head injury resulting from aircraft rollover during take-off or landing.</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• 5-Point harness
• Aircraft design (crashworthiness)
• Pilot simulator training</td><td colspan="3">• Does not protect from debris created during the rollover</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">Low</td><td colspan="2">Low</td><td colspan="2">Long Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Fuselage compromised by debris from the main rotor blade, leading to pilot injury.</td><td colspan="3">R1: B.IV.</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">The HAT considered the risks to be at ALARP with existing mitigation. Additional mitigation could include wearing a helmet.</td><td colspan="3">Existing mitigation felt to be effective. Helmet could possibly provide increased protection from head injury (from flying debris, crushing fuselage)</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">No additional mitigation necessary.</td></tr>
</table>

<table>
<tr><th colspan="6">Hazard</th></tr>
<tr><td colspan="6">HZ 5: Head injury as a result of an unsuccessful ditching
(Damage to aircraft; Fuselage does not remain intact)</td></tr>
<tr><th colspan="3">Existing Defences</th><th colspan="3">Defence Deficiency</th></tr>
<tr><td colspan="3">• 5-point harness
• Aircraft design (and crashworthiness)
• BST (crash position for PNF)
• Pilot simulator training
• SOPs</td><td colspan="3">• Impact force may exceed the design limits of the aircraft
• Simulator training based on calculations, not actual experience</td></tr>
<tr><th colspan="2">Importance</th><th colspan="2">Exposure</th><th colspan="2">Urgency</th></tr>
<tr><td colspan="2">High</td><td colspan="2">Very High</td><td colspan="2">Near Term</td></tr>
<tr><th colspan="3">Risks</th><th colspan="3">Likelihood / Severity</th></tr>
<tr><td colspan="3">R1: Death (directly due to head injury or from drowning) as a result of fuselage failure.

R2: Serious injury, compromising survivability, as a result of head injury.

R3: Loss in ability to think due to head injury caused by fuselage failure/collapse.</td><td colspan="3">R1: A.I.
R2: B.I.
R3: D.I.

Note: The severity and likelihood numbers data above reflect the situation given a helicopter has been involved in an unsuccessful ditching event. The actual likelihood of a helicopter being involved in an unsuccessful ditching is very low (Likelihood: IV)</td></tr>
<tr><th colspan="3">Potential Mitigation Strategies</th><th colspan="3">Appropriateness / Effectiveness</th></tr>
<tr><td colspan="3">• Helmet
• Improved crashworthiness (e.g., airbags)
• Enhanced simulated ditching training (fidelity)</td><td colspan="3">• Yes / Yes
• Yes* / Yes
• Yes** / Yes</td></tr>
<tr><th colspan="6">Recommendations Regarding Mitigation</th></tr>
<tr><td colspan="6">* Long-term. This option cannot help in the short term, with current aircraft.
** Mid-term

If night flight is resumed, there is a greater chance that if a helicopter is forced to ditch, the ditch will be unsuccessful given the current system.</td></tr>
</table>

Hazard	
HZ 6: Head injury as a result of an unsuccessful landing. (*Damage to aircraft; Fuselage does not remain intact)*	
Existing Defences	**Defence Deficiency**
• 5-point harness • Aircraft design (and crashworthiness) • BST (crash position for PNF) • Pilot simulator training • SOPs • Accurate weather forecasting • Landing lights	• Impact force may exceed the design limits of the aircraft • Simulator training based on calculations, not actual experience • Weather forecasting only accurate at approved landing sites • Helipad lighting only available at approved landing sites

Importance	Exposure	Urgency
High	Very High	Near Term

Risks	Likelihood / Severity
R1: Death (directly due to head injury or from drowning) as a result of fuselage failure. R2: Serious injury, compromising survivability, as a result of head injury. R3: Loss in ability to think due to head injury caused by fuselage failure/collapse.	R1: A.I. R2: B.I. R3: D.I. *Note: The severity and likelihood numbers data above reflect the situation given a helicopter has been involved in an unsuccessful landing. The actual likelihood of a helicopter being involved in an unsuccessful landing is extremely low (Likelihood: V)*
Potential Mitigation Strategies	**Appropriateness / Effectiveness**
• Helmet • Improved crashworthiness (e.g., airbags) • Enhanced simulated ditching training (fidelity)	• Yes / Yes • Yes* / Yes • Yes** / Yes

Recommendations Regarding Mitigation
* Long-term. This option cannot help in the short term, with current aircraft. ** Mid-term