AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9727		
Aircraft registration	**ZS-HBP**	**Date of accident**	15 August 2018		**Time of accident**	0742Z	
Type of aircraft	Robinson R22 Beta II		**Type of operation**		Private (Part 91)		
Pilot-in-command licence type	Commercial		**Age**	27	**Licence valid**	Yes	
Pilot-in-command flying experience	Total flying hours		3 215.5		Hours on type	703.6	
Last point of departure	Ithala Game Reserve, Eastern Cape Province						
Next point of intended landing	Ithala Game Reserve, Eastern Cape Province						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
Ithala Game Reserve (GPS position: 31°33'11.10" South 026°29'42.90" East) elevation 4 413 feet AMSL							
Meteorological information	Surface wind, Calm; Temperature, 13.6°C; Dew point, 6°C; CAVOK						
Number of people on-board	1 + 1	**No. of people injured**	1	**No. of people killed**	1		
Synopsis							

On Tuesday, 14 August 2018, a pilot flew from O.R. Tambo Aerodrome (FAOR) to Port Elizabeth Aerodrome (FAPE) to assist a game capture team to capture 75 antelope (Lechwes) on a private game reserve near Sterkstroom in the Eastern Cape province. The antelope were earmarked for a buyer in Namibia.

The pilot was collected at FAPE and was transported to a farm near Cradock where the helicopter was parked on a trailer. The game capture team then towed the helicopter to a private game reserve where they were to commence with the capture operation the next morning. The antelope were captured after being darted by a veterinarian from the helicopter, where after, a ground capture team moved in and loaded the antelope onto a capture vehicle, which in turn was offloaded at the 'station' where the trucks were waiting to transport the animals. Both doors of the helicopter were removed for this operation. The veterinarian was seated on the left-side of the helicopter and was secured by an additional harness which was secured to the helicopter's safety harness; this additional harness allowed him ample movement to dart the animals. According to available information, there were no eyewitnesses to this accident, but several members of the game capture team heard the impact and rushed to the scene where the helicopter was found lying on its left side 21 metres (m) from a set of high-tension power lines. The pilot was seriously injured in the accident and the veterinarian succumbed to his injuries at the scene as he was found trapped underneath the main wreckage.

The accident could not be attributed to the pilot, the helicopter or the environment, but to the actions of a third party, a person on the ground, who fired a rifle/gun at the helicopter. Following the shot being fired, which the pilot and the passenger most probably heard considering that they were flying at low level, it could have been that the pilot related it to a catastrophic failure of some sort and, to avoid colliding with the high-tension wires, he most probably induced a control input whereby the main rotor blades severed the tail boom; thereafter, control was lost, and the helicopter impacted the ground.

SRP date		Publication date	

Abbreviations	
°	Degrees
°C	Degrees Celsius
AGL	Above ground level
AIID	Accident and Incident Investigation Division
AMSL	Above mean sea level
BKN	Broken (cloud layer)
CAVOK	Ceiling and visibility OK
cm	Centimetres
C of A	Certificate of airworthiness
C of R	Certificate of registration
Cu	Copper (Periodic Table of Elements)
CVR	Cockpit voice recorder
EDS	Energy Dispersive X-ray Analysis
FAOR	O.R. Tambo International Aerodrome
FAPE	Port Elizabeth Aerodrome
FATP	New Tempe Aerodrome
FDR	Flight data recorder
FEGSEM	Field Emission Gun Scanning Electron Microscope
FOD	Foreign Object Damage
fps	Feet per second
ft	Feet
IPC	Illustrated Parts Catalogue
kg	Kilograms
kN	Kilo Newton
kt	Knot
l	Litres
lbs	Pounds
LDV	Light delivery vehicle
m	Metres
MB	Mega Bites
METAR	Meteorological Aeronautical Report
MR	Main Rotor
m/s	Metres per second
nm	Nautical miles
OEM	Original Equipment Manufacturer
POH	Pilot Operating Handbook
ROC	Rate of climb
ROD	Rate of descent
rpm	Revolutions per minute
SACAA	South African Civil Aviation Authority
SAPS	South African Police Service
SAWS	South African Weather Service
UHF	Ultra-high frequency
VHF	Very high frequency
Wt%	Weight percentage
Z	Zulu (Term for Universal Coordinated Time - Zero hours Greenwich)

Name of Owner	**:** GS Calitz
Name of Operator	**:** GS Calitz
Manufacturer	**:** Robinson Helicopter Company
Model	**:** R22 Beta II
Nationality	**:** South African
Registration markings	**:** ZS-HBP
Place	**:** Ithala Game Reserve, Eastern Cape Province
Date	**:** 15 August 2018
Time	**:** 0742Z

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 (2011), 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 apportion blame or liability.***

Investigation Process:

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was informed of an aircraft accident involving a Robinson R22 Beta II that occurred during a game darting operation at a private game reserve on 15 August 2018. The accident was reported to the AIID investigator-on-call on 15 August 2018 at 1200Z.

The AIID has appointed an investigator-in-charge with an investigation team. Notifications were sent to the State of Manufacture and Design, namely, the United States of America. A non-travelling accredited representative was appointed to the investigation. The AIID will lead the investigation and issue the final report.

The information contained in this report is derived from the factual information gathered during the continuing investigation into the occurrence.

The AIID reports are made available to the public at:
http://www.caa.co.za/Pages/Accidents%20and%20Incidents/Aircraft-accident-reports.aspx

Notes:

1. Whenever the following words are mentioned in this report they shall mean the following:

- *Accident — this investigated accident*
- *Aircraft — Robinson R22 Beta involved in this accident*
- *Investigation — the investigation into the circumstances of this accident*
- *Pilot — the pilot/s involved in this accident*
- *Report — this accident report*

2. Photographs and figures used in this report were obtained from different sources and may be adjusted for the sole purpose of improving clarity of the report. Modifications to images used in this report are limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or the addition of text boxes, arrows or lines.

Disclaimer:

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1. FACTUAL INFORMATION

1.1 History of flight:

1.1.1 According to available information, the pilot involved in this accident was employed as a commercial pilot by a helicopter operator based in Limpopo Province. Available records indicated that the pilot took unpaid leave from his employer over the period 14 to 22 August 2018. On Tuesday morning, 14 August 2018, he flew from O.R. Tambo International Aerodrome (FAOR) to Port Elizabeth Aerodrome (FAPE) on a scheduled domestic flight. On arrival at FAPE, he was collected by a person who transported him to a farm near Bedford in the Eastern Cape Province where he met with the game capture operator.

1.1.2 The pilot was then taken to a farm, which was located between Bedford and Cookhouse, where the helicopter with registration markings ZS-HBP was parked. The helicopter was used on the farm over the period 2 to 4 August 2018 as per the entries made in the flight folio. At the farm, a friend of the owner of the helicopter met up with the pilot. He was driving a single-cab light delivery vehicle (LDV) (Toyota Hilux), which belonged to the helicopter owner. The helicopter, which was parked on a trailer was then hooked up to the LDV. On the back of the LDV were two, 200-litre drums of fuel (Avgas), which the helicopter owner stated he had purchased at New Tempe Aerodrome (FATP), located near Bloemfontein. The pilot then drove the LDV with the helicopter owner's friend being the passenger, to Ithala Game Reserve, near Sterkstroom, which is also situated in the Eastern Cape Province. They arrived at the game reserve in the late afternoon, and then overnighted there. Early the next morning, the helicopter owner's friend left the game reserve with the LDV, driving it back to his farm, which is located near Zastron in the Free State Province.

1.1.3 On Wednesday morning, 15 August 2018, the pilot, accompanied by a veterinarian on a helicopter commenced with darting the antelope (Lechwes) that were to be captured and transported to a buyer in Namibia. The game capture team, their trucks and supporting vehicles were ready at the game reserve. Both the doors of the helicopter were removed. At the time of the accident, they had managed to dart 11 animals out of a total of 75 that were earmarked to be captured. As the veterinarian darted the animals, there was a ground support team that moved in and physically captured each animal. The animals were then loaded onto a truck(s) where after, they were injected with an anti-dose to revive them. The veterinarian was seated on the left-side of the helicopter. He was secured to the helicopter safety harness by an additional safety harness, also referred to as a monkey chain, which allowed him some additional movement during the darting operation.

1.1.4 The helicopter was found lying on its left side, the tail boom was severed and both main rotor blades were found to have separated from the main rotor hub assembly. The one main rotor blade was lying in proximity to the main wreckage and the other main rotor blade was approximately 41 metres (m) away. The main wreckage was lying 21m to the east of a set of power lines, which consisted of three electrical conductors (cables) that were 1.5m apart in the horizontal plain and approximately 10m (33 feet) above ground level (AGL). The two supporting wooden pylons were 190m apart on this specific segment. The electrical conductors (cables) remained intact; there was no power supplier disruption in the area. The middle wire displayed evidence of arcing.

1.1.5 The scene was contaminated as the ground impact markings were destroyed by people who rushed to the scene to assist the two occupants, as well as by emergency services. An Eastern Cape Provincial Ambulance dispatched to the scene, as well as a private EMS ambulance. A local farmer with a Robinson R22 was also called in for assistance; he landed some distance from the accident site. The local farmer was unable to airlift the seriously injured pilot as the helicopter he was flying was too small for the purpose. After he ascertained that he could not be of assistance, he returned to his farm. The EMS helicopter from East London was also notified of the accident but could not reach the accident site due to inclement weather conditions along the coast and the escarpment on that day (low cloud). The veterinarian succumbed to his injuries at the scene of the accident; and the pilot was transported by road ambulance to a private hospital in Queenstown. Following an assessment of his medical condition, he was transferred to a private hospital in East London where he underwent surgery. Several weeks later, he was transferred by an air ambulance from East London to Pretoria where he was admitted to a private hospital. After being discharged from hospital, he was admitted to a rehabilitation facility.

1.1.6 The accident occurred during daylight at Global Positioning System determined to be 31˚33’11.10” South 026˚29’42.90” East, at an elevation of 4413 feet (ft) above mean sea level (AMSL).

1.2 Injuries to persons

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

1.3 Damage to aircraft

1.3.1 The helicopter was extensively damaged during the accident sequence.

Figure 1: The helicopter as it came to rest.

1.4 Other damage

1.4.1 One of the three high-tension power line cables displayed evidence of arcing, but the cable did not appear to have been damaged, nor was there any power failure in the area as a result of contact with the wire.

Figure 2: The high-tension wires, with the centre wire displaying evidence of arcing.

Figure 3: Closer view of the centre wire arcing.

1.5 Personnel information:

1.5.1 Pilot-in-command (PIC)

Nationality	South African	Gender	Male	Age	27
Licence number	**********	Licence type	Commercial		
Licence valid	Yes	Type endorsed	Yes		
Ratings	Night, Cull and Livestock, Test Pilot (Class 2), Flight Instructor (Grade III)				
Medical expiry date	30 November 2018				
Restrictions	None				
Previous accidents	None				

Flying experience:

Total hours	3 215.5
Total past 90 days	75.6
Total on type past 90 days	1.0
Total on type	703.6

NOTE: The pilot's flying hours entered in the table above were obtained from his logbook, which was made available to the investigator.

Available evidence (pilot's logbook) indicated that the pilot started flying as a student pilot on 20 February 2009 at an accredited aviation training organisation (ATO) and was flying the Robinson R22 helicopter. On 14 August 2009, he was issued a private pilot licence following a skills test by a designated examiner.

On 30 October 2009, he completed his conversion onto the Robinson R44 type helicopter and, on 15 March 2010, he completed his night rating. On 8 December 2010, he was issued a commercial pilot licence on helicopters after he had successfully completed his initial skills test under the auspices of a designated examiner. On 14 December 2010, he completed his flight instructors test and was issued a Grade III flight instructors rating.

During the period 31 March to 2 April 2014, he successfully conducted his game/cull rating and was duly signed off in his logbook by a Grade II flight instructor.

The last entry in the pilot logbook was on 23 May 2018. According to his wife, he continued with active flying during the period 24 May 2018 until 15 August 2018.

Copies of the flight folio for the helicopter, Robinson R44 Raven II, ZT-RBL, were obtained from the helicopter owner. The pilot was a full-time employee of the helicopter owner and had flown the helicopter on a regular basis. The four flight folio pages that were received start from 1 May 2018 with the last entry by the pilot being on 8 August 2018. During this period, the pilot had flown 90.9 hours on this helicopter. These flying hours were added to his total flying hours in the table on page 9.

1.6 Aircraft information

1.6.1 Robinson R22 helicopter

The Robinson R22 is a light, two-place, single reciprocating powered engine helicopter with a semi-rigid two-bladed main rotor and a two-bladed tail rotor. The main rotor has a teetering hinge and two coning hinges. The tail rotor has a teetering hinge only.

The normal production variant has skid landing gear. The basic structure is welded chromoly steel tubing. The forward fuselage is made of fibreglass and aluminum with a Plexiglas canopy. The tailcone, vertical and horizontal stabilisers are aluminium. It has an enclosed cabin with side-by-side seating for a pilot and passenger. The doors may be removed for flight, as is often done for photographic flights, interior cooling in high temperatures or weight saving.

Figure 4: The helicopter, ZS-HBP. (Photograph courtesy of the helicopter owner)

Airframe:

Type	Robinson R22 Beta II	
Serial number	4331	
Manufacturer	Robinson Helicopter Company	
Year of manufacture	2008	
Total airframe hours (at time of accident)	1 993.4	
Last MPI (hours & date)	1 898.6	8 June 2018
Hours since last MPI	94.8	
C of A (issue date)	12 January 2012	
C of A (expiry date)	11 January 2019	
C of R (issue date) (Present owner)	25 August 2017	
Operating category	Standard Category (Rotorcraft)	

The last flight folio entry was on 4 August 2018 with the Hobbs meter reading entered as 740.6. The Hobbs meter reading on the scene of the accident was recorded at 744.8. Available evidence indicated that an additional 4.2 hours were flown with the helicopter for which there were no entries in the flight folio. Although the pilot was flying for some time on the day prior to the accident, he was not airborne for 4.2 hours when the accident occurred.

Engine:

Type	Lycoming O-360-J2A
Serial number	L-41134-36E
Hours since new	1 993.4
Hours since overhaul	TBO not yet reached

Main rotor blades:

Part number	A016-4
Serial numbers	2502, 2551
Hours since new	689.6
Hours since overhaul	TBO not yet reached

Tail rotor blades:

Part number	A029-2
Serial numbers	3891, 3894
Hours since new	1 518.4
Hours since overhaul	TBO not yet reached

Weight and Balance:

It was not possible to conduct an accurate weight and balance for the flight as there was no record available of what was the fuel status of the helicopter at the time of the accident.

What was known was the empty weight of the helicopter, which was 393.8kg (868.3 lbs). The helicopter was last weighed on 6 June 2018. Also known was the weight of the pilot, which was 65kg (143 lbs) and the weight of the deceased, which was 75kg (165 lbs). This information was obtained from the post-mortem report. The maximum gross weight for the helicopter according to the Pilot Operating Handbook (POH) was 590kg (1 370 lbs). The weight of the two doors was 5kg (11 lbs), which should have been subtracted.

With the information above, the weight of the helicopter was approximately 529kg (1 166 lbs) at the time of the accident. This, however, excludes the fuel weight and the dart gun. The helicopter was within its operating limits.

1.7 Meteorological information

1.7.1 An official weather report was requested from the South African Weather Service (SAWS). Fine weather conditions prevailed in the area at the time of the accident. The table below was populated with the information received.

Wind direction	Nil	Wind speed	Nil	Visibility	+ 10km
Temperature	13.6°C	Cloud cover	Nil	Cloud base	Nil
Dew point	6°C				

1.8 Aids to navigation

1.8.1 The helicopter was equipped with standard navigational equipment which comprised a magnetic compass. There were no reported defects.

1.9 Communication

1.9.1 The helicopter was equipped with a very high frequency (VHF) radio. There were no reported defects.

1.9.2 The helicopter was being flown outside of controlled airspace on a private game reserve; and the frequency 124.80 megahertz (MHz) was used.

1.10 Aerodrome information

1.10.1 The accident occurred on a private game reserve at Global Positioning System determined to be 31˚33'11.10" South 026˚29'42.90" East, at an elevation of 4413ft AMSL.

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 was it a regulatory requirement to be fitted to this type of helicopter.

1.12 Wreckage and impact information

1.12.1 The helicopter was conducting a game capture operation and it was approximately 5-10m above the power lines. There was an imbalance as a result of the main rotor which caused some difficulty in controlling the helicopter. The helicopter lost height and, during an attempt to avoid collision with power lines, the left skid made contact with the middle power line, resulting in the main rotor cutting the tail boom and the helicopter crashing.

1.12.2 The main wreckage of the helicopter was found lying on its left side 21m from a high-tension power line on a heading of 255°M. The wreckage displayed extensive

damage with the tail boom being severed by the main rotor blades at more than one location. The aft tail boom structure was located approximately 5m from the main wreckage. The vertical stabiliser and tail rotor drive assembly, which consist of the tail rotor gearbox, hub and blades were still secured to the aft tail boom structure and did not display any abnormalities that would have precluded normal operation. The cockpit/cabin area remained intact although slightly distorted during the impact sequence. The passenger was, however, secured by an additional safety harness and was found trapped underneath the helicopter, still secured to his harness.

Figure 5: A general view of the accident site, including the high-tension wires.

Figure 6: A closer view of the main wreckage and the aft tail rotor assembly.

1.12.3 Both main rotor blades were found fractured at the main rotor hub assembly during the impact sequence. The blade with serial number 2551 was located 41m from the main wreckage and, although damaged, it remained intact as seen in Figure 8. The blade with serial number 2502 was found in proximity to the main wreckage as seen in Figure 7. The blade had a perforated hole through it, which penetrated the blade from the bottom (black painted surface) and exited at the top (yellow and white painted surface) at a distance that was measured to be 84cm from the blade cuff. The damage observed to the blade raised several questions and the section of the blade was subjected to a forensic examination as discussed in this report. Both main rotor blades presented evidence that it severed the tail boom (red paint markings), which include the tail rotor drive shaft and the tail rotor control rod. The red paint markings at various distances on the two main rotor blades indicated that the tail boom was struck more than once by the main rotor blades; this was consistent with the smaller segments of the tail boom structure that was located at the scene.

1.12.4 The skid gear of the helicopter remained intact, except for the front left side which was found in proximity to the main wreckage, indicative that it had failed during the impact sequence. It was not possible to obtain any fuel samples as both fuel tanks had ruptured during the impact sequence.

Figure 7: The main wreckage and one of the main rotor blades, with serial No. 2502.

Figure 8: The other main rotor blade, with serial No. 2551.

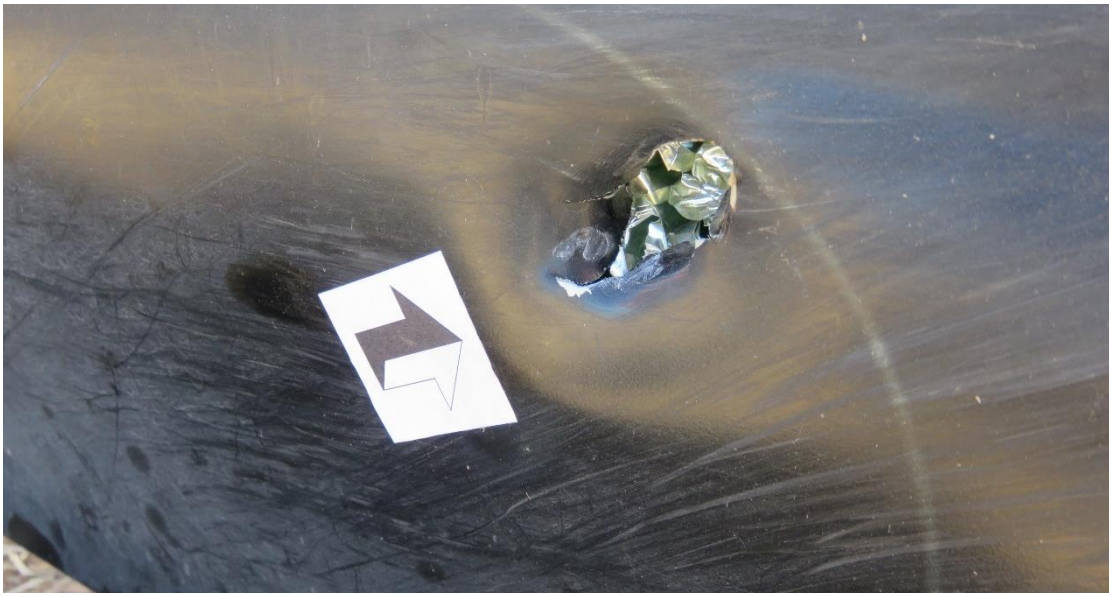


Figure 9: The perforated hole on the bottom surface of the main rotor blade, with serial No. 2502.

Figure 10: The perforated hole (exit point) on the top surface of the main rotor blade, with serial No. 2502.

1.12.5 The aft tail rotor assembly with the tail rotor gearbox, hub and tail rotor blades still secured to the tail boom structure were located approximately 8m from the main wreckage as seen in Figure 6. No evidence of overheating was noted on the tail rotor gearbox teletemp (heat sensor strips). The tail rotor gearbox and associated components were found to be rotating freely. One of the tail rotor blades was slightly bent towards the tail boom, which was attributed to ground impact after the tail boom structure was severed by the main rotor blades.

Figure 11: The aft tail rotor assembly with linkages still intact and secured.

Figure 12: Tail boom was severed near the centre fuselage (helicopter was turned upright).

Figure 13: Smaller section of the tail boom structure.

1.13 Medical and pathological information

1.13.1 The pilot was seriously injured during the accident.

1.13.2 The veterinarian succumbed to his injuries at the scene of the accident. The Medico-Legal post-mortem report concluded that the cause of death was multiple blunt trauma injuries.

1.14 Fire

1.14.1 There was no evidence of a pre- or post-impact fire.

1.15 Survival aspects

1.15.1 The veterinarian that was seated on the left side of the helicopter succumbed to his injuries at the scene of the accident as the main wreckage came to rest on its left side with him trapped underneath it. Cardiopulmonary resuscitation (CPR) was performed on him by one of the game capture members.

1.15.2 The veterinarian was not strapped onto the seat by means of the helicopter-equipped safety harness. Due to the nature of the operation, he made use of his personal safety harness (monkey chain), which he secured to the helicopter safety harness by means of a carabiner as shown in Figure 14. The safety harness, as per Figure 15, was secured to the second carabiner.

Figure 14: The carabiner secured to the helicopter safety harness (left seat).

Figure 15: The safety harness that was around the veterinarian's waist.

1.15.3 The pilot who was still secured inside the wreckage by means of the helicopter-equipped safety harness, was assisted by the first responders to the accident scene who cut off the safety harness and removed him from the wreckage. He was seriously injured and was attended to by paramedics at the scene of the accident.

He was then transported from the scene by road ambulance to a private hospital in Queenstown where his medical condition was assessed; and it was decided to transfer him on the same day to a private hospital in East London. The next day (16 August), he was transferred to another private hospital in East London.

On 30 August 2018, he was transferred by air ambulance from a private hospital in East London to a hospital in Pretoria where he stayed until 17 October 2018. He then went to a rehabilitation centre at another hospital in Pretoria where he stayed until 14 December 2018, when he was discharged.

1.15.4 The pilot did not make use of a flying helmet during the flight.

1.16 Tests and research

1.16.1 South African Police Service (SAPS) Forensic Science Laboratory test (main rotor blade):

During the on-site investigation, one of the main rotor blades with serial No. 2502 had a perforated hole at an angle through the blade (at the lower surface, out at the top),

which was 84cm from the blade cuff (exit hole above the blade surface). The section of the main rotor blade with the perforated hole was impounded by the South African Police Service (SAPS) and taken to the Forensic Science Laboratory (Ballistics Section) in Port Elizabeth for examination. According to their findings, the perforated hole was not caused by a projectile/bullet.

The ballistic examination report is attached to this report as Annexure A.

1.16.2 Pneu-Dart rifle

The Pneu-Dart rifle .50 calibre, model 389 bolt action, serial number 5722 on the barrel and MM33049C on the action that was used by the veterinarian was picked up close to the main wreckage by one of the first responders to the scene of the accident, a member of the game capture team. On arrival of the first police officials at the scene, the dart gun was handed over to one of the police officials and was booked in at the Sterkstroom Police Station as evidence. The following day during the on-site investigation, an unused cartridge that is used in the dart gun was picked up at the accident site. The cartridge was also impounded by the police, along with the dart gun, and were sent to the SAPS Forensic Science Laboratory (Ballistics Section) in Port Elizabeth for examination.

Figure 17: The dart gun that was located at the scene of the accident.

Figure 18: A cartridge used in the dart gun (picked up during the on-site investigation).

1.16.3 Shooting range

Approximately 142m from where the main wreckage came to rest was a boma that was used as a shooting platform, see Figure 19. Eight empty cartridges were in and around the boma. These cartridges were marked, photographed and collected by a forensic investigator from the SAPS in the presence of the accident investigators. The cartridges were also sent to the Forensic Science Laboratory (Ballistics section) in Port Elizabeth for examination. According to the ballistic report, six of the cartridges were from a .300 Winchester Magnum and two were from a 7mm Remington Magnum bolt action rifle.

According to the SAPS ballistic report, these empty cartridges could not be linked to the perforated hole in the main rotor blade (# 2502) as their assessment was that the perforated hole was not caused by a projectile/bullet. The ballistic report can be found attached to this report as Annexure A.

The Google Earth overlay, Figure 19, illustrates the layout of the shooting range in relation to where the main wreckage (ZS-HBP) was found. The main wreckage was located 66m from the target board as seen in Figure 21. The empty cartridges that were found lying on the ground inside and some outside the boma were collected and placed in police evidence bags as seen in Figures 24 and 25, respectively. The paper target, which was secured to the target board had two bullet holes. The paper target was removed from the target board and was impounded by police as evidence.

The power line, of which there was evidence that the helicopter made contact with prior to ground impact, ran diagonally between the boma and the target board as depicted in Figure 20. The two wooden power line supporting poles are also visible in Figure 20.

Figure 19: Overlay indicating the boma, the target, the back stop and the main wreckage. (Source: Google Earth)

Figure 20: View from inside the boma/shooting platform looking towards the target board and back stop.

Figure 21: The target board, which was 100m from the boma.

Figure 22: Shooting range distance marker (rock) indicating 100m from the boma.

Figure 23: The back stop of the shooting range, 200m from the boma.

Figure 24: Two of the eight empty cartridges which were located near the boma.

Figure 25: Four of the eight empty cartridges which were placed in SAPS evidence bags.

Figure 26: Four different types of projectiles used in a .300 Winchester Magnum. (Source: www.americanrifleman.org)

1.16.4 Main Rotor Blade Material:

According to available information that was obtained from the helicopter manufacturer, the following materials were used during the manufacturing process of the main rotor blade:

(i) The spar is made of corrosion-resistant steel, approximately 0.1 inches thick
(ii) The honeycomb core is made of Hexcel 3/16 inches cell honeycomb material
(iii) The skins are 0.25 inches thick 2024 aluminium

1.16.5 Microscopic Laboratory Analysis

The two sections of the main rotor blade were collected by the investigator from the SAPS after they have concluded their ballistic tests. The evidence (two blade sections) was taken by the investigator to an accredited microscopic laboratory where two small material samples from the perforated hole in the main rotor blade skin were cut out and subjected to a Field Emission Gun Scanning Electron Microscope (FEGSEM) evaluation by a competent person in the field of metallurgy.

Figure 27: The Zeiss Crossbeam 540 FEGSEM that was used for the analysis.

Figure 28: The perforated hole (lower blade surface) from where the two samples were taken.

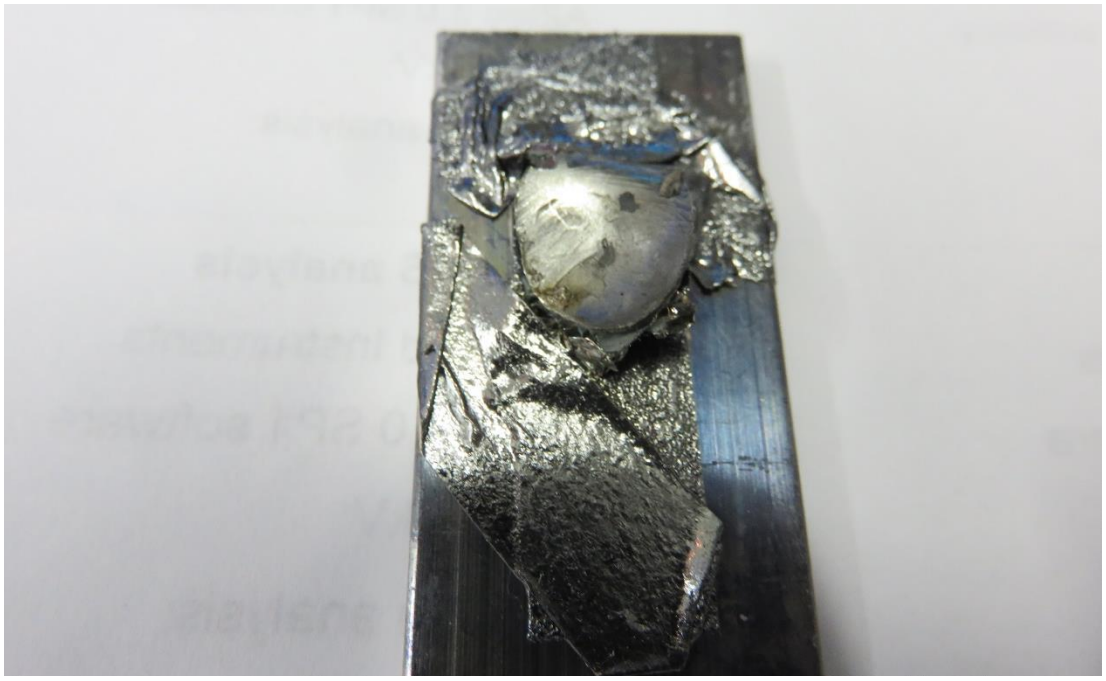


Figure 29: One of the samples that was taken from the perforated hole for FEGSEM analysis.

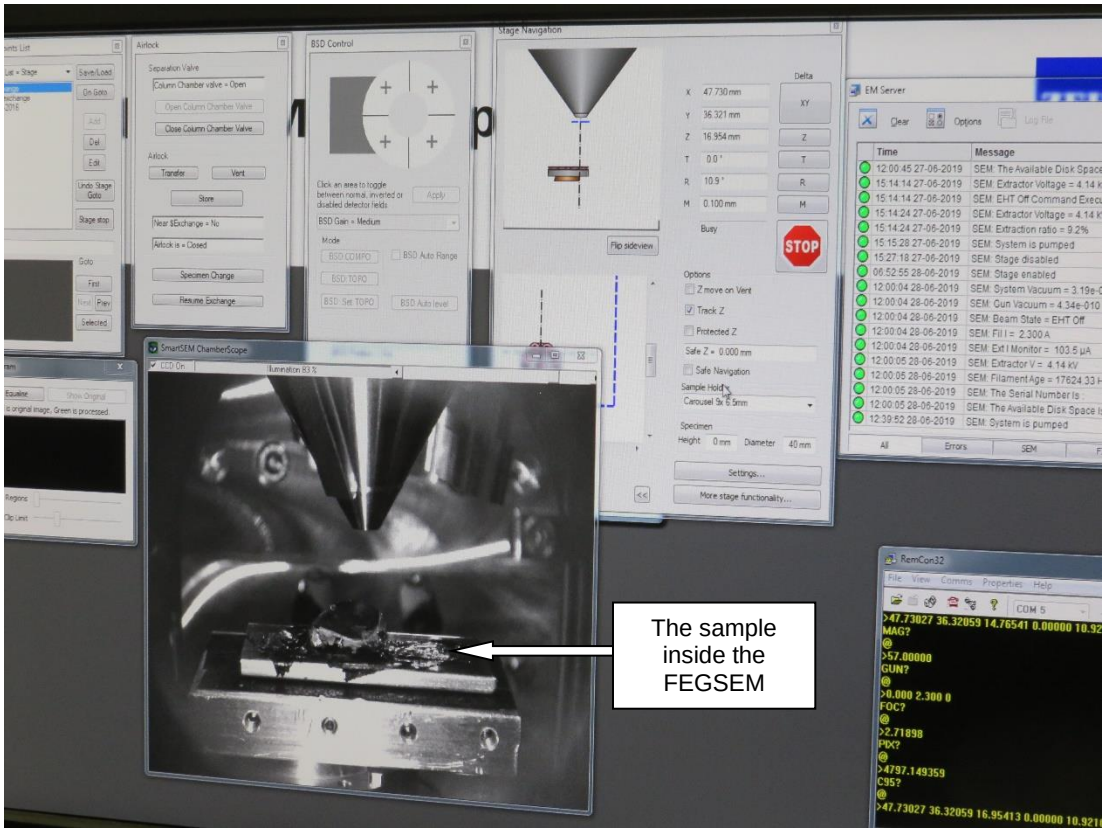


Figure 30: A screenshot of the sample inside the FEGSEM as displayed on the monitor.

1.16.6 Main rotor blade laboratory test

The section of the main rotor blade depicted in Figure 31 was submitted to the forensic laboratory. It should be noted that this section of the main rotor blade formed part of the blade with serial No. 2502, which was the same blade that had the perforated hole. The three holes, marked 1, 2 and 3 in Figure 31 came about during the static ballistic test that the police conducted, where they had fired three bullets at the blade. A material sample of hole 1 as illustrated in Figure 31 where the bullet entered the blade surface was cut out (see Figure 32) and was subjected to a FEGSEM analysis at an accredited microscopic laboratory.

The police ballistic report, however, does not state the following with regard to these tests:

(i) From what rifle/firearm were these three projectiles/bullets fired (at the main rotor blade)

(ii) Nor does it state from what distance were they fired

(iii) Nor does it mention if all three holes were from the same calibre of weapon, or from three different rifles/firearms

(iv) The report does not mention what type of ammunition was used

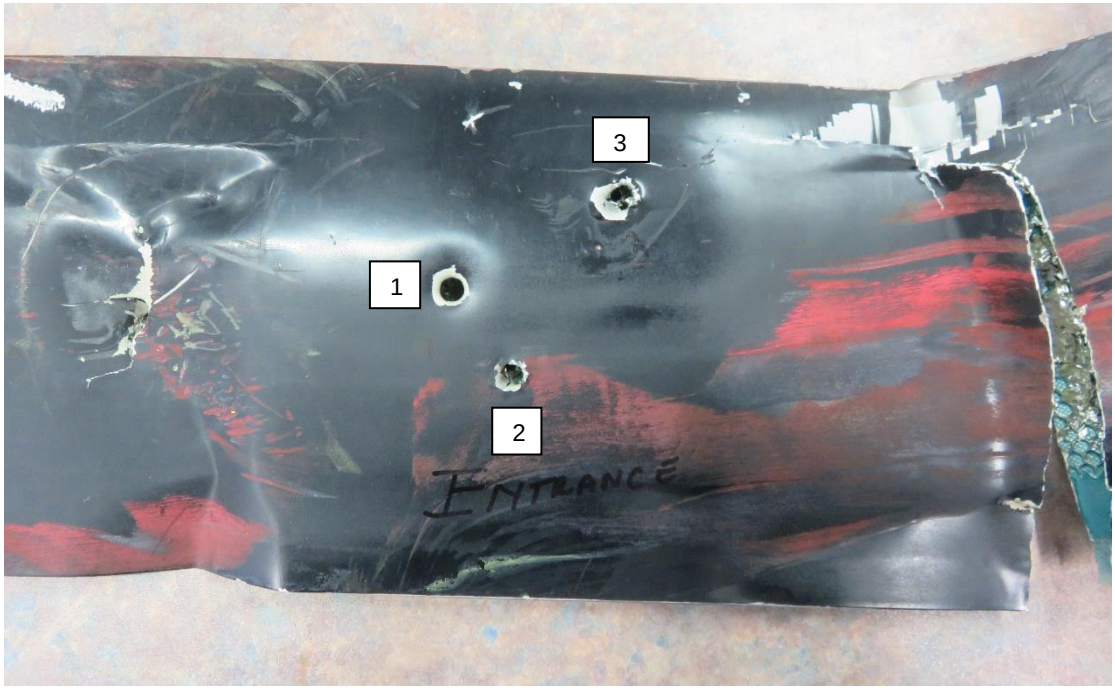


Figure 31: Section of the main rotor blade with three bullet holes.

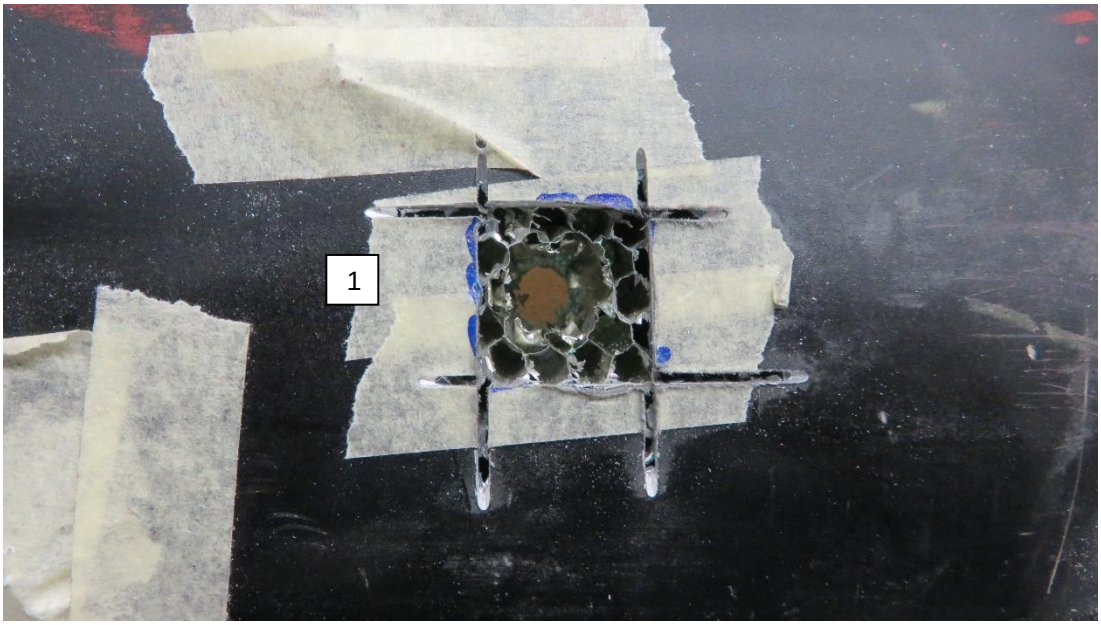


Figure 32: The sample from hole 1 that was cut to be used for the FEGSEM analysis.

1.16.7 Comparison material test between the perforated hole and the SAPS induced hole

What was factual about the two main rotor blades sections that were presented to the SAPS ballistic testing was that as part of their analysis, they had fired with a rifle or a gun three holes through one of the blade sections. They also concluded that the perforated hole was not a result of a projectile/bullet.

With this information available, two material samples were taken from the perforated hole, as well as a complete entry sample (360° cut out) from one of the bullet holes induced during the forensic test.

What was further known was the material composition of the main rotor blade, which was obtained from the original equipment manufacturer (OEM).

The samples in the report from the service provider (microscopic laboratory tests) are referred to as follows:

(i) FOD – refers to perforated hole sample
(ii) SAPS – refers to the holes where the SAPS fired with a gun/rifle at the blade

The material samples from the perforated hole (FOD) displayed the same properties as those of the induced hole (SAPS), with a high copper (Cu) content being present on the material of both these holes. The three EDS tables on pages 12 and 13 of the microscopic laboratory report provide the reader with three different values of the material detected on the perforated hole.

The conclusion from these tests was that the perforated hole (FOD) was most probably caused by a projectile/bullet that was fired at the helicopter prior to ground impact.

The report from the microscopic laboratory test is attached to this report as Annexure B.

1.17 Organisational and management information

1.17.1 This was a pre-planned game capture operation according to available information. One of the major hurdles was for the game capture team to obtain the necessary permits to transport and deliver the captured antelope across the border to Namibia to the new owner. According to available information, the game capture operation commenced on Wednesday morning, 15 August 2018, after all the necessary permits were obtained as well as the game capture team, the veterinarian, the pilot and helicopter were available.

The helicopter, which was going to be used in the operation was towed on a trailer to the game reserve behind an LDV from a farm near Cradock where it was parked. The pilot drove the LDV and arrived at the game reserve in the afternoon of 14 August 2018. On the back of the LDV were two, 200-litre drums of fuel (Avgas), which were off-loaded at the game reserve and were going to be used to refuel the helicopter during the game capture operation. These drums were, however, not on the game reserve when the accident investigation team arrived there the next day (after the accident).

1.17.2 No proof of an air operating certificate (AOC) could be produced to the investigating authority by any of the parties concerned.

1.17.3 The last mandatory periodic inspection (MPI) that was carried out on the helicopter prior to the accident flight was certified on 8 June 2018 at 1 898.6 airframe hours. Since the MPI was certified, a further 94.8 hours were flown with it. The helicopter was maintained by an approved aircraft maintenance organisation (AMO) which was in possession of a valid AMO-approval certificate.

1.18 Additional information

1.18.1 Statements from game the capture team members

Although there were several people involved in the game capture operation, according to available information, not one of the team members physically witnessed the helicopter accident. Several statements were taken from these members, which indicated that they heard the impact (a loud bang) and then responded to the scene of the accident. The two groups, which comprised five men in each group, were offloading some antelope from their respective capture vehicles at the 'station' (area where the trucks were parked that was going to transport the animals) when the accident occurred.

The first members of the game capture team who arrived at the scene removed the pilot from the helicopter by cutting off his safety harness. They carried him some distance away from the helicopter where he was placed on his back.

The veterinarian was trapped underneath the helicopter. Several members of the capture team lifted the helicopter to get him out after they had cut off his safety harness. He was seriously injured and one of the game capture members performed cardiopulmonary resuscitation (CPR) on him until paramedics arrived at the scene. He was declared dead at the scene.

The dart gun that was used by the veterinarian was picked up by a member of the game capture team. He stated that the dart gun was lying in proximity to the main wreckage. He handed the gun to the police officials when they arrived at the scene.

1.18.2 Difference between a gun and a rifle

Source: www.defferencebetween.net/object/difference-between-gun-and-rifle/

"A gun is a firearm or weapon that has a metal tube where bullets are fired at a high velocity into a flat ballistic arc while a rifle is a weapon or firearm that has a long barrel that is rifled or grooved giving bullets spinning motion for greater accuracy at a long range."

1.18.3 New evidence or possible main rotor blade damage prior to flight

On 15 August 2019, the family of the passenger (veterinarian) that succumbed to his injuries travelled to the accident site to pay their respects one year after the accident

occurred as they had never been to the location before. The family was accompanied by a person (not a family member) who was present at the game lodge on the day of the accident (member of the game capture team).

On Saturday, 17 August 2019, one of the family members sent an email to the AiidInbox email address, which had three photographs attached. These three photographs were taken by the passenger (veterinarian) in the helicopter ZS-HBP using his cellphone at approximately 0641Z (08h41 local time) according to the cellphone records. The photographs were taken prior to the first flight of the day, being 15 August 2018. The photographs were found on the cellphone of the passenger by his wife after his personal belongings were returned to her by a family friend that had travelled to the game lodge after the accident to collect his personal belongings.

From the three photographs, the family member(s) indicated that in their opinion there was a mark or a hole on one of the main rotor blades that could have indicated that the main rotor blade could have been damaged prior to the accident flight. (See below, in italics, the words as per her email message that was received by the SACAA).

"In a close up look there is damage to one of the blades before take-off. Please see comparison in photos."

The detective from the SAPS who had the docket was informed by the SACAA of this *"new evidence"* and arrangements were made by the SAPS official to collect the cellphone from the passenger's wife, who was residing in Port Elizabeth, to the SAPS cyber-crimes laboratory in East London where they retrieved the photographs from the cellphone. The three photographs had a resolution of 3.4, 3.3 and 3.5MB, respectively and were taken from the same position within 1 minute (0641Z). The three photographs were forwarded to the SACAA on 15 January 2020.

The focus from the family was on the main rotor blade that was pointing to the left (towards the tree) when looking at the photograph in Figure 33. The photograph was enlarged by the family member, and several comparisons were drawn with photographs that were shared with them (source unknown to the writer) that were taken at the scene of the accident after it occurred. These reference photographs could be seen in Figures 34, 35 and 36, respectively. The resolution of the photographs received via email was of poor quality, therefore, the SAPS official requested to obtain the photographs with maximum resolution from the cellphone of the passenger.

Figure 33: One of the photographs that was on the cellphone. This is a 3.5MB resolution photograph. (Source: passenger's cellphone)

Figure 34: The size of this photograph when received was 128KB. (Source: Passenger's cellphone)

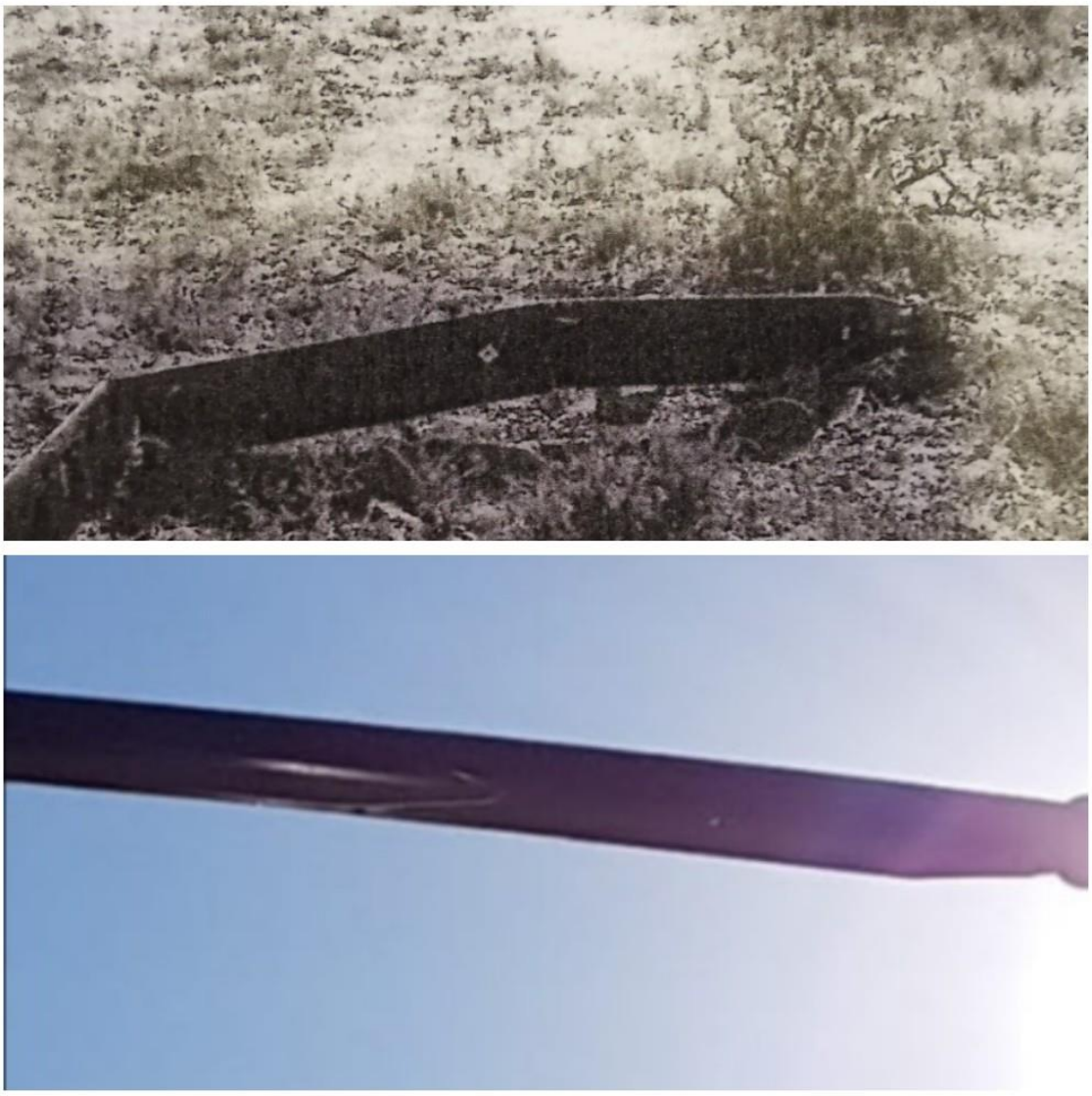


Figure 35: The size of this photograph when received was 198KB. (Source: Passenger's cellphone)

Figure 36: The size of this photograph when received was 88KB. (Source: Passenger's cellphone)

The design of the main rotor blades of the Robinson R22 includes two *doubler* transitions (terminology used by the OEM) – the inboard one is a transition between a *doubler* and another *doubler*, the outboard one is a transition between a *doubler* and the blade skin as indicated by red arrows in Figure 37, respectively. The reflection witnessed by the family member(s) on one of the main rotor blades (serial number unknown) that would appear to be that of "a hole or a mark", which was associated with a possible bullet hole on the blade was actually the sun reflection on the blade within the arc area of the *doubler* 1, which was approximately 48cm from the blade hub assembly. Also visible on the photograph, a much more pronounced reflection of the sun on the blade skin that projects from the second *doubler* arc, which was approximately 67cm from the blade hub assembly towards the blade tip. On all three photographs, Figures 34, 35 and 36, the *doubler* 2 as reference in Figure 37 is clearly visible.

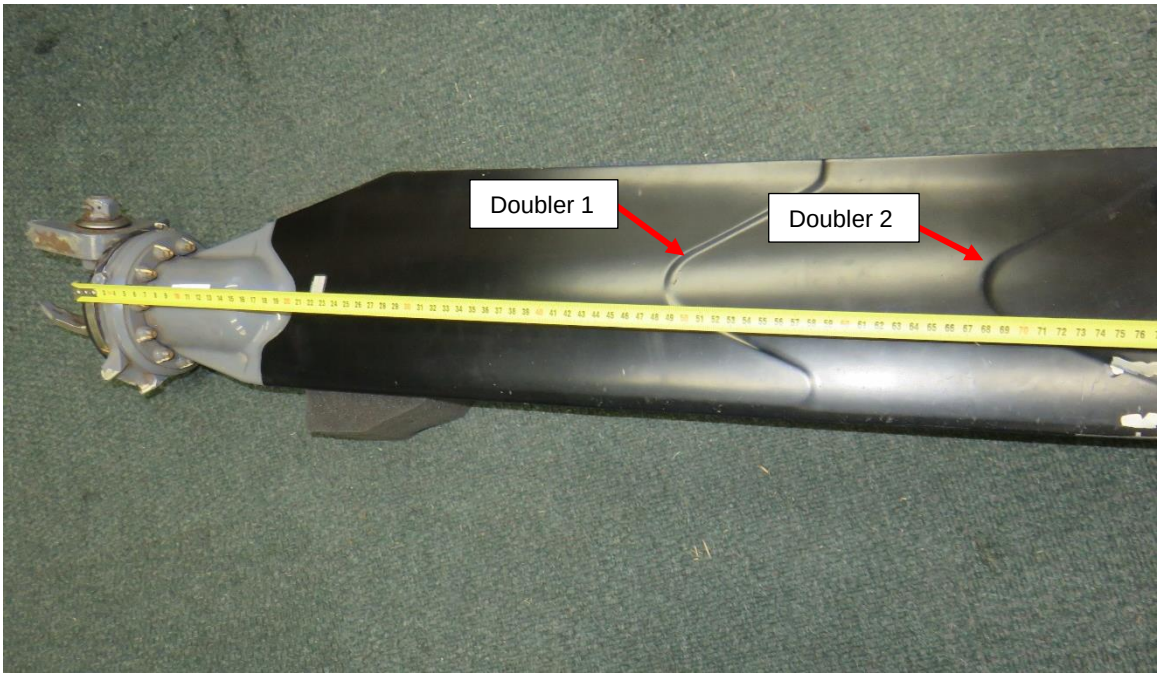


Figure 37: The two *doubler* transitions, indicated by red arrows on the actual main rotor blade in question.

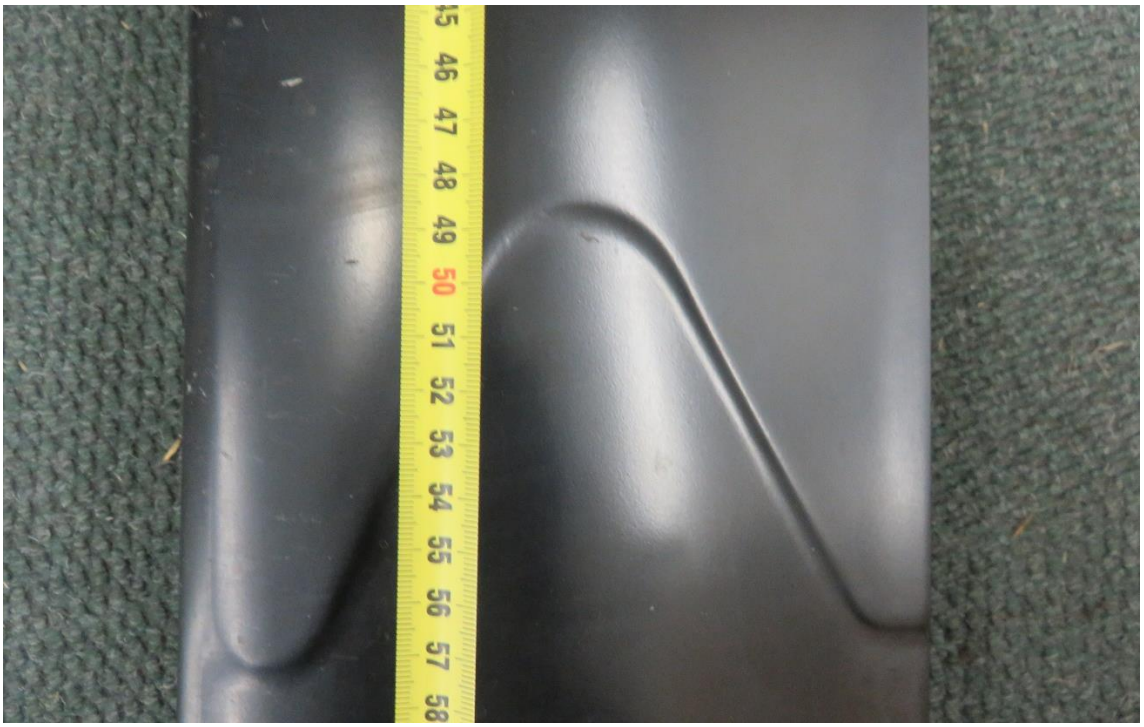


Figure 38: A closer view of the first *doubler* transition.

1.19 Useful or effective investigation techniques

1.19.1 The methods as discussed under subheading 1.16 were a first for the accident investigation as no such previous evidence had been witnessed following the establishment of the SACAA/AIID.

2. ANALYSIS

2.1 Man (Pilot)

The pilot was the holder of a commercial helicopter pilot licence. During his flying career, which commenced on 20 February 2009 until the day of the accident, he had flown 703.6 hours on the Robinson R22 and 2 511.9 hours on the Robinson R44 type helicopters.

The pilot completed his cull/livestock rating on 2 April 2014 and, according to his logbook, from that day onwards, he was engaged in game work on a full-time basis until the day of the accident. He had, therefore, extensive flying experience in the game work environment as he was permanently employed by a company that specialised in that field. According to his logbook, approximately 2 500 of his total flying hours were flown while engaged in game work.

The pilot arrived at the game reserve on Tuesday afternoon, 14 August 2018, where he spent the night. He, therefore, had ample time to be well-rested before the game darting operation commenced the next morning. With reference to the perforated hole on the lower surface of the main rotor blade (# 2502), the pilot would have seen this 'damage' to the blade during his pre-flight inspection and would not have commenced with the flight.

The pilot was seriously injured in the accident and, during his road to recovery, he was in five different hospitals, of which three were in East London and two in Pretoria. By the time this report was concluded, he was still busy with rehabilitation and he had no recollection of the accident.

2.2 Machine (Helicopter)

The helicopter was maintained in accordance with the approved maintenance schedule by an approved AMO. It had flown a further 94.8 hours since the last mandatory period inspection was certified. According to the flight folio, the helicopter last flew on 4 August 2018. The Hobbs meter indicated that an additional 4.8 hours were flown with the helicopter during the 11-day period for which there was no documented evidence. The game darting flight on the morning of 15 August 2018 prior to the accident was estimated to be approximately 1 hour.

Since the fuel quantity and the weight of the dart gun at the time of the accident were not known, it was not possible to calculate an accurate weight and balance. The zero-fuel weight was determined to be approximately 529kg (1 166 lbs), which was 61kg (135 lbs) below the maximum take-off weight. The helicopter was most probably operated at the time within the POH limitations of 590kg (1 370 lbs) as it was highly unlikely that they would have flown with a substantial amount of fuel on-board. For the purpose of the operation, the helicopter needed to be as light as possible because not only was it being operated within the dead man's curve for a substantial percentage of the darting operation, but less weight allowed the pilot an extra safety margin while he manoeuvres the helicopter to allow the veterinarian to dart the animals.

During field investigation, no evidence could be found that would have indicated that the mechanical integrity of the helicopter was compromised, which would have precluded normal flight.

The owner of the helicopter had indicated in an interview that he had purchased two, 200-litre drums of fuel (Avgas) from a petroleum service provider at New Tempe Aerodrome (FATP) outside Bloemfontein. These two drums were on the back of the LDV, which they used to tow the helicopter trailer to the game reserve. Although the helicopter trailer was still at the game reserve the day after the accident when the investigating team arrived, the two drums of fuel were not present and, therefore, no fuel samples could be taken.

2.3 Possible damage to one of the main rotor blades prior to the accident flight

With reference to an email that was received from a family member of the passenger which indicate that one of the main rotor blades (serial number unknown) might have suffered possible damage (perforated hole) prior to the accident flight required that the three maximum resolution photographs that were on the cellphone of the passenger be made available to the AIID. The photographs, which were taken from the same location within a 1-minute timeframe, displayed a reflection of the sun on one of the main rotor blade lower skin, from within the arc of *doubler* 1, as well as a reflection outwards towards the blade tip from the arc of *doubler* 2 as illustrated in Figure 37. Neither of the two main rotor blades displayed any lower blade skin damage in the area as questioned. The section of main rotor blade depicted in Figure 37 is the actual rotor blade that was found with a perforated hole at the accident site. Should there have been any damage to either of the main rotor blades prior to the flight, the pilot would have seen the damage during his pre-flight inspection and he

would not have continued with the flight as the integrity of the main rotor blades is essential towards safe flight.

2.4 Environment

Fine weather with clear sky conditions prevailed at the time of the accident, which was not considered to have had any bearing on the accident.

The terrain where the antelope were darted was flat and open. There was only one set of power lines in the immediate area, which was 10m (33 ft) in height.

What was of significance was that, approximately 142m from where the main wreckage impacted with the ground was a boma that was being used as a shooting range platform. In Figure 19 of this report, a Google Earth overlay indicates that there was a shooting range on the game reserve. There was a target board, with a paper target on it and two holes through it, and there was a back stop 200m from the boma. Eight empty cartridges were picked up inside and in the immediate surroundings of the boma. These cartridges were collected by a forensic investigator from the police and were made available to their forensic science laboratory. The accident happened to be in proximity to the shooting range.

2.5 Mission

The pilot was well familiar with the game work environment as he was involved in this field since April 2014 on a full-time basis. According to available information, this was not the first time that the pilot was involved in game work at this game reserve. At the time of the accident, several of the antelope that were earmarked for capture were already captured, which indicated that up to that point of the flight, all operations were normal.

2.6 Summary of events

Available evidence gathered during this investigation indicated that the pilot was qualified and rated to perform the flight. Fine weather conditions with good visibility prevailed, which had no bearing on the accident. Apart from the perforated hole on the main rotor blade (# 2502), no mechanical malfunction could be found with the helicopter, which could have precluded normal flight.

As discussed in this report, several items on and near the accident site were impounded by the police and taken to their forensic science laboratory in Port Elizabeth for examination. What was of primary importance to the accident investigation team was whether the perforated hole in the main rotor blade (# 2502) was caused by an external source (that is, a projectile/bullet). The ballistic report concluded that the perforated hole could not have been caused by a projectile/bullet.

The investigator approached an accredited microscopic laboratory with the primary aim to draw a material comparison between the perforated hole in the main rotor blade and one of the three holes that came about after the police shot three bullets through a section of the blade during their ballistic tests. A material sample (entry point) from one of the holes in the blade that came about after the police testing was cut out and two samples from the perforated hole were obtained. These samples were subjected to FEGSEM analysis by a competent person in the field of metallurgy.

The material specifications of the main rotor blade were obtained from the OEM, which is listed in this report. What was evident from the SAPS and FOD samples as they are referred to in the microscopic laboratory report was the displayed similarities, with copper being prominent in both.

One fundamental shortcoming that was not addressed in the police ballistic report was the fact that the main rotor blades were rotating during flight as this event did not take place while the main rotor blades were stationary, nor was it post-ground impact. Following consultation with the OEM, they indicated that the main rotor spins at 530 revolutions per minute (RPM) at normal governed RPM (104%). The blade speed in the area of the perforated hole at normal RPM was approximately 177 feet/second or 54 metres/second.

2.7 Conclusion

Following the email that was received from a family member on 17 August 2019, no evidence could be found that either of the two main rotor blades sustained any damage on the lower blade skin in the surface area from *doubler* 1 towards *doubler* 2 and further outwards, towards the blade tip.

With reference to the police ballistic report on the main rotor blade that had a hole through it, the report was found to be lacking critical content and the accident investigator could, therefore, not agree with their conclusion, nor could any logical

deduction be drawn when evaluating the report. It was, therefore, decided to collect the main rotor blade evidence pieces from the SAPS and subject them to a microscopic laboratory at an accredited facility for analysis. The test involved a materials comparison analysis where a sample of the lower blade skin of the perforated hole and one of the police induced holes (where it was known that the hole was caused by a bullet that was fired at the blade) were compared.

The sample comparison tests concluded that the perforated hole in the blade displayed the presence of the same material elements that were present in the SAPS induced bullet hole. With these results, the conclusion can be made that it was highly probable that the perforated hole was caused by a projectile/bullet that was most likely fired from a rifle/gun by a person on the ground.

The accident could, therefore, not be attributed to the pilot, the helicopter or the environment, but the likely hood is that a bullet was fired from the ground and impacted the main rotor of the helicopter. Following the shot being fired, which the pilot and passenger most probably heard considering that they were flying at low level; it could have been that the pilot related it to a catastrophic failure of some sort and, in an attempt to avoid colliding with the high-tension wires, he most probably induced a control input whereby the main rotor blades severed the tail boom and ground impact followed.

3. CONCLUSION

3.1 Findings

Pilot

3.1.1 The pilot was the holder of a commercial pilot licence (helicopter). He conducted a renewal of his pilot licence on 15 December 2017 with an expiry date of 31 December 2018. The helicopter type was endorsed on his licence.

3.1.2 The pilot was in possession of a Class 1 aviation medical certificate, which was renewed on 28 November 2017 with an expiry date of 30 November 2018.

3.1.3 The pilot conducted the flight in his private capacity as he took unpaid leave from his employer for this purpose.

3.1.4 The pilot was not wearing a flying helmet at the time of the flight. He was seriously injured during the accident sequence and was attended to at the accident scene by paramedics. He was transported by road ambulance to a hospital in Queenstown and, from there, he was transferred to a hospital in East London, thereafter, to another hospital in East London. A few weeks later, he was flown by air ambulance and admitted to a hospital in Pretoria.

3.1.5 The last entry in the pilot's logbook was dated 23 May 2018. An additional 65.7 flying hours were traced, which he flew over the period 24 May to 8 August 2018 on the helicopter ZT-RBX.

3.1.6 He was flying the helicopter from the right side and both doors were removed for the game darting operation.

Helicopter

3.1.7 The helicopter was issued a Release to Service certificate on 8 June 2018 with an expiry date of 7 June 2019.

3.1.8 The helicopter had a valid Certificate of Airworthiness (CoA). The original date of issue was 12 January 2012 with an expiry date of 11 January 2019.

3.1.9 The last maintenance inspection that was carried out on the helicopter prior to the accident flight was certified on 8 June 2018 at 1 898.6 airframe hours. Following the inspection, a further 94.8 hours were flown with the helicopter.

3.1.10 The last flight folio entry was dated 4 August 2018 with the Hobbs meter reading entered as 740.6. Available evidence indicated that an additional 4.2 hours were flown with the helicopter, for which there were no entries in the flight folio. This included the accident flight, which was the first flight of the day.

3.1.11 According to available information, the helicopter was refuelled from 200-litre drums. These drums were, however, removed from the game reserve prior to the arrival of the investigation team.

3.1.12 No evidence could be found that either of the two main rotor blades sustained any damage associated with a perforated hole prior to the accident flight. The email that was received by the AIID on 17 August 2019 from a family member of the passenger in this regard was referenced.

Weather conditions

3.1.13 Fine weather with clear sky conditions prevailed at the time of the accident. The weather was not considered to have had any bearing on the accident.

Operation

3.1.14 No evidence could be found to indicate that this operation was conducted in accordance with an air operating certificate (AOC).

Veterinarian

3.1.15 The veterinarian was seated on the left side and was secured to the helicopter safety harness by an additional safety harness to allow for additional manoeuvring while darting the antelope. He succumbed to his injuries at the accident scene.

3.1.16 The dart gun that was used by the veterinarian was found near the main wreckage and was handed over to the SAPS on their arrival at the scene.

Wreckage

3.1.17 The main wreckage was found lying on its left side 21m from a set of power lines, which consisted of three wires, 1.5 metres apart, in the horizontal plane and approximately 10m (33 ft) above ground level. The middle wire displayed evidence of arcing.

3.1.18 No evidence could be found that the mechanical integrity of the helicopter was compromised prior to ground impact.

3.1.19 Both main rotor blades fractured at the main rotor hub assembly. One of the main rotor blades (# 2502) had a perforated hole through the blade, which originated from an external source. The perforated hole met the material specifications of a bullet/projectile.

Additional Observations

3.1.20 In proximity to the main wreckage was a shooting range which consisted of a boma/shooting platform; a standalone target, which was 100m from the boma; and a back stop (heap of sand), which was 200m from the boma.

3.1.21 Inside and in proximity to the boma, eight empty cartridges were found, which were picked up and placed in evidence bags by a police official.

SAPS Forensic Science Laboratory (Ballistic Section)

3.1.22 The section of the main rotor blade (# 2502) with the perforated hole, as well as an additional section, the eight empty cartridges, the dart gun and the dart that were picked up at the scene were impounded by the SAPS and were taken to the SAPS Forensic Science Laboratory (Ballistic Section) in Port Elizabeth. Their observation was that the perforated hole in the blade was not caused by a projectile/bullet.

3.1.23 The additional section of main rotor blade was used by police officials for their ballistic testing and three bullets (calibre unknown) were fired at the blade from an unknown distance.

Microscopic Laboratory Analysis

3.1.24 Additional laboratory analysis were conducted by the investigation authority after the two sections of the main rotor blade were obtained from the SAPS. A sample from the perforated hole (lower skin surface of the blade) was removed and was subjected to a FEGSEM test.

3.1.25 A sample from one of the three bullet holes (lower skin surface of the blade) that the police officials fired at the blade was removed and was subjected to a FEGSEM test.

3.1.26 The information that was gathered during the laboratory analysis comparison test differ from the observations in the SAPS Forensic Science Laboratory (Ballistic Section) report.

3.1.27 Following the independent microscopic laboratory test analysis, the SAPS forensic report was found to be lacking critical information and their conclusion could, therefore, not be regarded as accurate.

3.2 Probable cause

3.2.1 The accident could be attributed to an external event (third party), which could be associated with an unintentional or deliberate act by a person or persons on the ground who either fired a rifle/gun at the helicopter, whereby the projectile/bullet penetrated one of the main rotor blades.

3.2.2 The pilot most probably not only heard the shot being fired (if a silencer was not used) but he would have felt a vibration on the helicopter flight controls after the projectile/bullet had penetrated the blade. He could have interpreted this as a catastrophic failure of some kind and, to avoid colliding with the power lines, he most probably made an unintentional control input by yanking back on the cyclic, which resulted in the tail boom being severed by the main rotor blades; thereafter, control was lost, and the helicopter impacted the ground.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that investigation be referred to the SAPS who should conduct a comprehensive ballistic analysis on the perforated hole in the main rotor blade. Available information that was gathered during the accident investigation process has provided significant evidence to conclude that the perforated hole was most probably caused by a projectile/bullet that originated from a rifle/gun that was fired from the ground while the helicopter was in flight.

5. LIST of APPENDICES

5.1 Appendix A (SAPS Forensic Science Laboratory Ballistics Report)
5.2 Appendix B (Impact Analysis Report, Laboratory for Microscopy & Microanalysis)

This report is issued by:
Accident and Incident Investigation Division (AIID)
South African Civil Aviation Authority
Republic of South Africa

APPENDIX A

LAB 329691/18
STERKSPRUIT CAS 14/08/2018

AFFIDAVIT IN TERMS OF SECTION 212 OF THE CRIMINAL PROCEDURE ACT, 1977 (ACT 51 OF 1977) (as amended):

ZAKHELE KHUTSO MHLANGA declares under oath and in terms of Section 212(4)(a) and 212(8)(a) of Act 51 of 1977 (as amended), as follows:

1.

I number 7203712-1 am a WARRANT OFFICER in the South-African Police Service, and in service of the State. I am attached to the Ballistics Section of the Forensic Science Laboratory, Eastern Cape at Eben Donges Building, Hancock Street, North End, Port Elizabeth with telephone number 041 407 6818 as a Forensic Analyst.

2.

I have been attached to the Ballistics Section since 2013 as an examiner of Forensic Ballistics related cases. I have to date examined in excess of more than 1571 cases

2.1 I have received in-service training in the following aspects of the Forensic Ballistics Science:

2.1.1 Identification of ammunition, fired bullets and fired cartridge cases.

2.1.2 Identification of firearms.

2.1.3 The examination of firearm mechanisms.

2.1.4 Techniques associated with the recovering and restoration processes of obliterated alpha-numeric figures on metals.

2.1.5 The use of microscopic equipment.

2.1.6 Microscopic individualization of ammunition.

2.1.7 Microscopic individualization of fired bullets and fired cartridge cases.

2.1.8 Microscopic individualization of tools and tool marks.

2.1.9 Physical Matching.

2.2 **I SUCCESSFULLY ATTENDED THE FOLLOWING COURSES:**

2.2.1 I received training on Shooting Incident Reconstruction presented by MICHAEL MALONEY of FORENSIC CRIME LABORATORIES.

2.3 **I OBTAINED THE FOLLOWING TERTIARY QUALIFICATION:**

I am in possession of a Diploma in Analytical Chemistry obtained in 2008 from WSU.

3.

On 2018/10/25 during the performance of my official duties I received intact sealed evidence bags with numbers PAR000050507- and PAB000259857 marked *inter alia* STERKSPRUIT CAS 14/08/18 from Case Administration of the Ballistics Section.

3.1 SEALED EVIDENCE BAG WITH NUMBER PAB000259857 CONTAINED:

3.1.1 SEALED EVIDENCE BAG WITH NUMBER PAR0001458813 CONTAINING:

3.1.1.1 ONE .50 CALIBRE DART MODEL 389 BOLT ACTION RIFLE WITH SERIAL NUMBER 5722 ON THE BARREL AND MM33049C ON THE ACTION.

3.1.2 SEALED EVIDENCE BAG WITH NUMBER PA6001815662 CONTAINING:

3.1.2.1 ONE .300 WINCHESTER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A4.

3.1.3 SEALED EVIDENCE BAG WITH NUMBER PA6001815660 CONTAINING:

3.1.3.1 ONE .300 WICHESER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A6.

3.1.4 SEALED EVIDENCE BAG WITH NUMBER PA6001815661 CONTAINING:

3.1.4.1 ONE .300 WINCHESTER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A5.

3.1.5 SEALED EVIDENCE BAG WITH NUMBER PA6001815659 CONTAINING:

3.1.5.1 ONE .300 WINCHESTER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A7.

3.1.6 SEALED EVIDENCE BAG WITH NUMBER PA6001815658 CONTAINING:

3.1.6.1 ONE .300 WINCHESTER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A8.

3.1.7 SEALED EVIDENCE BAG WITH NUMBER PA6001815657 CONTAINING:

3.1.7.1 ONE .300 WINCHESTER MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A9.

3.1.8 SEALED EVIDENCE BAG WITH NUMBER PA6001815667 CONTAINING:

3.1.8.1 ONE 7 mm REMINGTON MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A10.

3.1.9 SEALED EVIDENCE BAG WITH NUMBER PA6001815666 CONTAINING:

3.1.9.1 ONE 7 mm REMINGTON MAGNUM CALIBRE FIRED CARTRIDGE CASE MARKED BY ME 329691/18 A11.

3.1.10 SEALED EVIDENCE BAG WITH NUMBER PA6001815663 CONTAINING:

3.1.10.1 ONE DART UNMARKED.

3.2 SEALED EVIDENCE BAG WITH NUMBER PAR000050507- CONTAINED:

3.2.1 SEALED EVIDENCE BAG WITH NUMBER PAR000145879A CONTAINED:

3.2.1.1 SEALED EVIDENCE BAG WITH NUMBER PAR0001435492 CONTAINED:

3.2.1.1.1 ONE PIECE OF MAIN ROTER BLADE WITH A PERFORATING HOLE MARKED BY ME 329691/18 EXHIBIT 2.

3.3 SEALED EVIDENCE BAG WITH NUMBER PAB000259859 CONTAINING:

3.3.1 ONE PIECE OF ROTER BLADE MARKED BY ME 329691/18 EXHIBIT 3.

4.

The intention and scope of this forensic examination comprise the following Ballistics techniques:

4.1 The examination and identification of dart and fired cartridge cases.

4.2 Microscopic individualization of fired cartridge cases

4.3 Firearm mechanism examination.

4.4 Projectile trajectory examination.

5.

I examined the cartridges mentioned in paragraph 3 and found:

5.1 The cartridges were manufactured or designed to be fired by a centre-fire firearm.

6.

I examined and tested the rifle mentioned in 3.1.1.1 and found:

6.1 The barrel of the bolt action rifle mentioned in 3.1.1.1 is broken and because of this it was not able to discharge ammunition.

7.

I examined and tested the mechanisms of the bolt action rifle mentioned in 3.1.1.1 and found:

7.1 The device was manufactured or designed to discharge rim-fire ammunition.

8.

I examined the fired cartridge cases mentioned in paragraph 3 and compared the individual and class characteristics markings transferred to them by firearm components during the firing process using a comparison microscope and found:

8.1 The cartridge cases mentioned in 3.1.2.1-3.1.7.1 marked 329691/18 A4-A9 were fired in the same firearm but not in the rifle mentioned in 3.1.1.1 (2nd firearm unknown).

8.2 The cartridge cases mentioned in 3.1.8.1 and 3.1.9.1 marked 329691/18 A10-A11 were fired in the same firearm (3rd firearm unknown).

8.3 (Exhibit 2 was used for test purposes) I concluded that the hole in exhibit 3 does not have a typical appearance hole that was caused by a bullet.

9.

The conclusions arrived at were based on facts, established by means of an examination and process which require a knowledge and skill in Forensic Ballistics.

10.

After Examination the exhibits mentioned in 3 were disposed of as follows:

10.1 On 2018/10/31 the exhibits mentioned in 3.1.1.1 and 3.1.10.1 were sealed in an evidence bag with number PAR0001792948 and handed over to Case-Administration of the Ballistics Section.

10.2 On 2018/10/31 the exhibits mentioned in 3.2.1.1 were sealed in an evidence bag with number PAR0001792926 and handed over to Case-Administration of the Ballistics Section.

10.3 On 2018/10/31 the exhibits mentioned in 3.3.1 were sealed in an evidence bag with number PAR0001792937 and handed over to Case-Administration of the Ballistics Section.

10.4 On 2018/10/31 the exhibits mentioned in 3.1.2.1-3.1.9.1 marked 329691/18 A4-A11 were sealed in an evidence bag with number PA5001923569 and filed in case file with lab 329691/18.

11.

During the performance of my official duties the exhibits mentioned were for the purpose of their examination kept in my custody, under lock and key, from 2018/10/25 until 2018/10/31.

12.

I know and understand the contents of this declaration.

I have no objection to taking the prescribed oath.

I consider the prescribed oath to be binding on my conscience.

7203712-1

.....W/O

ZAKHELE KHUTSO MHLANGA

I certify that the deponent has acknowledged that he knows and understands the contents of this declaration which was sworn to before me and the deponent's signature was placed in my presence at **PORT ELIZABETH on** ....13....**of** ....NOVEMBER....**2018**.

WO
0534387-9
BOTHA J.P.
COMMISSIONER OF OATHS
JUDEN PATRICK BOTHA

FORENSIC BALLISTICS SECTION
EBEN DÖNGES BUILDING
HANCOCK STREET
NORTH END
PORT ELIZABETH
6000
WO : SA POLICE SERVICE

SUID-AFRIKAANSE POLISIEDIENS
FORENSIESE DIENSTE
19 NOV 2018
EASTERN CAPE
FORENSIC SERVICES
SOUTH AFRICAN POLICE SERVICE

lm/329691/18

APPENDIX B

COMPILED BY:	UNIVERSITEIT VAN PRETORIA / UNIVERSITY OF PRETORIA / YUNIBESITHI YA PRETORIA — LABORATORY FOR MICROSCOPY & MICROANALYSIS	PAGE 1 of 14
	IMPACT ANALYSIS REPORT: ROBINSON R22 HELICOPTER MAIN ROTOR BLADE, AIRCRAFT No ZS-HBP	DOCUMENT NUMBER IA-001-07-19
COMPILED FOR: SACAA (AIID)		DATE 2019-07-03 / ISSUE 1

ITEM: **MAIN ROTOR BLADE, PART No A106-6, SERIAL No 2502, ROBINSON R22, AIRCRAFT No ZS-HBP**

1. BACKGROUND INFORMATION

1.1. The remaining sections from a Main Rotor blade (Serial no 2502) originating from a Robinson R22 helicopter, registration no ZS-HBP (Photo 1), were submitted to determine the most probable cause/s towards the noted foreign object impact damage (Photo 3).

1.2. The relevant aircraft was involved in an accident (1x fatality) on the 15th of August 2018 (Photo 2).

1.3. The Investigator In Charge (IIC) reported no clear indications towards possible foreign objects on the accident scene that may have introduced impact mark/s with corresponding geometry and directional orientations.

Photo 1: ZS-HBP[1]

Photo 2: ZS-HBP accident site[2]

[1] Courtesy Joe Evans
[2] Courtesy SACAA

Photo 3: Foreign Object Impact damage, as received (Digital)

1.2. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) SACAA Preliminary Accident Report CA18/2/3/9727
(b) Robinson Helicopters R22 POH, OHM, IPC

3. DEFINITIONS

(a)	OEM	Original Equipment Manufacturer
(b)	FEGSEM	Field Emission Gun Scanning Electron Microscope
(c)	FOD	Foreign Object Damage
(d)	EDS	Energy Dispersive X-ray Analysis
(e)	rpm	Revolutions per Minute
(f)	fps	Feet per Second
(g)	m/s	Meters per Second
(h)	SACAA	South African Civil Aviation Authority
(i)	AIID	Accident and Incident Investigation Division
(j)	MR	Main Rotor
(k)	IPC	Illustrated Parts Catalogue
(l)	SAPS	South African Police Services
(m)	Wt%	Weight Percentage

4. PERSONNEL

(a) The investigative member and compiler of this report is Mr C.J.C. Snyman, ID number 6406105057080. Mr Snyman is a qualified Physical Metallurgist (H.N.Dip. Metallurgical Engineering, Tech. PTA, ECSA Registration: Prof. Eng. Tech. No 201670194), Radiation Protection Officer (RPO, NNR, No 281) and Aircraft Accident Investigator (SCSI).

5. APPARATUS AND METHODOLOGY

(a) The methodology included visual inspection of the affected part/s, sample preparation and Light-, Stereo- and FEGSEM/EDS analysis.

6. INVESTIGATION RESULTS

6.1. Visual Inspection

Note 1: *The R22 main rotor blade is of conventional bonded metal construction, comprising top and bottom skins of AISI 2024 Aluminium alloy (Extract 1) with an Aluminium honeycomb core, a hollow 'D' section leading edge spar of stainless steel, and a forged Aluminium alloy root-fitting.*[3]

The visual inspection revealed the impact mark (Photo 4) under investigation at ±990mm from position A (Diagram 2) adjacent to the leading edge main spar. The penetrating direction is from bottom to top with the trajectory at an approximate angle of 37° relative to the leading edge and ±55° relative to the top blade surface, viewed from the trailing edge.

Although elongated due to entry angle, the exit hole elliptical dimensions are ±8.2mm on the minor axis and ±10.6mm on the major axis. The minor axis proved to be more representative of the actual projectile diameter.

Impact induced (unconfirmed) surface scraping marks were noted on the areas surrounding the entry point of the FOD (Photo 4, red arrows; MR Bottom surface). Indications are that these marks do not extend throughout the FOD indented area (Photo 4, red dashed circle) suggesting that the FOD occurred prior to the aircraft impact hard ground. Pointing towards the same is the buckling geometry surrounding the FOD exit side (Photo 8) whereas the buckling progression were seemingly arrested at the point of FOD.

6.2. High Magnification Inspection

Note 2: *A section of the same MR blade was exposed to SAPS ballistic testing (x3; Photo 5; No's 1-3). The entry point of test impact mark No 1 (Photo 6) was selected and removed for reference purposes.*

The Stereo- and FEGSEM analysis was performed on both the FOD and SAPS test no 1 samples (Photo 7). The fractography revealed comparable results (Fractographs 1 to 3) relating to fracture surface geometries and general profile on the entry sides. However, some variations were noted between the FOD and SAPS tests regarding the exit side (Photo's 5 and 8) damage geometries. The exit geometries of the SAPS tests conform more closely to "*petaling*" (Diagram

[3] Courtesy Robinson Helicopters

3, (e)) while the FOD conforms to that of "*plugging*" (Diagram 3, (b)). *Variables to consider will be projectile velocity at the point of entry; relative directional velocity and angle of the MR blade; caliber (bullet)/diameter (projectile); entry angle; bullet/projectile construction, weight and material composition.*

6.3. EDS Analysis

Note 3: *To perform a comparative analysis, specific regions considered to be in contact with both the SAPS bullet and the unknown projectile (FOD sample) were selected for the EDS analysis.*

The qualitative EDS analysis results obtained from the SAPS Test No 1 (entry end) contact surface revealed clear indications of fragments originating from a source with a high copper content (EDS Map Result 1, Pictures (b), (c) and (d); Method B), an expected result from a known source, most probably a copper-based *full-metal jacket* bullet construction.

The qualitative EDS analysis results obtained from the FOD (entry-end) contact surface (Photo 4, yellow dashed square) revealed clear, and comparable to the SAPS reference sample, indications of fragments originating from a source with a high copper content (EDS Map Result 2, Pictures (a), (b) and (d), yellow arrows; Method B). Point and ID (Method A) analysis of the noted particulates confirmed the copper (Cu) content of **39.65 Wt% - 55.7 Wt%** to be exceedingly higher (EDS Results 1, 2 and 3; Method A) and thus *partially* unrelated to the expected **3.8 Wt% - 4.9 Wt%** copper (Cu) content of the AISI 2024 substrate alloy composition (Extract 1).

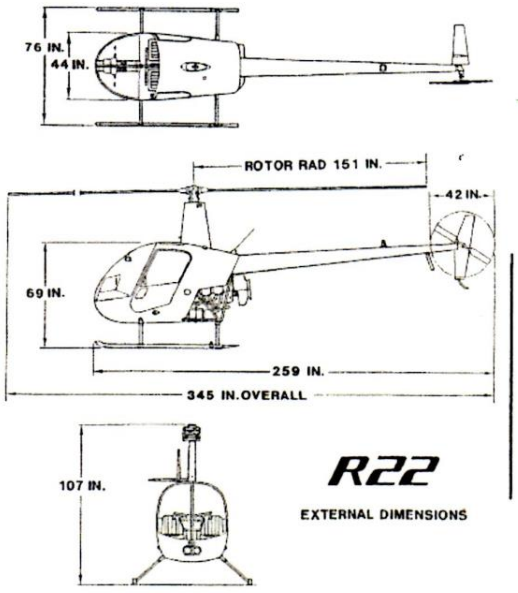


Diagram 1: Robinson R22 layout[4]

[4] Courtesy Robinson Helicopters POH

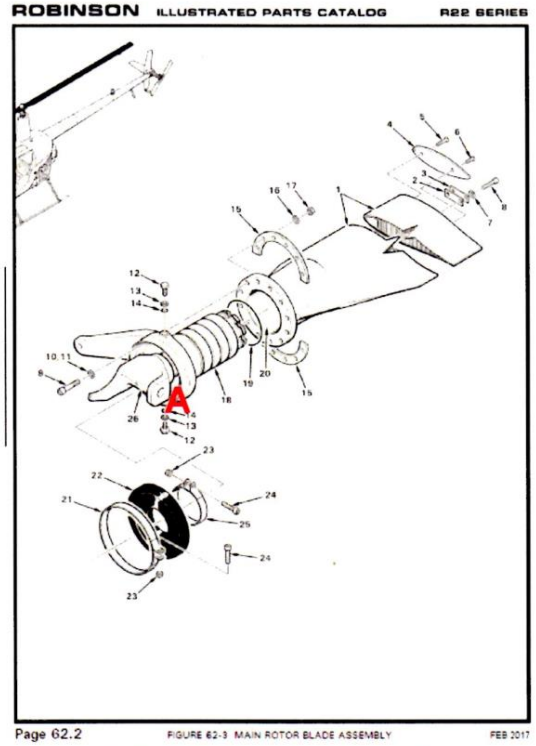


Diagram 2: R22 Blade construction[5]

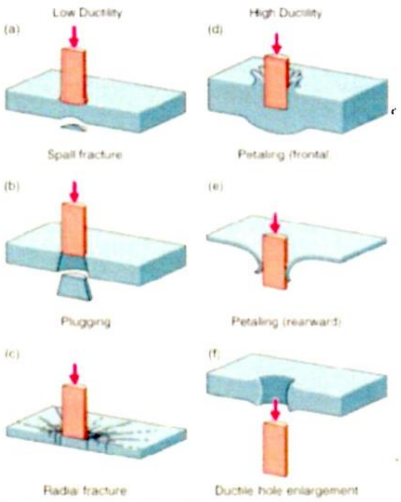


Diagram 3: Ballistic profiles for high speed projectiles

[5] Courtesy Robinson Helicopters IPC

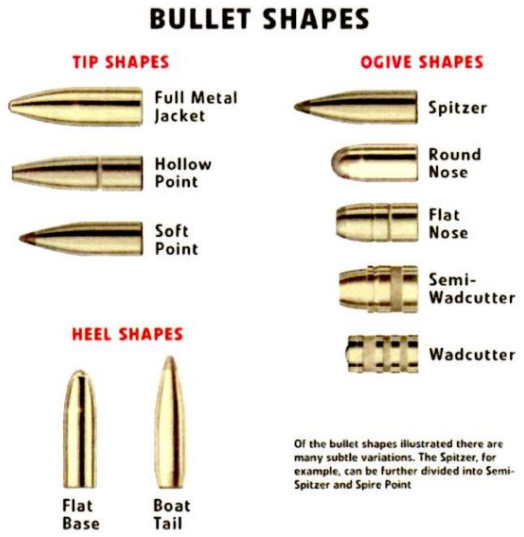


Diagram 4: Common bullet shapes[6]

GENERAL DESCRIPTION: ALLOY 2024

2024 is heat-treatable aluminum alloy with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. Due to its high strength and fatigue resistance, 2024 is widely used in aircraft structures.

TYPICAL CHEMISTRY LIMITS:

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others-Each	Others Total	Al
2024	0.50	0.50	3.8-4.9	0.30-0.9	1.2-1.8	0.10	0.25	0.15	0.05	0.15	Remainder

Extract 1: AISI 2024 Aluminium alloy composition[7]

[6] Courtesy Ammo.com
[7] Courtesy United Aluminium

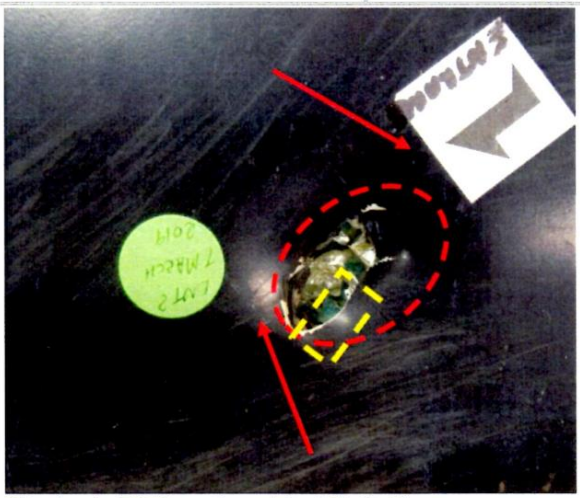


Photo 4: FOD, entry side (digital)

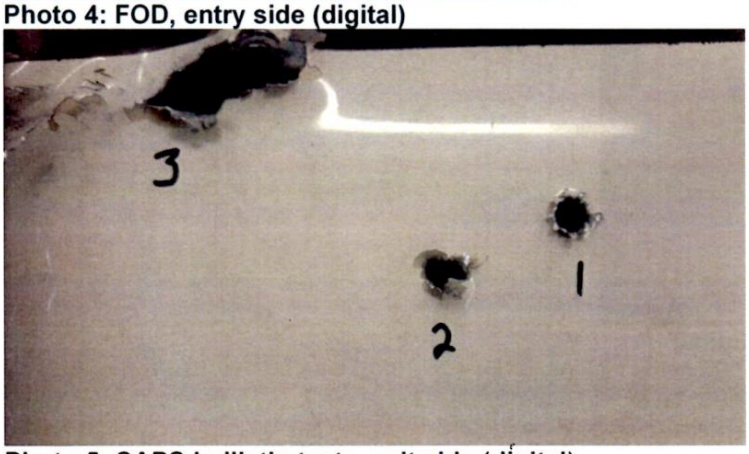


Photo 5: SAPS ballistic tests, exit side (digital)

Photo 6: SAPS induced bullet hole No 1, entry side, removed for reference (digital)

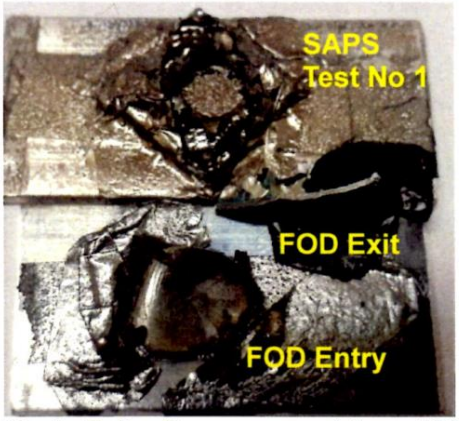


Photo 7: Sections removed from FOD area (digital)

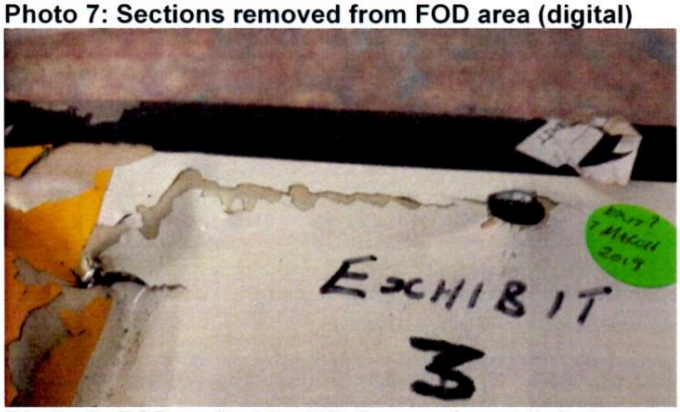
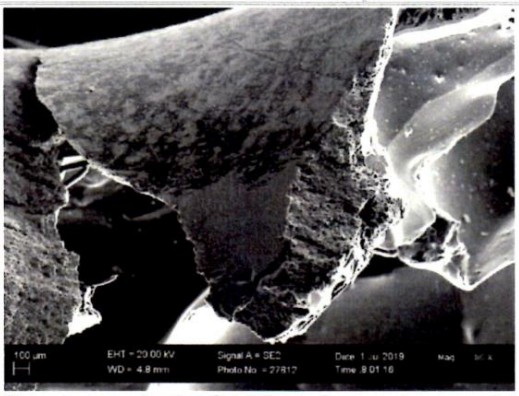
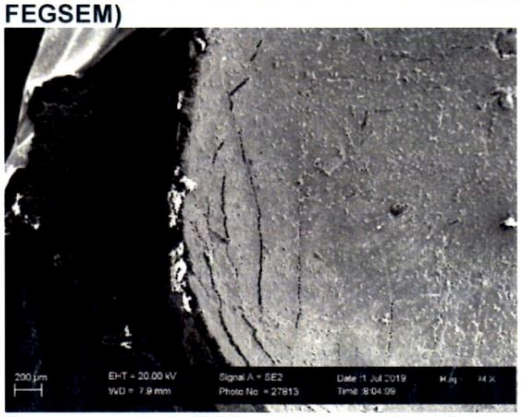


Photo 8: FOD, exit side, MR Top surface (digital)

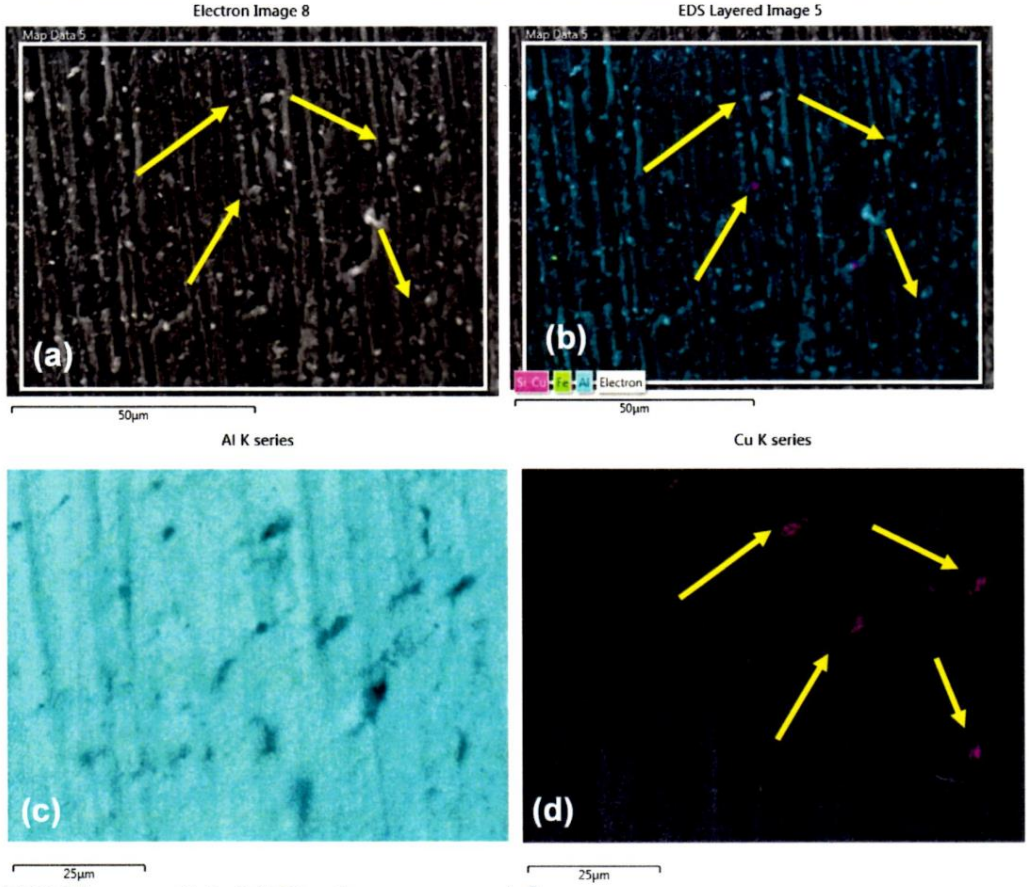
Fractograph 1: SAPS reference sample, smearing marks (1420X, 2kV, InLens, FEGSEM)



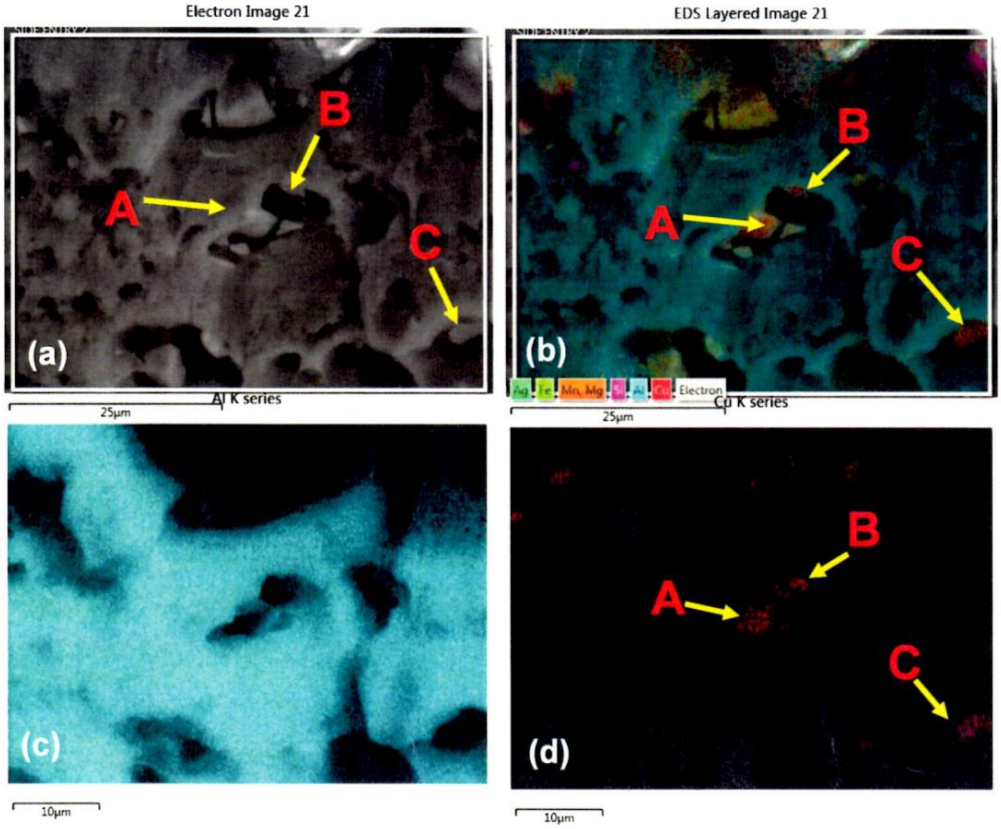
Fractograph 2: SAPS reference sample, point of entry fracture surfaces (86X, 20kV, SE, FEGSEM)



Fractograph 3: FOD sample, point of entry fracture surfaces (74X, 20kV, SE, FEGSEM)

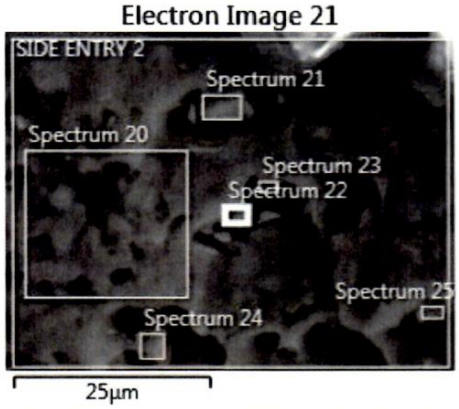


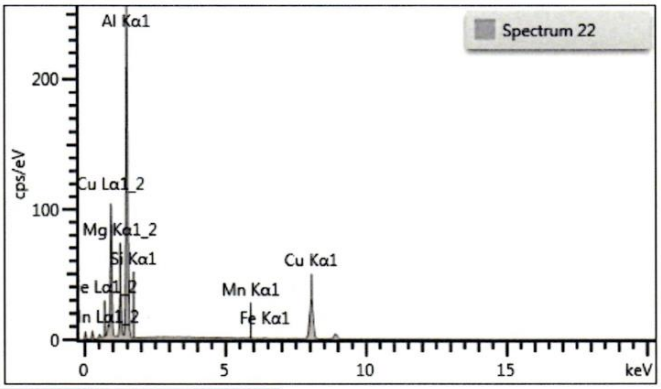
EDS Map result 1: SAPS reference sample[ii]



Element	Wt%	Wt% Sigma	Atomic %
Mg	1.27	0.02	1.49
Al	88.02	0.08	93.45
Si	0.70	0.02	0.72
Mn	0.92	0.03	0.48
Fe	0.90	0.03	0.46
Cu	6.60	0.06	2.98
Ag	1.58	0.04	0.42
Total:	100.00		100.00

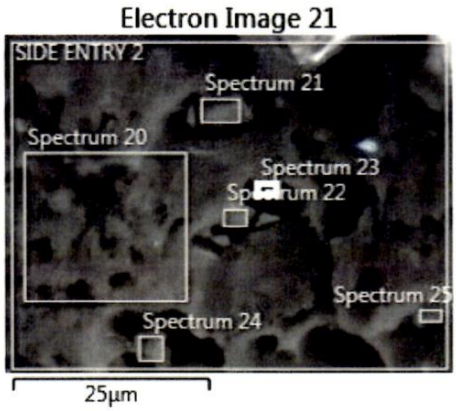
EDS Map Result 2: Contact area selection, FOD sample[ii]

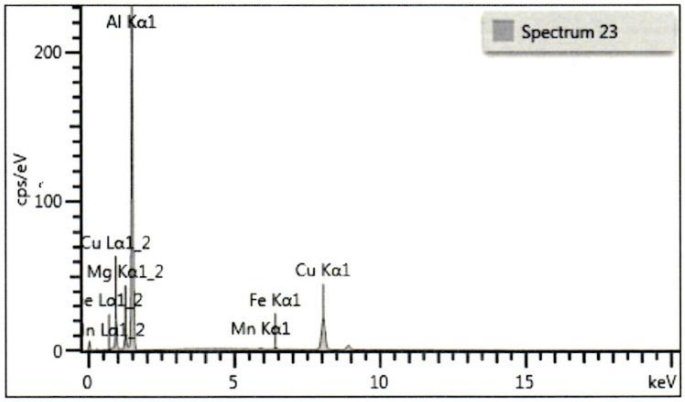




Element	Wt%	Wt% Sigma	Atomic %
Mg	7.90	0.08	11.26
Al	51.79	0.16	66.55
Si	0.22	0.03	0.28
Mn	0.16	0.04	0.10
Fe	0.28	0.04	0.17
Cu	39.65	0.17	21.64
Total:	100.00		100.00

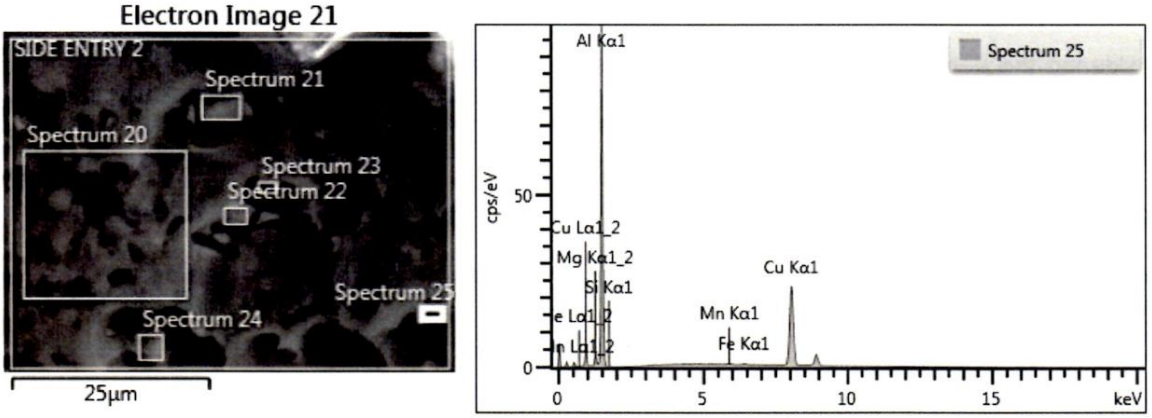
EDS result 1: Cu-rich particle A[i]





Element	Wt%	Wt% Sigma	Atomic %
Mg	2.41	0.05	3.44
Al	58.18	0.16	74.93
Mn	0.37	0.04	0.23
Fe	0.48	0.05	0.30
Cu	38.56	0.16	21.09
Total:	100.00		100.00

EDS result 2: Cu-rich particle B[ii]



Element	Wt%	Wt% Sigma	Atomic %
Mg	1.64	0.04	2.68
Al	41.95	0.13	61.82
Si	0.19	0.01	0.27
Mn	0.22	0.04	0.16
Fe	0.22	0.04	0.16
Cu	55.77	0.14	34.90
Total:	100.00		100.00

EDS Result 3: Cu-rich particle C[ii]

7. DISCUSSION AND CONCLUSIONS

Note 4: *The conclusions are based on the investigation results obtained from the supplied parts/components and information only. All information supplied to this investigation from other parties are considered to be factual.*

7.1. The visual inspection revealed FOD at approximately 990mm from the MR blade root, adjacent to the blade spar/leading edge, entry and exit points angled from the bottom towards the top surfaces while angled towards the main fuselage (refer p.6.1.). The FOD geometry and impact characteristics point toward a high velocity, circular shaped projectile with a representative diameter ascertained at approximately 8.2mm.

7.2. Buckling geometries and discontinuities in surface scrape marks, most probably induced unto the MR blade surface during the aircraft impact sequence (unconfirmed), suggest that the FOD was induced prior to final (aircraft) impact.

7.3. The EDS results, compared to the known SAPS ballistic tests, revealed that the (unknown FOD) projectile surface in contact with MR blade substrate to consist of a material with high copper (Cu) content.

8. RECOMMENDATIONS

8.1. Considering the detrimental effects on Flight Safety and the probability that the high speed projectile responsible for the noted FOD conform to that of a bullet fired from a lower height while angled towards the accident aircraft, seemingly during flight, it is recommended that an appropriate authority initiate further investigation.

9. DECLARATION

9.1. All digital images have been acquired by the author, unless otherwise stated, and displayed in an un-tampered manner.

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[i] Method B: Equipment: ZEISS 540 Crossbeam FEGSEM
Settings: Gun - 20kV; Detector - Secondary Electrons; Column - Analytical; Working Distance – 5mm; Aperture – n/a
Analytical Software: Oxford Aztec; Mapping; Dead Time – 40-60%

[ii] Method A: Equipment: ZEISS 540 Crossbeam FEGSEM
Settings: Gun - 20kV; Detector - Secondary Electrons; Column - Analytical; Working Distance – 5mm; Aperture – n/a
Analytical Software: Oxford Aztec; Point&ID; Dead Time – 40-60%