SOUTH AFRICAN CIVIL AVIATION AUTHORITY

Section/division Accident and Incident Investigation Division Form Number: CA 12-12a

AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

		Reference:	CA18/2/3/9420

Aircraft registration	**ZS-HBV**	**Date of accident**	8 March 2015	**Time of accident**	1000Z
Type of aircraft	Garlick UH-1H (Helicopter)		**Type of operation**	Fire fighting	
Pilot-in-command licence type		Commercial	**Age** 71	**Licence valid**	Yes
Pilot-in-command flying experience		Total flying hours	10 970.7	Hours on type	227.6
Last point of departure	Newlands Forest Station, Western Cape				
Next point of intended landing	Cape Point National Park, Western Cape				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
Open field in the Cape Point National Park (GPS position: 34°15.771' South 018°25.101' East)					
Meteorological information	Surface wind: ±160°/10kt gusting 20kt, Temperature: 16°C, Visibility: + 10 km				
Number of people on board	1 + 0	**No. of people injured**	0	**No. of people killed**	1

Synopsis

On 8 March 2015, at approximately 1000Z, a Garlick UH-1H helicopter, registration ZS-HBV, impacted terrain in the Cape Point National Park. The pilot, the sole occupant on board the helicopter, sustained fatal injuries, and the helicopter was destroyed by impact forces and post-crash fire. The helicopter was being operated by a licensed air operator on a water bombing mission. The flight originated from the Newlands Forest Station, at approximately 0945Z. Day visual meteorological conditions prevailed, and no flight plan was filed nor was one required for the flight. The flight of three helicopters took off from Newlands Forest Station with the accident helicopter in trail. About 17 nautical miles south of the departure point, the pilot of the accident helicopter radioed that he had a chip light in the cockpit, and, after being queried by one of the other pilots, indicated that it was in the back. The other two pilots understood "back" to mean that the chip light was related to one of the two tail rotor gearboxes. One of the pilots suggested that the accident pilot land on the road to Cape Point just below him. The accident pilot stated that he would fly on to where the helicopter support vehicle was located, which was about one nautical mile away. The other two helicopters flew on to the dam to pick up water using their Bambi buckets; however, about 10 seconds after the chip light reported, they heard the accident pilot call "mayday mayday mayday". At that point, the two other helicopters turned around and saw the accident helicopter at about 800 feet above ground level (AGL) spinning to the right and "gyrating wildly in very unusual attitudes". As the helicopter descended, the Bambi bucket, which was still attached to the accident helicopter, swung up into the main rotor. The helicopter descended rapidly, impacted terrain and subsequently caught fire. One of the pilots stated that he thought he could remember seeing the blades of the tail rotor, which indicated to him that they "weren't spinning at the correct speed".

Probable cause

The pilot was unable to regain control of the helicopter following a loss of tail rotor thrust, which was caused by fracture of the left-hand aft control cable during flight, followed by the failure of the tail rotor driveshaft.

SRP date	14 March 2018	Release date	

AIRCRAFT ACCIDENT REPORT

Name of Owner	: FFA Assets (Pty) Ltd
Name of Operator	: FFA Aviation (Pty) Ltd (T/A FFA, Working on Fire)
Manufacturer	: Garlick Helicopter Corporation
Model	: UH-1H
Nationality	: South African
Registration Marks	: ZS-HBV
Place	: Cape Point National Park
Date	: 8 March 2015
Time	: 1000Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to establish legal liability**.*

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 On Sunday, 8 March 2015 at 0934Z, the Newlands Fire Station received a call from a South African National Parks official that a fire in the Cape Point area had flared up again and they needed to dispatch three helicopters to assist in fighting the fire. A spotter aircraft, a Cessna 182 (ZS-TMT) was dispatched from Stellenbosch aerodrome (FASH) to the Cape Point National Park and three helicopters, each equipped with a Bambi bucket suspended below each helicopter, were dispatched from the Newlands Forest Station in Cape Town. The flight was conducted during daylight visual meteorological conditions, and no flight plan was filed nor was one required for the flight.

1.1.2 Three helicopters, all of them being UH-1H, with registration markings ZS-SLK, ZU-MST and ZS-HBV, took off from the Newlands Forest Station at approximately 0945Z, with the pilot flying ZS-SLK taking the lead followed by ZU-MST and then ZS-HBV. Shortly after take-off they encountered low cloud and climbed to about 2 000 feet above ground level (AGL) to clear the cloud and associated turbulence above it. While flying en route to the fire, approximately 10 nautical miles (nm) after passing over Ou Kaapse Weg, the pilot flying ZS-HBV broadcast on the company frequency 120.55 MHz that a transmission chip warning light (amber light) had come on on the caution/annunciator panel. The leading pilot then asked him if it was the front or back chip light (main rotor gearbox or tail rotor gearboxes), to which he replied that it was the back chip light. The lead pilot then suggested that he land as soon as possible on the service road leading to Cape Point, which was slightly to his left, as there was a truck on the road that could assist him as the ladder that was required to inspect the two tail rotor gearboxes (42° intermediate gearbox and the 90° tail rotor gearbox) was not available in the helicopter. The pilot of ZS-HBV then replied that he wanted to continue to where the helicopter support vehicle (HSV) was going to be at the head of the fire, namely about another 2 nm further to the south of his current position, as there would be people that could assist him. (The helicopter operator's manual, chapter 9, states that if the chip caution light, which is an amber light, comes on during flight, the pilot should land as soon as possible. Both the 42° intermediate gearbox as well as the 90° tail rotor gearbox were equipped with a magnetic plug, which should be removed and inspected for the presence of sediments, which may contain metal particles/wear debris, heavier than oil, which will settle to the bottom of the gearbox, where the magnetic plug(s) is located.)

1.1.3 The lead pilot had already uplifted his first load of water from the Sirkelsvlei dam and the second helicopter was positioning to uplift his load when they heard over the radio *"mayday, mayday, mayday"* from the pilot flying ZS-HBV. Both pilots immediately executed a 180° turn towards the north and saw the helicopter out of control at about 800 feet AGL with very little to no forward speed. The helicopter was spinning in a clockwise direction (to the right) and was gyrating wildly in very unusual attitudes. The pilot flying the second helicopter recalled that he could see the tail rotor blades, which meant that they weren't turning at the correct speed. The lead pilot told the pilot in ZS-HBV to *"cut the power"* twice, but the helicopter continued to spin wildly towards the ground. At approximately 70 feet AGL, he observed the Bambi bucket, which was still attached to the cargo sling, swinging up into the main rotor blades due to the helicopter oscillations. At this stage the helicopter was descending rapidly and it impacted the ground in a nose-down attitude, after which it rolled over and a post-impact fire erupted in the area of the main wreckage. The lead pilot then requested the other pilot to uplift water and start dousing the flames, as he had dumped his load and landed at the scene of the accident in aid of the pilot. The pilot flying ZU-MST continued to drop Bambi bucket water loads onto the burning wreckage. In an interview with the pilot he indicated that he dropped approximately twenty (20) loads of water before the fire was contained; nevertheless, the main wreckage was consumed by the post-impact fire.

1.1.4 The pilot who landed at the scene of the accident stated that he took the portable fire extinguisher on board the helicopter with him and ran to the wreckage. At that stage the flames were on the right of the wreckage, so he ran towards the left in an attempt to pull the pilot out of the wreckage. He then saw the pilot lying on the ground a few metres from the main wreckage. He was still strapped into his seat, which had been flung to the right of the impact point. He pulled him away from the wreckage, as he feared an explosion and getting splashed with burning fuel. He further stated that the pilot was too heavy for him to pick up and carry to his helicopter. He then unhooked the Bambi bucket underneath the helicopter and flew to the nearby service road where ground personnel were standing; he uplifted four ground crew members and flew back to the scene. They landed, carried the pilot to the helicopter and flew back to the service road.

1.1.5 The spotter aircraft pilot immediately informed dispatch at Newlands Forest Station as well as Stellenbosch aerodrome of the accident and requested medical assistance. At 1024Z an Air Mercy helicopter called inbound to the scene. The spotter pilot escorted the helicopter to the location on the service road. The pilot was fatally injured in the accident. The two remaining firefighting helicopters then withdrew from the area and returned to the Newlands Forest Station. The spotter aircraft also returned to the Stellenbosch aerodrome (FASH). All the relevant authorities were notified of the accident.

1.1.6 The accident occurred during daylight conditions at a geographical position that was determined to be 34°15.771’ South 018°25.101’ East, at an elevation of 272 feet above mean sea level (AMSL). The Sirkelsvlei dam, where water was uplifted by the pilot flying the lead and thereafter by the second pilot, who doused the flames of the crashed helicopter, was 620 m south-west of the accident site. The prevailing wind at the time in the area was south-south-easterly at 10 knots with gusts up to 20 knots. (All graphical overlays are provided in a north-up orientation.)

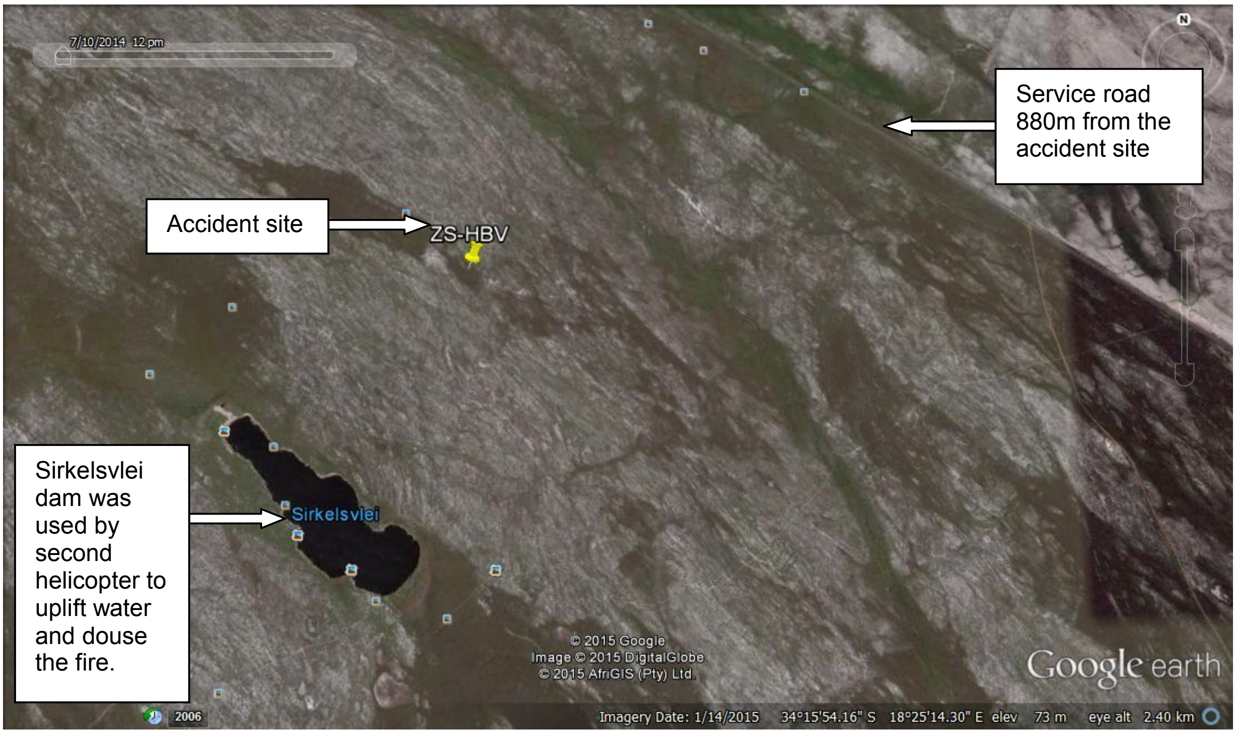


Figure 1. Google Earth overlay indicating the accident site in relation to the Sirkelsvlei dam and the service road

1.2 Injuries to persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to aircraft

1.3.1 The main wreckage was destroyed during the impact sequence and post-impact fire. The tail boom was severed from the fuselage during ground impact, with the forward as well as the aft section of the tail boom not being exposed to any fire damage.

Figure 2. The main wreckage

1.4 Other damage

1.4.1 An area of approximately 30 m² of vegetation was destroyed by the post-impact fire.

1.4.2 According to the pilot flying the second helicopter, he had dropped approximately 20 bucketloads of water on the burning wreckage, which he had uplifted from the Sirkelsvlei dam. The capacity of the Bambi bucket was approximately 1 200 litres.

1.5 Personnel information

1.5.1 Pilot-in-command

Nationality	South African	Gender	Male	Age	71
Licence number	0270161391	Licence type	Commercial pilot		
Licence valid	Yes	Type endorsed	Yes		
Ratings	Night, Undersling/Winch, Cull, Test Pilot class 2				
Medical expiry date	31 May 2015				
Restrictions	1. To fly with suitable corrective lenses 2. Annual stress ECG				
Previous accidents	None				

1.5.2 According to evidence obtained from the CAA pilot file as well as a pilot logbook entry, he had concluded his aircraft differences and familiarisation training on the Bell 205 type helicopter on 1 May 2011 through an approved aviation training organisation (ATO). On 19 May 2011 the required paperwork was received by the regulating authority and the helicopter type was endorsed on the pilot's licence.

1.5.3 According to available records (pilot logbook entry), the pilot had conducted a company proficiency check flight on 8 July 2014 on a Bell 205 helicopter with registration ZS-HLP. The flight was conducted with the company's chief pilot. According to available records (pilot logbook entry), his last commercial pilot revalidation skills test was conducted on 8 November 2014 on a Bell 205 helicopter with registration ZS-HHG. This flight was conducted under the auspices of a designated flight examiner.

1.5.4 During the period 1 January 2015 until 8 March 2015 (67 days) the pilot flew actively on sixteen days and conducted twenty-two flights. It was further noted that he had been on active duty from 28 February 2015 until 3 March 2015. He then had one rest day on 4 March 2015 and commence with active duty again the following day until Sunday 8 March 2015. During this period he flew operationally every day and conducted a total of ten flights, including the accident flight. The pilot flew this helicopter (ZS-HBV) the day prior to the accident flight, and according to the flight folio entry (page 0134) the duration of the flight was 1.6 hours.

1.5.5 Flying experience:

Total hours	10 970.7
Total past 90-days	54.0
Total on type past 90-days	54.0
Total on type	227.6

The pilot also held a fixed-wing pilot licence. The table below reflects his flying hours on both types.

Total fixed-wing hours	1 082.8
Total helicopter hours	9 887.9
Grand total	**10 970.7**

1.5.6 Aircraft Maintenance Engineer (AME - stamp #10)

Nationality	South African	Gender	Male	Age	59
Licence number	0272019795	Licence type	AME		
Licence valid	Yes	Type endorsed	Yes		

1.5.7 Aircraft Maintenance Engineer (AME – stamp #6)

Nationality	South African	Gender	Male	Age	55
Licence number	0272312042	Licence type	AME		
Licence valid	No	Type endorsed	Yes		

1.6 Aircraft Information

1.6.1 The Garlick UH-1H helicopter, with serial number 66-16024, was manufactured by Bell Helicopter as serial number 05718 in 1967 and was first registered in South Africa in July 2008. It had a thirteen-seat capacity. It had two main rotor blades, which rotate in an anti-clockwise direction when viewed from above, and a two-bladed semi-rigid tail rotor. The helicopter was powered by a single Lycoming T53-L-13B turboshaft engine, rated at 1 400 shaft horsepower. The maximum gross weight of the UH-1H helicopter was 9 500 pounds (4 309 kg). The pilot, who is provided with a four-point safety harness, normally flies the helicopter from the right seat. The helicopter was equipped with a skid-type landing gear.

Figure 3. The helicopter ZS-HBV, courtesy of Dale Carter

Airframe:

Type	Garlick UH-1H	
Serial number	66-16024	
Manufacturer	Garlick Helicopter Corporation	
Year of manufacture	1967	
Total airframe hours (at time of accident)	7 985.2	
Last phase inspection (hours & date)	7 920.7	20 January 2015
Hours since last phase inspection	64.5	
C of A (issue date)	14 August 2008	
C of A (issue expiry date)	13 August 2015	
C of R (issue date) (present owner)	19 August 2009	
Operating categories	Restricted Part 127	

Engine:

Type	Honeywell T53-L-13B
Serial number	LE-18532
Hours since new	1 622.4
Hours since overhaul	TBO not yet reached

1.6.2 The helicopter was maintained under the phase maintenance inspection schedule, with its most recent maintenance inspection, which was a phase 4 inspection, being certified on 20 January 2015 at a maintenance facility located on the farm Diepkloof near Malmesbury. According to the helicopter flight folio page 0129, a duplicate inspection on all flight controls was conducted by an aircraft maintenance engineer (AME), stamp #10 and AME, stamp #W3 (held an electrical AME licence), as per the approved maintenance schedule and relevant Civil Aviation Regulations (CARs), Part 43.04.8. The AME, stamp holder #W3, was not qualified to certify a duplicate inspection on the flight controls of this helicopter.

1.6.3 While the helicopter was deployed and maintained in the Western Cape, the airframe and engine logbooks were kept at the company maintenance headquarters at Nelspruit aerodrome. Following the phase 4 inspection, referred to in subparagraph 1.6.2, an AME, stamp holder #6 was found to have certified a dual inspection in the helicopter airframe logbook on page 95 as well as a dual inspection on page 44 of the engine logbook without being present at the maintenance facility on the farm Diepkloof near Malmesbury to conduct a visual inspection on the airframe and engine. He had also certified a duplicate inspection on the certificate relating to maintenance on an aircraft (CRMA) number 848. This was found to be in contravention of Part 43.01.2 and Part 43.02.2(1)(b). It was further noted that the AME who had signed off these entries in the respective logbooks was not the holder of a valid AME licence at the time. According to available evidence, his AME licence had expired on 1 June 2013 and was renewed with the regulating authority on 31 March 2015. He was therefore not the holder of a valid licence at the time he had made these entries in the logbooks and signed them off; this was found to be in contravention of Part 43.01.5(1)(a). It was further noted that the Phase 4 inspection had not been duly signed off on page 95 of the airframe logbook or on page 44 of the engine logbook by the maintenance engineer who had conducted the inspection, even though the relevant entries were documented in the respective logbooks.

1.6.4 Following further examination of the maintenance documents, it was found that the previous phase inspection (phase 3) dated 12 September 2014 on this helicopter had been conducted and signed off in the airframe and engine logbooks by an AME with stamp #6. At the time he conducted the maintenance, his AME licence was invalid. He had conducted maintenance and completed the relevant paperwork to support such an inspection not only in the logbooks, but also on the phase maintenance schedule/checklist contained in the work pack (reference number 803).

1.6.5 The approved maintenance schedule, UH-1H Phase Inspection Check Sheet QC/43/AMO 1116/00848/5, document number QC43/PM/UH-1H, was used during the Phase 4 inspection. This document makes provision for the inspection of the tail rotor drive chain on page 35 of the 42-page maintenance schedule, with the emphasis on the aft control cables and pulleys. The table below reflects the content that was applicable to the inspection under the subheadings. The inspection status on both of the subheadings (3 and 4) is indicated as 'S' (serviceable) and was accordingly signed off by two respective maintenance engineers. The page was signed off at the bottom by stamp holder #QC (Quality Controller). The helicopter had flown 64.5 hours since this inspection was certified.

Inspection Requirements:	**Status**	**Faults and/or Remarks:**	**Action Taken:**	**Mechanic Signature**	**CI Signature and Stamp:**
3. Tail rotor control aft cables for chafing, broken wires and security. (Access Panels 13 and 14, Fig 1-4)	'S'	NIL	NIL	Signed by stamp #2	Signed by stamp #10
4. Control cable pulleys for wear and damage. (Access Panels 13 and 14, Fig 1-4)	'S'	NIL	NIL	Signed by stamp #2	Signed by stamp #10

1.6.6 The approved maintenance schedules for both the non-type-certified aircraft (NTCA) as well as the certified UH-1H helicopters requires that daily inspections be conducted on these helicopters before or after every flight. These inspections are to be conducted by a type-rated certified AME who is duly authorised, as stated in the Aircraft Maintenance Schedule (AMS). During the review of the maintenance records (work pack no. 848) it was noted that the last daily inspection check sheet on file was signed off on 15 January 2015. No evidence could be found that any such daily inspections were conducted thereafter. For the purpose of the daily inspection, the check sheet *"UH-1H Preventative Maintenance Daily (PMD) Inspection Check Sheet number QC/43/AMO1116/00848/5 (document number QC43/PMD/UH-1H, consisting of 10 pages)"* was used by maintenance personnel. The table below reflects the content applicable to the aft control cable as contained in document number QC43/PMD/UH-1H, page 3 of 10, subheading 4.10.

Item and Procedure	Mechanic Signature:	CI Signature and Stamp:
NOTE: MANDATORY SAFETY OF FLIGHT INSPECTION ITEM		
4.10 Inspect vertical fin spar and vertical fin drive-shaft cover attachment channel for cracks. Cleanliness of chain, and condition of aft cables and grommets. Inspect chain/sprocket access cover attachment rivets for looseness and condition. Inspect for loose or missing rivets attaching the 90 degree gearbox attachment fitting.	Signed by stamp #10	Signed by stamp #10

Such an inspection was required to be recorded in the helicopter logbook or flight folio. The absence of such documented evidence subsequent to the signed form date 15 January 2015 was found to be in contravention of Part 43.02.1(1).

1.6.7 On 30 January 2015 a defect was entered on page 0130 of the flight folio stating: *"Tail rotor yoke to be removed".* The maintenance rectification action that was entered on the same page indicates that the tail rotor yoke serial number A-7601 was removed. The maintenance history of the helicopter (work pack no. 862) was reviewed. The work pack indicates that tail rotor yoke assembly with part number 204-011-722-5 and serial number A3-30756 were installed on the helicopter. The tail rotor yoke had accrued 1 116.1 hours total time since new and had a remaining service life of 383.9 hours. A copy of the component history form (also referred to as a component log card) was attached to the work pack and the original log card was available in the airframe component records file. This component was found to be installed on the tail rotor assembly at the time of the accident. However, it was found that the maintenance engineer had entered the serial number ABA-53140 on page 0130 of the flight folio, which was not the serial number of the tail rotor yoke assembly. It was further noted that all paperwork filed under this work pack consists of photocopies with no reference to the tail rotor yoke assembly that was removed, apart from the flight folio entry. The entry in the airframe logbook with reference to this maintenance was signed off by AME stamp #6; this person was not present at the time this maintenance was performed. The second entry on page 0130 of the flight folio calls for a *"Duplicate inspection to be performed"* under the "defect" subheading, but there was no signature on the maintenance action side of the page to indicate that such a duplicate inspection was performed.

1.6.8 On 11 February 2015 a defect was entered on page 0131 of the flight folio stating *"Severe medium vibration".* The maintenance rectification actions entered on the same page indicate that the main rotor hub assembly was removed, a static balance was performed and the hub assembly was re-installed on the helicopter. A duplicate inspection was performed on the main rotor controls and was signed off in the flight folio by the holder of a commercial pilot's licence. According to available evidence this was the last documented maintenance action that was performed on the helicopter prior to the accident flight. During the review of the maintenance history of the helicopter no evidence could be found that a logbook entry was made with reference to this task, nor was a work-pack available.

*NOTE: Reference made to the CARs as well as SA-CATS under this subheading can be found attached to this report as Annexure B.

1.6.9 According to an affidavit dated 10 March 2016 by the AME (stamp #10) he state that he had conducted maintenance on two helicopters (ZS-HBV and ZS-SLK) on Saturday, 7 March 2015, the day prior to the accident flight at the Newlands firebase.

The following maintenance was performed on ZS-HBV as stated by AME (stamp #10);

"I fixed the engine torque gauge, which I removed, cleaned and re-installed. We then did a ground run to check the torque indications were within limits. I also replaced the oil ring on the ground receptacle connection on the Mule Valve on the hydraulic system."

"We (that includes him and three pilots) were all present when I inspected the main rotor assembly, main transmission, 42 degree and 90 degree gearboxes, as they were all found to be in working order and the gearboxes had adequate oil. I also did a general visual inspection of the tail boom, with the drive shaft covers of the tail boom and the vertical fin open. I conducted these inspections with high ladder, which was specifically bought for these purposes by the pilot JM and stored at the Newlands base with the letters ZS-HBV painted on it."

"The aircraft received a fire call out that afternoon and flew without any reported further snags as pilot JM reported to me telephonically that evening that there were no further snags on ZS-HBV as reported to him by BM. I, hence did not have time

to enter the work on these aircraft by the time the accident with ZS-HBV occurred, as the airframe and engine logbooks were retained in Nelspruit at the AMO and all these logbooks and flight folios were subsequently removed by the CAA after the accident."

The flight folio of the helicopter was made available to the investigator on Monday afternoon, 9 March 2015 after he had returned from the accident site. And the airframe and engine logbooks were obtained during the investigators visit to the AMO in Nelspruit on Tuesday, 17 March 2015. The statement made by the AME was therefore inaccurate as he had ample time to bring the flight folio up to date.

Available information indicates that the last defect that was entered into the flight folio was dated 19 February 2015, and contained the following entry; *"Battery U/S".* This entry was made on page 0131 of the flight folio. For the next three pages, which includes eighteen (18) entries/flights not a single defect was entered in the flight folio by any of the flying crew, yet the AME (stamp #10) went to the Newlands firebase on Saturday, 7 March 2015 and conducted maintenance on two helicopters, of which ZS-HBV was one.

1.6.10 The pilot was the sole occupant on board the helicopter. According to the post mortem report he weighed 88 kilograms (kg) (194 pounds). The pilot had informed the dispatcher at the Newlands Forest Station that the helicopter had 410 kg (900 lbs) of fuel on board prior to take-off. According to the helicopter's last weighing sheet on page 85 of the airframe logbook, the empty weight of the helicopter was determined to be 2 535kg (5 590 lbs) as weighed on 11 September 2014. The only additional equipment was the cargo sling with the Bambi bucket suspended below it, which was attached underneath the helicopter. The Bambi bucket was empty during the flight. The helicopter had a maximum certified take-off weight of 4 309kg (9 500 lbs) and was operated well within the allowable weight limitations during the accident flight.

1.7 Meteorological information

1.7.1 An official weather report was obtained from the South African Weather Services (SAWS). The weather data on the report was extracted from SAWS Automatic Weather Station located at Cape Point. The data below was for 8 March 2015 at ±1000Z.

The surface wind was south-south-easterly at 10 knots with gusts of up to 20 knots.
Temperature was 16°C,
Dew point was 12°C,
Humidity was 82%,
Pressure altitude was 1017 hPa (hectopascal).

1.7.2 Cape Town International Aerodrome (FACT) was located 20 nm to the northeast of the accident site. The meteorological aerodrome report (METAR) for FACT that was issued by the SAWS on 8 March 2015 at 1000Z was as follows:
FACT 081000Z 18016KT 9999 FEW030 22/14 Q1018 NOSIG =

Wind	-	180° at 16 knots
Visibility	-	+ 10 km
Cloud cover	-	Few (1 to 2 octas) at 3 000 feet
Temperature	-	22 °C
Dew point	-	14°C
Barometric pressure	-	1018 hectopascal (hPa)
Other	-	No significant change (NOSIG)

1.8 Aids to navigation

1.8.1 The helicopter was equipped with standard navigational equipment as required by the regulator.

1.8.2 Also on board was a Garmin Aera 500 portable global positioning system (GPS). The unit, which sustained some fire damage, was recovered from the accident site and was forwarded to the National Transportation Safety Board (NTSB) Vehicle Recovery Division in Washington D.C. to assist with a possible download of the data pertaining to the accident flight. The download was conducted and is dealt with in more detail under subheading 1.16 (Tests and Research) of this report.

1.9 Communication

1.9.1 The four aircraft (one fixed wing and three helicopters) that were dispatched to the Cape Point Nature Reserve were communicating on the company-designated VHF frequency of 120.55 MHz.

1.9.2 The other three pilots heard the pilot of ZS-HBV saying over the radio that he had a chip warning light, tail. (The tail chip light could either be from the 42° intermediate gearbox or the 90° tail rotor gearbox, or both). The pilot flying the lead helicopter then told the pilot of ZS-HBV to land on a nearby service road and inspect the magnetic plugs on both tail gearboxes. He then replied that he would land at the helicopter support vehicle (HSV), which was approximately 2 nm to the south of his present location. Several seconds later the pilot broadcast *"mayday mayday mayday".* The pilot flying the lead executed a 180° turn after hearing the distress call and observed the helicopter spinning clockwise. He told the pilot over the radio to close the throttle. There was no further communication from the pilot flying the accident helicopter.

1.9.3 Following confirmation that the helicopter had crashed, the pilot flying the spotter aircraft informed air traffic control (ATC) at Cape Town International aerodrome as well as the dispatch centres at the Newlands Forest Station and Stellenbosch aerodrome of the accident and requested medical assistance.

1.10 Aerodrome information

1.10.1 The accident did not occur at or near an aerodrome.

1.11 Flight recorders

1.11.1 The helicopter was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor were they required by the regulations to be fitted to this type of helicopter.

1.12 Wreckage and impact information

1.12.1 Examination of the accident site and wreckage indicated that the helicopter struck the ground at a high rate of descent and low forward speed in a northerly direction. The tail section was severed by the main rotor blades after the helicopter struck the ground and separated from the main fuselage just aft of where it attached to the fuselage. The tail boom was found in two pieces, with the forward section being located approximately 35 m to the left of the initial point of impact and the aft section approximately 12 m behind the initial point of impact, as can be seen on the aerial photo in Figure 4. Most major components were located with the main wreckage, which came to rest approximately 30 m forward of the initial point of impact in an inverted attitude. The main wreckage was extensively burned and fragmented into large and small sections, even though approximately twenty Bambi bucket loads of water were dropped on the burning wreckage by one of the helicopters that were dispatched to the fire.

1.12.2 The main transmission, which included the main rotor gearbox, main rotor mast, main rotor assembly, including the head and blades, sustained extensive thermal damage. The flex frames on both ends of the main driveshaft were fractured. The tail boom and related components sustained the least amount of impact damage. The tail rotor blades exhibited minimal damage. One of the tail rotor pitch change links was found to have fractured in overload. The engine sustained extensive thermal damage; however, visual inspection of the turbine blades did not reveal any damage. It was not possible to establish the position of the throttle at the time of the accident.

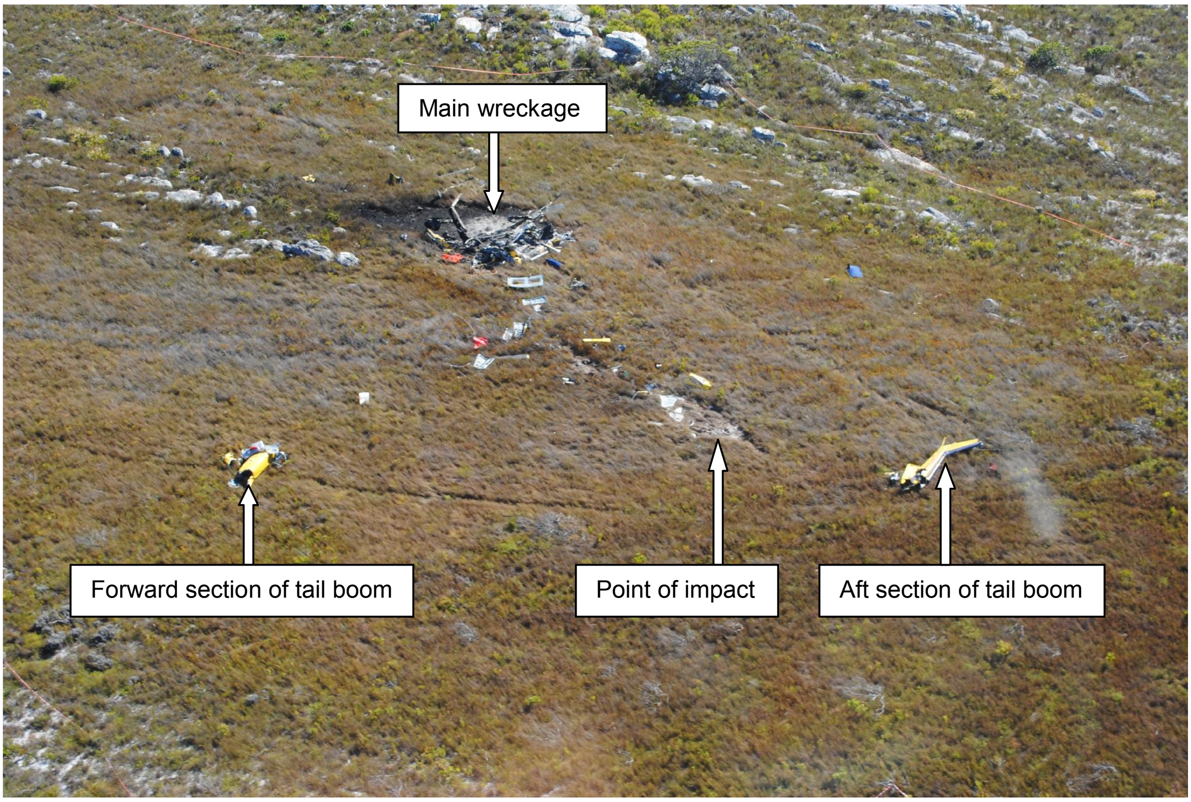


Figure 4. Aerial view of the accident site

1.12.3 Severe deformation of the main rotor blades was observed, as they had impacted the ground as well as the fuselage during the impact sequence. Several parts/components separated from the main body and were found spread along the impact line (looking forward from the initial point of impact towards the main wreckage). These included the wind shields, doors, door posts, rudder pedals, battery, fragments of the honeycomb structure from the main rotor blades, positioning mirrors, pieces of the Bambi bucket, parts of the skid gear and both pilot/front seats. The helicopter document folder, as well as two plastic tool boxes, was located in the area of the main wreckage. None of these items sustained any fire damage.

Figure 5. View from the initial point of impact in a northerly direction (towards the main wreckage)

Figure 6. The main rotor gearbox consumed by the post-impact fire

Figure 7. Aft section of the engine and main wreckage

1.12.4 The pilot did not jettison the Bambi bucket; it was found to be still secured to the cargo hook assembly. It displayed evidence of main rotor blade impact, which was consistent with the statements of both pilots flying the other two helicopters, who saw the bucket colliding with the blades prior to the helicopter impacting the ground (see Figure 8).

Figure 8. A section of the Bambi bucket that was severed by the main rotor blades

1.12.5 The tail boom was severed by the main rotor blades during the impact sequence. Neither the forward nor the aft section of the tail boom sustained any fire damage. Figures 9 and 10 show the location of main rotor blade contact with the tail boom. The tail rotor drive, which was still attached to the tail boom structure, is also visible. The aft horizontal section of the tail boom displays deformation of the tail driveshaft cowling (three areas) as well as in the area of the 42° intermediate gearbox cowling. Neither of the tail rotor blades (visible in Figure 9) displays rotational or ground impact damage. Blue paint was observed on both tail rotor blades, which is consistent with the blades making contact with the tail boom pylon cover as well as the pylon structure. Both tail rotor pitch change linkages were found to have failed. The aft tail boom section was lifted and placed in an upright position in order to inspect the tail rotor drive train and control system. It was noted that the tail rotor driveshaft located just forward of the 42° intermediate gearbox had fractured and had become displaced at the input coupling to the 42° intermediate gearbox as a result of the failure of the shaft assembly. It was further noted that the lower tail rotor control cable that connects to the chain assembly, which in turn connects to the tail rotor pitch change mechanism, had failed. The tail rotor driveshaft cowling (pylon) as well as the tail rotor driveshaft in the area where the cable had failed displayed evidence of shaving, to such an extent that the cowling was found to be shaven through at two locations. Neither the 42° intermediate gearbox nor the 90° tail rotor gearbox was damaged in the accident sequence. Both these gearboxes were free to rotate when turned by hand, with no unusual sounds. The magnetic plugs on both these gearboxes were removed during the on-site investigation. Neither of them displayed sediment deposits that could be associated with a chip warning light as was communicated by the pilot. The magnetic plug displayed in Figure 17 was from the 90° tail rotor gearbox. No oil was observed in the sight gauges of either of the two gearboxes, nor was there any evidence that oil had leaked from either of these gearboxes during the accident sequence (see Figure 18 (a) and (b)).

Figure 9. Aft tail boom and blades (tail boom was placed in an upright position)

Figure 10. The forward tail boom structure that was severed by the main rotor blades

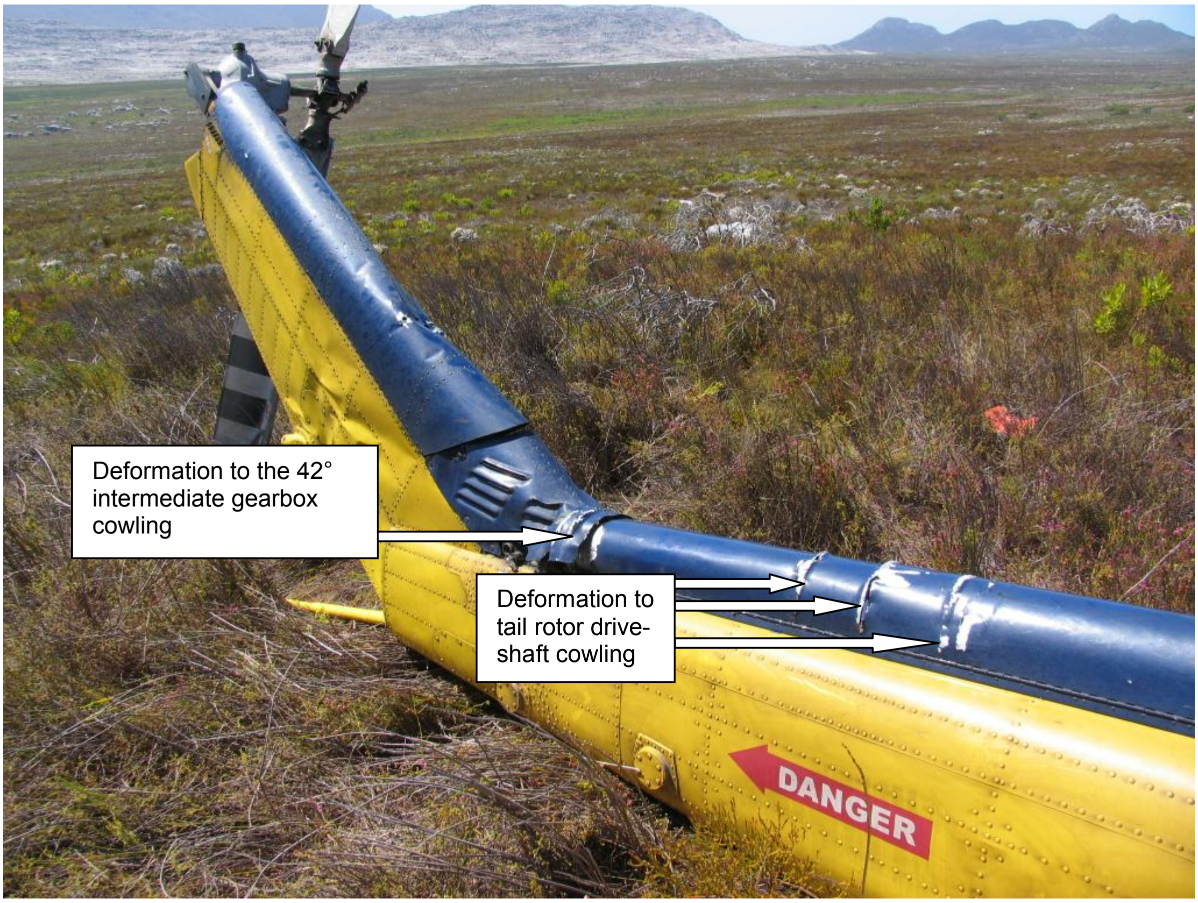


Figure 11. The aft tail boom structure with driveshaft cowling deformation visible

Figure 12. Tail rotor driveshaft just forward of the 42° intermediate gearbox fractured in torsional overload

Figure 13. A closer view of the failed tail rotor driveshaft

Figure 14. Photograph of both ends of the aft tail rotor control cable that was found to have failed

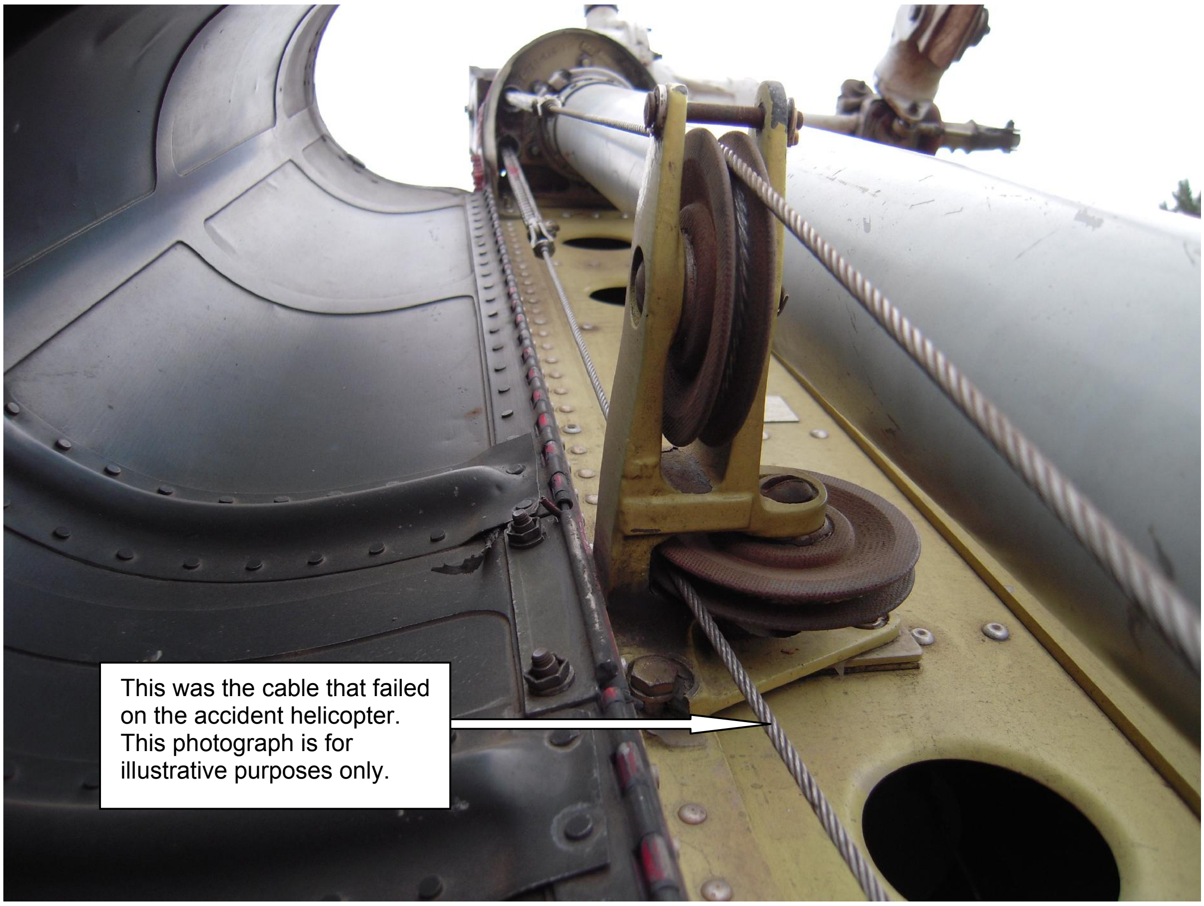


Figure 15. A photograph of the tail rotor control cable orientation on a serviceable helicopter (similar type)

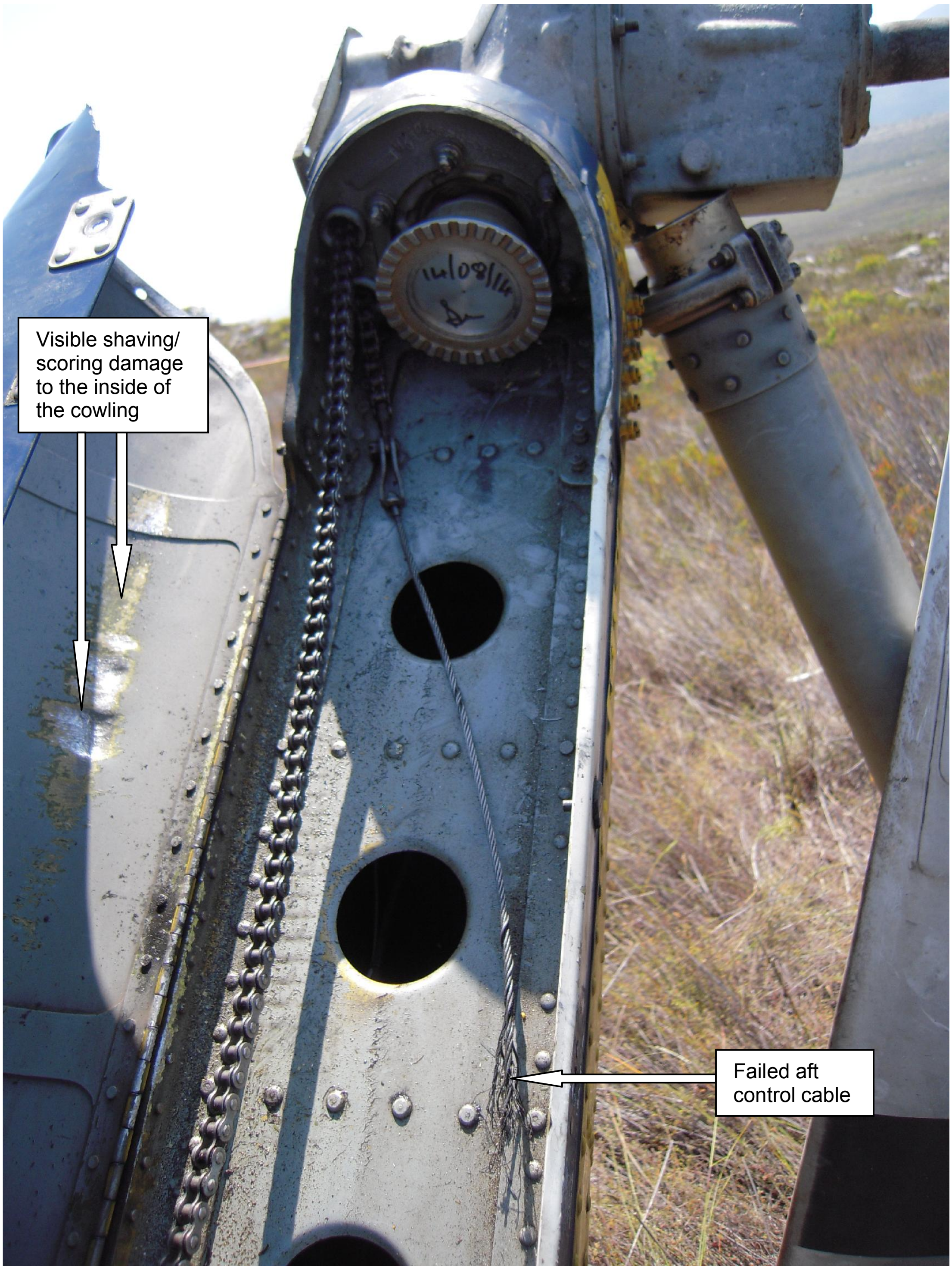


Figure 16. One end of the failed tail rotor control cable attached to the chain drive

Figure 17. Magnetic plug on the 90° tail rotor gearbox removed during the on-site investigation

(a) (b)

Figure 18. Oil sight gauges of the 42° gearbox (a) as well as the 90° tail rotor gearbox (b) with no oil visible in either

1.13 Medical and pathological information

1.13.1 On 10 March 2015 a medico-legal post mortem examination was conducted by the Western Cape Government, Directorate: Forensic Pathology Services. The report concludes the cause of death to be *"unnatural: multiple injuries".*

1.14 Fire

1.14.1 The fuselage of the helicopter, which includes the cockpit/cabin, main transmission and the engine, was consumed by the post-impact fire that erupted.

1.14.2 According to an interview with one of the helicopter pilots that was dispatched to the fire, he dropped approximately twenty Bambi bucket loads (1 200 litres of water per load) of water on the wreckage following the post-crash fire before it was contained.

1.15 Survival aspects

1.15.1 The accident was not survivable, as the impact was considered to be above that of human tolerance.

1.15.2 The pilot was wearing a helmet and flying overalls and was making use of the factory-fitted four-point safety harness.

1.15.3 Both pilot seats (left and right) were flung from the cockpit during the impact sequence. The pilot, who was in the right seat, was found to be still secured to his seat by the first person who arrived on the scene, who was the pilot flying the lead helicopter. He landed at the scene within minutes after the helicopter impacted the ground. He pulled the pilot away from the main wreckage area, which was on fire. After he had unhooked the Bambi bucket, he flew to the service road, where he uplifted four firefighters who could assist him in carrying and loading the pilot of the crashed helicopter into his helicopter, whereupon they flew back to the service road.

1.15.4 An emergency medical rescue helicopter was dispatched to the scene of the accident. The pilot was found to have succumbed to his injuries. The pilot's body was handed into the care of the Forensic Pathology Services and the police have opened an inquest docket.

1.16 Tests and research

1.16.1 The National Transportation Safety Board (NTSB), as the investigating authority of the state of design and manufacture, was duly notified of the accident and made an accredited representative available according to the provisions contained in document ICAO Annex 13. They in turn notified the manufacturer, Bell Helicopters, who made available an air safety investigator as well as a customer service engineer who visited the scene of the accident with the investigator-in-charge (IIC).

Following the on-site investigation, the components listed below were removed from the wreckage and forwarded to Bell Helicopters' field investigations laboratories in Fort Worth, Texas, for further investigation. Oversight during the laboratory examinations of the components was provided by the Federal Aviation Administration (FAA) on behalf of the NTSB and the state of occurrence. The information contained below was extracted from the laboratory report.

Part Name	Part Number	Serial Number
90° Tail Rotor Gearbox assembly	204-040-012-013	ABC-13223
42° Tail Rotor Gearbox Assembly	212-040-003-023	AHP-30038
Hub Assembly – Tail rotor	204-011-801-017	ABA-53140
Master caution system and fire warning indicator	204-075-705-045	A2375
Control panel assembly. - force trim, hydraulic control and chip detector	204-075-578-001	None
Cable Assembly. Quadrant to speed rig, anti-torque control 2 each)	205-001-720-001	None
Cable Assembly. Quadrant to Speed Rig, Anti-torque control	205-001-706-009	None
Shaft Assembly. Tail Rotor Drive, Transmission	204-040-620-007	A13-100103

1.16.2 90° Tail Rotor Gearbox and Hub Assemblies

The 90° tail rotor gearbox and hub assemblies are shown in Figure 19. The input and output gears and bearings were free to rotate by hand. The magnetic chip detector was removed and no noticeable accumulation of chips was observed. Almost no oil was present in the gearbox. The temperature indicator on the input coupling was not discoloured. The tail rotor yoke and pitch change bearings were also free to move and rotate by hand.

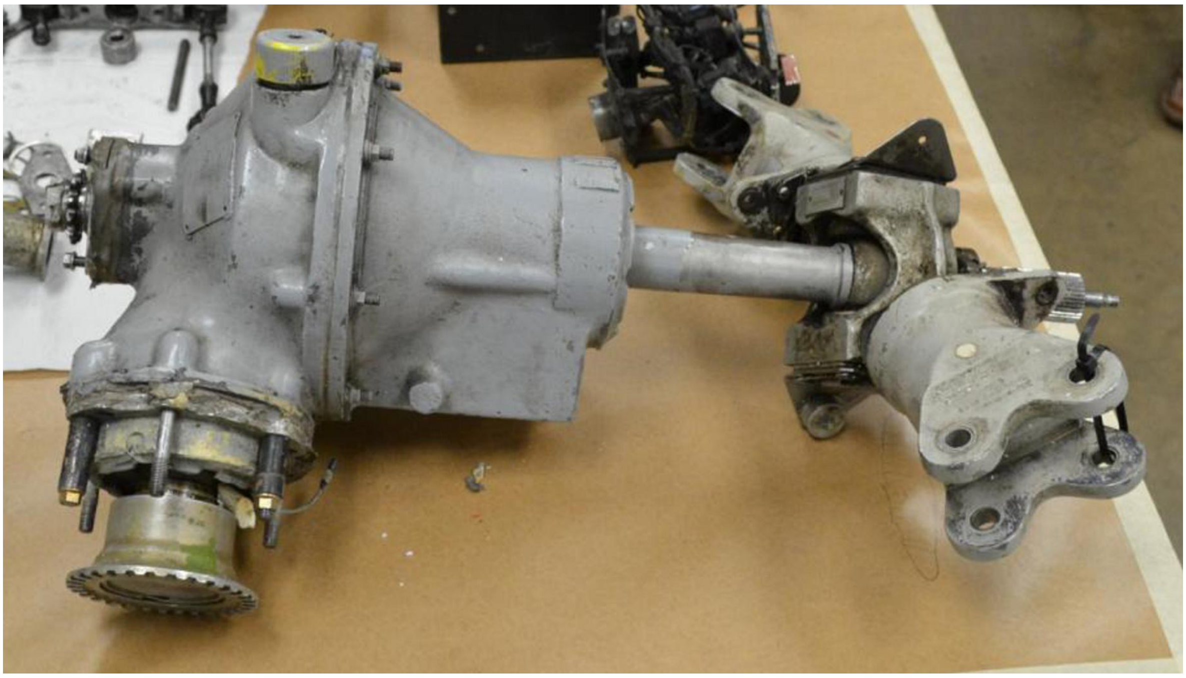
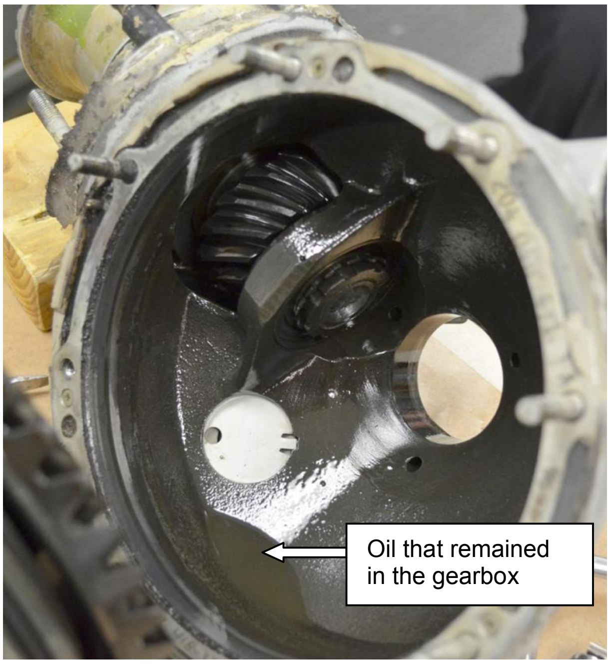


Figure 19. The 90° tail rotor gearbox



The gearbox contained almost no oil.

All gears and bearing were free to rotate by hand.

1.16.3 42° Intermediate Tail Rotor Gearbox Assembly

The 42° intermediate tail rotor gearbox is shown in Figure 20. The gears and bearings were free to rotate by hand. The magnetic chip detector was removed and no noticeable accumulation of chips was observed. The output quill assembly was removed from the housing. There was no noticeable damage to the gears of both input and output quill assemblies. The temperature indicator on the output coupling was not discoloured.

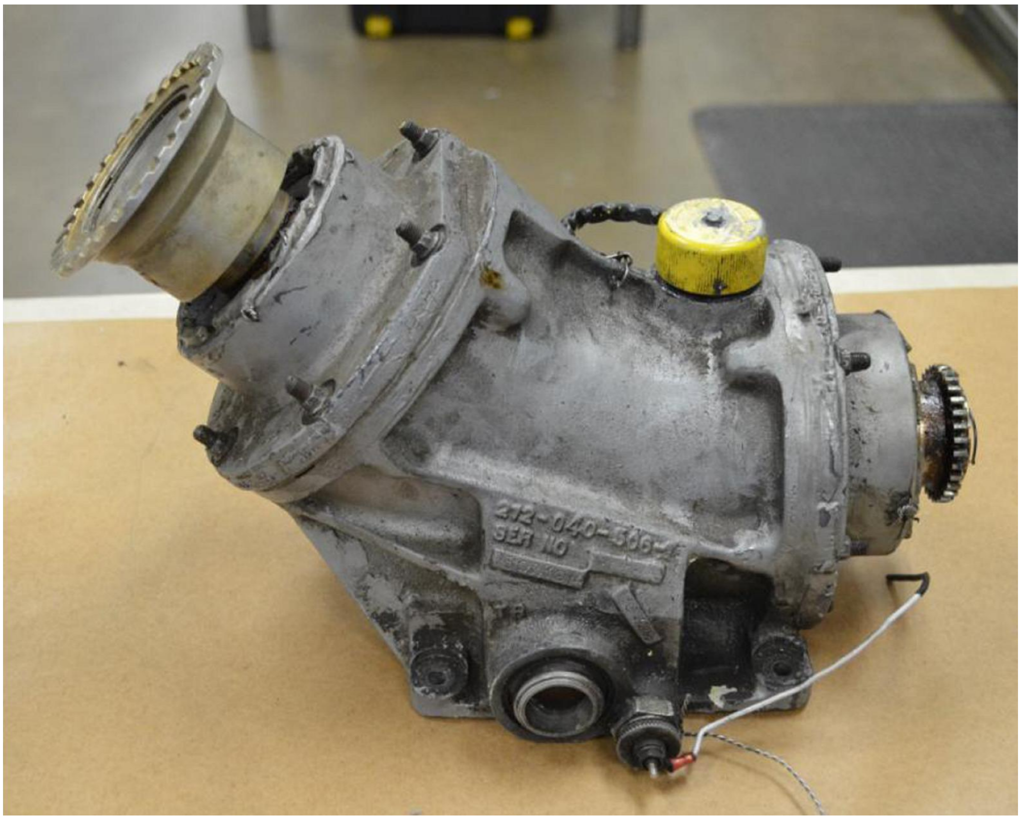
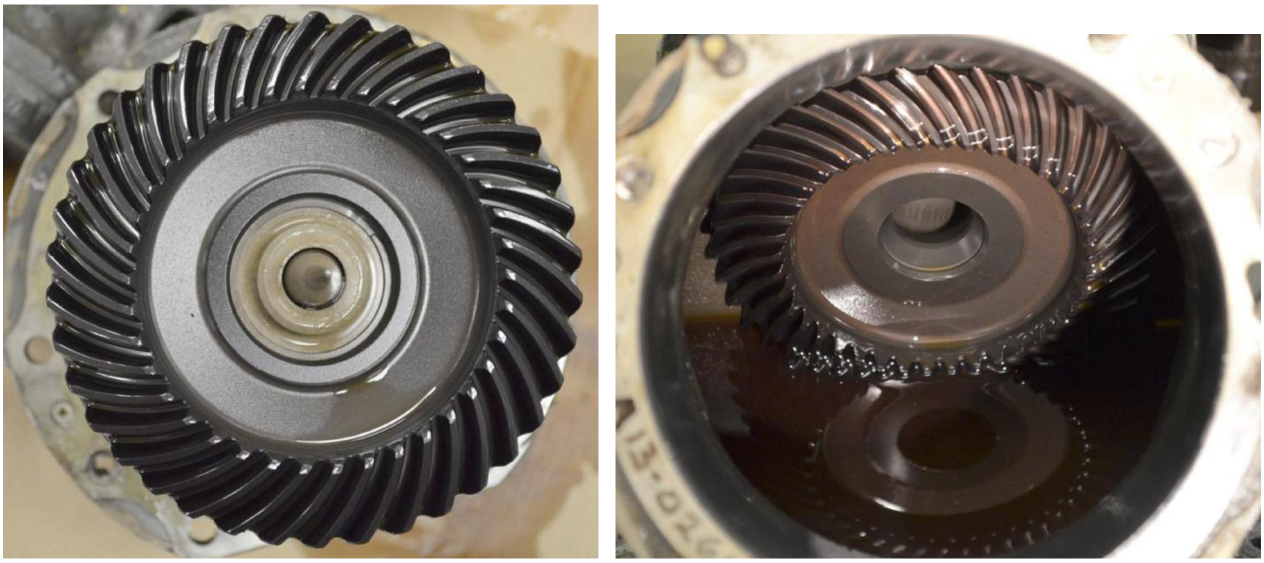


Figure 20. The 42° intermediate tail rotor gearbox



The gears and bearings were free to rotate by hand.

1.16.4 Caution/Warning Indicator Panels

The master caution/warning indicator panel and the force trim, hydraulic control and chip detector indicator panel were examined as shown in Figure 21 and 22. Both these units were located in the cockpit and sustained fire damage. The hydraulic control switch was observed in the "ON" position. The light bulb filaments were examined to determine if any indicator lights were burning upon impact with the ground, such as the chip detector indicator lights. The tungsten filaments become ductile when hot and stretch, provided there is enough G-force. Examination of the filaments revealed no stretching, which indicated no bulbs were burning during impact or there was not enough G-force to stretch any burning bulb filaments.

The "Xmsn" (main rotor gearbox) and tail rotor chip detector bulbs only come on when the flip switch completes the circuit when moved up to "Xmsn" or down to "tail rotor". The switch was found in the neutral position. The main rotor gearbox was consumed in the post-crash fire.

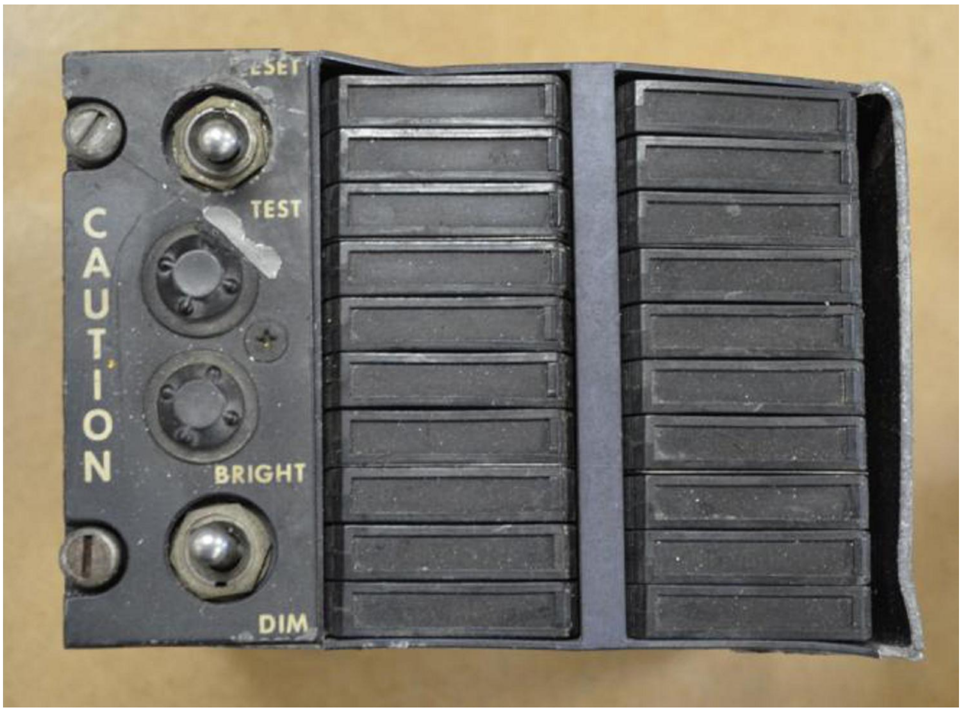
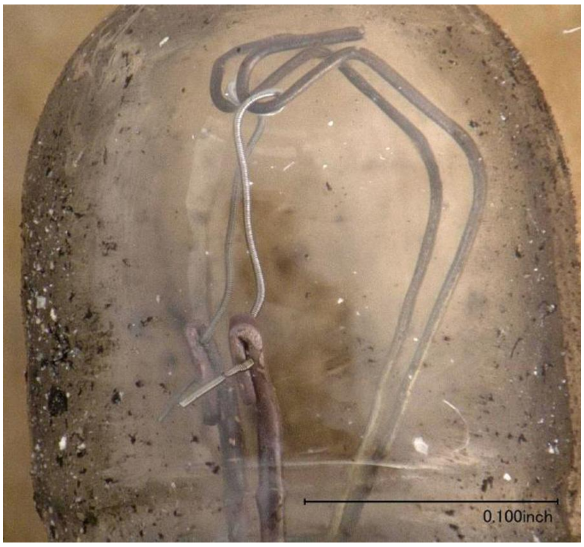
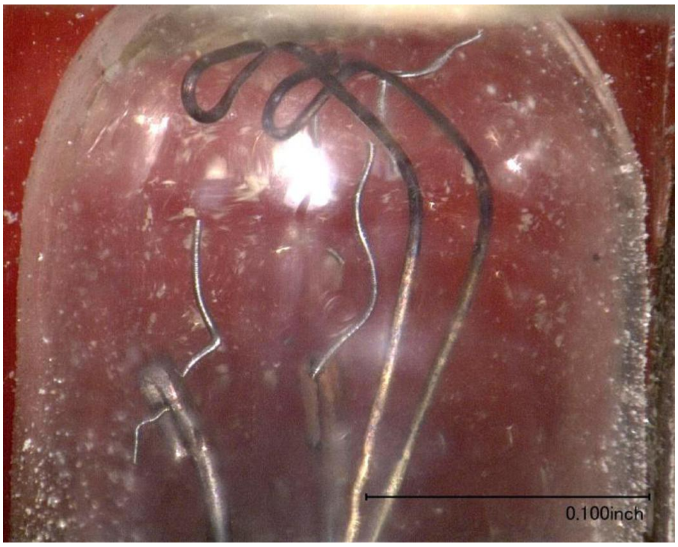


Figure 21. The master caution/warning indicator panel

Figure 22. Force trim, hydraulic control and chip detector indicator panel



(a)



(b)

No stretching of the light bulb filaments from the tail rotor chip indicator (a) and the Xmsn chip indicator (b) was observed

1.16.5 Tail Rotor Controls (Crosshead, Pitch Links, Control Rod, Control Chain and Cables)

The tail rotor crosshead bearing was free to rotate by hand. See Figure 23 for the tail rotor control cable and chain rigging schematic.

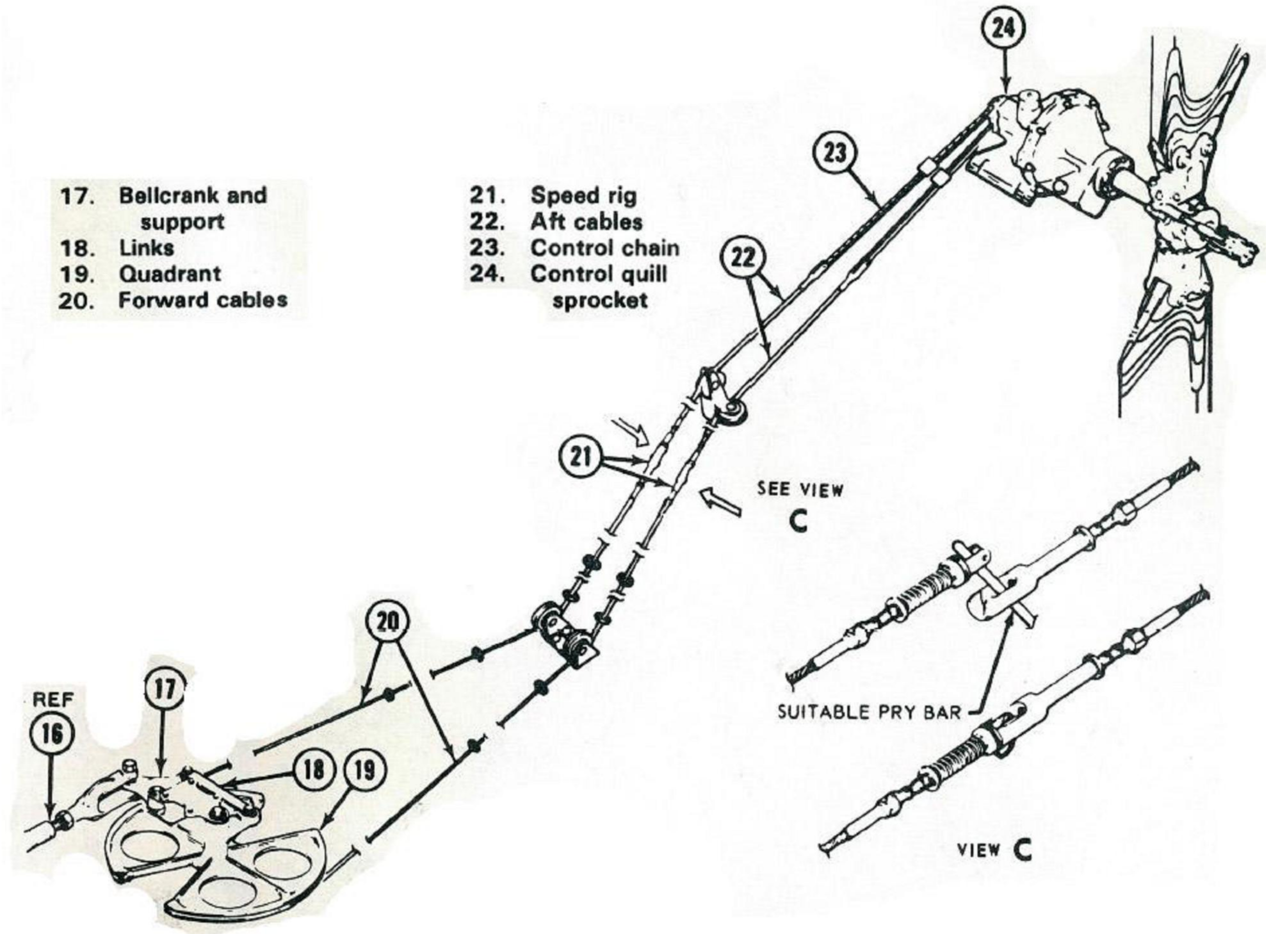


Figure 23: Schematic of the tail rotor control cables and chain rigging with the control quill sprocket (24)

1.16.6 Aft Control Cables

The forward right-hand control cable (Figure 24) and aft left-hand control cable (Figure 25) were received. Both these cables were fractured. The forward right-hand cable exhibited more unravelling at the fracture than the aft left-hand cable. This indicated that a relatively high energy event took place to fracture the forward cable, while a relatively low energy event fractured the aft cable.

Figure 24. Fractured forward right-hand control cable

Figure 25. Fractured aft left-hand control cable

Closer examination of both right and left-hand aft cables revealed worn flat areas around the entire circumference of the outer surface (see Figure 26), which resulted from repeated contact with the pulleys. The aft cable fractured 32-34 cm (12.5-13.5 inches) from the forward end. The intact right-hand aft cable had a fractured wire strand protruding from it.

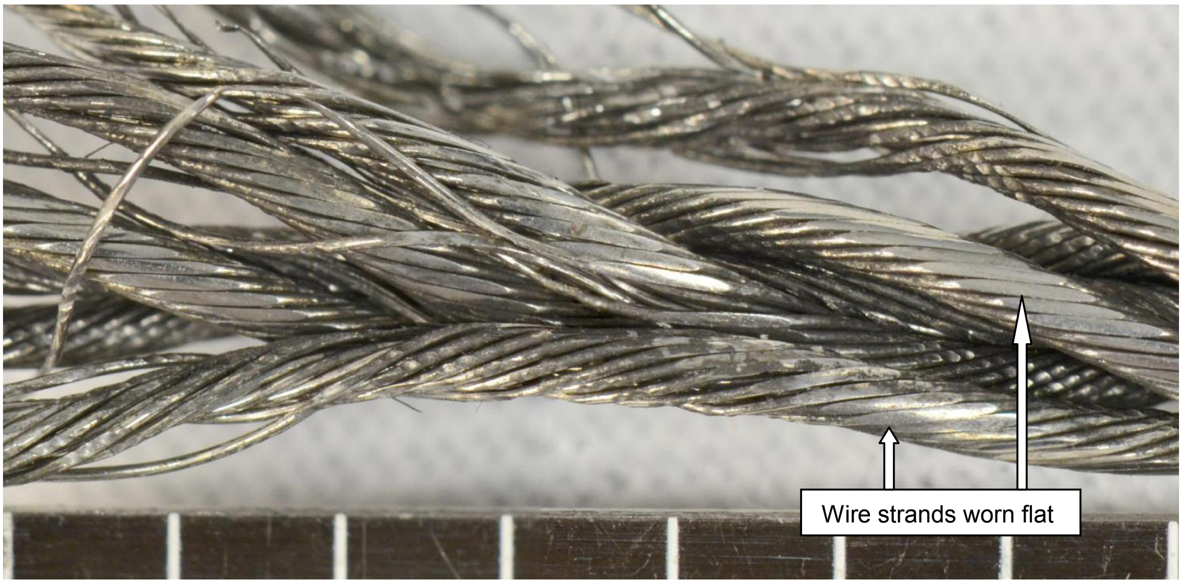


Figure 26. Close up view of the aft left-hand control cable showing the extent of wear

Figure 27 shows two fracture mechanisms of the left-hand aft cable wire strands. Approximately 92 of the 133 strands (7 bundles of 19 strands each) were worn completely through the wire thickness. Approximately 20 of the 133 strands fractured in tensile overload and approximately 21 strands fractured in overload that had roughly half the cross-sectional area worn away. An intact strand had an average diameter of 0.229 mm (0090 inches).

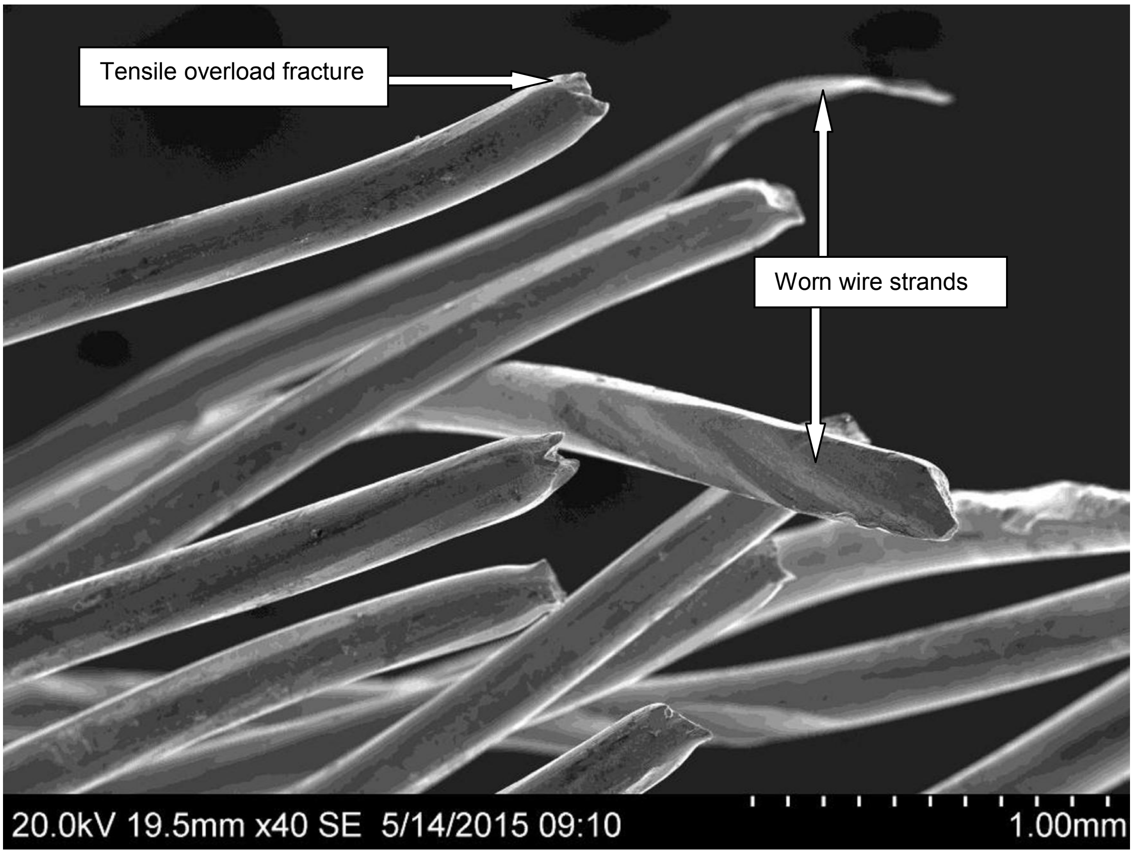


Figure 27. Scanning electron microscope photograph of wire strands displaying fractures due to wear

Technical Manual 55-1520-210-23 chapter 11-127b states: “Inspect tail rotor control cables for worn areas, broken wires and proper tension, kinked, twisted or unbraided cables must be replaced.” Chapter 11-129a stated, “Replace tail rotor control cable assembly if a break in a wire is evident.” Chapter 11-133 (a) stated, “Inspect pulleys for flat spots and damage. Pulleys with cable image impressed into groove should be replaced. (b) Inspect parts for binding or worn bearings.” The aft control cables had a phased maintenance inspection interval of 150 flight hours.

The pulleys were not received in the laboratory for inspection of the bearing condition. A seized pulley bearing would wear the control cable faster than a bearing that was free to rotate. The photograph in Figure 28 shows the condition of the pulley grooves for the aft control cables. A wear pattern that appeared similar to the braided cable was observed in the pulley grooves. The aft control cable that failed was supported by the lower (horizontally positioned) pulley.

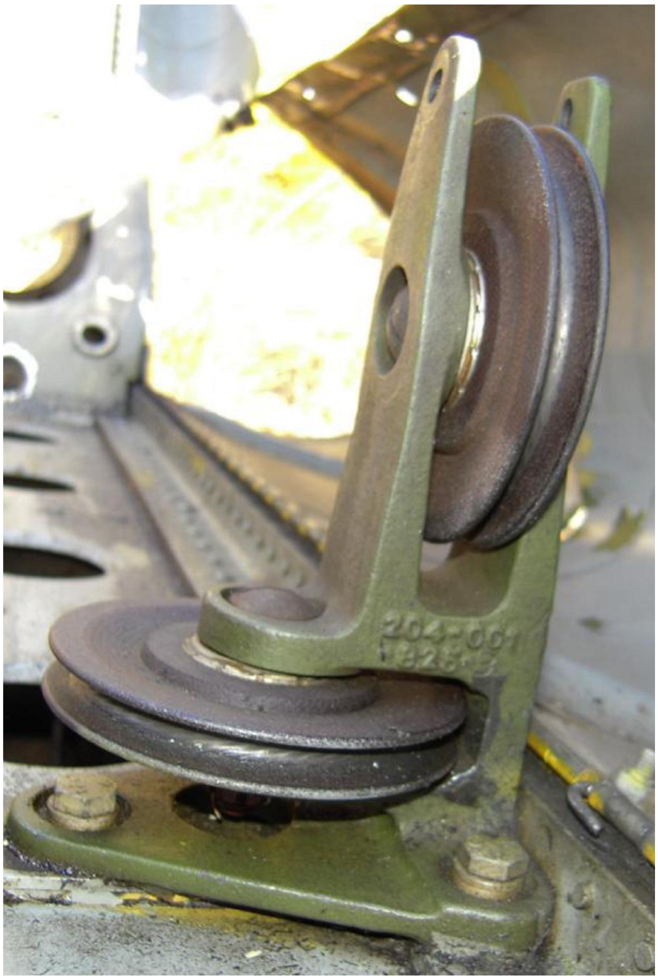


Figure 28. The pulleys that supported the aft control cables

Energy-dispersive x-ray spectroscopy confirmed the alloy composition of the fractured aft cable was similar to two stainless steels that were required. The outer diameter of the worn fractured aft cable measured 3.10-3.20 mm (0.122-0.126

inches) near the fracture. The required outer diameter for a new aft cable was 3.18-3.53 mm (0.125-0.139 inches). The outer diameter of the fractured aft cable in an unworn area measured 3.40-3.45 mm (0.134-0.136 inch). There was not enough cable to properly test the tensile strength.

1.16.7 Control Quill and Rod

During examination of the 90° tail rotor gearbox, the tail rotor pitch control quill sprocket could not be rotated by hand. The control quill comprises a worm gear that moves the control rod in and out to change tail rotor blade pitch. Bearings in the control quill and crosshead allow the control rod to not rotate with the tail rotor mast. The control quill has a sprocket attached to it outside of the 90° tail rotor gearbox, which is rotated by a chain linked to pedal inputs by the pilot.

Removal of the control quill and control rod from the 90° tail rotor gearbox revealed that the pitch control rod slider spline jammed into the brass control nut as shown in Figure 29. This indicated that there was a significant force on the intact right-hand control cable after the left-hand aft control cable fractured from wear. The significant force was the main rotor blade strike to the forward end of the tail boom. During this event, the intact right-hand forward control cable drove the control rod into the brass control nut and fractured due to tensile overload. The control nut and rod had to be separated using a hydraulic press. The control rod threads, which retain the crosshead bearing, were sheared in the direction consistent with a significant force on the intact right-hand control cables (see Figure 30). Damage to the sprocket teeth was also observed.

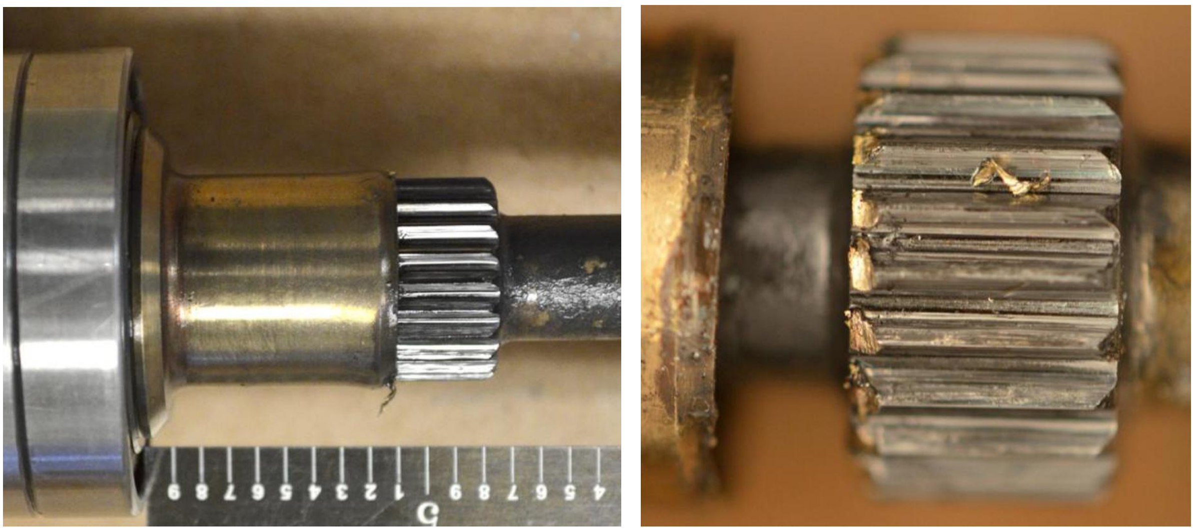


Figure 29. The pitch control rod slider spline that was jammed into the brass control quill nut

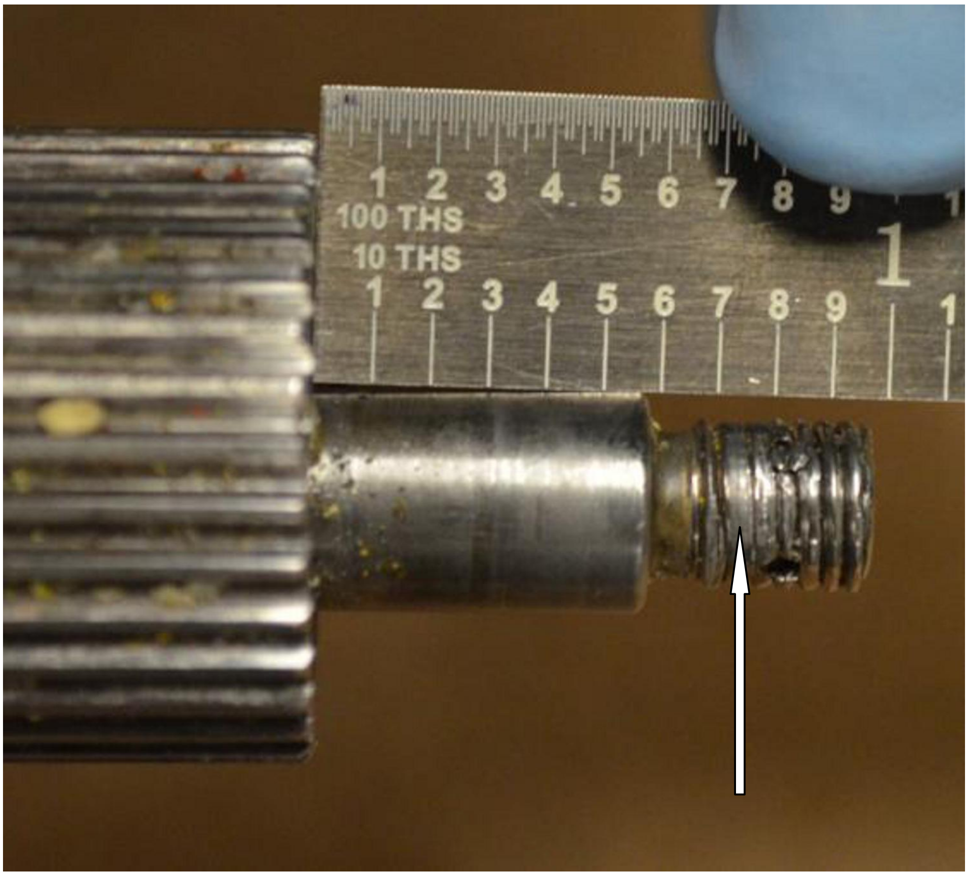


Figure 30. Pitch control with sheared threads that retained the crosshead bearing (see arrow)

Figure 31. The sprocket teeth displayed mechanical damage (indicated by arrows)

1.16.8 Fractured Tail Rotor Driveshaft Section

Figure 32 below shows the fractured tail rotor driveshaft, located just forward of the 42° intermediate gearbox, as received in the laboratory. Aft of the overload fracture was a twist in the driveshaft. The direction of twist indicated a sudden rotational stoppage in the drivetrain aft of the twist. It was reported that the tail rotor blades did not reveal any damage that could have contributed to the sudden stoppage. A photo of the wreckage showed that the female coupling attached to the fractured driveshaft was wedged between its mating male coupling attached to the 42° intermediate gearbox and the driveshaft enclosure. Damage observed on the female coupling and male coupling teeth confirmed this scenario after the female coupling was disengaged. This occurred after the left-hand aft control cable fractured and before the main rotor blade struck the tail boom.

Figure 32. The twist direction on the tail rotor driveshaft indicates a sudden rotational stoppage aft of the twist.

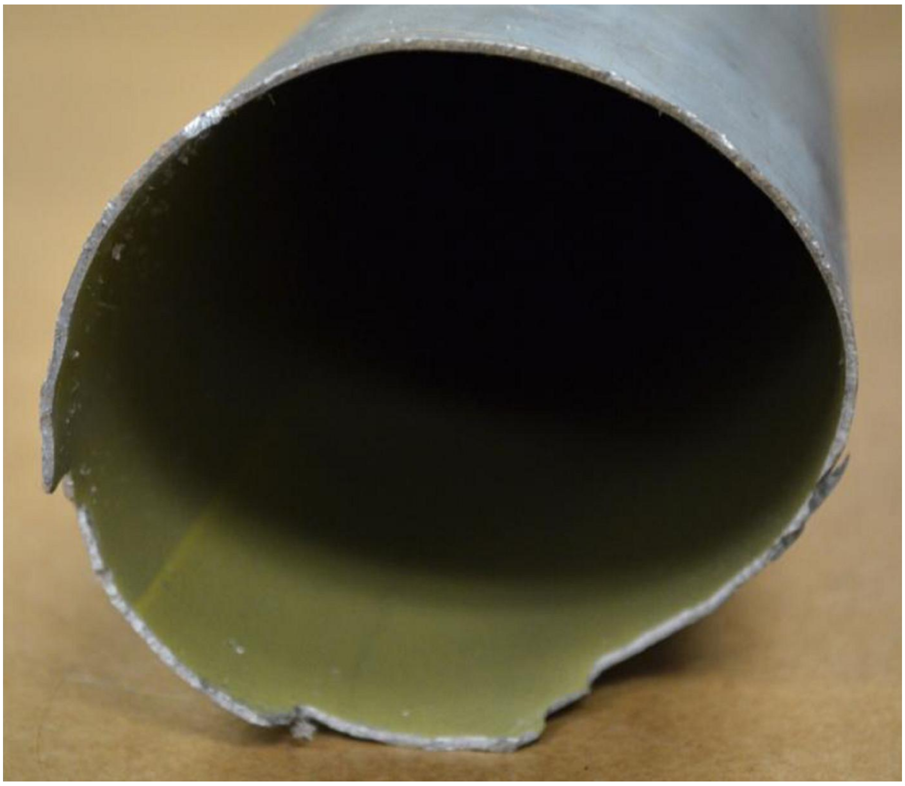
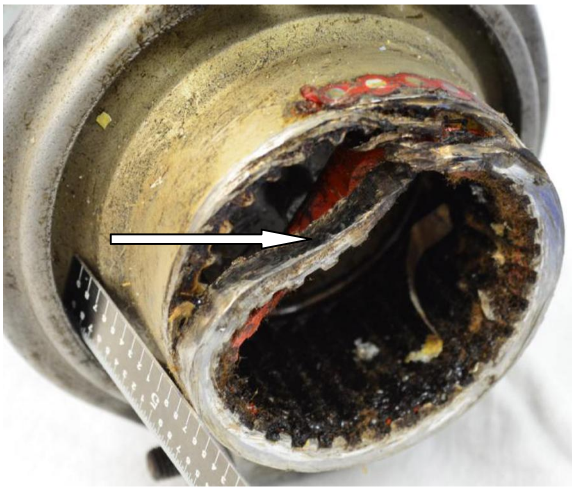
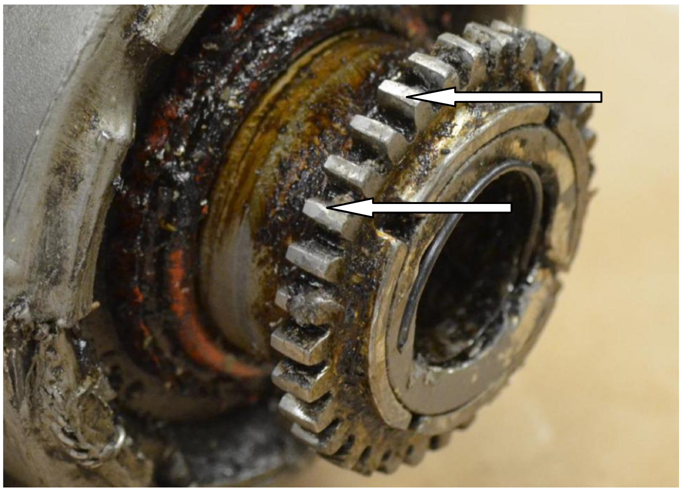


Figure 33. The fractured tail rotor driveshaft that failed in overload



(a)



(b)

Figure 34. Contact with male coupling (see arrow) Damaged male coupling teeth (see arrows)

1.16.9 Global Positioning System (GPS) data extraction

During the on-site investigation a Garmin Aera 500 GPS unit, which had sustained substantial heat damage, was recovered from the scene (Figure 35). The unit was forwarded to the National Transportation Safety Board (NTSB) Vehicle Recorder Division in Washington D.C in order to assist with the extraction of any possible data pertaining to the accident flight. The information contained below, including Figures 36 and 37, was extracted from the NTSB report.

Figure 35. The damaged Garmin Aera 500 GPS (taken during the on-site investigation)

Data recovery

The screen of the unit was removed, which revealed that the unit's internal circuit board was in an excellent condition. The device USB port was still intact and was connected to a PC via a standard mini-USB cable. Power was applied, the PC recognized the device and waypoint and tracklog information was downloaded normally using the manufacturer's standard procedure. Additionally, the non-volatile memory (NVM) chip was identified from the main circuit board and was removed. The chip was read out in binary format and was converted using laboratory software. The results of the two downloads were compared.

Figure 36. The internal circuit board with the screen removed

Data description

The accident flight was recorded starting at 09:40:03Z and data ended at 09:54:17Z on 8 March 2015.

The data extracted from the single chip NVM downloaded matched that of the USB download, with the exception of the time stamp information. Each log was examined, and the tracklog associated with the last tracklog of the USB download were in agreement and terminated in the same position.

Parameters provided

The data parameters provided by the GPS device were date, time, latitude, longitude and GPS altitude (feet). Groundspeed and track (true) were derived from the recorded parameters.

Figure 37 is a graphical overlay generated using Google Earth for the accident flight. The weather and lighting conditions in Google Earth are not necessarily the weather and lighting conditions present at the time of the recording.

The flight left the helicopter base at 09:40:09Z. The helicopter began tracking in a southerly direction and eventually settled into cruise between 2 000 and 3 000 feet and a derived groundspeed of between 80 and 110 miles per hour (mph). The data ended 0.6 nautical miles southeast of Kleinplaas Dam, showing the helicopter at a GPS altitude of 2 303 feet, on a derived track of 185° true and a derived groundspeed of 106 mph. Due to data buffering on the GPS unit, the date recording ended before the accident event. The last recorded parameter was at 09:54:17Z on 8 March 2015, which was approximately 5 nm before the crash site.

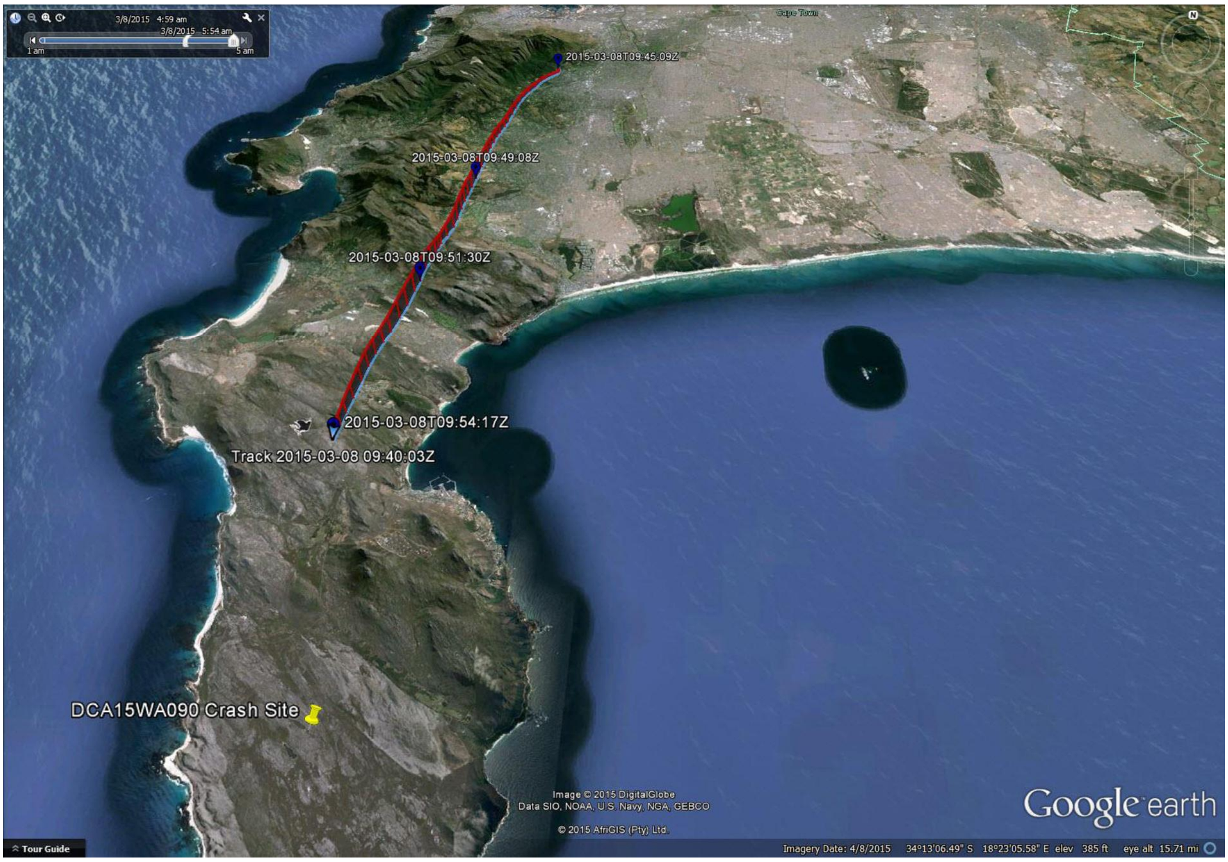


Figure 37. Google Earth overlay showing the entire recovered portion of the accident recording

1.17 Organisational and management information

1.17.1 The flight was conducted under air operating certificate (AOC) no. CAA/G921D, which was valid at the time of the accident. The AOC was issued on 17 February 2015 by the regulating authority and was valid until 6 February 2016. The helicopter ZS-HBV was duly authorised to operate under the G8 (fire spotting, control and fighting) and G15 (undersling and winching operations) categories.

1.17.2 The aircraft maintenance organisation (AMO) number 1116 that certified the last maintenance inspection (Phase 4) as well as unplanned maintenance on the helicopter prior to the accident flight was in possession of a valid AMO approval certificate that was issued by the regulating authority on 2 July 2014. The certificate was valid until 30 June 2015.

1.17.3 The AMO headquarters was at Nelspruit aerodrome (FANS). From an aircraft maintenance perspective, it became a logistic problem to ensure that the serviceability of both the helicopter and the fixed-wing fleet in use for firefighting was not compromised. These aircraft were spread all over the country, and apart from that they moved around as and when needed. Maintenance personnel then had to travel between the different locations in order to attend to defects and carry out planned as well as unplanned maintenance, including daily inspections.

1.17.4 The number of maintenance engineers employed by the AMO was found to be inadequate to allocate a designated maintenance engineer to look after a helicopter or in some instances more than one helicopter based at the same location. At the time of the accident three helicopters were based at the Newlands Forest Station, but there was no maintenance engineer based there on a full-time basis (during the fire season, which was a seasonal arrangement). Even though the regulations make provision for pilots to carry out maintenance, there are limits to what maintenance they may perform (see attached to this report Annexure B, reference SA-CATS 43.02.2), unless such pilot is the holder of a valid AME licence and is appropriately rated on type. During an interview with the quality assurance manager on 17 March 2015 at the AMO in Nelspruit, he was asked about the number of maintenance personnel they employed, and he indicated that they had at the time advertised on several career seeking websites in order to engage additional maintenance engineers.

1.17.5 Aircraft maintenance is essential to aviation safety. The primary role of aircraft maintenance is to ensure that aircraft presented *"on the line"* for flight operations comply with:

(i) all legal requirements (e.g. continuing airworthiness requirement, airworthiness directives, certificate of release to service, type certificate and supplementary type certificate),
(ii) operational equipage requirements (e.g. oxygen systems, first aid and flotation devices), and
(iii) appropriate equipment for the type of operation being flown (e.g. communication, navigation, surveillance and firefighting)..

1.18 Additional information

1.18.1 Helicopter Operators Manual, Chapter 9, Emergency Procedures

"9.20 Tail Rotor Malfunctions. Because the many different malfunctions that can occur, it is not possible to provide a solution for every emergency. The success in coping with the emergency depends on quick analysis of the conditions".

"9.21 Complete Loss of Tail Rotor Thrust. This situation involves a break in the

drive system, such as a severed driveshaft, wherein the tail rotor stops turning, or tail rotor controls fail, with zero thrust being produced.

a. Indications

(1) In flight

(a) Pedal input has no effect on helicopter.

WARNING

At airspeed below 30 to 40 knots, the sideslip may become uncontrollable, and the helicopter will begin to revolve on the vertical axis (right or left depending on the power, gross weight, etc.)

(b) Nose of the helicopter turns to the right (left sideslip).

(c) Roll of fuselage along the longitudinal axis.

(d) Nose down tucking will also be present.

b. Procedures

(1) In Flight

(a) If safe landing area is not immediately available and powered flight is possible, continue flight to a suitable landing area at above minimum rate of descent airspeed. Degree of roll and sideslip may be varied by varying throttle and/or collective.

CAUTION

The flare and the abrupt use of the collective will cause the nose to rotate left, but do not correct with throttle. Although application of throttle will result in rotation to the right, addition of power is a very strong response measure and is too sensitive for the pilot to manage properly at this time. DO NOT ADD POWER AT THIS TIME. Slight rotation at time of impact a zero ground speed should not cause any real problem.

(b) When landing area is reached, make an autorotational landing (THROTTLE

OFF). During the descent, airspeed above minimum rate of descent airspeed should be maintained and turns kept to a minimum.

(c) If landing area is suitable (i.e., level paved surface), touchdown at a speed above effective transitional lift.

(d) If the aircraft is uncontrollable, autorotate immediately.

(e) If the landing area is not suitable for a run-on landing a minimum ground run autorotation must be performed. Start to decelerate to about 75 feet of altitude so that forward ground speed is at a minimum when the helicopter reaches 10 to 20 feet; execute the touchdown with a rapid collective pull just prior to touchdown in a level attitude with minimum ground speed (zero, if possible)"

"9.24 Loss of Tail Rotor Effectiveness. This is a situation involving a loss of effective tail rotor thrust without a break in the drive system. The condition is most likely to occur at a hover or low airspeed as a result of one or more of the following.

a. Out-of-ground effect hover.
b. High pressure altitude/high temperature.
c. Adverse wind conditions.
d. Engine/rotor rpm below 6600/324.
e. Improperly rigged tail rotor.
f. High gross weight.

(1) Indications: The first indication of this condition will be a slow starting right turn of the nose of the helicopter which cannot be stopped with full left pedal application. This turn rate will gradually increase until it becomes uncontrollable or, depending upon conditions, the aircraft aligns itself with the wind.

(2) Procedures: Lower collective to regain control and as recovery is affected adjust controls for normal flight".

1.18.2 Emergency procedure when encountering a chip detector warning light

Operators Manual, Chapter 2, sub-heading 2.42 Indicators and Caution Lights

Transmission and Gearbox Chip Detector

"(1) Chip Detector Caution Light. Magnetic inserts are installed in the drain plugs of the transmission sump, 42° gearbox and the 90° gearbox. On helicopters equipped with ODDS, the transmission chip gap is integral to a full-flow debris monitor. When sufficient metal particles collect on the plugs to close the electrical circuit the CHIP DETECTOR segment in the CAUTION panel will illuminate. A self-closing, spring-loaded valve in chip detectors permits the magnetic probes to be removed without the loss of oil. The circuit is powered by essential bus and protected by the CAUTION LIGHTS circuit breaker.

(2) Chip Detector Switch. A CHIP DETECTOR switch (Figure 38) is installed on a pedestal mounted panel. The switch is labelled BOTH, XMSN, and TAIL ROTOR and is spring-loaded to the BOTH position. When the CHIP DETECTOR segment in the CAUTION panel lights up, position the switch to XMSN, then TAIL ROTOR to determine the trouble area. CHIP DETECTOR caution light will remain on when a contaminated component is selected. The light will go out if the non-contaminated component is selected."

The helicopter operator's manual contains a list of emergency procedures for the caution segments, which can be found attached to this report as Annexure A. If the chip detector light lights up on the annunciator panel in the cockpit, the corrective action should be for the pilot to <u>land as soon as possible</u>.

The operator's manual, sub-heading 9.3 (a) gives the following definition for <u>land as soon as possible:</u>

"The term <u>Land as soon as possible</u> is defined as executing a landing to the nearest suitable landing area without delay. The primary consideration is to assure the survival of occupants."

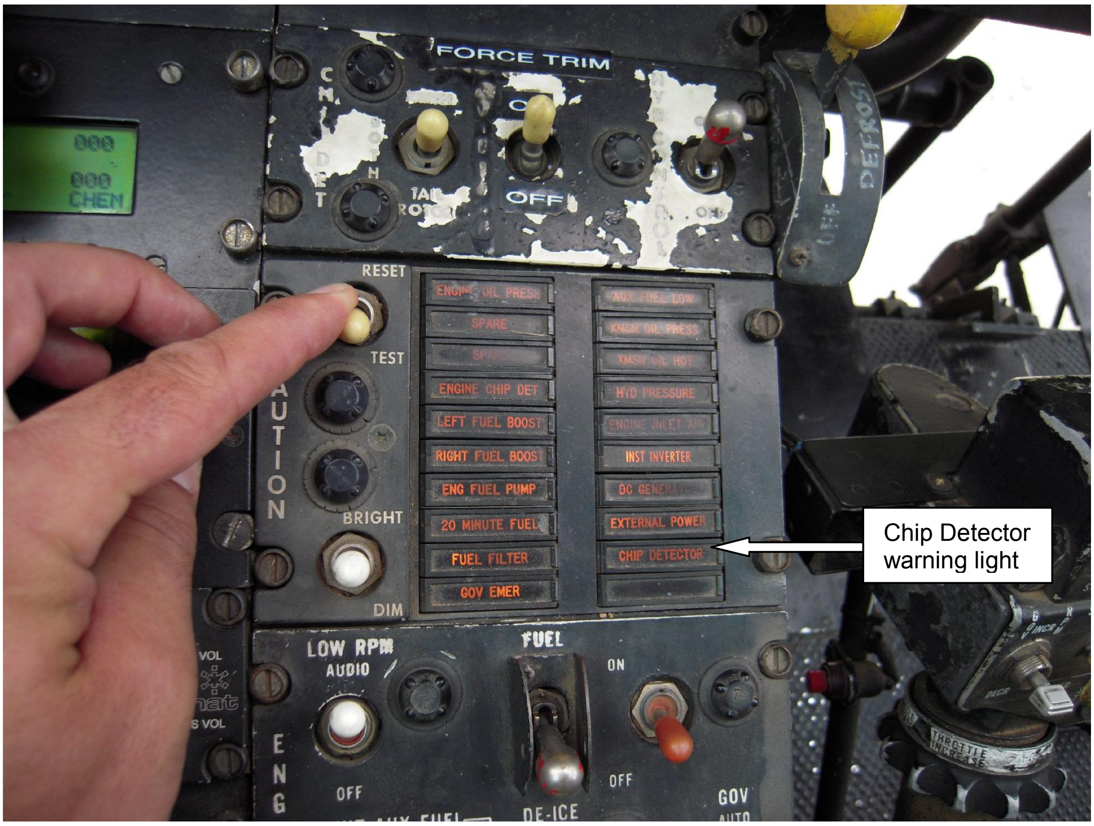


Figure 38. The caution segments on the annunciator panel (photograph was taken in another UH-1H)

1.18.3 Normal procedures, Operator's Manual, Chapter 8, Section II, Crew Duties

86. Crew Duties

a. *Responsibilities. The minimum crew required to fly the helicopter is a pilot. Additional crewmembers as required may be added at the discretion of the commander. The manner in which each crewmember performs his related duties is the responsibility of the pilot-in-command.*

b. *Pilot. The pilot-in-command is responsible for all aspects of mission planning, pre-flight and operation of the helicopter. He will assign duties and functions to all other crewmembers as required. Prior to or during pre-flight the pilot will brief the crew on the mission performance data procedures taxi and load operations."*

Section III, Operating Procedures

Pre-flight inspection (Tail boom and associated components)

"8-16. Area 3.

1. *Tail boom - Check as follows:*

a. Skin - Check condition.
b. Driveshaft cover - Check secure.
c. Synchronized elevator - Check condition and security.
d. Antennas - Check condition and security.
e. Tail skid - Check condition and security.

** 2. Tail rotor - Check condition and free movement on flapping axis. The tail rotor blades should be checked as the main rotor blade is rotated. Visually check all components for security.*

** 3. Main rotor blade - Check condition, rotate in normal direction 90° to fuselage, tiedown removed.*

8-17. Area 4.

** 1. Tail rotor gearboxes (90 and 42 degrees) - Check general condition, oil levels, filler caps secure.*

2. Tail boom - Check as follows;

a. Skin - Check condition.
b. Antennas - Check condition and security.
c. Synchronized elevator - Check condition and security"

The above information was extracted from the helicopter operator's manual and sets out the role and responsibility of the pilot-in-command as well what the pilot should look for during his/her pre-flight inspection of the tail boom and related components. During the on-site investigation it was found that neither of the two tail rotor gearboxes had any visible oil in the sight gauges once the tail boom was placed in an upright position. No evidence was found that oil had leaked from either of these two gearboxes. During the laboratory examination very little oil was found present in these gearboxes; however, they were still both in a serviceable condition and could be rotated by hand. No documented evidence could be found that the pilot had signed off a pre-flight inspection on the helicopter prior to the first flight of the day. It was further noted that the 42° gearbox was approximately 1.92m (6 feet 3 inches) from the ground and the 90° gearbox approximately 3.15m (10 feet 3 inches) from the ground when the helicopter was parked on a level surface. However, these values apply to a helicopter equipped with standard skid gear; the helicopter in question was equipped with an extended height landing gear kit, which provided significant extra ground clearance for the installation of belly-mounted equipment. The skid gear can be seen in Figure 3 on page 8 of this report, which would have raised the helicopter by approximately another 70 centimetres, or just over 2 feet from the ground when parked on a level surface. Therefore, when oil needed to be added in either or one of these two gearboxes the pilot would require a very long stepladder or another means of getting to the filler caps (i.e., a proper maintenance stand). To replenish the 42° gearbox, the gearbox cowling must be removed in order to gain access to the filler cap. As the Newlands Forest Station is not a maintenance base, no maintenance stands were available that maintenance personnel or pilots could use. They had to use a long stepladder or an alternative means of reaching these two gearboxes, especially the 90° tail rotor gearbox, which on this helicopter would have been approximately 4m (13 feet) from the ground.

1.18.4 Inspection of the aft control cable (displaying evidence of wear on another UH-1H)

On Wednesday, 11 March 2015 the investigator-in-charge (IIC) inspected a similar type of helicopter (UH-1H) at an aircraft maintenance facility at the Cape Town International aerodrome. During the maintenance inspection the aft control cable (the same cable that failed on the ill-fated helicopter) was found to display evidence of wear as well as several broken strands on the cable, which can be seen in Figure 39 on the next page. During that maintenance inspection the cable was removed and replaced with a new cable assembly, part number 205-001-720-001, serial number USFS468.

Routine maintenance requires a visual inspection of the control cables and their attachments. Maintenance personnel usually make use of a rag which they drag over the cable (if access allows such an action and if any wear on the cable is suspected). The rag will catch on the broken cable strands. The aft control cable on the UH-1H type helicopter was one of the cables that were accessible for a visual inspection to maintenance personnel following the opening of the tail rotor drive cowling as shown in Figure 15 on page 22 of this report. The aft control cable on this helicopter was between 8 to 13 feet from the ground. In order to inspect the cable an AME was required to make use of a proper maintenance stand or a long stepladder and open the tail rotor drive pylon cowling to gain access to the cables.

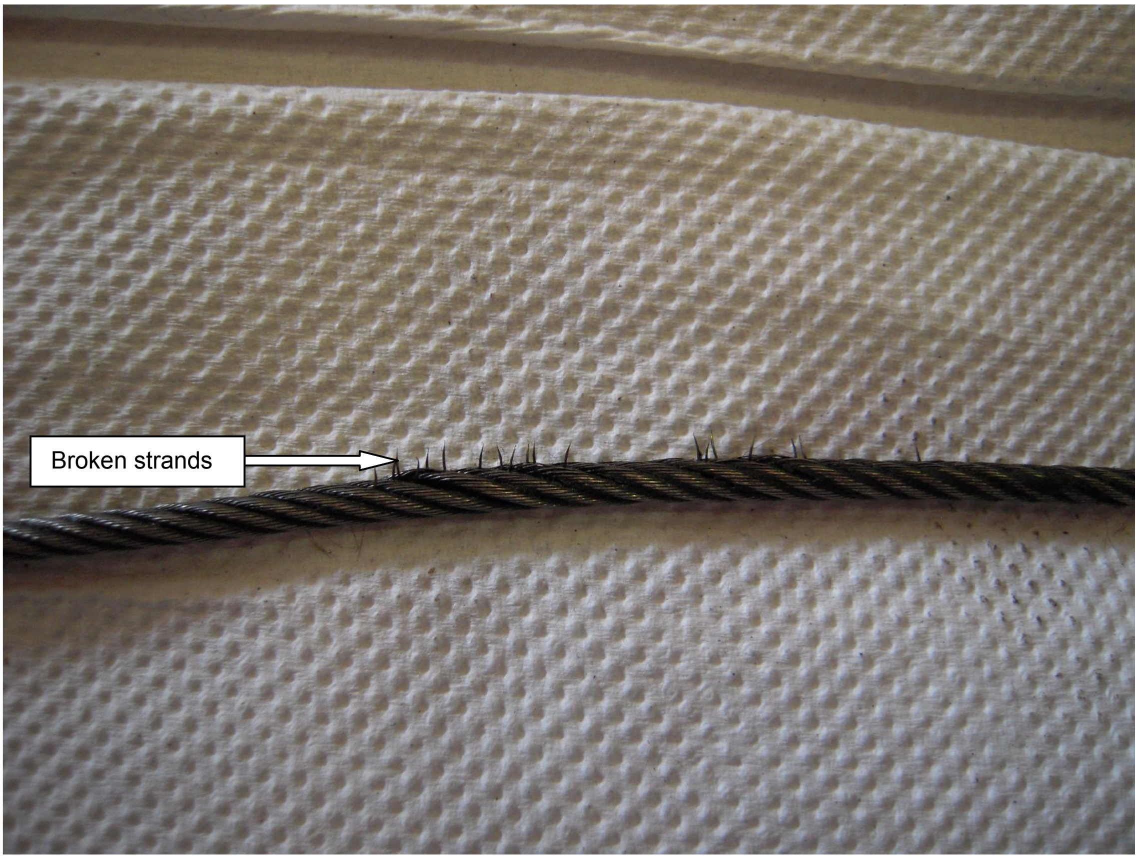


Figure 39. Several broken strands were visible on the aft control cable

1.19 Useful or effective investigation techniques

1.19.1 No new methods were applied.

2. ANALYSIS

2.1 Pilot (Man)

The pilot was the holder of a valid commercial pilot licence. He had concluded his type conversion to the Bell 205/UH-1H helicopter on 1 May 2011. The pilot last flew his licence proficiency skills check on 8 November 2014 on a UH-1H type helicopter with a designated flight examiner and was found to be proficient. The pilot held a valid aviation medical certificate with the limitation that he was required to wear suitable corrective lenses.

No documented evidence could be found that the pilot had signed off a pre-flight inspection prior to the flight, which was the first flight of the day. He most probably had conducted a pre-flight inspection, but had not noted that the oil level on both the 42° intermediate gearbox as well as the 90° tail rotor gearbox was below minima. The helicopter operator's manual states that during the pilot's pre-flight inspection the pilot needs to check the oil levels on both these gearboxes and ensure they are at the correct level. Both these gearboxes were at a substantial height from the ground, especially the 90° tail rotor gearbox, which was nearly 4 m (13 feet) from the ground, as the helicopter was fitted with the extended height landing gear kit. The fluid levels on the engine and airframe, which includes all the gearboxes, should have been checked by an appropriately type-rated maintenance engineer during a daily inspection, and if found to be low should have been replenished to the correct level. No documented evidence could be obtained that a daily inspection had been carried out, which shifts the responsibility to the pilot to ensure the oil levels were topped up prior to flight. While these low oil levels did not cause the accident, they might have caused problems during continued flight.

The pilot was flying on a direct route from the Newlands Fire Station to the Cape Point Nature Reserve; the flight time was approximately 20 minutes. Three UH-1H helicopters were dispatched on a firefighting operation to the Cape Point Nature Reserve, with the pilot flying ZS-HBV being number three. The pilot had extensive experience of flying helicopters as well as firefighting, and had flown the same helicopter the previous day. All three helicopters that were dispatched were flying with their Bambi bucket suspended below the helicopter.

The flight appeared to progress satisfactorily until the helicopter was approaching the vicinity of the Sirkelsvlei Dam, when the pilot broadcast over the company VHF radio frequency that he had a chip detector warning light in the cockpit (this is an amber light on the annunciator panel, as can be seen in Figure 38 on page 43 of the report). When the lead pilot asked which chip warning light it was, he stated it was the tail chip light. He was then advised by the lead pilot to land on the service road, which was located to his left, in order to inspect the magnetic plugs on the 42° intermediate gearbox as well as the 90° tail rotor gearbox. He opted to proceed ahead to where the helicopter support vehicle was located, which was approximately 2 nm to the south of his location at the time. Shortly thereafter he broadcast a mayday call. After he had executed a 180° turn and observed the helicopter at approximately 800 feet AGL rotating in a clockwise direction, the lead pilot told him to close the throttle and lower the collective pitch lever. There was no further communication from the pilot flying the ill-fated helicopter. The pilot flying the second helicopter also observed the helicopter rotating in a clockwise direction and making abrupt movements. It could not be determined why the pilot did not jettison the Bambi bucket when tail rotor control was lost. It could be that he became preoccupied when the chip detector warning light came on, as he was planning his intended landing at the helicopter support vehicle, starting to reduce speed to lower than cruising speed and was uncertain of the nature of the malfunction (loss of tail rotor control), which occurred unexpectedly shortly after the chip detector warning light came on. With the reduction in speed the need for anti-torque increased and directional control was jeopardized. Since power output is one of the major factors that determine the anti-torque requirement, power must be reduced by lowering the collective pitch lever and closing the throttle, using no power. The pilot probably realised that he had suffered a complete loss of tail rotor thrust when the fuselage started to rotate in a clockwise direction. He was unable to regain control of the helicopter before it impacted with the ground. No medical factor that could have affected the pilot's ability to fly the helicopter was detected during the medico-legal post-mortem.

2.2 Helicopter (Machine)

According to available evidence, the last daily inspection that was carried out on the helicopter prior to the accident flight was certified on 15 January 2015. No documented evidence could be obtained that any other daily inspections were carried or certified on the helicopter by maintenance personnel during the 52-day period following the inspection. The aircraft maintenance organisation made use of a designated form with reference; *"UH-1H preventative maintenance daily (PMD) inspection check sheet (Document number: QC43/PMD/UH-1H)"* for such inspections. The check sheet requires the signature by the maintenance engineer that conducted the inspection under each subheading provided for on the ten-page document. The inspection of the aft control cables was called for on page 3 of relevant document, under subheading 4.10.

Further to the above, the helicopter was maintained under the phase maintenance inspection programme. The last phase maintenance inspection prior to the accident flight was a phase 4 inspection that was certified on 20 January 2015. Subsequent to the inspection the helicopter flew a further 64.5 hours. According to the flight folio entries, these hours were flown over a period of thirty-three (33) flights, including the accident flight. What was of significance to this inspection was the fact that the dual inspection that was signed off on the airframe and engine logbooks at the maintenance headquarters in Nelspruit was conducted by a maintenance engineer who never inspected the helicopter, as he was not present at the maintenance base when this inspection was performed. Moreover, he also signed the certificate of release to maintenance of an aircraft (CRMA) as well as the previous phase 3 inspection carried out by him. All these maintenance-related tasks were performed by an AME who did not have a valid AME licence at the time. It was further noted that an AME who held an electrical AME licence signed off on a dual inspection on the flight controls during the phase 4 inspection that was certified on 20 January 2015. These actions, for which the maintenance organisation was directly accountable, were indicative of maintenance inspections that were conducted with limited maintenance personnel being available and display the aircraft maintenance organisation's disregard for the regulations referred to under subheading 1.6 of this report.

Subsequent to the two inspections addressed above, the following maintenance was performed on the helicopter prior to the accident flight:

(i) On 30 January 2015 the tail rotor yoke (entry on page 0130 of the flight folio) was replaced.

(ii) On 11 February 2015 maintenance was performed following a "severe medium vibration" (entry on page 0131 of the flight folio), which required the removal of the main rotor hub assembly followed by static balancing and re-installation of the hub assembly. The entry that was made in the airframe logbook pertaining to this task was signed off by a maintenance engineer who was not present when the tail rotor yoke was replaced. No further defects were noted in the flight folio, and it could not be determined whether any planned (i.e. daily) inspections or unplanned maintenance was performed on the helicopter prior to the accident flight.

The aft control cables installed on this helicopter were *'on condition'* items, which means they have no defined service life prescribed by the helicopter manufacturer and are replaced following assessment of the condition of the cables by maintenance personnel during the required maintenance inspections.

Following the analysis of the components subjected to laboratory examination, it was concluded that the aft control cable fractured due to wear in the area of the pulley location, which had progressed over an undetermined period of time. Following the failure of the cable the pilot would not have had any tail rotor control authority (yaw pedal input). The failure of the cable caused a secondary event, which resulted in a sudden stoppage of the tail rotor drive train, whereby the tail rotor driveshaft located just forward of the 42° intermediate gearbox failed in torsional overload. The sudden stoppage on the tail rotor drive train was brought about when the aft control cable fractured and the chain mechanism to which the cable was attached got wedged in underneath the 90° tail rotor gearbox input driveshaft coupling. Following the failure of the tail rotor driveshaft the pilot was faced with what the operator's manual describes as a *complete loss of tail rotor thrust*, which is an emergency associated with the failure of the tail rotor drive system. The helicopter yawed to the right (clockwise direction) and rotation increased, resulting in a high rate of descent; the pilot was unable to regain control of the helicopter before it impacted the ground.

With reference to the rail chip detector warning light, no evidence could be found to support such an observation as both tail rotor gearboxes (42° intermediate as well as the 90° tail rotor gearbox) were found to rotate freely, although very little oil was present in either of them (no oil leak was visible during the on-site investigation on either of the gearboxes). The respective magnetic plugs were found to be free from any noteworthy sediment that could have activated a chip detector warning light in the cockpit. The possibility of a short circuit in the system could be neither excluded nor substantiated.

The absence of progressive maintenance (daily inspections) subsequent to the phase 4 maintenance inspection was symptomatic of inadequate maintenance oversight/practices. This could be attributed either to a culture within the organisation whereby maintenance personnel omitted to perform certain maintenance tasks due to human error, or to a lack of maintenance personnel to support the entire helicopter fleet, or a lack of maintenance equipment (i.e., maintenance stands) at the outstations (i.e., Newlands Forest Station) for maintenance personnel to conduct a comprehensive inspection of each helicopter as required, or a lack of oversight by the maintenance organisation, or a combination of the above. Had these daily inspections been carried out as required, it is highly probable that maintenance personnel would have detected evidence of wear on the aft control cable during the early stages, (i.e., broken strands) similar to the wear observed on the cable shown in Figure 39 on page 49 of this report, and the cable would have been replaced. It was evident that the integrity of the cable was compromised over a period of time (this was not an instantaneous failure), and its subsequent failure led to an accident that in all probability could have been prevented.

Progressive maintenance in the form of daily inspections was essential, especially in view of the operator's ageing fleet of helicopters. Daily inspections were of paramount importance because they allowed maintenance personnel the opportunity to detect minor as well as major defects that could be rectified before the next flight. The number of maintenance engineers (mechanical) that was employed by the maintenance organisation was found to be inadequate to ensure that the entire helicopter fleet (which consisted of sixteen UH-1H helicopters at the time, spread over the country) was maintained according to the maintenance schedule. This was found to be significant in the investigation, as it showed a blatant disregard for the quest for aviation safety and the preservation of human life.

2.3 Mission

The helicopter was deployed in a firefighting application, operating under a restricted Part 127 certificate of airworthiness. The mission for which the helicopter was deployed was nothing unusual; the pilot was well familiar with the intended operation and well experienced in helicopter flying. The accident occurred approximately 20 minutes after take-off from the Newlands Forest Base with the helicopter descending for landing at the helicopter support vehicle following a chip detector warning light coming on in the cockpit.

The data that was obtained from the Garmin Aero 500 GPS unit indicated that the unit was not recording the last phase of the flight prior to impact. The pilot may have opted to switch the unit off once he approached the fire zone, as it could have been a distraction to him. The download data indicated that the flight was uneventful until the point the unit stopped recording.

2.4 Environment

The flight was conducted during conditions associated with visual meteorological flight (VMC). According to the information obtained from the automatic weather station at Cape Point the prevailing wind at the time was from the south-south-east at 10 knots with gusts up to 20 knots. The helicopter was flying in a southerly direction; therefore the wind would have been from the left in the 10 - 11 o’clock position. The prevailing wind was therefore very near to the ideal situation, as the pilot would have wanted to be flying into wind when he entered into autorotation following the loss of tail rotor thrust.

2.5 Conclusion

The examination of the wreckage suggested that the helicopter impacted the ground in a northerly direction in a nose-down attitude, with a substantial vertical component associated with a high rate of descent. The tail boom was severed by the main rotor blades on impact and separated from the main wreckage, which was consumed by the post-impact fuel-fed fire that erupted.

During inspection of the tail boom, which consisted of a forward and an aft section, it was found that the aft tail rotor control cable had fractured. Laboratory examination of the cable revealed that it had fractured due to mechanical wear in the area of the pulley. It was further noted that the tail rotor driveshaft located just forward of the 42° intermediate gearbox had failed in torsional overload, following a sudden stoppage of the tail rotor drive train. This was most probably brought about when the chain mechanism to which the aft control cable was attached got wedged under the 90° tail rotor gearbox input drive coupling. The failure of the tail rotor driveshaft caused a complete loss of tail rotor thrust, and the helicopter started to rotate clockwise followed by abrupt movements.

No evidence could be found on either of the two tail rotor gearboxes that could substantiate the pilot observation that the chip detector warning light ‘tail’ had illuminated in the cockpit. The emergency procedure in the helicopter operator’s manual indicates that the pilot should <u>land as soon as possible</u> following the activation of a chip detector light. The pilot indicated to the pilot flying the ‘lead’ that he would like to proceed to where the helicopter support vehicle was parked, which was approximately 2 nm from his current position straight ahead. Shortly after this communication the pilot broadcast a mayday call. The helicopter was then observed to rotate in a clockwise direction. The pilot flying the lead helicopter broadcast over the radio to the pilot to close the throttle and lower the collective pitch lever, as it was of paramount importance to reduce all power immediately following a loss in tail rotor thrust. However, the pilot was unable to recover from the situation and the helicopter impacted the ground.

3. CONCLUSION

3.1 Findings

<u>Pilot</u>

3.1.1 The pilot was the holder of a valid commercial pilot licence and had the helicopter type endorsed on his licence.

3.1.2 The pilot was the holder of a valid aviation medical certificate that was issued by a CAA-approved medical examiner.

3.1.3 The flight was nothing out of the norm for the pilot; he was well familiar with the type of operation (firefighting) to be conducted.

3.1.4 The pilot flew his last licence proficiency skills check on 8 November 2014 under the supervision of a designated flight examiner on a UH-1H type helicopter.

3.1.5 No documented evidence could be found that the pilot had signed off a pre-flight inspection prior to the ill-fated flight.

3.1.6 The pilot had communicated with dispatch at Newlands Forest Station and indicated that there was 900 pounds of fuel on board the helicopter on take-off.

3.1.7 The pilot opted to take off with the Bambi bucket suspended below the helicopter for the duration of the positioning flight. The Bambi bucket was secured to the cargo sling with a 5 m cable.

3.1.8 The pilot said on the company radio frequency 120.55 MHz that he had a tail chip detector warning light while en route to the fire zone. He was advised by the pilot flying the lead to land as soon as possible on the service road to his left and to inspect the magnetic plugs on the 42° intermediate gearbox as well as the 90° tail rotor gearbox.

3.1.9 The helicopter operator's manual states that a pilot should "Land as soon as possible" following a chip detector warning light activation in the cockpit. The pilot said on the radio that he would land at the helicopter support vehicle, which was approximately 2 nm to the south of his position at the time.

3.1.10 A short while later the pilot broadcast *"mayday mayday mayday",* no further communication was forthcoming thereafter from the pilot. The helicopter was observed to rotate in a clockwise direction, making abrupt movements, by the other two helicopter pilots.

3.1.11 The pilot did not jettison the Bambi bucket.

3.1.12 No medical factor that could have affected the pilot's ability to fly the helicopter was detected during the medico-legal post mortem.

Helicopter

3.1.13 The helicopter had a valid Certificate of Airworthiness at the time of the accident flight; however, inadequate progressive maintenance inspections were found to have impaired the serviceability status of the helicopter.

3.1.14 The helicopter was not equipped with an FDR or a CVR.

3.1.15 On 15 January 2015 a daily inspection was carried out on the helicopter and it was signed off by an AME on a designated maintenance document with reference number QC43/PMD/UH-1H.

3.1.16 No evidence could be found that any repetitive daily inspections were carried out on the helicopter over the 52-day period that followed the documented inspection dated 15 January 2015 and prior to the ill-fated flight.

3.1.17 On 20 January 2015 a phase 4 maintenance inspection was certified on the helicopter. Subsequent to the inspection a further 64.5 hours were flown with the helicopter.

3.1.18 A duplicate inspection was signed off on page 95 of the airframe logbook by a maintenance engineer who was not present during the phase 4 maintenance inspection. The same person had also certified a duplicate inspection on the certificate relating to maintenance on an aircraft (CRMA) number 848.

3.1.19 On 30 January 2015 the tail rotor yoke assembly was replaced. The airframe logbook entry (page 95) was signed off by AME stamp #6, who was not present during the maintenance task and did not have a valid AME licence at the time. It was further noted that the duplicate inspection that was required was not signed off in the flight folio on page 0130.

3.1.20 On 11 February 2015 a defect was entered into the flight folio stating that the helicopter had a severe vibration. The defect was rectified by removing the main rotor hub assembly doing static balancing. This was the last documented (flight folio) maintenance that was performed on the helicopter prior to the ill-fated flight.

3.1.21 During the on-site investigation it was found that the aft control cable had fractured. The laboratory examination revealed that the cable had fractured due to mechanical wear at the pulley location. The wear occurred over an undetermined period of time.

3.1.22 Following the failure of the aft control cable, a sudden stoppage occurred within the tail rotor drive train, which resulted in a torsional overload failure of the tail rotor driveshaft located just forward of the 42° intermediate gearbox.

3.1.23 The wear on the aft control cable went undetected due to the fact that maintenance personnel omitted to perform daily inspections on the helicopter following the phase 4 inspection that was certified on 20 January 2015.

3.1.24 Neither the 42° intermediate gearbox nor the 90° tail rotor gearbox had any oil visible in the sight gauges during the on-site investigation when the tail boom was placed in an upright position. There was no evidence that oil had leaked from either of these gearboxes, which were free to rotate by hand.

3.1.25 Neither the magnetic plug on the 42° intermediate gearbox nor on the 90° tail rotor gearbox displayed any evidence of sediment that would have activated a chip detector warning light in the cockpit, nor did the teardown inspection of the two gearboxes reveal any related evidence.

3.1.26 The helicopter was operated within its weight limitations, with the pilot being the sole occupant on board.

3.1.27 The AMO responsible for maintaining the helicopter fleet allowed an aircraft maintenance engineer employed by them to conduct maintenance on this helicopter and to make entries in official maintenance documents pertaining to phase inspections as well as dual inspections on flight controls, which he signed off without being present or holding a valid AME licence (licence expired 1 June 2013 and was renewed on 31 March 2015).

3.1.28 On Saturday, 7 March 2015 maintenance was conducted on the helicopter ZS-HBV by AME (stamp #10). There was no defects entered in the flight folio by any flight crew member nor did the AME enter the maintenance actions he performed on the helicopter in the document.

Environment

3.1.29 Fine weather conditions prevailed at the time, with the prevailing wind in the area being from a south-south-easterly direction at 10 knots with a gust up to 20 knots.

The pilot was basically flying into wind when he encountered a total loss of tail rotor thrust.

Other

3.1.30 The operator was in possession of a valid AOC to conduct fire-fighting and the helicopter in question was duly authorised to operate under the AOC.

3.1.31 The aircraft maintenance organisation that conducted the last phase inspection as well as the last maintenance on the helicopter prior to the accident flight was in possession of a valid AMO approval certificate at the time.

3.1.32 The maintenance engineering staff complement employed by the AMO at the time was found to be inadequate to conduct proper maintenance oversight of the operator's ageing helicopter fleet.

3.1.33 The Garmin GPS unit that was on board the helicopter stopped recording a few minutes before the accident occurred; up to that point the flight was uneventful.

3.1.34 Following the mayday call by the pilot in distress, the pilots flying the other two UH-1H helicopters observed ZS-HBV rotating in a clockwise direction and making abrupt movements before impacting the ground.

3.1.35 The main wreckage was consumed by the post-impact fuel-fed fire that erupted.

3.1.36 The tail boom was severed by the main rotor blades during the impact sequence. Neither the forward nor the aft section sustained any fire damage.

3.1.37 In view of the destruction of the cockpit/cabin area during the impact sequence, this was not considered a survivable accident.

3.1.38 The helicopter in question had been in service for 48 years since manufacture (ageing helicopter).

3.2 Probable cause:

3.2.1 The pilot was unable to regain control of the helicopter following a loss of tail rotor thrust, which was caused by fracture of the left-hand aft control cable during flight, followed by the failure of the tail rotor driveshaft.

3.3 Contributory factors:

3.3.1 The left-hand aft control cable fractured due to mechanical wear at the pulley location, which caused secondary damage and failure of the tail rotor drive train. This occurred 52 days after the last daily inspection on record was signed off on 15 January 2015 and 64.5 hours of operation after the last phased inspection was signed off on 20 January 2015.

3.3.2 Failure of the maintenance organisation and maintenance personnel to follow required maintenance procedures, thereby not detecting the deteriorating condition of the aft control cable timeously (absence of daily inspections). This should be regarded as a significant contributory factor to this accident, as the serviceability status of this helicopter was severely compromised.

3.3.3 The maintenance engineering staff complement employed by the AMO at the time was found to be inadequate to conduct proper maintenance inspections of the ageing fleet of helicopters as called for in the aircraft maintenance schedule. The lack of maintenance oversight was further aggravated by the fact that the helicopter fleet was scattered over a vast area of the country. An ageing aircraft fleet requires increased inspection activities and maintenance tasks, which in turn increases workload and requires more manpower.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended to the Director of Civil Aviation that a safety audit be conducted on the aircraft maintenance organisation and the operator following a spate of accidents involving the operator. Over a period of 3½ months (8 March to 18 June 2015) the operator had four accidents, two of which were fatal and resulted in the complete loss of three of the four aircraft and the death of three crew members. During the period February 2012 until June 2015 the operator had a total of eleven accidents, of which four were fatal. This is cause for serious concern and requires proactive intervention by the regulating authority in the interest of aviation safety.

*NOTE: This safety recommendation was complied with by the regulating authority and a safety audit was conducted at the operator and the aircraft maintenance organisation over the period 29 June until 3 July 2015, with the consequence that both the AOC and AMO certificates were revoked.

4.2 It is recommended to the Director of Civil Aviation that the authority seriously consideration the installation of a flight data recorder (FDR) or a similar type of recording device in these helicopters. These devices should be crashproof as well as fire resistant. They should not be seen as having a single purpose, but as an aid to progressive maintenance whereby data could be downloaded on a regular basis.

4.3 It is recommended that the operator implement clear guidance material to flight crew with reference to the position of the Bambi bucket during positioning flights. It is recommended in the interest of aviation safety that they consider introducing a standard whereby Bambi buckets are placed inside the cabin area during positioning flights (i.e. flights similar to the accident flight). Although it could not be conclusively proven, it is believed that the external position of the Bambi bucket at the time could have had an effect on the handling characteristics of the helicopter following a loss of tail rotor thrust.

4.4 It is recommended that the AMO responsible for maintaining the fleet of firefighting helicopters ensure that the manpower available is adequate to meet all necessary tasks, which would include planned as well as unplanned maintenance. With the fleet of helicopters in operation being an ageing fleet, maintenance inspections cannot be compromised in any way that would include the daily progressive maintenance program. These daily inspections should be signed off in the flight folio as well as on the designated form QC43/PMD/UH-1H, which will be appropriately kept by the AMO following the implementation of a proper record keeping procedure/system.

4.5 It is recommended to the Director of Civil Aviation that the Airworthiness division issue an emergency safety directive (ESD) calling for immediate inspection of the aft control cables on all Bell 205/UH-1H type helicopters on the South African register before their next flight.

4.6 It is recommended that the operator ensure that a documented system is incorporated (preferably in the flight folio) whereby the pilot would be required to sign off his/her pre-flight inspection prior to the first flight of the day. Proper record keeping of such documentation should be adhered to by the operator.

4.7 It was found that the Civil Aviation Authority (CAA) has no clear guidance material/regulations for ageing aircraft/helicopters from an airworthiness perspective. It is recommended to the Director of Civil Aviation that the authority compile such guidance material with reference to maintenance procedures involving ageing aircraft/helicopters. The term "ageing aircraft/helicopters" should also be clearly defined in such documentation/regulation(s).

4.8 It is recommended to the Director of Civil Aviation that during oversight inspections (planned or unplanned), the Airworthiness Inspectorate should ensure that all maintenance personnel employed by an AMO conducting maintenance in any manner on an aircraft/helicopter are appropriately licensed or comply with the Regulations, Part 43 (General Maintenance Rules) at all times. The fact that an AME was allowed to work under an AMO on helicopters and sign off maintenance documentation while his AME licence was invalid for a period of twenty-one months should raise serious safety concerns with regard to regulating oversight and AMO accountability.

5. APPENDICES

5.1 Annexure A (Operator's Manual, Chapter 9, Emergencies, Caution light segments)
5.2 Annexure B (Civil Aviation Regulations of 2011, Part 43 as well as SA-CATS43)
5.3 Annexure C (Technical comments from the operator where agreement couldn't be reached)
5.4 Annexure D (Actions by the operator following the accident)

ANNEXURE A

Table 9-1 Emergency Procedures for Caution Segments

Light	Corrective Action
MASTER CAUTION	Check the CAUTION panel for the condition. If master caution only (no segment light), land as soon as possible.
AUX FUEL LOW	INT AUX FUEL transfer switches-OFF,
DC GENERATOR	Check GEN AND BUS RESET circuit breaker in MAIN GEN switch RESET then ON. Switch to STBY GEN.
INST INVERTER	Switch to other inverter,
EXTERNAL POWER	Close door.
XMSM OIL PRESS	Land as soon as possible. (Ref to para 9-19)
XMSM OIL HOT	Land as soon as possible. (Ref to para 9-19)
ENGINE INLET AIR	Land as soon as practicable.
CHIP DETECTOR	Land as soon as possible.
LEFT FUEL BOOST	Land as soon as practicable.
RIGHT FUEL BOOST	Land as soon as practicable.
20 MINUTE FUEL	Land as soon as practicable.
IFF	Information/System Status
ENGINE OIL PRESS	Land as soon as possible.
ENGINE CHIP DET	Land as soon as possible.
GOV EMER	Information/System Status
ENGINE ICE DET	Land as soon as possible.
ENGINE FUEL PUMP	Land as soon as possible.
ENGINE ICING	Land as soon as possible.
FUEL FILTER	Land as soon as practicable.
HYD PRESSURE	Land as soon as practicable.
SPARE	Land as soon as possible.

ANNEXURE B

Civil Aviation Regulations of 2011

Part 43 General Maintenance Rules

SUBPART 1: GENERAL

43.01.1 Applicability

(1) This Part applies to the maintenance, and the release to service after maintenance, of-

(a) type certificated aircraft registered in the Republic; and
(b) aircraft components to be fitted to such aircraft.

(2) This Part does not apply to any aircraft specified in regulation 24.01.1. Falsification, reproduction or alteration of maintenance documents.

43.01.2 No person shall make or cause to be made –

(a) any fraudulent or false entry in any record, which is required to be made, kept, or used to show compliance with any requirement prescribed in this Part; or

(b) any reproduction or alteration for fraudulent purposes, of any record or report made in terms of the provisions of this Part.

43.01.5 Entries in logbooks

(1) (*a*) Entries in logbooks shall be made and signed by the holder of an appropriate licence, a person holding a valid authorisation issued in terms of part 145, or by a person approved for the purpose by the Director.

(*b*) Matters that could not have come to the notice of such licence holder or approved person shall be entered and signed by the pilot-in-command.

(2) Any record kept for the purpose of compiling a logbook entry or where reference is made to a record system other than the logbook shall be produced when called for in the event of any inspection or investigation by an authorised officer, inspector or authorised person.

(3) Entries in logbooks shall contain all the information and particulars provided for in the logbook.

(4) (*a*) Whenever corrections are made to entries in a logbook, the correction shall be made in such a way that the original entry still remains legible.

(*b*) The use of tippex or similar correction methods is prohibited.

SUBPART 2: MAINTENANCE

43.02.1 Aircraft maintenance schedules

(1) Every type certificated aircraft on the South African Civil Aircraft Register shall be maintained according to an approved aircraft maintenance schedule as prescribed in regulation 43.02.8.

(2) The owner of an aircraft shall draw up, or have drawn up a maintenance schedule for his or her aircraft in accordance with the provisions of technical standard 43.02.8 in Document SACATS 43.

(3) The owner or the responsible AMO shall submit the proposed maintenance schedule to the Director for approval.

(4) Provided the proposed maintenance schedule meets all the requirements of technical standard 43.02.8, the Director shall approve the proposed aircraft maintenance schedule either as submitted or as amended by him or her in the interest of aviation safety.

42.02. Persons to carry out maintenance

(1) Subject to the provisions of sub-regulations (2) and (3), no person shall carry out maintenance on a type certificated aircraft or aircraft component unless such person –

(a) is the holder of an AME licence with an appropriate rating issued in terms of Part

66;

(b) carries out maintenance under the direct supervision of the holder of an AME licence with an appropriate rating issued in terms of Part 66; or

(c) is authorised by the holder of an AMO approval with an appropriate rating issued in terms of Part 145, to carry out maintenance within the scope of such approval.

(2) The holder of a pilot licence with an appropriate type rating issued in terms of Part 61 or Part 62 may carry out the maintenance as prescribed in Document SA-CATS 43 if –

(a) such holder is the owner or operator of the aircraft; and

(b) the aircraft is used for non-commercial operations.

(3) The routine maintenance, scheduled inspections, structural integrity inspections, overhaul, modification, major repairs and structural repairs on aeroplanes with a MCM in excess of 5 700 kg or on helicopters with a MCM in excess of 3 175 kg shall be undertaken and certified by an appropriately rated approved AMO only.

43.02.8 Mandatory inspections

(1) Mandatory tests and inspections shall be carried in accordance with the approved maintenance schedule for a particular aircraft at the prescribed times or intervals.

(2) Mandatory inspections include—

(a) for aeroplanes with a MCM of 5 700 kg or less or a maximum approved passenger seating configuration of not more than 9 seats, and for helicopters with a MCM of 3 175 kg or less or a maximum approved passenger seating configuration of not more than 9 seats—

(i) a mandatory periodic inspection; and

(ii) inspections in accordance with an approved progressive inspection programme;

(*b*) for any aircraft, other than those referred to in paragraph (*a*), the approved maintenance schedule for the particular category and type of aircraft at the intervals prescribed by the schedule.

(3) An aircraft referred to in sub-regulation (2) (*a*) (i) that has not accumulated 100 hours within 12 months since its last inspection shall undergo a mandatory periodic inspection before it is being released to service.

(4) An aircraft referred to in subregulation (2) (*a*) (ii) that has not completed its progressive inspection programme within the period specified by the manufacturer or the Director shall undergo the remainder of the progressive inspection programme before it is being released to service.

(5) The maintenance schedules referred to in sub-regulation (1) are defined in Document SA-CATS 43.

SUBPART 3: RECORDING OF MAINTENANCE

43.03.1 Maintenance records

(1) Any person who carries out maintenance on an aircraft or aircraft component shall record, on completion of the maintenance—

(*a*) details of the maintenance including, where applicable, the type of inspection and any approved data used;

(*b*) for a mandatory periodic, progressive or scheduled inspection, whether a detailed inspection or routine inspection of the particular components or areas of the aircraft was carried out;

(*c*) the serial numbers, if any, of components removed or fitted;

(*d*) details of measurements or test results obtained, including the results of any ground or air tests;

(*e*) for an air speed indicator or altimeter system pilot static test and inspection, the date on which, and maximum altitude to which the altimeter has been tested;

(*f*) the date of completion of such maintenance;

(*g*) the references to the documents used to carry out the maintenance and their revision status;

(*h*) the name of the person completing such maintenance, if other than the person certifying the release to service;

(*i*) the location and, if applicable, the name of the facility where such maintenance was carried out; and (*j*) where such maintenance has been carried out as a consequence of the failure of any equipment, or damage caused by forced landing or accident, the reasons for carrying out the maintenance.

(2) The person who carries out the maintenance shall-

(a) record the details referred to in sub-regulation (1) in the appropriate logbook or in a maintenance record approved by the Director;

(b) where worksheets or other associated maintenance records are used to document the details of the maintenance, make a reference to those records in the logbook, flight folio or in the maintenance record approved by the Director.

(3) The manner for completion of logbooks, flight folios and maintenance records, referred to in sub-regulation (2), and the period for which such documents shall be retained are prescribed in SA-CATS 43.

SUBPART 4: RELEASE TO SERVICE

43.04.1 Persons to certify release to service

(1) No person shall certify an aircraft or aircraft component for release to service after maintenance unless such person –

(a) is the holder of an AME licence with an appropriate rating issued in terms of Part 66;

(b) is authorised by the holder of an AMO approval with an appropriate rating issued in terms of Part 145, to certify maintenance within the scope of such approval;

(c) is authorised by the Director to certify an aircraft or aircraft component for release to service; or

(d) for maintenance carried out outside the Republic, holds a licence or equivalent authorisation issued by an appropriate authority acceptable to the Director, for the type of aircraft or aircraft component.

(2) The holder of a pilot licence with an appropriate type rating issued in terms of Part

61 or Part 62 may certify maintenance which has been carried out in accordance with the conditions referred to in regulation 43.02.2(2).

43.04.11 Flight folio completion

(a) No person shall certify an aircraft or aircraft component for release to service in an aircraft flight folio unless each applicable section of the flight folio has been completed.

(b) This includes the section where any rectification of deferred defects must be recorded.

South African Civil Aviation Technical Standards (SA-CATS)

43.02.2 PERSONS TO CARRY OUT MAINTENANCE

1. Pilots

The maintenance that the holder of a pilot licence, other than a student pilot licence or learner's certificate, with an appropriate rating issued in terms of Part 61 or Part 62 may carry out is limited to the following items on an aeroplane with a maximum certificated mass of 5 700 kg or less or a maximum approved passenger seating configuration of nine seats or a helicopter with a maximum certificated mass of 3 175 kg or less or a maximum approved passenger seating configuration of nine seats:

(1) Emergency/en route maintenance comprising of the following, provided that only approved materials, parts and components are used:

(a) changing of tyres and tubes and repairing punctures;
(b) servicing landing gear shock struts with air;
(c) correcting defective locking wire and split pins;
(d) replenishing hydraulic fluid in the hydraulic fluid reservoir;
(e) small simple repairs to fairings, non-structural cover plates and cowlings by means of stop drilling cracks and fitting small patches or reinforcements which will not change contours or interfere with proper airflow;
(f) replacing side windows where such work does not interfere with the primary system;
(g) replacing safety belts; 51

(h) replacing seats or seat parts where such work does not involve any removal, dismantling or interference with a primary structure system;
(i) replacing pre-fabricated fuel and oil lines, provided that a fuel flow check is carried out in accordance with TS 43.02.8, Section A.2(6) “fuel flow checks”;
(j) replacing any electrical bulb, reflector, lens or fuse of navigation and landing lights;
(k) replacing or cleaning spark plugs and setting spark plug gaps;
(l) cleaning fuel and oil strainers;
(m) replacing batteries and checking fluid level and specific gravity;
(n) replacing tail wheels and tail-wheel springs;
(o) changing engine oil;
(p) removing and installing such dual controls as is designed for easy removal and installation;
(q) replacing the following instruments by others of the same type which have such markings as may be indicated in the appropriate owners manual:
(i) airspeed indicator;
(ii) altimeter;
(iii) engine speed indicator for each engine;
(iv) oil pressure gauge for each engine; and
(v) fuel contents gauge,

Provided that a pitot static check is carried out in accordance with TS 43.02.9 for subparagraphs (i) and (ii) above;

(2) Whenever it is necessary to carry out maintenance of this nature, the pilot must –

(a) notify the aircraft maintenance organisation or aircraft maintenance engineer normally responsible for the maintenance of the aircraft to assist in –
(i) supplying parts, if required;
(ii) giving technical advice;
(iii) supplying maintenance publications, where required; and

(b) ensure that any maintenance work done, is correctly recorded in the aircraft flight folio, including particulars of –
(i) maintenance publications referred to;
(ii) parts replaced (serial numbers where applicable);
(iii) parts repaired; and
(iv) tests carried out (if applicable).

(3) Entries in the aircraft flight folio must be accompanied by the pilot’s signature, licence

number and the date of entry.

(4) Unless the pilot is the holder of an aircraft maintenance engineer licence with an appropriate rating, such pilots may on no account sign an aircraft logbook in the column intended for the signature of the holder of an aircraft maintenance engineer licence or aircraft maintenance organisation approval.

43.02.8 MANDATORY INSPECTIONS

SECTION D

13. Duplicate inspections

(1) A duplicate inspection of all engine and flight control systems shall be carried out after initial assembly and at any time the systems have been disturbed in any way. The purpose of the duplicate inspection is to verify that the manufacturer's specifications and requirements have been met in full.

(2) An initial inspection of the control system shall be made and certified by a person in possession of a valid Aircraft Maintenance Engineer's (AME) licence, or who has been approved by the Director as an Inspector in an organisation, or holds company certification as prescribed in Part 145 of the Civil Aviation Regulations immediately after the maintenance is completed and before the aircraft is flown. Persons qualified to perform and certify duplicate inspections are:

(a) A type-rated AME or person holding valid company certification in terms of Part 145 of the Civil Aviation Regulation.

(b) An AME, holding a valid licence for the particular category, but not type-rated.

(c) The holder of valid company certification on a similar type.

(d) The holder of a valid airline transport pilot licence rated on the type concerned, if the persons referred to in subparagraphs (a), (b) or (c) are not available.

-END-

ANNEXURE C

Comments raised by the operator.

The investigating team has considered submission from the operator in respect of the aircraft accident ZS-HBV, subsequently we reviewed the said submission. Below are the comments which are non-editorial specific to technical aspects of the Final report upon which no agreement could be reached

Comments raised by the operator:

Page 1

1. *"We wish to strongly contest the fundamental assertion in the SACAA report, viz that the Probable Cause listed on page 1 of the report;"*

2. Page 2

Page 2, first paragraph;

"We were also able to download the exact GPS tract of ZS-SMT, the lead helicopter in the three ship squadron of Hueys."
On page 2 of the Kishugu Aviation document in question they state; *they have availed affidavits to key witnesses*, who according to their knowledge were not interviewed.

They include;

2.1 The pilot of ZS-SMT
The information in their comment/contestation document is correct; The Investigator never interviewed the pilot of **ZS-SMT** as this was a **Hawker Siddeley 125-3B** type of aircraft. The Investigator is of the opinion that the pilot of this aircraft did not engaged in a conversation with the deceased pilot on the chip warning light nor any other emergency situation.

2.2 The driver of the HSV

2.3 The engineer who performed maintenance on ZS-HBV

3. Page 3

Page 3, paragraph 1.2, last sentence;

"The first two helicopters, ZS-MST and ZS-SLK took off virtually together."

Pages 3, paragraph 1.2, first sentence;

"The flight of the three helicopters (ZS-SMT and ZS-SLK flight in tight formation) and ZS-HBV."

4. Page 6

Page 6 – ***"The fracture of right the tail rotor control cable:*** *The right aft tail rotor* *control cable failed as a result of the impact of the main rotor on the tail boom, just in front of the horizontal stabilizer, before the fuselage impacted with the ground".*

5. Page 20

Conclusion, Page 20

"4.2.1 The investigator did not interview all witnesses thoroughly. We include the lead pilot, the engineer and the other pilots at the base. We have submitted affidavits for all the relevant witnesses we contracted and interviewed in compiling the experts report"
The second pilot
The Newlands Dispatcher
The spotter pilot

"4.2.2 The timeline and positioning of events in the SACAA report is not consistent with the timelines we were able to construct by triangulation from the GPS download for ZS-SLK on the day. The SACA report compresses the time and location of the chip warning conversation and the later mayday call. The timeline and relative position between ZS-SLK and ZS-HBV which the experts reconstructed provides a more realistic picture and timing of the events surrounding the crash of ZS-HBV."

"4.2.3 The SACAA relies on a false positive observation of the tail rotor cable post-crash and proceeds to assume this to be both existent prior to the accident and furthermore posits this as the cause of the accident. The more plausible scenario in which the extreme force which was exerted on this cable when the main rotor impacted on the tail section immediately prior to impact with the ground, explains the nature of the fracture, a high tension fracture, as well as the thinning of the a cable fibres as it was violently pulled over the pulley. There simply no way the pressure of the footpedal could have occasioned such a fracture in cruise flight, even if the thinning had been present prior to the flight. "

"4.2.4 The SACAA report is economical with the facts when it claims there was not sufficient cable left to do a strength test. The components returned to us by the SACAA included sufficient cable to conduct such a test

"4.2.5 The SACAA report moves from the improbable cable fracture in flight, to a patently impossible assertion that the fractured cable and chain then jammed the drive train (turning at 4 300rpm) at the 90° gearbox, which caused the drive shaft in front of the 42° gearbox to fracture. The physical evidence in the components sent to Bell does not support any such blockage and the fact that the drive train fractured in front of the 42° gearbox and not in the segment where the blockage alledgedly took place, undermines the logic and lielihood of this assertion. "

"4.2.6 The SACAA report's suggestion that the helicopter took off on 8th March 2015 with little or no oil in the 42° and 90° gearboxes is supported by the condition in which these gear boxes were recovered at the accident site and described in the SACAA report. It is extremely unlikely that these gearboxes would appeared as serviceable as described in the SACAA report after the approximate 17 minute flight on the 8th March 2015 an the 1,6 hour flight on the 7th March 2015. As indicated in the expert report, the centrifugal forces generated by the spin produced the dispertion force through the breather hole in these gearboxes. Moreover the

comments about the height of the oil level sight glasses is simply not supported by the facts of pilots being able to see these oil levels."

"4.2.7 The SACAA report posists that there was a complete loss of tail rotor thrust which resulted in the accident. A complete loss of tail rotor thrust in straight and level cruise flight should not lead to an accident. The helicopter operators manual quoted in the SACAA report in fact clarifies what the pilot must do if he/she need to continue flying. The report of ZS-HBV had extensive experience and even if there had been a complete loss of tail rotor thrust, it should not have led to the accident where it took place as his destination (HSV) was still a way to go."

*"4.2.8 The SACAA report accurately describes the observation of the other pilots, viz. that shortly prior to impacting with the ground, ZS-HBV started porpoising till the main rotor blades caught bambi bucket line. Thus far we are in agreement. We clearly **posit** that the main rotor blades struck the tail assembly twice immediately prior to ground impact, allowing an aft section to fall to the ground without out much damage and the fore section flung away to one side.*

"4.2.9 More critical to understanding the sequence of events as set out in 2 above, the main rotor blades severed both the left and right aft control cables, break in the cables, first when passing over the pulley (causing the worn marks on the cable featured in the SACA report) and at the point just in front of the stabilizer. It is at this point when the left aft cable is pulled beyond it limits and causes damage to the spine controlling the tail rotors. The impact of this violent severing of both the cables is evident in the structures of the tail assembly through which they passed.

"4.2.10 The aft rotor cable did not break while under while flying in cruise configuration, where there is virtually no load on this cable. All the evidence points to a high tension fracture (with the tell tale pig's tale curvature) in the cable, which was induced when the main rotor struck the tail assembly. No input from the cockpit would have sufficient force to break the aft rotor control cable, even it in the degraded state the SACAA found, post-crash.

*"4.2.11 The improbability of a cable designed to withstand loads of **1760lbs** simply snapping in flight when according to the CAA's analysis, 15% (246lbs breaking strength) **of the cable only fractured under torsion overload**, not to mention a further 15% of the cable "having had roughly half the cross section worn away" (132lbs breaking strength) has been extensively canvassed in the experts report."*

"4.2.12 The chip warning light, although a significant event in the flight, clearly had little significance in terms of the probable cause of this accident as both the 42° and the 90° gearboxes were found to be in working order with no metallic particles on the chip detectors in these gearboxes.

"4.3 The likely scenario of the accident of ZS-HBV is extensively constructed in paras 4-8 in pages 31-42 of the expert report. The pivotal issue remains the explanation of the loss of directional control while ZS-HBV, was in straight and level cruise, at approximately 800 ft. AMSL, flying towards the HSV, some 2nm South East of the crash site. Flying into a moderate SE wind, the climate and environmental conditions were likely to have had no role in the onset to the crisis, which precipitated the "Mayday Mayday Mayday" broadcast. Section 9-21 of the Huey Operating Manual states: (a) WARNING. At speeds below 30-40 kts the sideslip may become uncontrollable and at (b) Procedures (1) In flight …..continue flight to a suitable landing are at above minimum rate of descent airspeed… It is all there, stated in the manual, and yet the CAA Report suggests that once tail rotor

thrust is lost the helicopter will immediately begin to spin around.

"4.4 We are hence confronted with the possibility of human, mechanical or a combination of these elements, which can explain what happened at the point and the 15 seconds afterwards until the impact with the ground."

"4.5 The central thesis in the SACAA report that the fracture of the aft tail rotor control cable while in level cruise flight, precipitated the jamming of the fracture of the tail rotor drive train, resulting in the complete loss of tail rotor thrust and an experienced pilot crashing due to this loss of tail rotor thrust simply does not add up, is not supported by any evidence and is counter to the eye witness accounts of ZS-HBV's flight path, the moments before and as it entered into the unusually scalloping and then, arcing, downwind spin towards the crash site.

"4.6 The analysis set out in the experts report represents the reconstruction of events as we were able on the basis of available evidence, including those not available to the SACAA investigation. In as much as we remain convinced about the onset of the crisis which precipitated the crash, we were not, however, on the basis of information available to us, able to identify the likely factors which gave rise to this crisis momement which resulted in the observed scallop and subsequent spin."

-END-

ANNEXURE C

Kishugu Aviation (Pty) Ltd [Previously FFA Aviation (Pty)]

The organisation conducted organisation review and changed several key management positions within the organisation, where by new post holders were introduced to the organisation.

Additional Training

1. **3 Additional Engineers** completed Bell 205 approved Helicopter Maintenance Course at Bell Factory in the USA.
2. **1 Engineer** completed a OEM Course on Bambi Buckets at their facility in Canada.
3. **All Pilots** trained to perform PDMI's as per Military Maintenance Manual.
4. **Flying Crewman** (flight engineers) were trained and allocated to each helicopter.

Other

1. **Weekly management meetings** are conducted (including Post Holders).
2. **FDP adjusted** as per SACAA recommendation.
3. **The AMO and AOC,** were subjected to the SACAA 5 phase inspection process for renewal of operating certificates.

Aircraft Actions

1. **All aircraft (fixed wing and helicopters)** were subjected to the SACAA 5 phase process by third party AMO's for renewal of certificates of airworthiness.
2. **PDMI's as per** as per Military Maintenance Manual has been implemented.
3. **Additional pilot training** on pre-flight inspections.
4. **Overhaul and replacement process** of all irreversible valves in the Helicopter Fleet implemented with FAA and EASA certified hydraulic service company in the USA.

-END-