CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FILE NUMBER:	1010-149914 (DFS 2-3)
DATE OF REPORT:	22 January 2008
AIRCRAFT TYPE:	CH149 Cormorant
DATE/TIME:	0330Z/0030L 13 Jul 06
LOCATION:	Over Chedabucto Bay, 2nm north of Canso, NS N45 22.0 / W061 00.4
CATEGORY:	"A" Category Accident

SYNOPSIS

TUSKER 914 was a CH149 Cormorant Search and Rescue helicopter with seven crew members that was authorized to conduct a night training mission from 14 Wing Greenwood, Nova Scotia. The helicopter and crew transited from Greenwood to Port Hawkesbury, where the helicopter landed to complete a required tail-rotor inspection. After this brief stop TUSKER 914 resumed its mission and contacted the fishing vessel *Four Sisters No.1* in preparation for a practice night boat hoist. As the helicopter was approaching the vessel the Aircraft Captain, seated in the jump seat, became concerned with the helicopter's decreasing altitude and directed the flying pilot, who was in the right seat, to go-around. During the attempted go-around the helicopter contacted the water at 69 knots calibrated air speed while in a nose-low attitude. Upon water impact the forward fuselage area was destroyed and the rear cabin area immediately filled with water. The three pilots in the cockpit and the Search and Rescue Technician (SAR Tech) Team Leader in the cabin were injured but survived the crash. The two Flight Engineers and the SAR Tech Team Member died. The surviving crewmembers were immediately rescued by the personnel of the *Four Sisters No.1* and taken to Canso for medical care.

TABLE OF CONTENTS

Annexes

1 FACTUAL INFORMATION

General

Aircraft CH149914 was a 413 Transport and Rescue (TR) Squadron Cormorant helicopter based at 14 Wing Greenwood, NS. The crew of TUSKER 914 had assumed SAR standby duties and was authorized to conduct a training mission to practice night boat hoists from the fishing vessel *Four Sisters No.1,* which is also a member of the Coast Guard Auxiliary. The cockpit crew consisted of a Level II Search and Rescue First Officer (FO) in the left pilot seat, a Level III SAR FO, acting as Aircraft Captain (AAC) in the right pilot seat and the actual Aircraft Captain (AC) seated in the cockpit jump seat. The AC was also a Cormorant Check Pilot. The remainder of the crew comprised a Flight Engineer (FE), a Flight Engineer under training (FEUT), a SAR Tech Team Leader (SAR Tech TL) and a SAR Tech Team Member (SAR Tech TM).

1.1 History of the Flight

The crew met at 2300Z (2000L) on 12 Jul 06 in the 413 (TR) Squadron Operations room to brief the training mission. The helicopter was loaded with 3,300 kilograms of fuel for the flight and no refuelling stop was planned. The plan was to fly under Visual Flight Rules to the airport at Port Hawkesbury NS (CYPD), where they would land and shut down the helicopter to perform a tail rotor inspection, which was required every three helicopter running hours. This planned tail rotor inspection would allow the crew to complete the remaining scheduled night boat hoist training in the Canso, NS area and then return to Greenwood before another three hour inspection was due.

The flight was on the Squadron’s flight program and as the AC was a designated Flight Authorization Officer, he was able to self-authorize the mission. The crew departed Greenwood at 0020Z (2120L 12 Jul 06) for an uneventful 1.7 hour flight to Port Hawkesbury. While on the ground in Port Hawkesbury the crew contacted the Captain of the *Four Sisters No.1* by phone to confirm that the weather in the area was suitable for the planned training scenario. The Captain of the Four Sisters No.1 stated that the weather was clear with good visibility and calm seas. The crew was then briefed by the AAC that they would continue to the Canso area to perform the night training mission and that once on site they would confirm the suitability of the weather.

At 0230Z 13 July (2330L 12 July) TUSKER 914 departed Port Hawkesbury for the position of the *Four Sisters No.1*, which was located in Chedabucto Bay at approximately N45 21.7 W060 59.9, about 2 nautical miles (nm) north of Canso, NS. Once airborne, the crew of TUSKER 914 contacted the *Four Sisters No.1* on the FM radio and “homed” (Direction Find) on the radio signal of *the Four Sisters No.1* to determine the ship’s precise location.

During the transit to the vessel's location the crew carried out the Coastal Check, which includes ensuring the flotation system is armed, matching the barometric and radio altimeters, engaging the applicable autopilot modes (Indicated Airspeed hold, Radio or Barometric altitude holds), and reviewing the ditching drill. The Over Water Transition Down (OWTD) brief was then carried out to prepare for the transition from 500 feet above water level (AWL) to a hover one-quarter mile behind the vessel. Following this brief the crew was ready to approach the vessel using the OWTD procedure. All cockpit crew members and the two flight engineers were equipped with helmet mounted Night Vision Goggles (NVGs).

The helicopter overflew the boat to establish its position, but the AAC was unable to correctly enter the fix in the helicopter's navigation system so they overflew the boat a second time and then turned 180 degrees to begin the OWTD procedure. The FO in the left seat was the Flying Pilot (FP) as the AAC engaged the "Transition down 1" (TD 1) mode of the autopilot to begin the descent to 200 ft above water level (AWL). The FO was making small heading corrections according to verbal directions given by the AAC. At approximately one to one and one-half miles back from the vessel the AAC engaged the TD2 mode of the autopilot, which brought the helicopter, via the automatic flight control system, into an automatic hover at its predefined altitude of 100 feet AWL.

As the helicopter came into a hover at 100 ft AWL, about one-quarter to one-half mile back from the boat, the AAC determined he had good visual references with the boat, raised his NVGs ("de-goggled"), took control of the helicopter and assumed FP duties. The FO relinquished control, kept his NVGs in the lowered position and began to divide his attention between monitoring of the Hover Page of his navigation display and looking outside the cockpit. The AAC proceeded to fly visually without the NVGs towards the "rest" position, a position next to a vessel that provides adequate hover references for the FP and a clear path for the final move into the hoist position. At that time the *Four Sisters No.1* was steering 330 degrees true at five knots and the helicopter was stable at 100 feet AWL and slowly approaching the boat from behind on a heading of approximately 300 degrees magnetic. The Hover Mode of the autopilot was engaged.

As the helicopter neared the boat the FE advised the AAC he had the boat visually at the helicopter's two o'clock position, to which the AAC responded "visual". The AAC then directed the FO to place his search light beam on the highest point of the boat. After some difficulty locating the appropriate switch in the dark on the unlit collective, the FO manoeuvred the search light beam onto the boat. As the light tracked he noticed wisps of rotor spray or mist outside. Coincidently, the helicopter began a slow climb, peaking at 170 feet AWL. The AAC then noticed the altitude deviation and initiated a gentle descent back towards 100 feet AWL. Meanwhile, the FE advised the crew over the intercom that the SAR Check was complete, "tails" (restraint harnesses) were on everybody and that he was standing by for clearance to open the rescue (cargo) door. The AAC responded “clear” but then quickly said “standby. “ As the helicopter descended through 110 feet the descent rate increased to approximately 500 fpm. About this time the FO advised the AAC that he had lost visual references on the left side. The call was not acknowledged by the AAC. Seconds later the helicopter’s “low-height” audio warning annunciated, followed immediately by the AC, seated in the jump seat, verbalizing the radio altitudes over the intercom as the helicopter descended through 80 feet. The FO then checked his radio altitude display and noted the altitude was about 70 feet but he was not alarmed and felt the situation was under control. The FO then began to attempt to locate or “landmark” the inboard hoist button on the centre console in anticipation of the upcoming hoist. As the helicopter continued to descend the AC twice verbally directed the AAC to go-around. The AAC acknowledged the go-around command and the transition-up mode of the autopilot was engaged by either or both of the pilots. The helicopter briefly levelled off at 60 to 70 feet AWL in a near level pitch attitude. The helicopter then began to pitch nose-down and move forward until, five seconds prior to impact, the helicopter had reached a 17 degree nose-down attitude. The helicopter then began to descend at an increasing rate and the nose down pitch attitude continued to increase, reaching a maximum of 24 degrees nose down before coming back up to 18 degrees nose down, at which point the torque values began to increase beyond 100%. The AC was in the process of calling out the high torque values over the intercom when the helicopter struck the water in an 18 degree nose-down attitude at 69 knots calibrated airspeed with a descent rate of approximately 800 fpm.

1.2 Injuries to Personnel

Injuries	Crew	Passengers	Others	Total
Fatal	3	0	0	3
Serious	3	0	0	3
Minor	1	0	0	1
Total	7	0	0	7

Table 1: Injuries to Personnel

1.3 Damage to Aircraft

The helicopter was damaged beyond economical repair during the crash. The forward area, including the entire cockpit area, broke away from the rest of the helicopter at the lower forward modular joint X4859 and the upper forward modular joint X4200 (just forward of the right hand cargo door). The airframe separated fairly cleanly. A number of the lift beams in the area of the break showed significant cracking and the one nearest the cargo door was completely fractured.

The Cormorant’s crashworthy fuel system has three main and two transfer tanks. Upon impact the forward two fuel bladders ruptured, releasing large quantities of fuel. The remaining fuel tank frangible switches opened on impact, shutting off fuel delivery to the engine.

Aft of the main fuselage break, the main cargo door (also known as the rescue door) had separated from the helicopter and the right aft spotter's window was shattered. The SAR Tech's storage cabinet, located just forward of the cargo door, was displaced and broken up. The remaining interior cabin area and contents exhibited little impact damage but some of the stowed equipment shifted position.

All five main rotor blades broke at the thin section of their respective tension links and had separated near the blade root just outboard of the rotor head. The fractures at the roots of the main rotor blades were very consistent in location and appearance, indicating a common failure mechanism. Further outboard on each blade there had been a failure of the "D" spar, which showed a very splintered appearance where the carbon fibre structure of the spar had broken. The blades also showed additional breakage farther out near the blade tip. There was evidence of a single main rotor blade strike to the aft left portion of the upper fuselage.

The tail rotor was severely damaged, including some post-crash damage incurred during recovery and transport of the helicopter from the accident site to the Shearwater hangar. Two of the four blades were broken near the blade root but not completely severed. A third blade was broken and severed near the root. The two half hubs were each relatively intact at one end but had been severely bent in the flexure area at the other end. There were no apparent fractures in the "window" areas. The tail rotor hardware, including pitch change links, crosshead, scissors assemblies, trunnions, "H" brackets and elastomeric bearings were relatively undamaged. The two half hubs were analyzed using the Through Thickness Ultra-Sound (C-Scan) Method which confirmed that the "window" areas were intact.

The flight control actuators were found undamaged and in a relatively neutral position, between the extreme extended or retracted end of the range of travel. The pitch links were not bent or broken. The swash plate was in a neutral, flat position and did not show any indications of damage or failure.

1.4 Collateral Damage

The helicopter crashed two nautical miles from the nearest shore. Fuel was released as the helicopter broke up and contaminated the area around the crash site. A responding Canadian Coast Guard ship recovered some of this fuel. Helicopter debris, mostly from the forward fuselage area, settled to the bottom of the ocean. This has been mapped and surveyed but not recovered. In the days following the accident, 14 Wing Recovery and Salvage personnel recovered additional debris washed up on the shores surrounding the crash area. No claim against the Crown is anticipated.

1.5 Personnel Information

	AC	AAC	FO	FE	FEUT	SARTech TL	SARTech TM
Aircrew Category	Valid	Not Valid[1]	Valid	Valid	Valid	Valid	Valid
Currency requirements	Current	Not Current[1]	RUET expired[2]	Current	Current	Current	Current
Total flying time (hrs)	3,400.6	4,721.9	2,194.7	1,588.5	232.7	6,389.3	457
Hours on type	732.1	309.8	89.5	1,032.5	232.7	Not Applicable	Not Applicable
Hours last 90 days	38.4	10.5	60.0	69.8	84.5	Not Applicable	Not Applicable
Hours last 30 days	19.2	10.5	13.3	7.8	23.7	Not Applicable	Not Applicable
Night Hours - Total	234.5	263.3	321.2	205.5	8.2	Not Applicable	Not Applicable
Night hours – last 90 days	8.9	0.0	3.8	5.9	4.0	Not Applicable	Not Applicable
Night hours - last 30 days	2.0	0.0	1.8	0.0	4.0	Not Applicable	Not Applicable
Duty time (hrs) – Day of Accident	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Table 2: Personnel Information

Notes:

1. Aircrew currency standards are designed to ensure that operational personnel maintain standards by mandating the performance of certain evolutions, sequences, or flying rates within a specific period. CH149 pilots shall fly a minimum of 30 hours within the previous running three month period. Failure to achieve this objective denotes a loss of currency and shall result in the individual being downgraded to a Restricted Category (Under Training) status until the successful completion of a suitable supervised training event. The Squadron Commanding Officer shall inform the Transport/Rescue Standards and Evaluation Team (TRSET), by message, of a failure to achieve 30 flying hours in the previous three months. A copy of this message shall be placed on the member's Aircrew File. Upon successful completion of the appropriate training event the member shall regain an Operational category. The AAC was not current for this flight according to 1 Cdn Air Div Orders 5-503 Para 15 in that he only flew 11.1 hours in the previous three months, vice the 30 that is required. This loss of currency would also invalidate his aircrew category, as described above, until the suitable supervised training event was satisfactorily completed.

2. The FO was not current with respect to Rotary-Wing Underwater Egress Training/Emergency Breathing System (RUET/EBS) training. However, 1 Canadian Air Division Order 5-306, Paragraph 2a stipulates that a member has up to one year to complete the training after finishing the Cormorant Conversion Course.

1.5.1 **The Aircraft Captain**

The AC was an experienced multi-tour SAR helicopter pilot. He joined 413 (TR) Squadron in June 2003 and upgraded to SAR Aircraft Captain in August 2004. This was his first CH149 tour. He had flown 732.1 hours on the CH149 and was a designated CH149 check pilot. His night boat hoist currency had expired 14 April 2006 and a request was submitted for a 30 day extension. The email granting the extension incorrectly used a 30 April 2006 expiry date instead of the 14 May 2006 that was intended. After some discussion between the Wing Headquarters and the Squadron they decided not to amend the extension E-mail but to proceed as if the extension had been granted to 14 May 2006. Because of a lack of training opportunities he was unable to complete the sequence during this time and on 14 May 2006 his Aircraft Captain category was therefore, in accordance with the Orders, downgraded to Under Training. He successfully completed a suitable training flight with a night boat hoist on 6 June 2006 and his SAR AC category was re-instated by the Squadron's Commanding Officer.

1.5.2 **The Acting Aircraft Captain**

The AAC was an experienced multi-tour SAR helicopter pilot with his previous SAR experience being flown in the CH113/A Labrador Helicopter. This was his first CH149 tour. He joined the Squadron after completing the Cormorant Conversion Course in March 2005 and was assigned to duties as the Standards Flight Commander. He upgraded to FO Level III/Utility Aircraft Captain in December 2005 and was in the process of working towards an AC upgrade. He was not progressing with the upgrade as quickly as the Squadron had anticipated. In April 2006 he took an extended period of leave to attend to personal matters. His last flight prior to departing on leave, flown on 12 April 2006, was a supervised night training flight, rated as acceptable, which included a night (land) hoist but not an OWTD procedure. On his return from leave in July 2006, the AAC was scheduled for a 90-Day check but he advised one of the CH149 Check pilots that he only required a 30-Day Check to regain his flying currency. A 30-Day Check normally comprises a take-off, landing and an instrument approach, all flown to an acceptable standard. However, in accordance with the Division Order 5-503, a 30-Day Check was insufficient to reset his currency and his aircrew category because he had flown less than 30 hours in the previous three months (see note 1 above). An appropriate training event, which would have included other training manoeuvres and practice emergencies, was actually required. The Check Pilot did not confirm whether anything more was required and a 30-Day Check was flown satisfactorily on 5 July 2006. The AAC then resumed regular SAR flying duties as an FO III/UAC. His last OWTD was flown on 10 April 2006 and his last night boat hoist was done on 30 January 2006.

1.5.3 **The First Officer**

The FO was an experienced helicopter pilot but new to the CH149 and the primary SAR role. All of his previous operational experience had been on the CH135 Twin Huey/CH146 Griffon in the Tactical Aviation role. He had accumulated over 200 hours of NVG flying time. The FO completed the CH149 conversion course in March 2006 but had not completed the night boat hoist training Performance Objective (PO) because of training limitations imposed by 1 Canadian Air Division in a letter dated 9 June 2005 (he had completed the Day Boat Hoisting PO). This letter stated that, to maintain the desired throughput of pilots, 1 Canadian Air Division had delegated the completion of the night boat hoist PO (and the Fly in Mountainous Terrain PO) to the operational squadrons to complete. Once these items were completed by a squadron, a CH149 FO category could be awarded but squadron COs could, at their discretion, employ the pilots immediately. The 1 Canadian Air Division Order 5-401 CH149 Safe Training Practices was informally amended by an email from TRSET to restrict multi-tour FO IIs to executing a night boat hoist with training or standards pilots only until a consistent “Level 3” was achieved.

Following the CH149 conversion course the FO joined 413 (TR) Squadron and completed the "Unit Check Out". He was immediately (7 April 2006) awarded an FO Level II category (bypassing Level I because of his previous helicopter experience) and assigned to operational SAR duties. His first day boat hoist training sequence as a Squadron pilot was completed on a supervised training flight on 30 May 2006. He completed his first ever night boat hoist as a CH149 pilot on a 20 June 2006 night supervised training mission. The manoeuvre was first demonstrated by the training pilot and the FO was awarded a satisfactory Level 3 grade on his attempt. On this same training mission the FO flew a satisfactory night OWTD using the autopilot modes.

1.6 Aircraft Information

1.6.1 General

The CH149 Cormorant is the Canadian Forces’ variant of the AgustaWestland EH101 all-weather, day and night operational, multi-role, medium-lift helicopter [Photo 1]. The helicopter airframe makes extensive use of composite materials.

Aircraft CH149914 was serviceable when released for its flight from Greenwood on 12 Jul 06 at 2345Z. The helicopter was airworthy and all maintenance had been conducted in accordance with the Approved Maintenance Program (AMP). At 0215Z 13 Jul 06 the helicopter was re-released serviceable for flight after the Flight Engineer carried out the required three hour “Zone 4 Tail Rotor inspection” in accordance with the AMP. At the time of the accident CH149914 had accumulated 1,139.3 rotor hours.

In order to understand the operation of the aircraft prior to the accident it is important to know how the flight controls and automatic flight control systems function and interact.

1.6.2 Flight Controls

The helicopter's conventional hydraulically powered flying controls are interfaced to the Automatic Flight Control System (AFCS) by an actuation system consisting of dual series actuators and single parallel actuator in each of the four control axes, i.e., collective, pitch, roll, and yaw.

The four electrically operated parallel actuators are connected in parallel with each of the control axes. They are normally controlled by the autopilot and are considered to be slow acting with large control authority. They operate in response to inputs from the AFCS to implement long-term control changes for both trim and autopilot functions. Each parallel actuator contains a coiled spring that provides the pilot with artificial feel in the cyclic pitch and roll axes when flying "hands on". The collective lever position is maintained by the spring when not being moved by the pilot.

The series actuators consist of a DC electric motor driving a linear rod. Two of these actuators are connected in series to produce a double acting control rod in each control run. The series actuators normally respond to signals received from the AFCS to carry out, in the short term, fast movements of the flying controls in order to trim and maintain stabilization of the helicopter's altitude and attitude. They react quickly but have little control authority. The pitch series actuators will become saturated (reach maximum travel) at a pitch rate of approximately –2.5 degrees per second. If the series actuators become saturated they essentially become a solid link in the control system and while in this state the rate-dampening function is lost. As a result, relatively small control inputs can result in relatively large control movements through the parallel actuators. The parallel actuators then slowly adjust to re-centre the rate dampening capability.

1.6.3 Automatic Flight Control System

The Cormorant is equipped with a modern and very capable AFCS. The system incorporates an autostabilization system, an autopilot and autotrim functions through duplicated pitch, roll, yaw and collective channels. Control of the helicopter is done through the flying controls linkages, augmented by the autostabilization system. It is capable of altitude, airspeed and heading hold modes, and automatic transitions to and from the hover. It provides stability augmentation and attitude hold in the pitch, roll and yaw axes by detecting helicopter motion via sensors and applying corrective control inputs through the helicopter actuation system to the flying controls. The system incorporates two identical flight control computers and a Pilot's Control Unit (PCU). It interacts with the flying controls through the series and parallel actuators. Each flight control computer controls a series actuator in each axis and the parallel actuator in two axes, and provides a reversionary control for the parallel actuators in the other two axes should their associated flight control computer actuator drive signal fail. The pilot's control of the flight control computers is primarily through the PCU and the cyclic and collective handgrips. The autostabilization function is transparent to pilot control inputs i.e., it does not oppose pilot control commands when manually manoeuvring the helicopter. Pilot inputs are detected by force-sensing switches in the cyclic control and pedals, which open and allow the pilot to easily override the autostabilization system.

Flight control datum parameters and mode status are passed to the Electronic Instrument System (EIS) for display on the Primary Flight Display (PFD), the Navigation Display and the Secondary Power Systems Display and the Primary Power Systems Display. The PCU shows the engagement status of the AFCS together with series actuator positions. When an AFCS mode is engaged a green mode annunciator is displayed on both pilot's primary flying displays.

All the AFCS modes are engaged from the PCU by pressing the required mode pushbutton. The Go Around (GA) or Transition Up (TUP) modes may also be selected from the GA switch located on each pilot’s collective lever.

1.6.4 Autostabilization (ASE) Modes

1.6.4.1 Attitude Hold Mode

Helicopters are inherently unstable aerodynamically and a deviation in a given direction will tend to continue unless a positive correction is applied. Autostabilization systems are employed to mitigate the instability and make the helicopter easier to fly. ASE functions are provided in the pitch, roll and yaw axes whenever the autostabilization is engaged, whereas AFCS control of the collective axis is only applied when a collective autopilot mode is engaged. The autostabilization is engaged/disengaged via the PCU and provides an attitude hold function to stabilize helicopter attitude when flying hands-off and to provide acceptable handling characteristics when manoeuvring hands-on. With no pilot control commands, the helicopter pitch, roll and yaw attitudes are controlled to the datum values set at the time of engagement.

1.6.4.2 Cyclic Manoeuvre Mode

If the cyclic stick is moved against the spring feel in either pitch or roll a corresponding force-sensing switch opens. Rate stabilization is applied in the manoeuvre axis to provide smooth handling, but the autostabilization does not oppose the pilot commands through the cyclic stick. Allowing the stick to return to zero spring force returns the helicopter to its original attitude (the attitude that existed when the force-sense links were opened) in pitch and roll.

1.6.4.3 Cyclic Manual Beep Trim Mode

Manual force applied to the cyclic (the force sense link is open) while the cyclic stick pitch TRlM switch is engaged initiates the “manual beep trim mode”. This allows large pitch trim changes to be made rapidly by manoeuvring the helicopter against the spring feel and then using the beep trim switch to remove the stick forces. When stick force is reduced to zero the TRIM switch can be released leaving the cyclic stick in its new position. Operation of the roll TRlM switch is identical to the pitch operation. The manual beep trim mode causes the parallel actuator to be driven directly resulting in faster trim rates to quickly reduce the applied stick force.

1.6.4.4 Cyclic System Beep Trim Mode

This mode enables small precise adjustments of cyclic attitude while flying 'hands-off'. With the cyclic force sense links closed (no manual force on the stick) operation of the TRlM switch results in adjustment of the pitch and roll attitude at a fixed rate. Cyclic stick datum changes slowly under autotrim action to adjust the helicopter trim attitude accordingly.

1.6.4.5 Cyclic Trim Synchronization

Pressing the cyclic stick TRlM REL button disengages the pitch and roll spring feel clutches, allowing free movement of the cyclic stick to enable new pitch and roll datums to be rapidly established. On releasing the button, the clutches are re-engaged thus re-initializing the stick position datum. The new pitch and roll attitude datums are taken as those existing when the TRlM REL button is released. The trim release button on the cyclic should be depressed during all large cyclic movements. If the trim release button is not used the series actuators can become saturated and the autostabilization capability is degraded or lost.

1.6.4.6 Collective Autostabilization

There are no independent collective autostabilization functions. When a collective autopilot mode is engaged the AFCS provides collective actuator control, including a Low Height Safety Feature. This monitors helicopter radio altitude height and rate of descent. If the rate of descent at a given height exceeds a preset profile, the collective actuation is driven to increase torque and arrest the rate of descent, ultimately bringing the helicopter to a height hold of 20 feet or 10 feet, depending on the initiation height. This feature primarily guards against erroneous autopilot collective demands at low height in conjunction with auto hover and transition modes.

1.6.4.7 Collective Beep Trim

With a collective autopilot mode engaged, the collective lever trim switch can be used to adjust the collective datum.

1.6.4.8 Collective Trim Release/Synchronization

Actuation of the TRIM REL switch on the collective allows the pilot to rapidly establish a new datum helicopter height. Height hold and spring feel re-engages at the new datum when the button is released. With a collective autopilot mode engaged, operation of the collective lever TRIM REL button allows new collective lever positions to be rapidly established by the pilot. Except in emergency conditions, the collective lever should not be moved without operating this button.

1.6.4.9 Autotrim

The autotrim function operates continuously as part of the autostabilization system. It seeks to maintain the nominal central position of the series actuators by backing off any trend through a corresponding adjustment to the parallel actuator position. This ensures maximum available authority for the series actuators in the event of a large transient requirement that may otherwise cause saturation, and limits failure effects should a series actuator run away occur.

1.6.5 Autopilot Modes

1.6.5.1 General

The AFCS includes several autopilot functions for helicopter flight path control, utilizing the stabilized flight characteristics provided by the autostabilization system. Autopilot modes are primarily engaged/disengaged via the PCU with engagement status being indicated by captions on the PCU and annunciators on the primary flight displays. Only the modes pertinent to accident flight scenario will be discussed below.

With the exception of the collective modes, the autopilot modes cannot be used without prior autostabilization engagement in the corresponding axes. Selection of a collective autopilot mode automatically engages collective autostabilization. When engaged, the autopilot modes, including Barometric Altitude Hold (BAR), Radio Altitude Hold (RAD), Indicated Airspeed Hold (IAS), TD1, TD2, Hover (HOV) and Transition Up (TUP), may be controlled by either pilot. Their datums may be adjusted by using the cyclic beep switch (for IAS and HOV) and the collective beep switch (for BAR, RAD Hold modes).

1.6.5.2 Barometric Altitude Hold

The Barometric Altitude Hold mode is engaged via the BAR button on the PCU. It operates through the collective axis to provide barometric altitude hold throughout the airspeed range and maintains helicopter height during forward flight and during turning manoeuvres. The datum height is the barometric altitude existing at the time of engagement but may be adjusted using the collective beep trim or collective trim release.

1.6.5.3 Radio Altitude Hold

The Radio Altitude Hold is engaged via the RAD button on the PCU. It operates through the collective axis to provide radio altitude control over a height range of 20 ft to 5000 ft, and over the full airspeed range and while manoeuvring at attitudes of up to 25 degrees of roll and 30 degrees of pitch up or down. The altitude datum is the altitude existing at the time of engagement. The datum may be adjusted using the collective beep trim or collective trim release.

1.6.5.4 Transition Modes

Transition modes are pilot selectable on the PCU and are primarily concerned with the control of transitions in height and speed and transitions to controlled hovering flight. The hover height control is used to set the desired hover height either prior to or during a transition down. The radio altitude control and airspeed control are used to set the exit height and airspeed for the transition up mode.

The Transition Down mode operates through the pitch, roll and collective axes and provides an automatic descent and forward deceleration to a controlled hover at a pilot-selected hover height. The transition down is accomplished in two stages. Stage 1 (TD1) causes the helicopter to descend, at a constant airspeed (IAS mode engages), to a “gate height” of 200 feet AWL. When entry gate conditions are reached the HOLD caption is illuminated and the TD1 caption on the Primary Flight Display (PFD) is replaced by a GATE caption. A second press of the TDN button initiates the final transition down. When selected, this stage 2 (TD2) causes the helicopter to descend and decelerate to zero groundspeed at a pilot selectable hover height. On completion of the transition down, the hover mode automatically engages at the datum height preset by the pilots on the PCU and HOV is displayed on the PFD. Operation of the cyclic TRIM switch can be used to adjust longitudinal and lateral speed data values and the yaw pedals provide directional control.

The Transition Up mode controls acceleration and ascent from an automatically controlled hover into forward flight. The mode operates through the pitch, roll and collective axes to achieve a pilot pre-selected exit indicated airspeed (IAS) and radio altitude. When the exit conditions are achieved the Radio Altitude and IAS modes engage automatically. The Transition Up mode is activated either by pressing the “T Up” button on the PCU or by pressing the “GA” (go-around) button on the collective handgrip. In either case the green 'ascent' symbol, in the T UP button, is illuminated to confirm engagement. The helicopter’s speed and rate of climb will vary depending on the desired final target altitude and speed, but the helicopter will not descend during the T UP manoeuvre.

1.6.5.5 Hover Mode

This mode is engaged automatically following an automatic Transition Down and may be engaged between 10 feet and 200 feet AGL. Groundspeed must be less than 20 knots when the mode is selected.

1.6.5.6 Go-Around Mode

Depressing the collective GA button with APPR MODE engaged will result in the helicopter conducting an AFCS flown overshoot in which the autopilot will carry out a 500 ft/min climb at 75 KIAS until the mode is disengaged. If the GA button on the collective is activated when APPR MODE is not engaged (as was the case in this occurrence where the AFCS was in HOV MODE) the AFCS will begin a transition up or "TU", as described previously in paragraph 1.6.5.4.

1.6.5.7 AFCS Failure protection

Autostabilization functions can survive a first failure. This means that there is minimal disturbance of the helicopter, with no significant effects on handling and stability characteristics. No corrective pilot intervention is required and the system returns the helicopter to the original trim condition. After the first autostabilization failure the pilot is required to fly passive hands on.

Autopilot functions have fail-soft (capable of continued operation with reduced capability) characteristics, which provide minimum disturbance. EIS cautions and system failure alleviation features provide a minimum of 6 seconds intervention time. For most autopilot first failures, the system reconfigures to enable continued operation, at the pilot's discretion, with a corresponding requirement for an increase in attentiveness.

1.6.6 Radio Altimeter System

The radio altimeter system consists of two identical radio altimeter transceiver assemblies, which provide a height measurement above the ground or water in a 0 through 5000 feet range. It operates in all-weather, all-terrain and all flight conditions. The antennae are located on the underside of the helicopter, between the main landing gear assemblies.

The radio altimeter output is routed to the EIS for height display and low-height warning management. Barometric altitude is the default main display and shows in the upper right corner of the PFD as an electronically presented analog gauge, while radio altitude displays digitally inside a rectangle in the lower right corner of the PFD. The pilot can switch the two displays. There is a pilot selectable low height bug, which sets the limit for the low height warning in five foot increments below 200 feet and 10 ft increments above 200 feet. If the helicopter descends below the bug height the helicopter will generate a repeating “Check Height” voice warning over the intercom.

1.7 Meteorological Information

The accident occurred over the ocean at 0330Z. The nearest Environment Canada reporting station was at Hart’s Island (CWRN), which is located 2nm to the southeast of the accident location.

METAR data for Hart Island (45’21N 60’59W):
(*The following data is from Thursday July 13 2006)*

UNOFF CWRN 130300Z AUTO 31005KT 16/16 RMK ALTM MISG SLP185 50004=
UNOFF CWRN 130340Z AUTO 31003KT 16/16 RMK ALTM MISG SLP186 58001=
UNOFF CWRN 130400Z AUTO 32003KT 15/15 RMK ALTM MISG SLP186 55002=

Additionally, the Captain of the *Four Sisters No.1* reported that prior to the accident there were clear skies, good visibility and calm seas with local fog patches. Within minutes of the accident a thick fog rolled into the accident area and remained there during the ensuing rescue of the survivors. At the time of the accident the moon was nearly full (95 percent illuminated) and located at 141 degrees (True) azimuth and 15 degrees elevation above the horizon. This would placed the moon low in the sky at the helicopter’s approximate six o’clock position at the time of the accident.

Water temperature in the area at the time of the accident was approximately 10 degrees Celsius.

1.8 Aids to Navigation

The crew were navigating from Port Hawkesbury to the *Four Sisters No.1* using a combination of visual techniques and onboard aids including the Global Positioning System, Direction Finding steers and the weather radar. Fixed ground based navigation aids were not applicable in this accident.

1.9 Communications

VHF FM radios were used to communicate between TUSKER 914 and the *Four Sisters No.1.* There were no distress calls made by the helicopter prior to the accident. Immediately following the accident the personnel of the *Four Sisters No.1* contacted the Joint Rescue Coordination Centre via FM radio and made a “*Mayday*” call at approximately 0030L hrs on 13 July 06.

All crewmembers were connected to the helicopter’s intercom system.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

The helicopter was equipped with a DRS Technologies (Manufacturer) Emergency Avionics System 3000 Flight Data Recorder and a Cockpit Voice Recorder System (FDR/CVR). Included in this system is the Beacon Airfoil Unit (BAU) – 35, located on the right aft exterior of the fuselage. The BAU was recovered post-accident still attached to the BAU helicopter mount on the helicopter. The BAU exterior skin had been punctured which allowed some seawater to permeate the interior of the unit. The internal memory cards were flushed with fresh water and dried. The information from the Flight Data and Cockpit Voice Recorders was successfully recovered and processed by the National Research Council Flight Recorder Playback Centre. Analysis of the data confirmed that all parameters had been recorded properly.

The helicopter is also equipped with a maintenance recording system operated through the helicopter's main computers, both of which were recovered. Unfortunately, the computers did not retain any helicopter information, as the batteries do not operate after being submerged. Additionally, the transfer of maintenance data requires a manual step of transferring data to the Data Transfer Cartridge, which was not recovered.

1.12 Wreckage and Impact Information

Based on FDR data, the helicopter impacted the water at 69 knots Calibrated Air Speed with a descent rate of 800 fpm in an 18 degree nose-low attitude with very little roll or yaw angles. The helicopter struck the waters of Chedabucto Bay at the coordinates of N45 22.0 / W061 00.4, approximately 2nm north of Canso, NS, (Annex E). Upon impact, the forward portion of the helicopter, including the entire cockpit area, was destroyed, creating an opening the full width of the cabin, just aft of the forward spotters' windows, through which seawater quickly engulfed the cabin [Photos 2 and 3]. The cargo door, located on the right side of the cabin and was closed at impact, ripped off of its mountings, causing it to dismount from the sliding rails and depart the helicopter.

The forward port and right flotation bags inflated on impact and were immediately torn from the helicopter structure and deflated. Both main (aft) flotation bags remained stowed in the main landing gear sponsons. The system can be deployed automatically via the activation of any two of the four water immersion actuators on the underside of the aircraft. In this case the rear bags will inflate first and then, following a three second delay, the front bags will inflate. All the bags will deploy at once if the manual override switch on either of the cyclic controls is activated. This involves first raising a switch guard and then depressing the override button on the same cyclic. The pilots did not knowingly activate this switch. The flotation system exhibited an out-of–sequence inflation. It is possible that the manual system was activated inadvertently during the impact forces and break-up of the cockpit area, but power was cut to the rear bags before they could deploy and before the water immersion switches could trigger.

The main airframe body, less the forward structure, quickly came to rest inverted and almost completely submerged [Photo 4]. Various pieces of the separated nose section and the main rotors were recovered, as much of this structure was made of composites and was light enough to float and wash ashore. The heavier components from the cockpit area, including the seats, main instrument panel, center console and flight controls were not recovered and were presumed to have sunk to the bottom of the ocean.

The Canadian Coast Guard Ship *Sir Wilfred Grenfell* was tasked to search for any debris that may have settled to the bottom of the ocean. Using Side-Scan Sonar and a Remotely Operated Vehicle the *Grenfell* was able to locate an 80-meter long oval shaped debris field. The debris is on a muddy bottom at depth of 105 meters. Video of the debris was taken. The debris comprises small pieces of yellow and green metal along with other unrecognizable parts.

Helicopter fluid sampling did not reveal any pre-existing contamination.

1.13 Medical

All aircrew medical categories were valid at the time of occurrence.

The force of the helicopter's impact with the water and the crash dynamics were such that none of the crewmembers were fatally injured on impact. The four crewmembers who ultimately survived received injuries ranging from serious to minor. The AAC suffered from amnesia and has been unable to recall details of the accident from the moment of the handover of controls to when he surfaced in water after the impact. The bodies of the FE, the FEUT and the SAR Tech TM were recovered from inside the helicopter's inverted and submerged cabin area. Autopsies, performed by the Nova Scotia Chief Medical Examiner, determined that drowning was the cause of death for the three deceased crewmembers.

Blood and urine samples were taken from the four survivors and sent by the 14 Wing Greenwood Wing Surgeon to the Armed Forces Institute of Pathology (AFIP) in Washington DC for toxicological analysis. Blood, urine and selected tissue samples were taken from the deceased crewmembers during the autopsies and sent by the investigating flight surgeon to AFIP in Washington DC for toxicological analysis.

Forensic examination and toxicology analysis did not indicate any physiological conditions or the presence of foreign substances capable of causing intoxication or performance impairment of any crewmember.

1.14 Fire, Explosives Devices, and Munitions

1.14.1 Fire

There was no pre-crash or post-crash fire.

1.14.2 Explosive Devices

At the time of the impact the helicopter was carrying four C2A1 smoke markers, two diver recall munitions, five day/night Flares and 20 mini flares, as detailed in the helicopter's Search Stores Record. Additionally, the helicopter had 20 30-06 shells, one 30-06 rifle and one Emergency Flare Kit. All of these were turned over to the CFB Halifax Military Police Detachment. There was no detonation of munitions during the crash sequence.

1.15 Survival Aspects

On impact the front end of the helicopter was destroyed and the remainder of the helicopter quickly rolled inverted and ended up floating inverted, approximately 85-90% submerged, with the tail in a slightly elevated position. Other than the opening created by the destruction of the front portion of the helicopter, the only other openings into the cabin, immediately following the impact, were the shattered right aft spotter's window and the opening created by the loss of the cargo door. All other cabin area windows remained in place after impact.

1.15.1 Cabin Emergency Exits

The CH149 design incorporates 11 emergency exits in the cabin area. There are four "Type IV"[1] primary emergency exits, two on each side of the fuselage cabin. On the right side of the cabin, one is located at the forward end of the cabin and one to the rear of the cabin cargo door, adjacent to the Flight Engineer's seat. The remaining two Type IV exits are installed on the left side of the cabin, one at the forward end of the cabin and one at the rear of the cabin, just forward of the Flight Engineer storage cabinet. These exits are provided with a recessed release handle to enable the window to be jettisoned from either inside or outside the helicopter. The two forward primary exits were in line with the area where the cabin became severed from the front end in the impact. There are six secondary emergency exits installed in the cabin, two on the right side and four on the left side. They are jettisoned (inboard or outboard) using pull-tabs available both internally and externally. There is one "Type III" emergency exit provided within the cabin cargo door. It is designed to be jettisoned either from inside or outside the helicopter using recessed release handles.

By the very nature of its demanding role the CH149 is required to routinely carry a great deal of equipment [Photos 5 and 6]. The Aircraft Flight Manual identifies

[1] Exit type designations are defined in the Federal Aviation Regulations, Part 29.

that in the Standard SAR Configuration all secondary exits on the left side of the cabin are blocked or unavailable and the forward secondary exit on the right side is blocked (see Annex B). The impediments to the secondary escape routes included hard mounted items such as the passenger seats, stretcher holders and the Flight Engineer and SAR Tech storage cabinets. All primary exits are normally available, however, the four fold down passenger seats in position aft of the stretcher are a significant obstacle should either the left hand secondary escape windows or left rear primary escape window be required. The seat backs, when left in the normally installed position, partially block the windows [Photo 7]. When lowered, these same seatbacks cover floor space required for placement of the stokes litter or rescue basket. The rear secondary exit on the right side of the cabin is partially blocked by the ladder, which is stored lengthwise on the cabin floor below the exit [Photo 8 and 9]. The rescue basket is also stored on the floor in front of this exit, beside the ladder. Despite the above noted impediments, in the Standard SAR Configuration, the CH149 exceeds the Joint Aviation Requirements (Europe) and Federal Aviation Requirements 29 (US) approved requirement for emergency exits in the cabin area of the helicopter.

All cabin emergency exits, including the cargo door exit, are provided with a Helicopter Emergency Exit Lighting System (HEELS). The system consists of a total of 25 electro-luminescent units (ELUs) mounted to provide illumination around emergency exit windows. Automatic illumination of the ELUs is achieved by the use of an inertial switch or an input from flotation system submersion actuators. Of note, the emergency exit in the cargo door is also illuminated by ELUs; however, the fuselage area around the cargo door itself is not marked by any ELUs.

1.15.2 Life Support Equipment

1.15.2.1 Flight Clothing

The pilots and the flight engineers were wearing standard issue flying suits, approved flying boots and gloves, except the FO, whose gloves were off at the time of the accident. Neither the pilots nor the flight engineers were wearing immersion suits. 1 Canadian Air Division Orders, Vol 2, 2-007 allows the requirement for immersion suits to be waived by the Aircraft Captain when a ship or another aircraft is capable of rescue within 15 minutes and is in constant visual and radio contact. The exercise with the *Four Sisters No. 1* met this requirement.

In anticipation of the planned hoisting training, both SAR Techs were wearing “Mustang MS185 Classic Suit” floatation coveralls, “Danner” boots, kneepads and suitable gloves. The “Mustang” floatation coveralls have inherent positive buoyancy.

1.15.2.2 Helmets

All crewmembers were wearing the issue SPH-5CF lightweight, dual visor helmet and the three cockpit crewmembers and two flight engineers had NVGs mounted on their helmets. The AAC's helmet came off at some time during the impact sequence or immediately thereafter and was recovered about a month after the accident. The FEUT and SAR Tech TM's helmets were relatively undamaged. The AC, AAC, FO, FE and SAR Tech TL helmets received varying degrees of damage but remained intact.

1.15.2.3 Strobe Lights

All of the crewmembers were supplied with either Firefly 2 or ACR MS-2000(M) strobe lights. The AC activated his strobe light while waiting for rescue. All were functional and none of the strobe lights leaked in any manner.

1.15.2.4 Life Preserver Safety Vests (LP/SV)

The pilots and flight engineers were wearing the Transport/Helicopter Life Preserver Safety Vest (LP/SV). This integrated life preserver and survival vest comprises an aircrew life preserver fully integrated with a survival vest. The life preserver provides emergency flotation via a two-lobed bladder and is designed to prevent flotation in a facedown attitude. The bladder is in a protective container and is designed to minimize interference with the crewmember's helmet. It has the shape of an inverted "U" and has slide fasteners running on the outside of the "U". These slide fasteners separate to allow the flotation bladder to expand.

All the LP/SVs except the AAC's were either inflated by a crewmember immediately after the accident or were activated during the course of their recovery. The LP/SV worn by the AC and the FO only partially inflated (the left side lobe did not inflate) when activated; however, both surfaced and remained afloat despite the reduced buoyancy. The FEUT's LP/SV bladder did not fully inflate when it was activated during the recovery because the bladder cover zipper remained intact for approximately six inches at the centre of the collar.

The "Bear Claw" knife sheath affixed to the FE's LP/SV was not an authorized modification for the LP/SVs worn in the CH149. MOD C-22-521-000/CF-013 authorized the "Bear Claw" modification for LP/SVs worn in the CH146 fleet.

The SAR Techs were wearing issue Life Preserver Yokes, SAR (commonly known as Aqualung Flotation Life Vests). The CO2 cylinders on the vests were not discharged.

1.15.2.5 Emergency Breathing Systems (EBS)

The emergency breathing system (EBS) used by the helicopter's crew is a compact, lightweight breathing assembly intended for emergency use by helicopter aircrew in the event of a ditching or crash landing in water. The EBS provides air on demand for a duration of one to three minutes, depending on water temperature, pressure (depth), and the user's breathing characteristics. It comprises an air cylinder and first stage regulator assembly (stored in a purpose-made pocket on the LP/SV), which is attached to a rubber hose that in turn connects to a second stage regulator and rubber mouthpiece assembly. The mouthpiece is stored in a small pocket on the front of the LP/SV.

There were EBS assemblies on board for all crewmembers. The pilot's and flight engineer's EBS's are carried on their LP/SV. The AAC and FO's EBS remained attached to their LP/SV but were unused and full. The AC had tried to use his EBS but could not locate it. The AC's EBS assembly was found separated from his LP/SV. His EBS cylinder was recovered still full. The hook and pile fastener on the bottom of the cylinder pocket was almost perfectly closed together but the strap was not looped around the LP/SV waist strap, as it should have been. The AAC has no recollection concerning the use of his EBS. The FO did not attempt to use his EBS. He had never been formally trained on EBS because it was not available for CH135 aircrew when he last attended RUET (circa 1995) and therefore its use was not an ingrained part of his egress drills.

The FE's EBS cylinder was found with his LP/SV but out of its storage pocket. It was empty. The FEUT's EBS assembly was found unattached to his LP/SV and empty. EBS assemblies are not compatible with the SAR Tech floatation vests so theirs were stored at their respective crew seats. Of the two EBS assemblies assigned for use by the SAR Techs [Photo 10], one was found in the wreckage with the cylinder empty and the glass on the pressure gauge cracked. The other EBS assembly was not recovered.

Finally, it must be noted that the crew's LP/SVs and EBS assemblies were subjected to a degree of handling through the course of the rescue, recovery and subsequent medical activity before they were finally received by the investigators as part of a larger collection of assorted aircrew life support equipment. This may account for the dislodgement of some components from the LP/SVs before the investigators received them. Witnesses involved in the recovery of the deceased were unable to recall specifically whether the FE's EBS was attached to his LP/SV when they found him.

1.15.2.6 Harnesses and restraint systems

The AC was seated in the jump seat wearing a four-point harness (seatbelt). The AAC and FO were sitting in their respective pilot seats wearing five-point harnesses. The two pilot seats incorporate a quick release buckle for normal harness release and an emergency harness release tee-handle which releases the harness seat attachment pins allowing the complete harness to be pulled away. The jump seat has a harness quick release buckle but no emergency tee-handle.

The crewman's safety restraint harness is designed to provide maximum safety to the wearer while working near an open door, hatch, or ramp of an aircraft in flight (e.g. during hoisting). The harness is constructed of standard parachute harness nylon webbing and metal fittings with additional attachment points for various tethers. A D–ring is fastened to the rear waist strap for attachment of a static line anchor strap ("monkey tail") to allow movement around the cabin. The length of the anchor strap is adjustable. The harness does not incorporate a quick-release capability. The anchor strap attachment on the back of the harness can be set up for either a right or left hand release [Photo 11]. The release cannot be activated if the strap is under tension. The other end of the anchor strap is attached to one of four hard points located in the ceiling of the cabin area.

All four crew in the back of the helicopter were attached to overhead hard points by the anchor straps connected to the back of their respective restraint harnesses.

1.15.3 Crew Egress

The impact forces created when the helicopter struck the water were assessed as survivable. All the crew members were surprised by the impact with the water and had no time to prepare, brace for the impact or even take a breath of air before being completely and instantaneously submerged in cold sea water.

Immediately after the impact the AC found himself submerged, disoriented and still restrained to the jump seat by his harness. He tried at least twice to rotate and release the harness before he was able to successfully extricate himself out of the seat after surfacing. He activated his LP/SV after surfacing but the left lobe of the bladder failed to break out of the bladder cover.

The AAC found himself submerged in the water, unrestrained and out of his seat. He has no recollection of having released his seatbelt harness or how he got to the surface.

The FO also found himself submerged in the water, unrestrained and disoriented. He eventually managed to inflate his LP/SV, although the cover over the left lobe of the bladder did not open, and he rose to the surface.

At impact, the FE, FEUT, SAR Tech TL and SAR Tech TM were wearing their safety harnesses secured via anchor straps to hard points on the ceiling of the cabin. The SAR Tech TL was secured to the forward hard point, resting his buttocks against the patient stretcher. The FEUT was also secured to the forward hard point, standing in front of the SAR Tech TL just beside the SAR cabinet located between the right forward spotter’s window and the cargo door. The FE was secured to the second hard point, kneeling on one knee, leaning back against the FE seat by the cargo door. The SAR Tech TM was secured to the third hard point, standing just beside the FE’s seat aft of the cargo door.

The SAR Tech TL was unable, at first, to release the anchor strap attachment on the back portion of his safety harness. His anchor strap was hooked up to the back of his safety harness and was set up for a right hand release. His first attempt to release the attachment was done using his right hand but this attempt was unsuccessful due to an injury to his right hand sustained during the impact. The SAR Tech TL was then attracted to a window by the illumination of the HEELS lighting, and once there he was able to take two quick breaths from a small pocket of air trapped in the window. Following these two breaths, the SAR Tech TL was ultimately, after numerous attempts using his left hand and just as he was about to lose consciousness, able to release the anchor strap from the back of his safety harness. He subsequently surfaced and remained afloat. The SAR Tech TL could not recall which opening he used to exit the helicopter.

The FE was found in amongst the wreckage debris at the front of the cabin area adjacent to the missing cargo door. He was wearing his helmet and harness with a portion of the anchor strap attached. He had received some minor facial and head injuries during the impact. One-half of the FE's anchor strap was still attached to the helicopter hard point and the free end was severed. The other half of the anchor strap was attached to his harness and was removed during the extraction of his body from the wreckage and was not recovered. The “Bear Claw” knife sheath affixed to his LP/SV was empty but the knife itself was not recovered.

The FEUT was found in the vicinity of the right rear secondary exit with his helmet removed and wearing his harness. His anchor strap was disconnected from the harness.

The SAR Tech TM was found in the rear of the main cabin/ramp area with his helmet and harness removed.

As described in the Aircraft Flight Manual, a number of secondary escape exits were obstructed or partially obstructed by the equipment in the cabin. Some equipment, such as the ladder and the SAR basket had become dislodged or shifted at impact. The ladder, which normally blocks access to the lower pull tab of the right rear secondary exit, had shifted towards the ceiling when the helicopter became inverted, and was blocking approximately 50 percent of the exit. The rescue basket had also shifted and was partially blocking the route to the exit.

1.15.4 Emergency Transmitters

The Emergency Locator Transmitter (ELT) system is contained within the BAU. It is designed to provide emergency distress signal on both 121.5 MHz and 406.0 MHz frequencies from the beacon if deployed adjacent to a downed helicopter. The system will only transmit a distress signal from a deployed beacon.

The Airfoil Release Unit (ARU) is used in conjunction with a fixed latch to secure the BAU to the helicopter. When any one of the four frangible switches (mounted in various places in the airframe) is broken, crash detection sensors are activated, triggering the ARU to deploy the BAU via a pressure cartridge and spring mechanism. The system also incorporates a hydrostatic switch located internally on the underside of the helicopter. If the helicopter ditches in fresh or salt water the switch contacts close at a pressure greater than 17.4 psi (which is equivalent to an approximate depth of 50 feet) and the ARU is triggered. The ARU can also be manually activated by a switch in the cockpit. The frangible, hydrostatic and cockpit control unit switches are in parallel in a circuit which requires any one switch to 'make' in order to activate the deployment. Power is provided by an auxiliary battery pack, which uses a capacitor for energy storage and thus is independent of the helicopter's power supply. The entire deployment process takes less than 50 milliseconds. Deployment of the BAU automatically starts the ELT transmission at the time of release.

The BAU Release System did not activate during the crash sequence and the BAU remained attached to the helicopter's fuselage. As a result, the ELT distress signal was not transmitted.

1.15.5 Search and Rescue

The fishing vessel *Four Sisters No.1* rescued the four survivors within a few minutes of the crash. The crew of the *Four Sisters No.1* also transmitted a Mayday call, alerting the Joint Rescue Coordination Centre of the situation.

Two crewmembers were on, or holding onto, the inverted submerged fuselage of the helicopter, and the other two crewmembers were in the water within close proximity of the wreckage. All four survivors were extracted from the water onto the deck of the *Four Sisters No. 1* at approximately 0040L. They received basic first aid and comfort from the personnel of the ship while waiting for other vessels to arrive at the scene.

Once relieved by other vessels that were in the vicinity, the *Four Sisters No. 1* then transited towards Canso NS, situated 2 nm south of its position. The *Four Sisters No. 1* docked at Canso at approximately 0130L, where ambulances were waiting to transport all four survivors to the local hospital in Canso.

Upon receipt of the Mayday call the Joint Rescue Coordination Centre notified 14 Wing Greenwood of the downed helicopter. The SAR Standby CC130 Hercules aircraft, numerous Canadian Coast Guard ships (CCGS) and a CH124 Sea King helicopter from 12 Wing Shearwater were tasked to participate in the search and rescue for the missing crew members. A CH149 was also launched from Greenwood at 0130L. When the CH149 arrived at the scene of the crash, two SAR Techs were hoisted down from the helicopter onto the deck of CCGS *Earl Grey*, from which they made their water insertion. The two SAR Techs rapidly confirmed to the personnel of CCGS *Earl Grey* that the three missing crewmembers were deceased and located inside the submerged fuselage. The SAR Techs assisted the crew of CCGS *Earl Grey* in securing the wreckage of CH149914 to the ship's crane by tying the main landing gears to cargo straps. Once the wreckage was secured, they proceeded with the extraction of the bodies from the helicopter.

1.16 Test and Research Activities

The investigation team visited the EH-101 simulator facilities at RAF Benson in the UK to better understand the particulars of the accident sequence, the functioning of the various ASE and auto-pilot functions and to attempt to re-create the situation using data from the flight recorders.

Several simulation runs were conducted by the simulator staff using the data from the FDR to attempt to replicate as best as possible the performance of the helicopter at the time of the accident. Particular attention was paid to the performance and response of the helicopter with failed pitch series actuators and with pitch series actuators that were in a saturated state.

1.17 Organizational and Management Information

1.17.1 Airworthiness and the Risk Assessment Process

Overall airworthiness authority in the DND/CF has been delegated by the MND, through the CDS, to the Chief of the Air Staff. This authority has been further delegated, with some exceptions, to two authorities that can formally accept airworthiness risk. These are the Technical Airworthiness Authority (TAA) (the Director General of Aerospace Equipment Program Management) and the Operational Airworthiness Authority (OAA) (Commander 1 Canadian Air Division). The OAA is responsible for the regulation of flying operations, which includes operational procedures, flight standards, operator training, qualification and licensing, aerospace control operations and Operational Airworthiness Clearance of aeronautical products[2] prior to operational service. Operational Airworthiness is defined in the 1 Canadian Air Division Orders as a standard of safety for air operations and aeronautical products as they relate to flying operations (including aerospace control, aircraft utilization,

[2] Aeronautical Products are defined in the Aeronautics Act as "…any aircraft, engine, propeller or aircraft appliance or part … "

operator training and proficiency), in addition to compliance with airworthiness policies, regulations, orders and standards.

During the period that the tail rotor half-hub related flight restrictions were in place the applicable official DND/CF policy guidance available to the 1 Canadian Air Division staff for operational airworthiness decisions and risk assessments lay primarily in two documents: the Technical Airworthiness Manual (TAM) and 1 Canadian Air Division Order 1-623, Operational Airworthiness. The high level overall airworthiness policy document, A-GA-005 DND/CF Airworthiness Program, was in draft and was not officially published until November 2006.

The TAM is a comprehensive document primarily intended for TAA staff which, as its title would suggest, provides airworthiness instructions to personnel responsible for the design, manufacture, maintenance and materiel support of aeronautical products, as well as for the training and qualification of technical personnel. It incorporates a procedure to assess and manage the safety risk associated with airworthiness-related decisions and technical airworthiness functions and includes direction for the preparation and approval of the technical airworthiness content of a Record of Airworthiness Risk Management (RARM). A RARM is a document prepared in concert by both the TAA and OAA, primarily when the airworthiness of an aeronautical product is assessed.

The TAM states that in most cases where a risk assessment conclusively indicates that the accepted level of safety is maintained, there is no requirement for a formal RARM development and submission. However, the risk assessment must be documented and records produced to enable substantiation of the decision not to raise a RARM. The decision as to whether or not a RARM is required is based on sound engineering principles and judgement, and is to be made by an appropriate level of authority with the advice of the TAA staff.

1 Canadian Air Division Order 1-623, Operational Airworthiness, was the primary direction related to the conduct of operational airworthiness processes. It states the purpose of the Operational Airworthiness Program is to provide a framework or system for regulating the operational aspects of aviation activities, facilities and services to achieve and maintain aeronautical products as airworthy and to provide for the safe operation of those aeronautical products. The intent of the program is to ensure that these aeronautical products are operated within their design limits and in conformity with the applicable operational regulations, orders, directives and standards. Perceived or actual deficiencies with respect to training, equipment or procedures may cause an operational restriction to be imposed. When an operational restriction exists and continued, modified, or reduced operations are required or when normal operating limits must be exceeded, a risk analysis is required before an operational waiver is provided. The risk analysis would consider the possible consequences and probability of equipment failure as well as the effect of reduced training/aircrew qualification within the context of the priority of the mission.

Annex A to1 Canadian Air Division Order 1-623 provides instructions for the Air Division staff on the completion of a RARM. It does not mention “trigger” points for the initiation of a risk assessment but it does contain detailed instructions for the assessment of an operational risk as part of an overall risk assessment. It is largely based on the RARM completion instructions contained in the TAM.

1.17.2 Half-Hub Tail Rotor Flight Restrictions

In 2002, cracking was discovered in the half-hub assembly of the tail-rotor of EH-101 helicopters, including the Canadian Forces’ CH149 Cormorant variant. A technical solution has yet to be found. Numerous formal risk assessments were completed and documented in corresponding RARMs. Risk mitigation actions included the implementation of a rigorous inspection cycle to catch any potential cracking at an early stage. In October 2004, the Commander of the Air Division imposed an operational restriction on the CH149 fleet that limited training flights to a maximum of two hours between half-hub inspections. Additionally, in December 2004, to mitigate the exposure/risk to the aircrew, 1 Canadian Air Division expanded the operational restrictions placed on the CH149 fleet. These restrictions limited CH149 operations to essential SAR missions for the preservation of life where weather conditions offered a fair or better probability of success. Training was restricted to the minimum essential training required to ensure crew currency levels were maintained to support SAR operations. All training flights were to be conducted as close as reasonably possible to the main operating base and all quarterly currency requirements were to be completed in the minimum amount of time. Finally, all non-operational SAR flights were limited to a two-hour duration between tail rotor inspections.

Following some technical modifications, and with the benefit of the additional confidence gained through increased operating history, another formal risk assessment was completed in 2006. Based on this risk assessment the 18 month long imposition of the two hour restriction was relaxed on 29 June 2006 to allow up to three hours of flying between tail-rotor inspections for non-SAR sorties.

The two-hour flight and related training restrictions were in place during the upgrade of all three occurrence pilots and during the entire training period of the two flying pilots. All of the Squadron pilots who had experience flying the Cormorant prior to the imposition of the RARM restrictions had already been posted from, or ceased flying with, the Squadron by the time the restriction was modified to three hours.

1.17.3 Flight Safety Stress Points

Beginning in 2005, the Air Division implemented a “bottom up” process for units and wings to report “stress points” up the chain of command. It was intended as a tool to ensure the Chain of Command was aware of critical Flight Safety issues. The stress points would be submitted by individual units, vetted and collated at the Wing level and then forwarded biennially to the Air Division. A stress point was defined as a condition of elevated risk in flight safety over a sustained period of time. They would be colour coded GREEN, YELLOW or RED, depending on their assessed effect. Stress points identified as RED were those that were assessed as critical flight safety concerns or those for which the cumulative risk to flight safety operations was judged to be high. There was no formalized process at the Air Division to respond to the stress points.

In June 2005, 14 Wing began reporting a RED stress point for 413 (TR) Squadron CH149 Cormorant aircrew proficiency. In their submission, 14 Wing stated that due to the two-hour flight restrictions imposed on the CH149 fleet between half-hub inspections, proficiency of aircrew for critical tasks such as boat hoisting has deteriorated to an unacceptable level. This RED stress point was repeated in the next two successive stress point submissions to the Air Division prior to the accident.

1.17.4 413 (TR) Squadron CH149 Flight Safety Survey

In January 2006, the 14 Wing Flight Safety staff conducted a survey of 413 (TR) Squadron CH149 aircrew to assess how they viewed their overall level of proficiency and their overall confidence in the helicopter.

The responses to the survey indicated that, primarily due to the two-hour flight restriction, the aircrew were unable to do what they considered to be proper training. They stated that compulsory flying sequences were rushed and could only be practiced once with no opportunities to re-fly them in an attempt to improve crew's skill levels. As a result, the aircrew felt they were barely maintaining currency and that proficiency was dropping to unacceptable levels. Boat hoisting was identified as the greatest problem area. Some aircrew felt that proficiency had deteriorated to the point that crew proficiency was becoming a greater safety risk than the potential for tail rotor half-hub cracking. During the period of the two-hour flight restrictions there were five CH149 Flight Safety boat hoist training incidents reported, three of these involved 413 (TR) Squadron aircrew. These incidents involved minor damage to the helicopter and/or the Coast Guard vessel due to inadvertent contact between the helicopter and the vessel's whip antennas, or damage to or from the hoists/rescue baskets being lowered. No specific Flight Safety incidents were filed that involved circumstances similar to those that occurred in this accident.

The results of the CH149 aircrew survey were provided to the Commander of 14 Wing Greenwood who in turn communicated them to the Commander of 1 Canadian Air Division. In January 2006, in reaction to the survey results, the A3 SAR staff at the Air Division prepared two briefing notes for the Division Commander. The first briefing note contained two options: (1) to maintain the status quo while awaiting further technical data; or (2), consider an incremental increase in the two-hour training limitation by one hour to three hours. The A3 staff recommended the Commander consider Option 2. One week later a further briefing note was provided to the Commander. This briefing note provided three options for the Commander to reply to the 14 Wing Commander's concerns: Option 1 was to advise the affected Wing Commanders that the two-hour training limit would remain in place until sufficient (technical) data had been collected; Option 2 was to consider an incremental increase to the two-hour training limitation by one hour; and Option 3 was to have TRSET make recommendations with respect to training with Canadian Coast Guard lifeboats and then have the Commander brief CH149 operators on the way ahead. Option 3 was the recommended course of action. It was noted that the Commander would not relax the two-hour restriction until technical data became available that would support a reduced technical risk and substantiate a lifting/relaxation of the two-hour restrictions.

In April 2006 the A3 SAR staff provided a further briefing note to the Commander that outlined the quantifiable advantages that would be incurred by allowing a three-hour training limit. At the time, it was known that additional technical data was forthcoming which would support a reduced technical risk and a revisit of the RARM. This briefing note recommended that the Commander increase the current two-hour training restriction to three-hours. Based on the reduced risk indicated by new technical data, on 29 June 2006 the Commander agreed to relax most of the restrictions and allow up to three hours of flying between tail-rotor inspections for training sorties.

1.18 Additional Information

1.18.1 Crew Complement and Pilot Seating Positions

1 Canadian Air Division Order 3-101 specifies the minimum crew complement for the CH149, including the pilot minimum qualifications and where the AC must be seated. The orders state that a pilot designated as the AC shall occupy a pilot position during take-off and landing. For pilot training flights an exception is authorized for acting AC (AAC) missions and AC upgrade check rides at the discretion of the Standards or Training pilot, provided that a Level II or Level III FO is paired with the AC candidate. The Training or Standards Pilot is to evaluate the combination of FO experience and other mitigating circumstances during an AAC mission and, if deemed appropriate, they are to occupy one of the pilot positions for take-off or landing.

1.18.2 CH149 Standard Manoeuvre Manual

CH149 operators do not have published Standard Operating Procedures but do have a CH149 Standard Manoeuvre Manual (SMM), which defines the standard procedures that should normally be used by the CH149 crewmembers. It describes crew duties for specific sequences and how common manoeuvres are to be flown. The following information is extracted from the CH149 SMM.

1.18.2.1 Crew Duties

Regarding crew duties, the SMM states that unless otherwise directed by the AC, crew duties will generally be divided as per the following:

> “The Flying Pilot (FP) is responsible for accurately flying the helicopter, conducting the immediate actions required in the response to an emergency and ensuring the crew is aware of his/her intentions before performing a manoeuvre. During hover manoeuvres, the FP must fly using references outside the cockpit. The crew can don and remove NVG on the ground, in flight and in the hover as required, provided adequate visual references exist to safely control the helicopter at all times. In some instances it may be desirable or necessary to operate with mixed crew, i.e., some crewmembers on NVG and some off. Pilots must advise when donning or removing NVG.”
>
> “The Non-Flying Pilot (NFP) is responsible for switch selections on the centre and overhead consoles, radio transmissions, monitoring temperatures and pressures, assisting the FP for emergency response, and during approaches for landing monitor torque values. During NVG flight the NFP is responsible for monitoring the helicopter flight instruments and advising the FP of flight parameters such as heading, airspeed, and altitude. This is especially important during hover manoeuvres, takeoffs, landings, shore crawls, or when the FP is not in a position to crosscheck the helicopter flight instruments. The NFP should be ready to take control during critical phase of flight in the event that the FP loses visual references or in case there is an NVG failure.”

It also states that regardless of who may have control of the helicopter at a given moment, the AC is responsible for the overall conduct and the safe completion of the assigned mission, response to emergencies, and mission accomplishment.

The hoist operator (Flight Engineer) and other crewmembers required to assist in the recovery must always wear approved restraining harnesses when working in the vicinity of open door or ramp. The harnesses shall be attached and the monkey tail adjusted in such a way as to prevent no more than one-half of the person's body from projecting beyond the door opening (adjustment end secured to helicopter hard point with other end secured to D-Ring on back of restraint harness).

1.18.2.2 Use of Automation

The SMM states that in low visual cueing environments (such as during a night boat hoist) the pilot should attempt to maintain attitude by avoiding the use of the Cyclic Trim Release button. Small and precise attitude changes can be made using the Cyclic Beep Trim switch only. Alternatively, the pilot can easily move the cyclic in the manoeuvre mode then use the beep trim to relieve control forces, resulting in faster trim rates.

When engaging autopilot functions, the FP will focus on instruments and maintain attentive "hands on" the controls while the NFP will engage the required modes.

Where ambient light conditions are minimal and no horizon is discernable, autopilot modes can be employed to reduce pilot workload and assist with hover stability and the use of the autopilot should be considered and utilized wherever practical. The autopilot modes are particularly useful at night and when hover references are poor. When conditions permit, the AC may elect to only use basic ASE mode. Both RADALT warning bugs should be adjusted to provide the crew with adequate terrain avoidance warning. Following low altitude aural voice warning, an immediate climb should be initiated if loss of altitude was unintended; otherwise, the FP shall verbalize his/her intentions to the crew.

Over water, hover references may not be available. The pilot in the right seat will have better visual references during a boat hoist. While hovering over vessels, the RADALT will periodically lock onto the deck of the ship or other higher obstacles. Where the deck height is significantly higher than the water level, use of the AFCS RADALT Hold function could result in uncommanded and dangerous collective inputs. The flying pilot should make good use of the RADALT Hold / Auto Hover (or BARALT Hold depending upon conditions).

1.18.2.3 Activity Enroute to a vessel

The SMM states that at a point approximately 20 minutes back, the cabin should be configured, FE and SAR Techs should be suited up and applicable safety checks conducted. Pilots may approach the vessel by means of a visual approach or an OWTD. If weather or darkness necessitate, the crew should prepare for an OWTD procedure. Normally, the approach will terminate in a hover with the vessel at the 1 o'clock position relative to the helicopter. At night, the FE and SAR Techs should remove their NVG in preparation for the hoist sequence while pilots may elect to keep theirs on and hover using unaided cues below the NVG.

If the right seat pilot decides to de-goggle, the approach will normally terminate with the vessel at the 12 o'clock position in order to provide good hover references while de-goggling. The helicopter will then be flown to the rest position as per normal. The flying pilot should make good use of the RADALT Hold / Auto Hover (or BARALT Hold depending upon conditions). Once in the rest position the FE is given clearance to open the cargo door in preparation for the hoist. This also allows the FE gain a better visual perspective by having an unimpeded view of the area surrounding the right side of the helicopter.

1.18.2.4 The Overwater Transition Down Procedure

The transition procedure is defined in the SMM as a controlled descent to the hover to acquire visual reference and conduct the SAR sequence (Annex D). The over water transition down procedure can be used for approaches to vessels in instrument meteorological conditions, at night or anytime deemed necessary. A manual approach, a coupled approach or a Hover Point Approach can be used, as required, as long as they are briefed properly. During low visibility and marginal weather conditions, a coupled approach is recommended.

Crewmembers are assigned specific duties throughout the procedure. Generally, the pilot in the left seat will fly the approach while the pilot in the right seat will monitor the approach and direct the FP during the procedure until the NFP is in a position to take control and establish a visual hover with the target. After the control transfer the left seat pilot shall continue to monitor the instruments. The NFP shall call 50 ft above and arriving at all briefed altitudes when 100 ft AWL or higher. Below 100 ft AWL, 10 ft increments will be called.

The SMM states that the SAR Techs should be prepared for the hoist sequence before the approach and should be stationed in the most suitable bubble windows. During the final phase of the approach, they are to call visual with the water and/or the target.

A coupled approach (such as that used by the crew in this accident) is an approach where the AFCS transition down functions, TD1 and TD2, are used (see also paragraph 1.6.5.4). The FP shall be attentive “hands on” during this procedure. In the initial approach phase the crew overfly the boat at a safe altitude (normally 500 ft AWL) to fix its location. They then turn outbound at 70 KIAS on a heading 20 degrees left or right of the reciprocal of the inbound track. At a minimum of 2 nautical miles back from the target, or as briefed, the crew conducts a level turn to intercept the desired inbound track. Once established inbound, the NFP confirms clear to descend to 200 ft and readjusts the Low Height Bugs. The NFP can engage TD 1 or request the FP to commence a descent to 200 ft AWL. On final, the NFP will provide navigation inputs to align the helicopter into wind and toward the target. Prior to reaching the final approach fix (a point one mile back from the target) the crew confirms that the FP’s navigation display is selected to Hover mode and the NFP’s navigation display is set to RADAR mode and 60-degree scan. The helicopter should pass the final approach fix level at 200 feet AWL at which point it enters the final approach phase.

The NFP will advise the crew when crossing the FAF and at that point the NFP re-adjusts the Low Height Bug and engages TD 2 as required, or gives the FP a heading, altitude and airspeed to fly. The NFP continues to provide steering and airspeed information based on RADAR and navigation systems information and the FP adjusts as required. Airspeed is adjusted to reach a specified hover position and the hover position will be established and maintained based on Hover Page information and/or visual references, if available. The helicopter is normally established in a hover using either the HOVER or RAD HOLD mode with the target at 12 o’clock and well outside the downwash. From a position short of and visual with the target, using the Hover Page as primary reference, the FP uses the cyclic beep trim to initiate a four to five knot hover taxi towards the target. The con is then passed to the FE and the helicopter is conned over to the target/hoisting area. Once the optimum altitude has been selected, the pickup is normally conducted utilizing a combination of manual and autopilot modes, as applicable.

If a go-around is required, for whatever reason, the FP will adjust heading to avoid overflying the target and execute the go around procedure. The FP commences the go around using the GO AROUND / T UP mode or manually, as required; however, it is recommended that the GO AROUND / T UP mode be used.

1.18.3 NVGs and NVG Limitations.

The CH149 SMM states that proper pre-flight adjustment of the NVGs is critical for enhancing Flight Safety. The monochrome video image tends to produce a flat picture, which makes depth perception difficult. Depth perception, distance estimation and contrast are adversely affected by the use of NVGs. At low heights, the lack of depth perception makes it difficult to detect height changes, especially during flight over open water. Poorly adjusted NVGs will exacerbate the reduction in crew visual acuity.

Visual acuity is a function of technical limitations, illumination level, object or terrain contrast, and adjustment techniques. Even under optimal lighting conditions, aircrew will not obtain the best resolution possible unless NVG are properly adjusted and aligned for their optical axis. Reduced visual acuity can go undetected, even by experienced aircrew. It can be caused by a lack of precise, correct positioning and focusing of NVG. It is not physiologically possible for a person to quantify visual acuity without the aid of a known sized target placed at a fixed viewing distance. Of note, a pilot flying unaided at night will typically have a visual acuity of approximately 20/200. In Canada, a visual acuity of 20/200 in the better eye meets the legal definition of blindness.

There are several NVG adjustment methods but the most recommended is the use of the ANVS 20/20. It ensures optimum adjustment for as long as the system is properly calibrated. It is the only method that effectively provides control over the potential variations in light conditions, contrast and focusing distance. The ANVS equipment was available to the accident crew at 413 (TR) Squadron and was used by the AC and AAC to adjust their NVGs. The FO, the most experienced NVG user on the crew, used outside references to adjust his NVG, as was his custom, because the use of the ANVS 20/20 gave him headaches.

If outside objects are used to adjust the NVG it generally results in low/varying visual acuity levels. Visual acuity will vary as a function of pilot experience, object size, shape or texture, contrast and illumination and distance of focus and can vary from 20/300 to 20/40 under the same conditions.

The ability to interpret the NVG image is dependent on an individual's understanding of how different types of ground cover reflect ambient light. Water is the most difficult of all surfaces from which to judge height, speed or drift under NVG. The rotor downwash will create a wave motion, which further induces the illusion of aircraft drift. Recirculating water will cause light refraction and add to the difficulty in judging position. These water and rotor downwash effects also occur while operating unaided, but can be exacerbated by the use of NVGs because of the reduced peripheral vision.

The SMM states that the crew can don and remove NVG on the ground, in flight and in the hover as required, provided adequate visual references exist to safely control the aircraft at all times. In some instances, it may be desirable or necessary to operate with mixed crew, which is some crewmembers on NVG and some off. That is how the crew of TUSKER 914 was operating at the time of the accident.

1.18.4 Spatial Disorientation

Spatial Disorientation of aircrew can be defined as the failure to perceive, or to perceive incorrectly, the position, motion and attitude of the aircraft. There is an inherent ambiguity of our organ of balance that detects acceleration along the spinal (z) axis of the body that often leads to uncertain and erroneous perception of the direction and velocity of the vertical motion, especially when external visual cues are limited or unavailable. Aircrew can be predisposed to experience unrecognised spatial disorientation due to a number of factors such as currency, time pressure, poor scanning technique and inadequate visual cues.

1.19 Useful or Effective Investigation Techniques

Not applicable.

2 ANALYSIS

2.1 General

The investigation to determine why the helicopter flew into the water required a detailed examination of “the man, the machine and the environment.“ Although the AAC could not recall the particulars of the last moments of the flight, the remaining surviving crewmembers and the comprehensive data captured from the CVR and FDR were instrumental in determining the precise sequence of events and the crew’s interaction with the automatic flight control system. The Human Factors analysis of the final events leading to the crash focuses on the three pilots since the rest of the crew were in the cabin, and because the standard operating procedures required the cargo door to remain closed until the aircraft was established in the rest position, neither the FEs nor the SAR Techs were in a position to effectively observe the aircraft’s flight path and therefore had no possibility to influence the actions of the pilots or the outcome of the flight. While the FE had observed the boat visually through the window, only with the door open would the FE have had enough visual perspective to potentially warn the pilots of the impending water impact.

The flight was uneventful until the helicopter attempted to become established in the hover at the end of TD2 and began to manoeuvre towards the rest position behind the boat. The initial analysis will focus on the last 90 seconds of the flight to explain what control inputs were made and how the flying pilot interacted with the autopilot. The analysis continues with an examination of the organizational influences on procedures and proficiency and then examines the actions of the cockpit crew and how the environmental factors played a role. Finally, egress procedures, helicopter and aircrew life-support equipment are analysed to explain why not all crew members were able to successfully egress the helicopter following the impact with the water.

2.2 CVR and FDR Analysis

The following analysis of the last portion of the flight is based on a detailed review of the helicopter’s recorder data that was recovered by the National Research Council Flight Recorder Playback Laboratory. In addition to numerous flight and power parameters such as altitude, airspeed, torque, pitch and roll attitude, the FDR records all the autopilot functions, the actuation of the cyclic and collective trim releases switches, the position of the cyclic, the collective, the parallel and series actuators and whether the force-sense link switches are open or closed. Manual pilot inputs to the cyclic can be determined by detecting when the force-sense switches are open and by the number of degrees the cyclic moves in pitch or roll. One important parameter that is not recorded is the helicopter’s speed over the ground or water, i.e., its groundspeed. In accident reconstructions groundspeed was calculated using the recorded changes in the latitude and longitude positions.

As the helicopter completed the autopilot-flown Transition Down it entered slow, level forward flight towards the northwest in the Hover Mode at the radio altitude hold datum of 100 ft AWL. It was in a normal seven-degree nose-up attitude, using about 85 percent torque. The FO was the flying pilot and he was allowing the autopilot to maintain altitude and attitude. In accordance with SMM procedures, as they approached the vessel, control of the helicopter was then transferred from the FO to the AAC. Following the transfer of control, the position of the force-sense links indicate that the AAC began to occasionally apply control forces to the cyclic, simultaneously engaging the cyclic pitch and roll trim release switches on the cyclic. He then began to manoeuvre the cyclic without engaging the cyclic trim synchronization or cyclic trim release (i.e., operating in cyclic manoeuvre mode). As the helicopter continued to manoeuvre towards the rest position the AAC engaged the collective trim release/sync and increased collective, causing the helicopter to slowly climb to 170 ft AWL and, via a nose down cyclic input, accelerate to 30 knots. He then released the collective trim release/sync and, with the autopilot back in control, the helicopter slowed and attempted to re-enter a slow speed forward hover at the new datum of 170 ft AWL.

Once the AAC noticed he had climbed to 170 ft he engaged the collective trim sync and lowered the collective, which reduced torque and caused the helicopter to begin to descend. He released the trim sync at 144 ft AWL causing the Hover mode of the autopilot to re-engage at the new datum (144 ft). Concurrently, he was intermittently applying manual roll and pitch inputs, which opened the force-link switches, overriding the autopilot attitude hold functions. With the collective autopilot mode still attempting to capture the new height datum the aircraft nose attitude increased to 10 degrees nose-up and the torque began to increase. The AAC then depressed the collective sync trim release again and lowered collective, presumably in an attempt to continue the descent down to the desired altitude of 100 ft AWL. The AAC also manually moved the cyclic forward a few degrees. The helicopter began to descend at a rate of about 200 feet per minute but as it approached 100 ft AWL the rate increased to about 500 feet per minute and the aircraft overshot the intended 100 ft altitude and continued to descend. The AAC released the cyclic and the pitch parallel actuator, controlled by the autopilot, moved the cyclic slightly forward to maintain the previous pitch attitude. As it descended through about 85 feet the helicopter’s low height audio warning (“Check Height”) activated. At 80 ft the AC began calling out the radio altitudes and then called three times in quick succession for or a go-around. The collective trim release/sync was briefly released, resetting to the new datum of about 75 ft AWL and concurrently the AAC began to manually override the cyclic in pitch and roll. The Hover Mode of the autopilot once again began to try to maintain the new altitude datum and torque began to increase. The AAC then depressed the Collective Trim Sync and pulled additional collective, causing a brief torque spike of 116%. He quickly reduced the collective, moved the cyclic forward and advised the AC he was going around. Simultaneously, either the FO or the AAC engaged the Transition Up function of the autopilot. However, the

Transition Up function of the autopilot could not control the helicopter because the AAC was manually manipulating the cyclic and collective. At the time of the Transition Up engagement the helicopter was in near level flight at 68 ft AWL, 6 degrees nose down with less than 20 knots of airspeed and 82% torque. The pitch series actuator was now saturated.

With the pitch series actuator saturated the helicopter had lost the rate dampening capability of the autostabilization system and it began to pitch further nose-down. The nose down pitching rate increased to about six degrees per second and the helicopter quickly reached a 20 degree nose-down attitude. For the pitch series actuator to become unsaturated at this point either one of two things had to occur: Either the pitch parallel actuator had to move (which it couldn't because the pilot was overriding the cyclic) or the pitch rate had to be attenuated to a lower magnitude i.e. less than 2.5 degrees per second (via pitch cyclic inputs from the pilot). Neither of these occurred, as the pitch parallel actuator was disabled due to the AAC's manual over-ride of the cyclic and the lack of trim sync use by the AAC when re-adjusting the position of the cyclic.

Six seconds prior to impact the AAC released the cyclic for one second, allowing the autopilot to immediately move the parallel pitch actuator in an attempt to accomplish the commanded transition-up manoeuvre. This caused the aircraft to recover slightly by pitching upward to a 17 degree nose-down attitude. However, this brief pitch parallel actuator motion was not sufficient to un-saturate the pitch series actuator. Five seconds prior to impact the AAC let go of the collective trim sync and the autopilot regained control of the collective. The autopilot responded by raising the collective and increasing torque to approximately the maximum autopilot authority of 100% torque in an attempt to carry out the commanded Transition Up manoeuvre. However, the combination of manual cyclic inputs and the steep nose down attitude prevented the helicopter from achieving a positive climb rate or even level flight. As the nose began to rise from 20 degrees nose-down to 17 degrees nose down the AAC moved the cyclic slightly further forward, which quickly pitched the unstabilized helicopter to a 25 degree nose-down attitude. As before, the pitch parallel actuator remained fixed in position (i.e., disabled). Two seconds prior to impact the AAC pulled back on the cyclic slightly, reducing the aircraft's pitch attitude to about 18 degrees nose down. Simultaneously, the low height safety feature of the collective autostabilization system began to engage, causing the torque values to increase above 100% in an attempt to arrest the descent. The AC focused on the increasing torque values and began to call them to the attention of the AAC. The aircraft then struck the water in an 18 degree nose down attitude with torque increasing through 113%.

2.3 Aircraft Systems and Performance

A review of the maintenance records, witness statements and the CVR/FDR data indicated that the helicopter was serviceable and all systems were functioning normally at the time of the accident.

The possibility of an ASE/AFCS malfunction was examined to see if this may have caused the nose-down attitude and the failure of the helicopter to climb once the overshoot was initiated. The design of the system is such that it does not oppose pilot control commands and the pilot can easily overcome any AFCS inputs. As described in Section 2.2 the position of the force links are captured by the FDR so it can easily be determined when the pilot is manually overriding the ASE/AFCS and when the AFCS is in control of the helicopter. The FDR data indicated that the aircraft nose-down pitch change occurred while the pitch force-sense link was open, indicating that the change was not AFCS induced. When the pilot continually makes manual inputs to the cyclic without using the trim release switches the series actuators become saturated and rate dampening in the pitch and roll axis is lost. This loss of rate dampening combined with the helicopter's inherent instability can result in a small control input or other disturbance causing a larger than intended attitude change and/or the attitude will continue to change at an increasing rate unless a positive corrective input is made with the cyclic. The FDR data indicated, and the flight simulator trials confirmed, that the observed helicopter performance was consistent with the control inputs that were made by the AAC while the series actuators were in a saturated state.

At the aircraft's weight and given the ambient conditions there should have been ample power available/climb capability to easily accelerate and generate a positive rate of climb in the overshoot. During the last several seconds of flight all engines were operating normally and the torque values were either at or exceeded the maximum continuous allowable of 100% torque and at times exceeded the intermediate limit of 106% torque. However, the ability to climb was negated by the large nose-down attitude of the helicopter. As the nose-down attitude increased the rotor disk was correspondingly tilted forward and the vertical portion of the overall force generated by the rotor blades (lift) was diminished to the point that the aircraft could not generate enough of an upward vector to effectively climb away from the water or even maintain altitude. Conversely, this same nose-down attitude generated a strong forward acceleration vector, as indicated by the rapid airspeed increase in the final few seconds prior to impact. As the helicopter began to accelerate it passed through translational lift and this may have provided additional impetus for the nose-up pitch change from the recorded maximum of 25 degrees nose down 2 seconds prior to impact to the 18 degrees nose-down at impact.

In summary, the helicopter responded normally to manual and AFCS inputs and there was no evidence that a system malfunction contributed to the accident.

2.4 Tail Rotor Half-Hub Flight Restrictions

A review of the original Record of Airworthiness and Risk Management (RARM) developed to deal with the tail rotor half-hub cracking in the CH149 fleet revealed that the technical risk was well covered but the potential operational risk, due to a steadily declining overall proficiency was examined, but underestimated. The introduction of the two-hour flight restrictions had an unintentional but significant impact on the overall proficiency of the Cormorant aircrews. Specifically, the risk mitigation measures established in the RARM restricted training to the minimum essential training required to ensure crew currency levels and this led to a steady decline in their proficiency levels. The crews, for the most part, could maintain currency by achieving the minimum requirements but, as time progressed, repeatedly meeting just these minimum requirements was not enough to keep their skills at a level where the 413 (TR) Squadron crews felt safe. The risk mitigation measures put in place to minimize the risk exposure of the aircrew eventually became a risk in of themselves. The results of the survey of CH149 crews conducted by 14 Wing certainly indicates that the crews were losing confidence in their proficiency and their ability to safely carry out their assigned role. The length of time that the restriction was in place was a factor in the accident as the accepted norm for hoist training was significantly changed by the restriction and no corporate memory of the previous proficiency norms remained at the Squadron. The Flight Safety occurrences involving boat/helicopter contact were additional evidence of lowered proficiency and experience levels. However, if there were precursor incidents to this accident, i.e., similar circumstances but with a more positive outcome, they were not reported through the Flight Safety network. Flight data monitoring programs can be very useful tool to monitor for operational deviations, and with the CH149's very capable Flight Data Recorder, it is possible that the steady decline in proficiency and inappropriate handling techniques may have been caught and corrected before the accident had some form of appropriate flight data monitoring or quality assurance program, such as Line Oriented Safety Audits, been in place and utilized.

The restriction that all training flights were to be conducted as close as reasonably possible to the main operating base was particularly problematic for 413 (TR) Squadron because of its geographical location. There were very limited opportunities to practice boat hoisting in the Bay of Fundy and an overland transit to get training opportunities on the Atlantic was deemed to be not in compliance with the direction above. As an example of the stress these restrictions put on proficiency training, even the AC in this accident, who was a CH149 Check Pilot, lost his AC category in the month before the accident when he could not complete the annually required night boat hoist sequence before his currency expired, despite an approved 30 day extension, Finally, the requirement to attain all quarterly currency requirements in the minimum amount of time meant that crews were unable to repeat sequences a second time and improve above the minimum standard. All of this led to a steady decline in the overall proficiency levels of CH149 crews, but particularly for the crews at 413 (TR) Squadron. The crew's proficiency concerns were in turn reflected in the 14 Wing survey results.

The results of the survey and related concerns were passed up the chain of command and the Division A3 SAR staff, in recognition of the decreasing proficiency levels, prepared several briefing notes for the Commander with various options proffered to mitigate the concerns. However, the last two briefing notes prepared for the Commander recommended an increase in the two-hour limit only after additional technical data related to the tail rotor half-hub risk was available. In turn, the Division Commander would not revise the operational restrictions in the absence of further mitigating technical data. In the end, the decision to relax the restriction from a two-hour to the three-hour limit was based primarily on a revised reduced technical risk, but it was also influenced by recognition of the decreasing proficiency levels of CH149 aircrew. Of note, it appears that no alternative training-related mitigation strategies were offered, such as increased utilization of the simulators. The change to a three-hour limit on training flights occurred just two weeks prior to the accident and overall proficiency levels had no chance to improve significantly in that short interval.

2.5 The 1 Canadian Air Division Risk Management Processes

As the flight restrictions became prolonged, the Division Commander and his staff were certainly aware that there was an increased, albeit unquantified, risk to CH149 operations due to lowered proficiency levels. While this did result in the initiation of some staff work to the Commander, nothing in CH149 operations was changed as a result. No formal risk assessment was raised by the 1 Canadian Air Division Headquarters staff to assess the risk posed by low levels of aircrew proficiency as a discrete issue stemming from the flying hour restrictions.

Realistic risk assessments and the resultant management of that risk are key elements in the overall airworthiness process. However, in the period leading up to the accident, the risk assessment guidance available to the operational staff was oriented towards the operational risk management of technical issues/deficiencies. Operational airworthiness aspects were typically considered in the context of dealing with the operational ramifications of a technical issue, not in the context of mitigating a strictly operational issue. The only time the Operational Airworthiness Order explicitly called for a risk analysis was with respect to operational restrictions or when normal operating limits must be exceeded. However, the declining proficiency levels reported in the Flight Safety Stress Points from 14 Wing represented a hazard, which, although rooted in a technical problem, was a separate phenomenon and created a purely operational risk of unknown magnitude. As defined in Section 1.17, proficiency is one component that must be considered in the overall determination of Operational Airworthiness. Thus, from an Operational Airworthiness perspective, it can be argued that the collective and widespread lowered proficiency levels among CH149 aircrew comprised a missing component for the maintenance of the overall airworthiness of the CH149 fleet.

The TAA could do nothing to address the proficiency problem. Unfortunately, no clear requirement existed for the OAA to risk assess this purely operational airworthiness issue. Nowhere in the governance documents was there clear direction that a formal risk assessment should be completed in response to a Flight Safety hazard identified via the stress points. The stress reporting system was viewed as a trial process, and, with no defined response mechanism, there was no defined response and no requirement to initiate a formal risk assessment of the situation. To the extent that they provided an awareness of certain issues to higher levels of command, Flight Safety Stress points were useful, but as a process considered as being under trial, it lacked rigour and discipline in terms of how the hazards were to be identified and the actual level of risks such hazards (stress points) represented to operations.

Commanders, and indeed all aircrew, regularly make informal risk assessments and manage risk as part of their normal duties. However, informal processes neither provide traceability, nor support accountability, nor impose discipline and rigour in decision-making in the manner of formal processes. While it cannot be stated with certainty, a formalized approach to assessing this particular risk might have led to other possible mitigating actions and would have served to better inform the Commander as to the level of risk he was tacitly accepting with respect to proficiency in maintaining the two-hour and associated flight restrictions. The critical missing step was a specific trigger mechanism to force the formalized assessment and acceptance of the Flight Safety risk stated in the stress point report and the survey.

2.6 Currency and Proficiency

2.6.1 Definitions

1 Canadian Air Division Orders state that currency standards are designed to prevent the erosion of knowledge and skill, ensuring that personnel maintain a level of performance consistent with operational safety and minimum levels of operational effectiveness. The Orders do not define proficiency but define proficiency standards as those used to gauge an individual’s effectiveness in a given operational or instructional role.

The Oxford dictionary defines proficiency as: “*Skillfulness in the command of fundamentals deriving from practice and familiarity, synonyms: technique.”* An occurrence involving a performance discrepancy in proficiency can therefore be related to skill retention, which is a capability one would expect to correlate well with opportunity to practice, i.e.: flying hour availability.

John Patrick[3] is cited in several aviation investigation reports in view of his work on task/skill analysis and skill retention. He states that skill retention degrades with time following training and the amount of degradation is related to the following:

a) The level of retention is positively related to the level of learning at

[3] *Training: Research and Practice*, J. Patrick, May 12, 1992 ISBN-10: 0125466609

the end of the training;

b) The skill retention gets worse, the longer the retention interval: and

c) The rehearsal of skill mitigates against skill loss.

A Canadian Transportation Safety Board report [4] captures well the conundrum of skill retention: "*In essence, skills can be expected to be most effectively maintained when they are well mastered during training, retrained on a regular basis, and rehearsed regularly between training sessions. This cycle of retraining is most critical for procedural tasks, which consist of a number of discrete steps (for example, responding to an in-flight emergency such as an engine failure), since these types of tasks have been shown to degrade the most over time. Conversely, continuous tasks, which are more automatic and for which cues are provided by the environment (for example, manually flying an aircraft on a visual approach), show minimal degradation over time.*"

Most aircrew would agree that currency and proficiency are not the same and being current in a particular sequence does not necessarily imply more than a minimal level of proficiency at that sequence. Currency is being "legal", whereas proficiency, by definition, means performing a given task with "expert" skill. An aircrew member, while legally current, may not be adequately proficient in certain critical flight sequences to be confident of success in carrying out a highly challenging manoeuvre. Regular and repeated practice is required to maintain proficiency. Maintaining minimum currency may be acceptable for a short time but, if allowed to persist and become the norm, proficiency will degrade. This is the very situation that the 413 (TR) Squadron aircrew found themselves in, i.e., a relatively prolonged period of maintaining minimum currencies leading to an overall degradation in skill levels, i.e.: a loss of proficiency. The actual amount of degradation will depend somewhat on an individual's experience and personal abilities. Unfortunately, proficiency remains difficult to quantify, but typically it is either informally measured by the individual's own comfort level with the sequence or more formally judged by a qualified standards or training pilot. Furthermore, proficiency is often considered on an individual basis and not in an overall or collective sense. Again, it is difficult to quantify, but in the case of the 413(TR) Squadron aircrew, via the survey results, the group in question had self-assessed their proficiency as being less that that required to safely carry out their designated role. In the absence of other suitable metrics, this self-assessment should have been a key consideration in the determination of the overall airworthiness of the CH149 fleet, at least at 413(TR) Squadron.

[4] Transportation Safety Board of Canada (TSB) report number A05O0147, released on 22 February 2006.

2.6.2 AAC Currency and Proficiency

Prior to the accident the AAC was actively working towards upgrading to AC in minimal time. However, he was concurrently responsible for running the Standards Flight and had a number of other non-flying related duties that required a lot of his attention. Based on his performance on AAC training flights it became apparent that the AAC was progressing at an average rate and that he would not upgrade as quickly as first anticipated. It was also noted that he required more work on knowledge of aircraft systems. His training and the upgrade process were interrupted when he took 10 weeks off to attend to personal matters. A 10 week hiatus from flying would, for any pilot, lead to a loss of currency and inevitably some loss of skill level or proficiency.

The AAC had intended to get as many of the currency requirements (required sequences) completed before he departed on leave in April so he could quickly return to operational status upon his return in July, and he was mostly successful in that endeavour. However, he was not able to obtain 30 hours in 90 days. Upon his return from extended leave he asked to be given a 30-day check. Normally, the Standards and Training pilots would have confirmed his currency requirements and hours flown to determine what type supervised training event was required to regain his currency. In this case, since the AAC was a multi-tour SAR pilot and the former Squadron Standards Flight Commander, there was apparently a “Halo” effect and the Standards and Training pilots assumed that the AAC knew what was required and no further questioning or document / training file review was done to verify the requirement. As a result, the more thorough supervised training/proficiency check required to re-validate the pilot’s proficiency level was not done and the requested 30-day check was completed satisfactorily. The AAC was immediately returned to operational duties, with both the AAC and the CH149 Check Pilots unaware that he had still not completed the required training to regain his operational FOIII/UAC Category. While primarily an administrative oversight, it did mean that the AACs proficiency in certain operational manoeuvres and emergency handling were not demonstrated and assessed, as they should have been.

2.6.3 FO Currency and Proficiency

Following his Unit Check Out and based on his previous non-CH149 flying experience the FO, with the recommendation of the CH149 Check Pilot, bypassed the FO Level I category and was immediately awarded an FO Level II category by the Squadron Commanding Officer. The existing orders permit this for all new multi-tour (helicopter) pilots, regardless of where or on what type of helicopter the previous tours were flown and regardless of whether all the sequences were completed on the CH149 conversion course. At the time the FO was awarded the category he had still not seen a night boat hoist sequence in the CH149. Without his previous flying experience he would not have been eligible to upgrade to FO Level II until he had accumulated between 100 and 200 hours flying the CH149 and completed a proficiency check. The FO II category implies a certain level of competence and familiarity with the helicopter and the SAR role. While there is some transfer of basic handling skills and aeronautical knowledge/airmanship when moving from one helicopter type/role to another, the immediate awarding of an FO II category could be perceived as premature. The role of the CH149 is very different than the Tactical Helicopter role he came from, so in this case the FO was attempting to adjust simultaneously to a different helicopter, a new role, different sequences and different operating procedures. Moreover, he was still becoming accustomed to the CH149 cockpit environment, the location of certain switches and the appropriate non-flying pilot duties and had received very limited exposure to some of the basic SAR sequences. Specifically with respect to the night OWTD procedure to a boat hoist, he had only seen one of these before the accident flight, and that was as the flying pilot (vice as the non-flying pilot, which requires a different set of skills and procedures). Although awarded an FO II category, for the reasons listed above his proficiency was judged to be at the lower end of what could be expected of an average FO II.

2.7 Training

2.7.1 Cormorant Conversion Training

The CH149 pilots training course, run by the Operational Training Flight (OTF) of 442 (TR) Squadron, was based on the original Labrador conversion syllabus that was changed to become a Cormorant Conversion course. The OTF was not optimally designed to meet the CH149 SAR squadrons' requirements and the course did not fully emphasize the new capabilities and advantages that the Cormorant's highly capable automatic flight control system offered. As such, students become aware of the AFCS modes and functions almost as a by-product of learning to fly the CH149 rather than learning from the outset what could be a preferred method of operating the helicopter.

CH149 training at the OTF did not emphasize non-flying pilot duties. The primary focus was on achieving the required competency levels as the flying pilot. However, once graduated and returned to squadron, the new FOs will spend at least 50 percent of their time, particularly on operational missions, as the non-flying pilot. This had been noted as a deficiency by the receiving squadrons in that new FOs were not totally conversant on their specific duties as the non-flying pilot. This may have been a factor in this accident as it relates to the FO's prioritization of his attention during the overshoot.

To meet the demand for new CH149 pilots, the OTF was authorized by 1 Canadian Air Division to cut their training short and defer certain sequences to the operational squadrons to complete. This raises two concerns. First, new CH149 pilots saw these sequences for the first time on a squadron supervised training mission, where squadron check-pilots would teach them. Although they hold the Flying Instructor qualification, the squadron check pilots receive minimal training (one or two flights with a Squadron Check Pilot) in practical airborne instruction and are not specifically trained in defensive flying techniques. This distribution of the training to the squadrons also introduces a potential element of variability in the quality of the training and the standard expected. Secondly, although the OTF Course Reports stated that the FO category could be awarded after satisfactory completion of the night boat hoist, 1 Canadian Air Division gave Squadron Commanders the discretion (and they exercised it) to immediately employ the FOs operationally. As a result, the FO involved in this accident was assigned to SAR standby duties following the OTU and UCO without ever having been trained in the night boat hoist sequence. Although there was an email to the squadrons from TRSET that specified that FO Level IIs could only do night boat hoists with training and standards pilots until "Level 3" skill was demonstrated, the 1 Canadian Air Div Safe Training Practices Order was not amended. As a result, ACs were not generally aware of this restriction and it introduced an element of risk for operational SAR missions where an AC could be paired with an incompletely trained FO. In such a situation, without the benefit of actually being trained in the manoeuvre, the FO would not be able to provide the expected support to the crew.

2.7.2 Simulator Training

CH149 pilots use the civilian-operated EH-101 simulators located at RAF Benson in the UK. At the time of the accident Cormorant crews were required to complete simulator training once every 12 months, extendable to a maximum of 18 months. The EH-101 simulator is a high fidelity simulator that can be used to simulate most phases of flight, standard SAR scenarios and the full spectrum of system failures and emergencies.

The simulator staff does not instruct the CH149 crews *per se* but rather facilitate their training in the simulator. The actual continuation training for FO's is done either by a CH149 Aircraft Captain or, occasionally, by a CH149 Check Pilot. The civilian simulator staff at RAF Benson have the benefit of a very wide perspective on EH-101 operations because of the many and varied crews that come there for training. When queried by investigators on the overall performance of CH149 crews, the simulator staff noted that in comparison to other EH101 crews, the Cormorant crews were performing to a lower level in the simulator than other operators. This was not meant as a reflection on individual abilities; rather, it was their opinion that, in comparison to other EH-101 operators, the CH149 pilots were permitted too much variability in how they performed procedures, set up their displays and handled malfunctions. In general, it was their opinion that better and more detailed descriptions of standard operating procedures in the CH149 Standard Manoeuvre Manual would be beneficial. Finally, they remarked that they commonly saw CH149 pilots using techniques that they felt were a carry-over from the non-automated, manual flying procedures used in the CH113/A Labrador.

The observations of the simulator staff corroborate other evidence that the overall proficiency of the CH149 crews was less than might have been achieved given a more rigorous approach to simulator training, and training in general, and that some procedures and techniques used by our crews were not consistent with “best practices” for operating a sophisticated automated helicopter as utilized by other operators. The EH-101 simulator is a high fidelity simulator that had the potential to bridge the gap between currency and proficiency that was generated by the flight limitation on the CH149 through additional utilization to make up for some of the training shortfalls.

2.8 Standard Manoeuvre Manual Procedures

The CH149 Standard Manoeuvre Manual (SMM) was reviewed to see if it provided the requisite direction to CH149 pilots regarding their individual duties and the performance of standard manoeuvres. Specifically, with respect to this accident, the following SMM content is pertinent:

> During NVG flight the NFP is responsible for monitoring the helicopter flight instruments and advising the FP of flight parameters such as heading, airspeed, and altitude. This is especially important during hover manoeuvres, takeoffs, landings, shore crawls, or when the FP is not in a position to crosscheck the helicopter flight instruments. The NFP should be ready to take control during critical phase of flight in the event that the FP loses visual references or in case there is an NVG failure.
>
> After the control transfer the left seat pilot shall continue to monitor the instruments.

These statements from the CH149 SMM provide sound basic direction in that they emphasize the use of instruments by the NFP to back-up the FP in the low visual cueing environment. This, however, was not followed completely by the FO in that he was also attempting to maintain references using the NVGs and, due to his relative inexperience in the CH149, was distracted by attempts to locate various switches in the dimly lit cockpit.

> In low visual cueing environments the pilot should attempt to maintain attitude retention by avoiding the use of the Cyclic Trim Release button. Small and precise attitude changes can be made using the Cyclic Beep Trim switch only. Alternatively, the pilot can easily move the cyclic in the manoeuvre mode then use the beep trim to relieve control forces, resulting in faster trim rates.

The AAC was using the manual manoeuvre mode but was not regularly using the beep trim to relieve the control forces. However, the effect of manual control inputs on the series actuators, and therefore the consequences it will have on the ASE, and the ability of the autopilot to carry out the intended manoeuvre is not discussed in the SMM.

> Where ambient light conditions are minimal and no horizon is discernable, auto-pilot modes can be employed to reduce pilot workload and assist with hover stability and the use of the autopilot should be considered and utilized wherever practical. During low visibility and marginal weather conditions, a coupled approach is recommended.

A coupled approach was flown, in accordance with the SMM, but the advantages of this were negated by the manual control inputs of the AAC. The visibility and weather were adequate for the planned exercise (in accordance with the applicable flying orders) on the night of the accident, but the available outside references were limited, and as such, a coupled approach was in accordance with the recommended procedure. Nonetheless, as the SMM does not mandate that a crew uses a coupled approach for night boat hoists, the manually flown boat hoist would still be an acceptable procedure as per the SMM. This gives crews the leeway to not use the automation according to their assessment of the situation or personal preferences, but what benefit there could be in allowing this option is not stated.

> If a go-around is required, for whatever reason, the FP will adjust heading to avoid over-flying the target and execute the go around procedure. The FP commences the go around using the GO AROUND / T UP mode or manually, as required; however, it is recommended that the GO AROUND / T UP mode be used.

The SMM recommends that the autopilot be used to accomplish the go-around. This is appropriate but unfortunately, in this case, although the crew actuated the Transition-Up/Go-Around mode, the AAC's control inputs precluded the autopilot from successfully carrying out the manoeuvre. Of note, there is no specific emphasis on the requirement to monitor the instruments during a go-around in a low-visual cueing environment.

In summary, the SMM provides guidance of a general nature and is oriented towards safe practices but, intentionally or not, the SMM leaves a lot of room for individual interpretation and application. It is judged that had the accident crew followed the SMM verbatim and in its most conservative interpretation, this guidance should have kept the accident crew safe. However, the SMM does not actively encourage the maximum use of the CH149's automation capability to improve the safety of flight. It is also lacking in detail in that specific duties during various manoeuvres or tasks for the FP and NFP are not described, nor are limits on flight path parameters for various manoeuvres (maximum acceptable pitch, bank, climb or sink rates, etc) described. This additional information would improve the level of standardization and crew coordination during CH149 flight operations.

2.9 NVG Use

The AAC elected to remove his NVGs prior to taking control at the end of the OWTD procedure as he was attempting to become established in the rest position while the FO elected to remain on NVGs throughout the whole sequence. This is in accordance with the CH149 SMM, which does allow for operation with mixed crews. By way of comparison, CH146 tactical aviation operations are not permitted with mixed (one pilot on, one pilot off goggles) crews, while the CH146 used in the SAR role does. This different methodology is because of the SAR crews' particular lighting usage during manoeuvres, such as during hoisting, where all white lights available are normally used. This better reflects the requirements of SAR crews and is more applicable and typically done when operating in the low altitude overwater environment. The NVGs inherent lack of depth perception makes it difficult to detect height changes, especially at low height during flight over open water. Additionally, ground speed and rate of closure are difficult to judge during NVG operations. In this case, the smooth water conditions, lack of contrast and distant shoreline at the time of the accident did not provide sufficient visual cues to maintain the FO's situational awareness, despite his use of NVGs. Potentially, the introduction of a night HUD display, similar to those in use by the CH146 Tactical Aviation community, could be used to improve pilot situational awareness in these situations. Nevertheless, the current limitations of NVGs dictate that a good instrument scan be maintained by the crew while at low altitude over water, even when using NVGs.

Poorly adjusted NVGs will exacerbate the reduction in NVG visual acuity. The FO elected to adjust his NVGs using outside objects vice the available and recommended ANVS 20/20 equipment. Studies have shown this will result in a degraded visual acuity, ranging from 20/300 to 20/40, depending on the users experience. Although it cannot be stated with certainty, it is possible that lowered visual acuity of the FO's NVGs contributed to his inability to perceive the helicopter's final flight path using outside references.

2.10 Crew Complement

The night boat hoist sequence is generally agreed upon by Cormorant crews to be one of the most demanding tasks that a crew can be called upon to perform. To be clear, this accident occurred during an attempted overshoot while the crew was manoeuvring into the "rest" position and the boat hoist phase was never actually entered. Nevertheless, operating in the low altitude over water environment with very limited visual cues is a demanding task that requires a high level of individual proficiency and crew coordination.

The 1 Canadian Air Division Orders allowed an FO II and an AAC to occupy both pilot seats for take-off and landing during an AAC training ride provided the flight did not involve VIP transport and if, in the Check Pilot's judgment, there were no mitigating circumstances to preclude this seating arrangement. Of note, no reference to other critical phases of flight is mentioned in the 1 Canadian Air Division Order, just take-offs and landings. As allowed by this Order, it was a common and accepted practice on CH149 AAC training flights to pair an FO II with an AAC to allow the AC (also a Check Pilot) to watch from the jump seat to better assess the AAC's ability to act as a SAR AC with a real FO, instead of the AC acting as an FO. The rationale for such a decision is that once an AAC upgrades to AC they could be paired with any FO for any SAR mission and the Check Pilots wanted to observe the prospective AC's performance with a real FO. Ultimately, the decision on whether to allow two FOs to occupy the two pilot seats is a judgment call by the AC. In making that determination the AC must consider the individual pilot's experience, the FO Category level and the category restrictions, if any, their pilot proficiency, the type of mission and finally, any environmental factors.

In this accident the AC apparently considered these factors but still felt comfortable allowing these two FOs to fly together to conduct one of the more demanding SAR training sequences. He had conducted the FO's UCO and recommended his immediate upgrade to FO II. He was unaware that the AAC was not current and that his category should have reverted to UT. Had he been aware of this, undoubtedly he would not have allowed the two FO's to occupy the two pilot seats. In fact, it would have been contrary to the Orders. The AAC's lack of currency notwithstanding, the FO and AAC involved in this accident should not have been paired together to conduct the mission. The FO, while on paper a Level II FO, was at the lower end of that skill set, with only a basic familiarisation with night boat hoist procedures on his single previous night boat hoist training experience with a check pilot, and his very limited overall experience in the CH149. To pair this FO with an AAC who had flown only 10.5 hours, and no night, in the last 90 days, introduced a higher level of risk than necessary into the mission. The AC, as a Check Pilot, would have had a good overview of the relative capabilities of the two pilots but, in this case, he put too much faith in their previous experience and did not take into account their overall lower proficiency levels for what was a very demanding mission.

Regardless of who may have control of the helicopter at a given moment, the AC ultimately remains responsible for the overall conduct and the safe completion of the assigned mission, including the response to emergencies and mission accomplishment. While in the jump seat the AC may provide verbal assistance to the FO's if required, but it is impossible for the AC to physically intervene or take control of the helicopter, should it be required. Further, the position of the jump seat provides a less than ideal view of the flight instruments and would compromise the effectiveness of his instrument scan. These limitations appear contradictory to the responsibilities of an AC, as described above. The fact that the person responsible for the safe completion of the flight (and in this case the most experienced CH149 pilot on the crew) would not be in a position to physically take control of the aircraft during critical phases of flight is seen as an oversight in the Orders. Critical phases of flight include take-off and landing, but also, for the CH149, as defined in the SMM, include flight below 100 ft AGL/AWL and/or below 45 KIAS, which would therefore include other higher risk/higher skill sequences such as low altitude manoeuvring, boat hoists and confined area landings, etc. While the SMM defines critical phases of flight, the 1 Canadian Air Division Orders do not, and neither document imposes any restrictions on crew seating arrangements based on operations in critical phases of flight.

2.11 Pilot Technique

The AAC took control of the aircraft too early in the sequence and could have made better use of the automation to achieve the rest position, particularly in the low visual cueing environment. Once he took control, the technique used by the AAC did not make optimum use of the automation. He immediately engaged the collective trim and began to climb (unintentionally) instead of allowing the collective height hold function of the autopilot to maintain height. It is possible that the climb from 100 ft AWL may have been initiated by an inadvertent up-collective input while the AAC was actuating the “top hat” four-way search light control switch on his collective. The autopilot is very capable of safely maintaining flight and a more frequent instrument cross check by either pilot would have caught this deviation before the climb reached 170 ft. Further, the AAC was manually manoeuvring the helicopter without regularly updating the trim while an autopilot mode was engaged. This is not a recommended procedure.

The AAC’s go-around/overshoot technique was inappropriate in two respects. First, he had the autopilot engaged but was concurrently attempting to manually fly the overshoot. The flight control computer was instructing the flight control actuators to do one thing but the manual inputs were contradicting those commands. The design is such that manual inputs will override the automatic systems with the net result being that the manual inputs caused the pitch series actuators to become saturated to the point that stability augmentation was lost. The manual technique that the AAC appeared to be attempting to use was an “acceleration over altitude” departure, which is more suitable for day visual conditions with no obstructions in the departure area. An “altitude over acceleration” would be the more appropriate departure technique for this situation, and this the one that the transition-up mode of the autopilot would have flown, had it been allowed to.

Second, the evidence suggests that AAC attempted to use unaided visual cues to monitor the helicopter’s performance and departure flight path in a low visual cueing environment. If he had been monitoring the instruments it is difficult to understand how a 20 degree nose down attitude and decreasing radio altitude height could have been overlooked. The AAC may have been focused on the lights of the boat or he may have been looking for a horizon. This cannot be determined with certainty given the AAC’s amnesia but, either way, the references he was using were clearly insufficient to maintain situational awareness and a safe flight path. The correct technique would have been to immediately revert to an instrument scan, or if unable, pass control to the NFP, who should have been maintaining an instrument scan.

The FO was inexperienced in night OWTDs and night boat hoists and relatively new to the helicopter. Despite the duty requirements as stated in the SMM, the FO felt somewhat uncertain of his specific left seat duties. This may have been related to the lack of training on NFP duties he received while on the CH149 conversion course. He was pre-occupied with items other than monitoring the instruments and instead was dividing his attention between attempting to locate switches on the centre console and attempting to use his NVGs to acquire outside references. His predilection for NVGs over instruments, while inappropriate in this environment, is assessed to be a by-product of his multi-tour tactical aviation flying experience in the low-altitude over-land environment, where the preference is to use NVGs whenever possible to see and avoid obstacles. The FO's stated loss of outside references as the helicopter approached the boat should have been a further prompt that in this situation an instrument scan was the most suitable method to ensure a safe overshoot trajectory was maintained.

The AC was able to maintain an instrument scan and situational awareness up until the overshoot began. He displayed sound judgment in calling for the overshoot as soon as he deemed that the situation had become unstable. He last noted the radio altitude to be approximately 60 feet and therefore assumed that they had sufficient altitude to safely conduct the overshoot. Based on his belief that they were at a safe altitude and that the AAC was capable of safely carrying out the overshoot, he focused his attention on the torque readings, concerned about avoiding an over-torque. In any event, even if he had realized what was happening, all he would have been able to do was verbally warn the AAC, since he could not physically take control of the aircraft from the jump seat.

In a two-pilot crew situation with limited visual cueing, the primary reference during the go around should have been the instruments. If there is some concern with obstacle clearance, such as perhaps avoiding the boat on the overshoot, if one pilot is looking outside, there should still be a regular instrument scan by the other to ensure that the desired performance and flight profile is being achieved. One pilot should have his head "inside" and the other "outside" the cockpit. In this situation neither the AAC, nor the FO, nor the AC were monitoring the instruments and therefore were unable to perceive the actual performance, attitude and flight path of the helicopter from the time the overshoot began until it hit the water.

2.12 The Environment

The accident occurred during the hours of darkness, under mostly clear skies, with a nearly full moon illuminating the smooth water surface from a low angle directly behind the helicopter. A very limited visual horizon was created by the sparse lighting on the shoreline approximately 12nm in front of the helicopter. The visibility of the horizon would be enhanced with the use of the NVGs. However, the water was calm and under these conditions it would have been very difficult to make an accurate visual determination of helicopter's height above the water, even with NVGs. As the helicopter descended towards 100 ft AWL in a normal nose-up attitude, the helicopter rotor wash would have began to cause a wake in the water that radiated away from the helicopter. A perception of waves moving away from the pilot may induce a sensation of backward motion. The sensation of backward motion, especially in a night low-flying hover over water, is disorienting and commonly induces a false sensation of "backing down". This can result in an incorrect and subconscious control input to climb and move forward. This may also have been the impetus for the initial unintended climb from 100 ft to 170ft and the increase speed to 30 Kts as the helicopter approached the boat. As the helicopter descended back down below 100 ft AWL its rotor downwash began to kick up a spray, which further diminished the available forward visual references. This could have been why the FO reported that he had lost all visual references, meaning he could no longer see anything outside the cockpit, even with his NVGs. The AAC had elected to de-goggle his NVG and given the conditions described above it is doubtful the AAC could have had any visual reference other than the lights on the boat. As the overshoot began and the nose attitude decreased, the rotor wash effect on the water would have been below and behind the helicopter. Looking forward, the AAC would not have had a visible horizon and, with no surface texture on the water, no usable height cues. These conditions would not provide sufficient visual references for the flying of the helicopter, with or without NVGs, based on outside cues. Attempting to fly visually under these conditions, especially unaided by NVGs, would predispose all three pilots to unrecognized spatial disorientation.

Inadequate crew coordination can precipitate and or exacerbate spatial disorientation. Conversely, good crew coordination may prevent spatial disorientation and can help recovery from spatial disorientation. The normal countermeasure is to communicate at the first suspicion of disorientation to let the other pilot know. Unfortunately, in this case both front seat pilots succumbed to unrecognized spatial disorientation. That none of the three cockpit crewmembers realized they were about to fly into the water is clear evidence that the use of external references, aided or unaided, in these conditions was insufficient to maintain safe separation from the water. Allowing the helicopter to conduct the overshoot automatically would have been the best course of action, but if flown manually, the only mitigation strategy against disorientation would have been a constant and effective instrument scan.

2.13 Survivability

This was not a helicopter ditching scenario. Ditching is a controlled or at least semi-controlled pre-meditated emergency landing on the water. It implies some time, however minimal, to prepare for a relatively low energy, intentional emergency landing on the water. This accident involved an unintentional controlled flight into the water with significant forward speed, a steep nose down attitude and the resultant destruction of major sections of the helicopter. Regardless, the basic survival requirement remains the same – to successfully egress the helicopter before the available air supply is exhausted. The difference in this situation was that there was no time to prepare, no time to take the assigned ditching seats, and no time to review procedures. Despite the energy involved, the crash dynamics and restraint systems in use and medical evidence were such that none of the crew were judged to have been rendered unconscious or otherwise immobile by injuries sustained during the initial impact. Based on this, the initial crash forces were judged to be survivable.

2.13.1 Cockpit crew

The pilots did not egress the aircraft, rather, the impact and hydrodynamic forces immediately destroyed the cockpit area of the helicopter around them and the three pilots found themselves instantly submerged in the water at a relatively shallow depth. The reason for the release of the FO's and AAC's five-point harness system could not be specifically determined, as neither seat was recovered. However, it is likely that the hydrodynamic pressure present, once the cockpit ruptured, either actuated the main quick release buckle or actuated the emergency release handle, freeing both pilots from their harness and seat. It should be noted that the injury patterns indicate that the FO and AAC's harness did act to restrain the individuals during the initial deceleration on impact and prevented much more serious injuries, before they were subsequently released due to the hydrodynamic forces. The jump seat restraints for the AC, which are of a different design and do not incorporate a quick release, remained connected and he had to manually undo his harness.

The AAC has no recollection of how he got to the surface and his EBS was found full and attached to his LP/SV. The AC, as soon as he realized what had happened and that he was submerged, instinctively reverted to his RUET training. He attempted to landmark his position but was unsuccessful in orienting himself because there was no aircraft structure remaining around him. The next step was to use the EBS. The AC could not immediately locate his EBS mouthpiece but while he was looking for it he bobbed to the surface in his seat and undid his straps. His cylinder pocket was not attached to the LP/SV waist strap and so it, along with the rest of the EBS, may have been torn from his LP/SV during the impacts sequence. The FO's RUET training was not current[5] and because he had not been formally trained in the use of EBS, he did not attempt to find his EBS and instead went for the inflation beads on his LP/SV. His initial attempts to reach for the beads were impeded by his injuries but, with his air running out, he persevered and was eventually successful at inflating his vest and rising to the surface. The bladder on his LP/SV only partially inflated.

Several of the LP/SVs used by the crew experienced an incomplete bladder deployment on inflation due to the failure of the left lobe cover zipper to completely separate. This malfunction was also seen during the LP/SV inflations for some crewmembers involved in the accident to Sea King 12438. This failure can have potentially very serious consequences such that the LP/SV may not keep the face of an unconscious wearer out of the water. The Quality Engineering Test Establishment (QETE) was tasked to investigate the inflation times of the LP/SVs in cold temperatures and to recommend possible alternate configurations. Based upon QETE's findings, the Technical Airworthiness Authority modified the design of the LP/SVs used on Helicopter and Transport aircraft. These modifications incorporate a change to the extra wide bladder

[5] Although the FO's RUET currency had expired, as described in Section 1.5 Note 2, he had received the training when he was flying CH146 Griffon.

cover and the replacement of the manual inflation device to ensure complete bladder deployment on inflation. The modification has been approved but has not been implemented at the time of writing pending the procurement of new inflators.

2.13.2 Flight Engineers and SAR Techs

The semi-intact helicopter fuselage quickly overturned due to the inherent high centre of gravity that all helicopters have because of the location of the engines and transmissions on the top of the fuselage. The crewmembers had to cope with in-rushing water, cold shock, severe disorientation caused by inversion and darkness, difficulties in releasing their restraint systems, and then locate and open exits. Therefore, to successfully egress the helicopter each crewmember had to, before running out of air and in the dark, orient themselves to the situation, disconnect or remove their harnesses and/or anchor straps, find an unblocked emergency escape exit/window, activate the escape exit jettison mechanism, get through the exit and then make their way to the surface. Studies have shown in simulated generic helicopter underwater escapes that the average breath-hold time in cases of a sudden immersion into cold (10 Deg C) water is 17 seconds. These same studies showed that typically it takes between 17 and 47 seconds to escape a submerged helicopter. EBS, if available, should provide from one to three minutes of additional air, depending on breathing rates and other factors. The flight engineers and SAR Techs were trained and current in RUET; however, only the flight engineers had an EBS immediately available due to the current incompatibility of the SAR Tech flotation vest with the EBS assemblies. The SAR Tech EBS were kept by their designated crew seats so that in the event they became aware of an imminent ditching they could strap into these seats and would have had their EBS available. As stated above, this was a crash rather than a ditching and the SAR Techs were out of their seats and unprepared for the impact.

The CH149 SMM stated that as the helicopter approaches the hover position the SAR Techs are to be seated next to the bubble windows. The two forward bubble windows are equipped with crew seats and are also primary escape exits. The SAR Techs' EBS units were stored at these positions. The rear bubble windows cannot be jettisoned, have no associated crew seats and are neither primary nor secondary escape exits. In this accident the SAR Techs were standing in the cabin area in anticipation of the upcoming hoist exercise rather than seated by the forward bubble window primary exits. Given that the aircraft broke apart in the area of the forward bubble windows it cannot be determined with any degree of certainty what the net effect would have been on SAR Tech accessibility to their EBS bottle or their overall chances of survival had they been seated by the forward bubble windows.

All the cabin area crewmembers managed to disconnect from their restraint harnesses and/or anchor straps, but they all did it in a different manner. The SAR Tech TL said he was able to undo his anchor strap only with great difficulty.

This is because the design of the release mechanism required that, before use, it be set up for either a left or right hand actuated release and also because the mechanism cannot be released when under tension. Also, because the anchor points are on the ceiling of cabin, when the helicopter inverts in the water, a crew member's positive buoyancy would cause them to float towards the floor of the aircraft (i.e. away from the ceiling anchor points), which could pull the strap tight, depending on the pre-set length of the strap. The SAR Tech TL, with the time gained from a breath taken from a chance pocket of air, finally managed to use his good left hand to take the tension off the anchor strap and then had to use his injured right hand to release the lock. Although he doesn't remember specifically how he got out, since no other emergency exits were removed and there was tangle of debris at the forward end of the cabin, he likely exited via the opening created by the missing cargo door. The SAR Tech TM, who did not have an integral EBS for the reasons stated previously, had managed to remove his harness but was unable to get to an emergency exit before running out of air. The inability of the SAR Tech TM to escape the submerged helicopter was likely a combination of several circumstances. The SAR Tech TM's anchor position put him the furthest aft in the helicopter and under any water immersion situation he would be in the most vulnerable position in regard to finding a good exit. There were no primary exits in his immediate vicinity - the nearest exit on the right side was the secondary exit which was significantly obstructed by the ladder and the primary on the left side was on the other side of the FE cabinet and partially obstructed by the passenger seats. There was no evidence that an attempt was made to open either of these exits. His ability to orient and move to an exit was likely complicated by his position and, with the longest monkey tail, he had the most potential for the longest throw at impact. The SAR Tech TM's use of the Mustang floatation coverall likely also inhibited his successful escape from the aircraft. The inherent positive buoyancy of the suit, and any air trapped within when he donned the suit, had the potential to pin the member to the top of the cabin (which was actually the floor because the helicopter was inverted) with enough force that he was sufficiently restricted in his attempt to make his way to an emergency exit before running out of air. Of note, the SAR Tech TL's escape was not effectively hindered by the use of his Mustang Floater™ suit. It is possible that the SAR Tech TM had more trapped air in his suit, which contributed to his excessive positive buoyancy.

The MS-185 Mustang coveralls have a 25 to 27 lb inherent buoyancy and Mustang does not recommend the use of these coveralls inside aircraft, although it is below the maximum 35 lb buoyancy standard set for safe helicopter egress. For over water work, including boat hoisting, SAR Techs had the option of wearing the Mustang Floater™, a Dry Suit or a Wet Suit. Both the Mustang Floater™ coveralls and the Dry Suit are used during RUET so that the SAR Techs are familiar with how both of the suits react in a ditching situation. The Mustang Floater™ coveralls are no more buoyant then the Dry Suit but are less buoyant than the Wet Suit. The SAR Techs require some protection from the elements during the hoisting process but there are alternatives and a less inherently buoyant suit should be employed. 1 Air Division issued direction to discontinue the use of the Mustang Floater™ coveralls on 28 July 2006.

The FE's EBS cylinder was found empty and serviceable, and since it is a demand system vice constant flow, this suggests he probably used his EBS during his escape attempt. Although injured during the impact, he either attempted to but was unable to release his harness or decided immediately to use an alternate method. Based on the evidence that his anchor strap was cut by a serrated blade and his Bear Claw knife (which has a serrated edge) was missing from its sheath, it can be deduced that he cut the anchor strap in an attempt to escape. It is assessed that the "Bearclaw" modification to his LP/SV did not impede his attempted escape. The reason for his subsequent failure to escape before his air ran out may be related to being caught up in some of the debris near the damaged SAR Tech cabinet. Alternatively, he may have been disoriented and/or, because there was no HEELS lighting surrounding the cargo door opening, he was unable to recognize in the dark that the cargo door opening was close by and available as an exit.

The FEUT had EBS available and his bottle was found serviceable and empty, suggesting he probably used it during his egress attempt. He had managed to undo his anchor strap attachment and had moved aft in the cabin but was unable to successfully egress the helicopter. He was found beside the rear right side secondary window exit. Notably, half of the exit, including the emergency release pull-tab, was blocked by the maintenance ladder, which had shifted upwards when the helicopter became inverted. A portion of the ladder also blocked the lower portion of the nearby Type IV primary exit jettison handle and pull-tab. The rescue basket, which is stored beside the ladder, had shifted from its stored position as well but it is not clear whether it contributed additional blockage. No apparent attempt was made to jettison either the primary or the secondary exit window indicating that the FEUT was unable to accomplish this task before running out of air.

2.13.3 BAU failure to deploy

The failure of the BAU to deploy is significant for at least two reasons. First, the ELT will not begin transmitting until the BAU is jettisoned. Thus if a similar crash were to occur when the helicopter was operating by itself and away from potential visible witnesses, no one would be made aware, for some time, that the helicopter had crashed and there would be a commensurate delay in commencing a search and rescue effort. Second, from an investigative standpoint, if there had been no survivors and the helicopter had sunk to the bottom with the BAU it would be difficult to locate the wreckage and recover the CVR/FDR.

The reason for the BAU's failure to deploy from the aircraft was investigated by QETE. The mechanical release device of the BAU was checked and found functional. The auxiliary battery pack was located on the aircraft and appeared to be in good condition. The hydrostatic switch located near the port sponson was also retrieved. The hydrostatic switch was sent to the QETE Fluid and Vehicle Systems Lab for pressure tests. The switch required 20 psi of pressure (50 feet underwater) to close the BAU circuitry, which is in accordance with specifications. Hence, the hydrostatic switch was also functional. As the helicopter never reached this depth, the hydrostatic switch could not deploy the BAU.

Three of the four frangible switches on the aircraft were recovered. The missing frangible switch was located underneath the co-pilot's seat and presumably sank into the ocean with the rest of the nose section of the aircraft after the accident. The wire bundles attaching the switch to the ABP have extra slack that would extend during the break-up sequence before the wires finally failed. This delay would have allowed the electrical signal to be transmitted to the ABP. The recovered frangible switches were tested and were found to be in the "opened" position, indicating that they were intact and serviceable at the time of accident. The frangible switch assembly originally located at the tail section of the helicopter was then sent to the QETE Vibration Lab for shock tests in order to determine the amount of acceleration force required to break the switch hence closing the BAU circuitry. The frangible switch was subjected to a range of acceleration forces from +10G to +45G with a range of shock duration from four milliseconds to 11 milliseconds. After 63 trials of half sine pulse shape shocks and 90 trials of terminal peak saw tooth pulse shape shocks, the frangible still remained intact.

The glass bulbs of the two remaining frangible switches were subjected to a gradual load to determine if the switches meet the manufacturer's specifications. The first bulb broke at a load of 92 lbs and the second one broke at 30 lbs. The experimental results showed that the strength of the glass bulb varies greatly among the frangible switches and is much higher that the prescribed value.

Based on the analytical findings, it appears that the individual components of the BAU system were functional at the time of accident; however, the design of the entire BAU system precluded it from deploying. A frangible switch operates when the crash sensitive structure, where the switch is usually placed, deforms during the crash situation and breaks the glass bulb of the frangible switch, closing the BAU circuitry. It usually requires a direct impact in order for the glass bulb to break. In the CH149914 accident the frangible switches were inadequate in detecting the impact, even though the nose area of the aircraft was torn off from the rest of the fuselage. Currently, all the frangible switches are located in areas that are protected by robust structure. Frangible switches that are more sensitive and require less impact force to activate should be considered as well. A more reliable solution would include inertia switches to augment the frangible switches.

3 CONCLUSIONS

3.1 Findings

3.1.1 Flight restrictions imposed over the 18 months previous to the accident, including a limit of two flying hours for training flights, due to tail rotor half hub cracking, had severely limited the training opportunities and proficiency levels for CH149 crews, particularly at 413 (TR) Squadron.

3.1.2 The formal Risk Assessment process used to impose the flight restrictions focussed on technical risk and underestimated the potential risk to safety of flight associated with the resultant reduction in training flights and proficiency levels.

3.1.3 14 Wing Greenwood reported three successive RED stress points for CH149 aircrew proficiency in the 13 months preceding the accident.

3.1.4 A survey of 413 (TR) Squadron CH149 crews in January 2006 revealed that aircrew felt that their proficiency levels were decreasing to the point where the risk to safety of flight from their low proficiency levels exceeded the risk of an aircraft loss due to tail rotor half-hub cracking.

3.1.5 The results of the 413 (TR) Squadron survey were passed up the chain of command to 1 Canadian Air Division Headquarters.

3.1.6 Although there were several flight safety occurrences reported that could be related to Boat Hoisting proficiency, no specific flight safety events were entered into the Flight Safety Occurrence Management System database that were similar to the circumstances of this occurrence.

3.1.7 There was no clear direction in the airworthiness program documentation available to the OAA staff that a formal risk assessment was required in response to the stated concerns regarding declining CH149 aircrew proficiency.

3.1.8 No formal risk assessment was initiated related to the concerns raised regarding CH149 aircrew proficiency.

3.1.9 Based on a reassessment of the technical risk, the two-hour restriction was relaxed to three hours between inspections. The change in the restrictions was issued three weeks prior to the accident.

3.1.10 CH149 crews were required to attend a simulator training session once every 12 to 18 months. The simulator instructors at RAF Benson remarked on some of the different procedures that the CH149 pilots used, as compared to crews from other countries that operated the EH-101, and asserted that, in general, CF crews demonstrated a lower than expected level of proficiency than other EH101 crews of their experience.

3.1.11 To meet the demand for new CH149 pilots, the OTF was authorized by 1 Canadian Air Division to defer the Night Boat Hoist and other sequences to the operational squadrons to teach and complete.

3.1.12 CH149 training at the OTF does not adequately emphasize non-flying pilot duties.

3.1.13 CH149 training at the OTF does not adequately emphasize the use of automation in the operation of the CH149.

3.1.14 The CH149 SMM describes basic crew duties and methodologies for flying the OWTD procedure and recommends the use of automation in low visual cueing environments.

3.1.15 The CH149 SMM is lacking in specifics on how manoeuvres are to be carried out and what techniques are appropriate to a given mission scenario.

3.1.16 The AC had lost his currency and therefore his AC category in May 2006 because he was unable to complete the required night boat hoist sequence due to a lack of training opportunities. He subsequently completed the required training in June 2006 and his AC category and Check Pilot status were re-instated.

3.1.17 The AC was a multi-tour SAR and CH149 Check Pilot and was qualified and current for the mission.

3.1.18 The AAC was appointed the Squadron Standards Flight Commander.

3.1.19 The AAC was an FO Level III and had been working towards his AC upgrade, but was progressing at a slower than expected rate.

3.1.20 The AAC did not fly between 12 April 06 and 5 July 2006 due to an extended period of leave to attend to personal matters.

3.1.21 Upon returning to flying duties the first week of July, the AAC asked for a 30-day check to reset his currency. However, in addition to carrying out the 30-day currency requirements, 1 Cdn Air Div Orders required that an appropriate supervised Training Event be completed.

3.1.22 The Squadron check pilots assumed the AAC's request for a 30-day check was appropriate and did not confirm his re-currency requirements. He was erroneously given a 30-day check to reset his currency vice the appropriate Training Event and therefore remained non-current with a U/T Category.

3.1.23 Neither the AC nor the AAC himself were aware that the AAC was not current.

3.1.24 The FO was an experienced CH135/CH146 Tactical Aviation helicopter pilot who had just completed the CH149 conversion course in March 2006.

3.1.25 Following completion of his UCO the FO was immediately awarded an FO Level II category based on his previous non-SAR helicopter experience.

3.1.26 The FO was still becoming accustomed to the CH149 and was not yet fully proficient at operating the CH149 and fulfilling non-flying pilot duties.

3.1.27 As allowed for by 1 Canadian Air Division Orders, and as was the customary practice in the CH149 squadrons for AAC training flights, the AC chose not to sit in a pilot seat but rather to put the FO II in the left seat and the AAC (FO III) in the right seat for the duration of the mission.

3.1.28 The helicopter was serviceable at the time of the accident.

3.1.29 The switches on the collective are unlit and the individual switches can be very difficult to see in the dark.

3.1.30 The weather conditions were suitable for the planned training.

3.1.31 As was his custom, the FO did not use the recommended and available ANVS 20/20 equipment to calibrate his NVGs prior to the accident flight.

3.1.32 During the final approach to the boat the FO remained on NVGs while the AC and AAC de-goggled.

3.1.33 During the attempt to correct an unintended altitude deviation the AAC overshot the 100 ft target altitude and descended to approximately 60 ft AWL.

3.1.34 As the helicopter descended through about 100 ft AWL the FO stated he lost all external visual references.

3.1.35 As the AC began calling out radio altitudes during the inadvertent descent the FO briefly checked his own instruments, and, comfortable that the situation was under control, elected at that time to attempt to locate the hoist switches on the centre console in anticipation of the upcoming hoist sequence.

3.1.36 As the helicopter descended through 80 ft AWL the AC, seated in the jump seat, directed the AAC to go-around.

3.1.37 Although the Transition Up / Go-Around mode of the autopilot was engaged, the AAC overrode the autopilot and his use of manual cyclic inputs and inappropriate trim techniques saturated the series pitch actuators.

3.1.38 Due to the saturation of the series pitch actuators, there was a loss of rate dampening that combined with the helicopter's inherent instability to quickly develop a large nose-down attitude and a high descent rate.

3.1.39 The AACs manual inputs to the cyclic combined with the large nose down attitude precluded the autopilot's Low Height Safety Feature from effecting a positive recovery.

3.1.40 None of the three pilots were effectively monitoring the helicopter's final flight path as it descended towards the water.

3.1.41 The AAC was attempting to use external visual references to monitor the helicopter's performance and flight path.

3.1.42 The FO was not actively monitoring the flight instruments during the overshoot attempt.

3.1.43 The AC was fixated on the torque readings during the later portion of the overshoot attempt.

3.1.44 The external visual cues available to the pilots at the time of the accident were not suitable for maintaining safe separation from the water's surface, either with or without NVGs.

3.1.45 The initial crash forces were survivable.

3.1.46 The cockpit restraint systems functioned to prevent more serious injury to the pilots during the initial impact.

3.1.47 With the exception of the FO, all crewmembers had current RUET.

3.1.48 In the main and alternate standard SAR configuration at least two primary exits are available and unobstructed, which meets the Federal Aviation Regulations Part 29 requirements for transport category helicopter emergency exit requirements.

3.1.49 In the main and alternate standard SAR configuration, as specified in the CH149 Flight Manual, all secondary exits on the left side of the cabin and the forward secondary emergency exits on the right side are unavailable for use because they are obstructed by equipment or cabinets.

3.1.50 All emergency exits are marked by HEELS lighting. The HEELS lighting functioned as designed.

3.1.51 HEELS lighting does not mark the main cargo door entrance.

3.1.52 The storage location of the maintenance ladder partially blocked access to both primary and secondary exit emergency jettison devices. The blockage was exacerbated when the helicopter became inverted, causing the ladder to shift further towards the ceiling, blocking half of the available right side secondary exit and the jettison handle for the right side aft primary exit.

3.1.53 The current storage location of the rescue basket in the cabin and the restraint mechanisms in use create a potential for it to shift during inversion and block a secondary exit.

3.1.54 The four passenger seats maintained in position aft of the stretcher are a significant obstacle should either the left hand secondary escape windows or type IV escape window be required.

3.1.55 The crewman anchor strap/harness connection must be pre-set for either a right hand or left hand release and cannot be released when under tension.

3.1.56 The evidence indicates the FE cut his anchor strap with his “Bear Claw” knife but was unable to exit the cabin before using up the supply of air in his EBS.

3.1.57 The "Bear Claw" knife sheath affixed to the FE’s LP/SV is not a current modification for the CH149. MOD C-22-521-000/CF-013 is a published modification for the CH146 fleet only. It is assessed that this modification to his ALSE did not impede his attempted escape.

3.1.58 The FEUT was able to disconnect his anchor strap and move towards a rear secondary exit but was not able to open either the secondary or primary exit in the area of the ladder before his EBS air supply was exhausted.

3.1.59 The SAR Tech TM undid his harness but his position at the back of the cabin and the lack of an available EBS combined with the inherent buoyancy of the MS-185 Mustang Floater™ coveralls precluded his successful egress from the submerged helicopter.

3.1.60 The Aqualung Floatation Vest worn by the SAR Techs is incompatible with the current EBS assemblies.

3.1.61 Several of the LP/SVs used by the crew experienced an incomplete bladder deployment on inflation due to the failure of the left lobe cover zipper to completely separate.

3.1.62 The BAU did not deploy because the aircraft structure surrounding the frangible switches did not deform enough to activate the frangible switches.

3.1.63 Because the procedures required the cargo door to remain closed until the aircraft was established in the rest position, the FE was not in a position to effectively influence the actions of the pilots or the outcome of the flight when the helicopter was approaching the “rest” position or during the overshoot attempt.

3.2 Cause Factors:

3.2.1 Active Cause Factors

3.2.1.1 The flying pilot’s use of inappropriate trim techniques negated the helicopter’s autopilot capabilities such that there was an unrecognized loss of the helicopter’s rate dampening and stabilization capabilities leading to an unintended large nose down attitude and a significant descent rate.

3.2.1.2 The pilots did not perceive the aircraft’s attitude and flight path correctly because they did not adequately reference their flight instruments in the low visual cueing environment.

3.2.2 Latent Cause Factors

3.2.2.1 The prolonged imposition of the two-hour flight restriction and associated imposed training limitations contributed to a degradation of skill levels and an overall lack of proficiency among 413 (TR) Squadron aircrew.

3.2.2.2 The processes used by 1 Canadian Air Division Headquarters staff did not identify timely or effective mitigation measures to deal with the specific risk represented by the lowered proficiency levels identified in the Flight Safety Stress Points report and the Flight Safety Survey.

3.2.2.3 The overall lack of aircraft system knowledge and flying proficiency on the part of the AAC and FO, coupled with the AC’s decision to allow them to occupy both pilot seats during a critical and demanding phase of flight, contributed to the accident.

3.2.2.4 Also contributing to the accident was the lack of CH149 SMM detailed information describing the specific duties, techniques and procedures to be used by CH149 crews in conducting standard sequences.

3.2.2.5 The CH149 SMM provides direction of a general nature and is oriented towards safe practices but the SMM leaves too much room for individual interpretation and application. Specifically, the SMM does not actively encourage the optimum use of the CH149's automation capability to improve the safety of flight.

4 PREVENTIVE MEASURES

4.1 Preventive Measures Taken

4.1.1 All FOs at 413 (TR) Squadron were re-assessed on co-pilot (FP and NFP duties) during the transition procedures. New pilots arriving from the OTF have completed a confirmation training flight as part of their UCO to confirm OWTD procedural knowledge prior to receiving their SAR category.

4.1.2 The use of the MS-185 Mustang coveralls inside the helicopter is no longer authorized. 1 Canadian Air Division directed it be discontinued in the message DCOMD FG 038 281845Z JUL 06. SAR Techs are continuing to use dry suits for training and operations.

4.1.3 The 1 Canadian Air Division Order 3-101 allowing two CH149 FO's to fly together has been rescinded via TRSET message OC110 291851Z NOV 06.

4.1.4 The partial inflation malfunction of the LP/SV is being addressed through a modification to the bladder cover and a replacement of the manual inflation device. Following trial and evaluation, a modification has been approved by the TAA and modifications to the LP/SVs will begin in the first quarter of 2008.

4.1.5 When unused, the two centre seats are to be removed and stowed behind the stretcher and below the left side secondary escape exits. The stowed seats are secured to allow no movement if the helicopter should become inverted.

4.1.6 Pending formal changes to the SMM, 413 (TR) Squadron introduced procedures that require the pilots, during transitions, to verbalize attitude, airspeed and altitude deviations from the norm, as well as additional calls to improve crew situational awareness. Beeping is being emphasized as the preferred way to having the aircraft move while in HOVER mode. The Squadron is highly recommending to its pilots that all night boat departures be flown using the go-around mode vice manually flown.

4.1.7 A coordinated Aeronautical Engineering and Test Establishment / Transport Operational Test and Evaluation Flight project is underway to test a new Crewman Restraint Release for use on the CH149 and CH146 aircraft.

4.2 Further Preventive Measures Required

4.2.1 It is recommended that the TAA take action to have the maintenance ladder moved from its present location below the windows at the rear of the FE seat and to place it in a location that will not cause the ladder to obstruct any emergency escape route.

4.2.2 It is recommended that the TAA take action to either relocate the current rescue basket, or by some other means, ensure that a rescue basket can be carried that will not shift and block an exit should the helicopter become inverted.

4.2.3 It is recommended that OAA and TAA initiate a full review of the CH149 Cormorant cabin configuration to ensure that emergency exits are kept completely unobstructed in sufficient numbers to allow all cabin occupants unimpeded access to one primary and one secondary emergency egress route in case of crashes over land or water. The egress routes must consider the tendency of the helicopter to roll inverted following water emergency landing.

4.2.4 It is recommended that the TAA and OAA find a suitable means to ensure that SAR Techs are able to have ready access to EBS while wearing their floatation vests and restraint harnesses.

4.2.5 It is recommended that the TAA and OAA replace the current harness/anchor strap attachment mechanism with a safety harness that incorporates a quick release single-action system (paragraph 4.1.7 relates to the initial work carried out with respect to this recommendation).

4.2.6 It is recommended that the TAA and OAA certify the use of the “Bear Claw” knife (or some similar knife) for use by Flight Engineers aboard the CH149.

4.2.7 It is recommended that TAA install a HEELS lighting system around the main cargo door frame with a method to ensure it would activate if the main door were to depart the helicopter.

4.2.8 It is recommended that OAA modify the CH149 SMM to include more information on the non-flying pilot’s duties.

4.2.9 It is recommended that OAA modify the CH149 SMM to include detailed descriptions of the OWTD and TU procedures. The new material must describe very precisely the individual crew duties, with no deviations permitted unless they are briefed as a non standard procedure.

4.2.10 It is recommended that the OAA take steps to ensure that the CH149 and other automated fleets are flown in a way that optimizes the safety advantages conferred by the aircraft's automatic flight control system.

4.2.11 It is recommended that the CH149 Conversion course be modified to provide more training in non-flying pilot duties and that the use of automation receive greater emphasis in syllabus.

4.2.12 Until the Half-Hub Tail Rotor Flight Restrictions are lifted, it is recommended that simulator training frequency be optimized to maintain a high level of proficiency.

4.2.13 It is recommended that the OAA implement a process to formally assess CH149 simulator training sessions and implement a feedback process to the TRSET and the units.

4.2.14 It is recommended that the OAA confirm the validity of NVG mixed crew operation in the different SAR mission profiles through appropriate operational trial and evaluation to better assess the consequences on the crew's situational awareness and performance.

4.2.15 It is recommended that the OAA cause the use of the NVG HUD to be operationally tested and evaluated to determine its suitability for use in the CH149 SAR role.

4.2.16 It is recommended that the OAA modify the SMM to have the FE open the cargo door and visually assist the pilots as they move from the TD 2 hover position to the "rest" position during night OWTD procedure.

4.2.17 It is recommended that the DFS engage with the OAA and TAA to investigate the implementation of flight data monitoring or other such flight operational data gathering processes, such as Line Oriented Safety Audits, where applicable and practical.

4.2.18 It is recommended that TAA modify the BAU system to ensure its deployment in all crash scenarios.

4.2.19 It is recommended that the OAA, in consultation with the Airworthiness Authority and in consideration of the A-GA-005 DND/CF Airworthiness Program document, provide clear direction to the OAA staff on the circumstances that would require a RARM to be completed for operationally oriented risks. It is also recommended that, when applicable, the RARM process fully consider, mitigate, and revisit as required, the potential risks associated with the reduced aircrew proficiency resulting from any imposed flight restrictions.

4.3 Other Safety Concerns

Nil.

4.4 DFS Remarks

This investigation had two main objectives: to determine why multiple layers of defences failed to keep the crew of TUSKER 914 safe, and to recommend measures to prevent a recurrence.

This accident occurred during a period when the Canadian Forces was making strenuous efforts to mitigate the most prominent risk to the Cormorant fleet: a possible failure of the tail rotor half-hub. Cracks in the half-hub represented a significant risk to the safety of flight. These cracks were evident, their appearance and growth could be recorded and specific technical measures were taken to reduce the risk to safety. Engineers estimated that by restricting the length of training missions to two hours, (later revised to three), there could be a high degree of confidence that unacceptable cracks would be detected before they could pose any real threat. These restrictions imposed on training flights were reasonable and responsible measures to have been taken in the face of this problem. The defences put in place dealt very well with this specific technical risk as identified. Nonetheless, the slow degradation of crew proficiency that resulted from the combination of flying hour restrictions and low Cormorant availability presented another kind of risk, against which the existing defences proved inadequate.

The 413 (TR) Squadron flight safety survey indicated that aircrew proficiency was becoming a concern, and the wing commander forwarded this to the Air Division headquarters as a “red” flight safety stress point. Although the headquarters staff recommended increasing training flight duration from two to three hours to alleviate the proficiency concerns, the effect such relaxation might have had on the risk presented by half-hub cracking could not be reasonably estimated until further technical data became available. As the headquarters staff proposed no other options to alleviate the proficiency concerns, it is hardly surprising that the Division Commander declined to accept an unknown increase to the risk related to half-hub cracking to mitigate an unquantified and uncertain amount of risk related to the assertion that proficiency levels might be too low for safety. Unfortunately, no other measures to mitigate the proficiency risk were taken. The Flight Safety Stress Points submission was viewed as an informational situation report, and was not regarded by command or staff as a trigger for a formal risk assessment of the concerns identified in the reports. The Commander and the staff noted and sought to ameliorate the concerns, but the focus remained on clarifying the technical issues surrounding half-hub cracking. There is no documentary evidence that increased use of the simulator at RAF Benson, imposing restrictions on certain mission profiles, or any other measures were considered among the possible ways to address the proficiency issue. This points to a weakness in the risk management process then employed at 1 Canadian Air Division, in that an opportunity to more fully analyse the proficiency risk and perhaps mitigate it was missed. The result was that all levels of command up to and including the 1 Canadian Air Division tacitly accepted an unanalysed level of proficiency related risk in the Cormorant operation at 413 (TR) Squadron by accepting the status quo.

Assessing risk related to aircrew proficiency levels can be extremely difficult. As explained earlier in the report, flying orders regulate currency by mandating a certain number of flying hours be flown and/or sequences be performed over a specified period. Proficiency, as such, is assessed formally only during check flights that occur annually or when required because of specific situations, such as a lapse of currency. These check flights represent limited data points when it comes to assessing the overall proficiency of a unit. Many airlines, and some air forces, use flight data monitoring regimes to proactively identify operational problems, such as aircrew proficiency, on a continuous basis. Flight data monitoring is the routine and automatic analysis of flight data to find events of interest and to identify problems without having to wait for a serious outcome, such as a mishap. Flight data monitoring programs routinely examine many parameters (sometimes thousands in modern aircraft) automatically to identify individual events that, if left unresolved, might eventually result in an accident. The Cormorant is fitted with modern flight data recorders that have the potential to support a flight data monitoring program. Had such a program been in place since the acquisition of the Cormorant, there would have been a far higher level of certainty concerning the question of whether or not aircrew proficiency represented a serious risk, and there would have been a basis for taking stronger action to address the concerns posed by the 14 Wing surveys and reports. In the absence of a flight data monitoring program, the Flight Safety Occurrence Management System was the only other mechanism whereby proficiency concerns might have been flagged to the chain of command. However, it did not identify any precursors to this mishap. Unfortunately, as the Flight Safety Occurrence Management System depends upon the voluntary reporting of errors and a manual input of data, there cannot be a high level of confidence that an absence of reports equals an absence of problems. A well-designed flight data monitoring regime might have flagged more clearly a decrease in the proficiency of challenging manoeuvres such as boat hoisting to the chain of command. Such a regime did not exist and so a potentially important source of information was not available for analysis, resulting in a bias towards maintaining the status quo.

The fact that Cormorant aircrew reported losing confidence in their proficiency did not of itself make this accident inevitable. The automated safety features of the Cormorant helicopter were a significant defence against this type of mishap, even in a scenario of generalized diminishing crew proficiency. The CH149 is extremely sophisticated and has all the necessary systems to allow its crew to operate safely in a low visual cueing environment over water. Yet, the actions of the pilots essentially negated the safety features of the aircraft. The inappropriate manipulation of the controls by the flying pilot made it impossible for the automation to maintain the helicopter within safe flight parameters. Further, the misprioritization of cockpit duties on the part of the pilots not-at-the-controls meant that the gravity of the situation was never perceived. That the crew did not employ these systems properly is the consequence of missed opportunities in the design of the Cormorant Conversion Course, of inadequate direction given in the Standard Manoeuvre Manual and of the sub-optimal conduct of simulator training at RAF Benson. More broadly, this speaks to systemic deficiencies in how modern aircraft are fielded by the air force and the standards to which crews fly them. Although modern technology has been introduced piecemeal into the air force through new aircraft acquisitions and aircraft upgrades, on the whole the air force did not grasp the impact that automation has on modern flight operations. The air force operates some automated aircraft, but the crew training for these occurs at civilian contractors or with foreign air forces. As a result, the concepts related to the use of automation did not become embedded in air force culture and therefore the optimal employment of automation was not sufficiently emphasized in the CH149 training. As a result pilots retained too much discretion as to how and when to use automation when manoeuvring the aircraft. The air force needs to address this cultural issue as a priority, given the number of advanced aircraft that will be introduced over the next few years.

Lastly, once the aircraft crashed, a number of factors combined to cause the deaths of the three crewmembers. The analysis of this aspect of the accident noted deficiencies in aviation life support equipment and aircraft configuration. This crash presented a worst-case egress situation given the total lack of warning and the massive destruction of the front end of the aircraft. Remedying the aviation life support equipment and configuration issues should improve the chances for crew egress should a similar crash occur in the future. Similarly, implementation of the other preventive measures recommended should reduce the chances for a similar mishap to recur.

C.R. Shelley
Colonel
Director of Flight Safety

ANNEX A

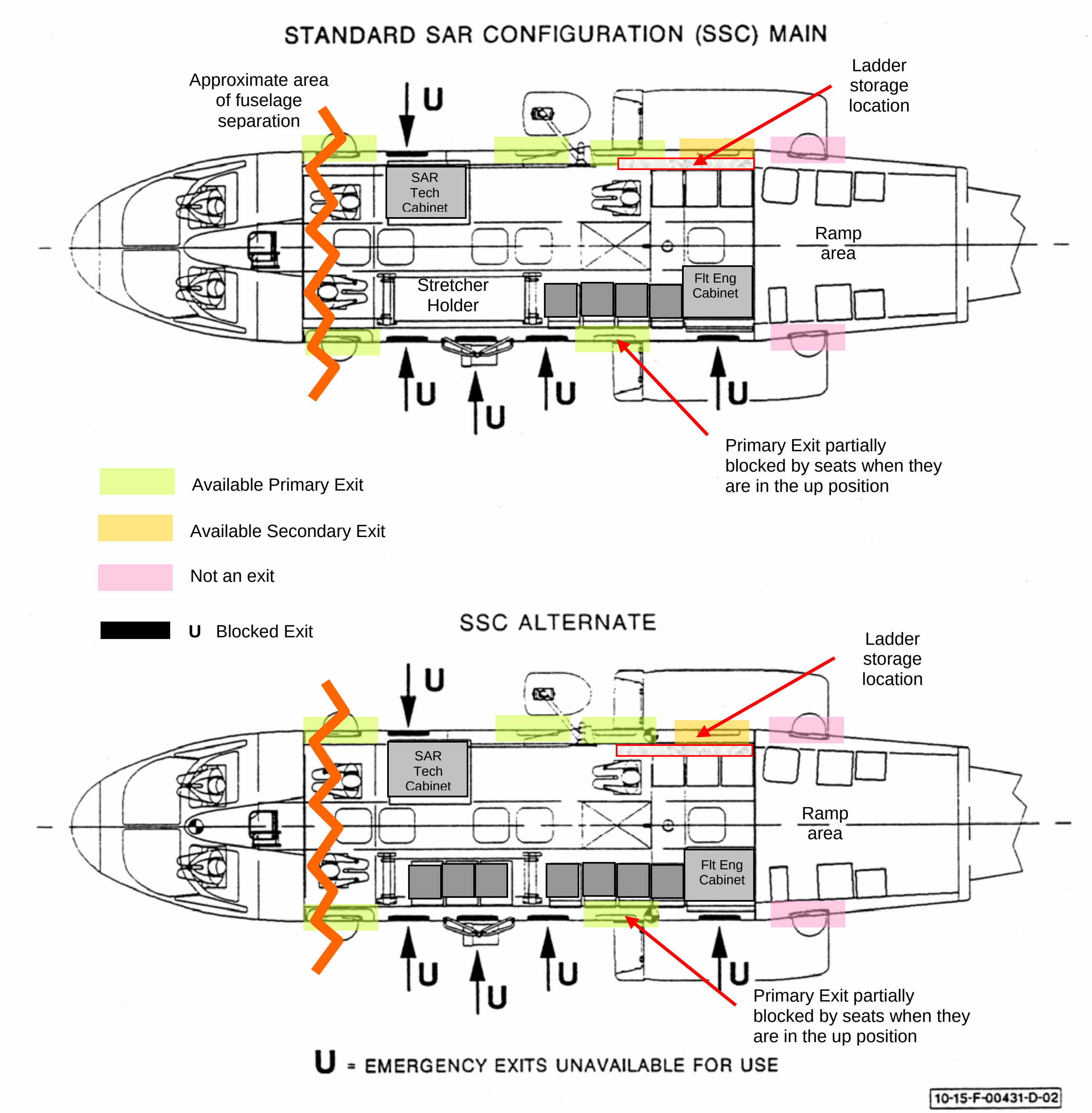
ABBREVIATIONS

1 Cdn Air Div	1 Canadian Air Division
AAC	Acting Aircraft Captain
ABP	Auxiliary Battery Pack
AC	Aircraft Captain
AFCS	Automatic Flight Control System
AFIP	Armed Forces Institute of Pathology
AMP	Approved Maintenance Program
ARU	Airfoil Release Unit
ASE	Autostabilization System
AWL	Above Water Level
BAR	Barometric
BAU	Ballistic Airfoil Unit
CCGS	Canadian Coast Guard Ship
CDS	Chief of the Defence Staff
CFB	Canadian Forces Base
CO	Commanding Officer
CVR	Cockpit Voice Recorder
EBS	Emergency Breathing System
EIS	Electronic Instrument System
ELT	Emergency Locator Transmitter
ELU	Electro-luminescent Unit
FAF	Final Approach Fix
FDR	Flight Data Recorder
FE	Flight Engineer
FEUT	Flight Engineer Under Training
FO	First Officer
FP	Flying Pilot
fpm	Feet per minute
FSIR	Flight Safety Investigation Report
GA	Go-around
HEELS	Helicopter Emergency Exit Lighting System
HOV	Hover
HUD	Heads Up Display
IAS	Indicated Airspeed
LP/SV	Life Preserver / Survival Vest
METAR	Meteorological Actual Report
MND	Minister of National Defence
NFP	Non-Flying Pilot
NVG	Night Vision Goggle(s)
OAA	Operational Airworthiness Authority
OTF	Operational Training Flight
OWTD	Over Water Transition Down

PCU	Pilot Control Unit
PFD	Primary Flight Display
PO	Performance Objective
QETE	Quality Engineering and Test Establishment
RAD	Radio
RARM	Record of Airworthiness Risk Management
RUET	Rotary Underwater Egress Training
SAR	Search and Rescue
SAR Tech	Search and Rescue Technician
SMM	Standard Manoeuvre Manual
TAM	Technical Airworthiness Manual
TD	Transition Down
TL	Team Lead
TM	Team Member
TR	Transport and Rescue
TRSET	Transport and Rescue Standards and Evaluation Team
TUP	Transition Up
UAC	Utility Aircraft Captain
UCO	Unit Check Out

ANNEX B

CH-149 Cabin Configurations



ANNEX C

Photographs

Photograph 1: A CH149 Cormorant

Photograph 2: Damaged fuselage of CH149914

<u>Photograph 3</u>: Damage to the front of CH149914

<u>Photograph 4</u>: CH149 floating inverted, tethered to the CCGS Earl Grey

Photograph 5: Typical SAR Cabin configuration of the CH-149 (looking forward from the back of the cabin)

Photograph 6: Standard SAR configuration layout, looking at the left side of the cabin.

Photograph 7: Secondary exits partially blocked by passenger seats.

Photograph 8: Secondary exit with external view with the ladder positioned as it was found, blocking the exit in CH149914

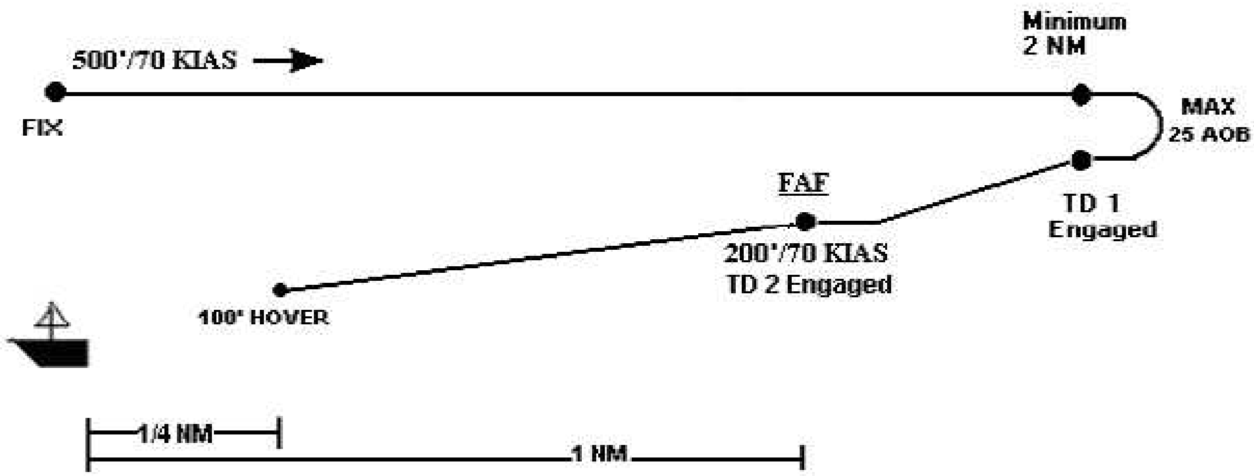
Photograph 9: Secondary exit (in the foreground) with the maintenance ladder and rescue basket stowed beneath it. Note HEELS lighting around the exit. The window release pull tab is hidden behind the ladder.

Photograph 10: SAR Tech seat beside the left side forward primary exit. Note EBS bottle located to the lower left of the window.

Photograph 11: Anchor Strap attachment point to restraint harness.

ANNEX D

The Overwater Transition Down Procedure



KIAS: Knots Indicated Airspeed
NM: Nautical Miles
AOB: Angle of Bank
FAF: Final Approach Fix
TD Transition Down

Annex E
To 1010-149914 (DFS 2-3)
Dated: 22 January 2008

ANNEX E
Map of Accident Location