TITLE

GENERAL INFORMATION:

Name of Operator:	Air Services Ltd
Aircraft Manufacturer:	Bell Helicopters Ltd
Aircraft Model:	Bell 206 L4
Nationality and Registration Marks:	8R-GTR
Place of Accident/Region:	Near to Hicks Camp, Karouni Region7, Guyana
Date of Accident:	10th September 2018.
Time of Accident:	17:30hrs UTC

REPORT No. GAAIU 3/1/25

This investigation was conducted in accordance with ICAO Annex 13 and therefore, it is not intended to apportion blame, or to assess individual or collective liability. Its sole objective is to draw lessons from the occurrence which may help to prevent future accidents. Consequently, the use of this report for any purpose other than for the prevention of future accidents could lead to erroneous conclusions.

Note: - All times in this report are Coordinated Universal Time (UTC) unless otherwise stated. UTC is four hours ahead of Guyana Standard Time (GST).

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GLOSSARY OF ABBREVIATIONS

ADS-b	-	Automatic Dependent Surveillance – Broadcast. A satellite navigation system to support airborne traffic separation.
AIP	-	Aeronautical Information Publication
AMEL	-	Aircraft Maintenance Engineer Licence
AMO	-	Approved Maintenance Organisation
AOC	-	Air Operator Certificate
ASL	-	Air Services Limited
ATC	-	Air Traffic Control
CAVOK	-	Ceiling and Visibility OK
CPL	-	Commercial Pilot Licence
EFCIA	-	Eugene F. Correia International Airport
FOD	-	Foreign Object Damage
FOM	-	Flight Operations Manual
GAAIU	-	Guyana Aircraft Accident and Incident Investigation Unit
GARs	-	Guyana Aviation Requirements
GCAA	-	Guyana Civil Aviation Authority
GCARs	-	Guyana Civil Aviation Regulations
GDF	-	Guyana Defence Force
ICAO	-	International Civil Aviation Organisation
MEL	-	Minimum Equipment List
NTSB	-	National Transportation Safety Board, USA
RWY	-	Runway
S/N	-	Serial Number
Sta.	-	Station
TBO	-	Time before Overhaul
TOT	-	Turbine Outlet Temperature
TSN	-	Time since New
TSO	-	Time since Overhaul
VMC	-	Visual Meteorological Conditions

Synopsis

The helicopter flew from EFCIA to Hicks Camp. Shortly before reaching its destination, the Engine Oil Pressure Gauge began to flicker and dropped to zero, and a chip light illuminated. The aircraft was over a rain forest, so the pilot elected to continue flight to the destination. During final approach, at ~70ft AGL, the pilot heard a loud bang and the helicopter lost power. The pilot performed an autorotational descent to the ground with no injury. Damage to the aircraft was cowling penetrations from the engine failure. After touchdown, the pilot extinguished a fire which had begun in the engine nacelle.

There was a fire and the helicopter had suffered engine damage.

There were no injuries or fatalities.

1. Factual Information

1.1. History of Flight

The aircraft took off from the operator's home base at the Eugene F. Correia International Airport, (EFCIA) Guyana on a gold pickup mission. This was the first flight of the day. During takeoff, the tower advised the pilot that the aircraft's engine was smoking. The pilot returned to base where a ground check was carried out while the engine was running. By the time the check was conducted the engine had stopped smoking and the ground crew found no cause for the smoking issue. The pilot then took off for his intended destination, at Hicks Camp. This was a 45min flight. There were 2 passengers on board.

During the flight, about ten minutes before touchdown, the pilot noted a minor oil pressure fluctuation. A few minutes after the minor fluctuation, the oil pressure dropped to zero and a chip light illuminated. The aircraft was over a rain forest, but the destination was in sight, so the pilot elected to continue flight to the destination. During final approach, at about 70ft AGL, the pilot heard a loud bang and lost power. The pilot performed an autorotational descent to the ground with no resultant injury or damage with the exception of cowling penetrations from the engine failure. After touchdown, the pilot extinguished a fire which had begun in the engine nacelle.

1.2. Injuries to Persons

Table: 1- Showing Injuries to Persons

Injury	Crew	Passengers	Others	Total
Fatal	0	0	0	**0**
Serious	0	0	0	**0**
Minor/None	1	2	0	**3**
Total	**1**	**2**	**0**	**3**

1.3 Damage to the Aircraft

Damage to the aircraft consisted of several cowling penetrations (inside to out) in-plane with the engine turbine module. The upper surface of the engine cowling exhibited thermal damage consistent with a post-landing fire. A hole was observed in the rear slanted surface of the exhaust stack and material was "petaled" inward, consistent with debris striking the stack from the rear to front. The engine was mounted securely in the airframe and the inlet particle separator was intact and not clogged. The engine inlet was normal in appearance and the impeller displayed a single impact mark on one of the blade leading edges. The impeller blades exhibited erosion on the leading edges as well.

Several oil and pneumatic tubes located in-plane with the gas generator turbine rotor were cut and bent. The aircraft mounted fuel filter was full of fuel and a sample was retained from the bowl. The filter element was clean, and the fuel smelled and appeared normal. Battery power was supplied to the aircraft and the engine chip caution light illuminated in the cockpit. The TOT exceedance warning light illuminated as well. Proper fuel control unit and power turbine governor rigging were verified from the cockpit to the engine.

The gearbox was normal in appearance. The upper magnetic chip detector displayed ferrous material which completed the circuit to illuminate the cockpit indicator. The lower chip detector retained less material, which was not enough to activate the cockpit indicator.

The engine mounted oil pressure filter was clean with no debris noted. The aircraft mounted scavenge oil filter retained some ferrous debris, although not enough to extend the bypass indicator. Metallic debris was also collected from the engine oil scavenge line, which connects the engine gearbox to the scavenge filter. Less than ½ liter of oil remained in the aircraft mounted engine oil reservoir. An oil sample was retained from the oil reservoir and also from the scavenge oil filter bowl. All of the aircraft mounted oil lines and connections were inspected and no loose fittings or cracked lines were observed. The oil cooler and reservoir were undamaged. The engine oil supply and scavenge lines were flow checked and no blockages, leaks or damage were noted. The 6/7 oil sump can was dry with no oil remaining.

Both the power turbine support and gas generator support casing were ruptured at multiple locations, exposing the inside of the turbine module. The damage was consistent with debris exiting outward with significant energy. The first stage turbine wheel (T1) was not intact, and the second stage turbine wheel (T2) hub remained on the N1 shafting. The energy absorbing ring bulged outward. The N2 rotor was locked and the fourth stage turbine wheel (T4) blades were intact when viewed from the exhaust collector. The N1 rotor turned when the impeller was manipulated by hand and the compressor was connected to the starter and the gas generator shafting, which retained the T2 wheel hub.

1.4. Other Damage

There was no other damage.

1.5Personnel Information – The Pilot

Gender:	Male
Date of Birth/Age:	7th December 1978
Nationality:	Guyanese
License:	CH00019
Date of issue:	15th September 2017
Date of last medical:	23rd March 2018
Valid until:	30th September 2018
Aircraft type rating:	B206B, Robinson R44
Last Proficiency Check on Type:	14th April 2018
Total hours:	2225hrs Approx.
Hours in last 30 days:	18.3hrs
Hours in last 7 days	4.8hrs
Hours in last 24 hours:	3.3hrs

The pilot is required to wear corrective lens and to have a second pair of spectacles readily available while exercising the privileges of his licence.

The pilot was freelancing with the operator. He had acquired the required minimum qualifications and had completed all the required training as listed in the company's Flight Operations Manual. He had also completed required type checks and Route and Area checks to a satisfactory standard. His flight and duty times were within limits.

The pilot stated that he was assured by the maintenance crew that the pre-flight inspection was completed, and the aircraft was ready for flight. He also carried out the normal pilot's pre-flight inspection, the inspection was satisfactory. However, during the takeoff, he was advised by Air Traffic Control that the aircraft was smoking from the exhaust. He returned to the helipad and put the helicopter in flight idle. He did not shut down the engine or exit the aircraft. Shortly after he was advised by maintenance that there was no issue, and the helicopter was safe to conduct the flight. He then proceeded on the flight. About twenty-five minutes later, he observed the engine oil pressure gauge began to flicker, but it was still in the green arc. A cross check of the other propulsion instruments showed that the engine oil temperature gauge was stable at around 90°C, and both transmission temperature and pressure were in the green arc. The torque was at 70% in which position it was set for the entire cruise profile after takeoff. The N_2 and N_R needles were married. The TOT gauge was also in the green arc. He made the decision to continue the flight, since he was close to his destination. Further, given the aircraft's position over the jungle he believed that the destination presented the most suitable landing site, and he knew that assistance would be available if necessary.

With about five minutes to go and destination in sight, the engine oil pressure gauge became more erratic. The needle moved from green all the way to zero psi. The torque gauge was also fluctuating from 70% to about 40%, but the N_2 and N_R. needles remained stable.

At this point he indicated to the passenger that there was a problem with the aircraft.

With two minutes remaining to the destination, the engine chip light illuminated. He knew that he should land the helicopter as soon as possible after this, but the landing area was in sight and this was the safest area for approach and landing. He proceeded to short base for the approach and by this time the engine oil pressure was between 0 – 30psi and the torque gauge was very erratic. He estimated that when the aircraft was about 50 - 70ft above ground and while he was trying to manipulate the collective to control the descent, he heard what sounded like an explosion from the engine and the helicopter lost complete power as if the engine had failed. He lowered the collective and pushed the nose over slightly in an attempt to reach the helipad. The aircraft fell toward the ground and he gradually increased the collective to cushion the landing. After the aircraft impacted the ground, he turned off the fuel valve. He was not sure if he did pull the ignition and starter circuit breakers.

He then checked on his passengers, who were both unhurt. He and the passengers quickly exited the helicopter.

He used a fire extinguisher to extinguish the engine fire.

1.6 Aircraft Information

1.6.1. General

Manufacturer:	Bell Helicopters Textron, Canada, Ltd.
Aircraft Model:	Bell 206L4
Date of Manufacture:	1995
Aircraft S/N:	52138
Certificate of Registration:	8R-GTR; No.300 issued-1st Nov. 2012
Certificate of Airworthiness:	Valid until 5th December 2018
Total Airframe Hours:	8508hrs
Maximum Take-off Weight:	4 550lbs
Last Scheduled Inspection:	300hrs
Time since last Inspection:	21hrs
Next Inspection Due:	39hrs
Engine Model:	Rolls Royce 250-C30P
Engine S/N:	CAE 895892
Engine TSN:	8334hrs
Rating	650 Shaft Horsepower
Main Rotors/hours:	A6558 & A6559/1963hrs
Tail Rotor:	C162 & C163/ 1048hrs

1.6.2 Maintenance

The helicopter is powered by an Allison M250-C30P gas turbine engine, S/N CAE 895812. The maintenance records indicate the last engine inspection was a 300hr inspection on 27 July 2018 at an engine time of 8315hrs.

Review of the engine records by a representative from the Rolls Royce Accident Investigation group revealed a recent adjustment to the oil pressure regulator along with maintenance records indicating oil consumption exceeding 1qt per five hours of operation. The following oil system service entries were recorded in the engine maintenance documentation:

Table 2: Oil System Service Entries from Engine Logbook

Time	Discrepancy	Action
8334	Low oil	1 qt oil added
8331	Low oil	1 qt oil added
8321	Low oil	1 qt oil added
8313	300hr due	Performed 300hr, oil and filter changed
8286	TOT stuck at 0 during start	1 qt oil added,
8271	Low oil	1 qt oil added
8265	Low oil	1 qt oil added
8260	TOT stuck at 0 during start	Fuel system inspection
8260	Low oil	1 qt oil added
8218	Oil pressure red lined,	adjusted regulator to reduce oil flow
8198	Oil pressure lower than normal	Changed oil and both filters
8189	Low oil	1 qt oil added
6880	Turbine time out	Install O/H turbine

The pilot reported that he was advised by the ground crew that a gasket had been changed on the aircraft. There was no record of this activity in the Engine logbook. The Engineering Manager confirmed that a gasket was changed, and he had worked on this. this was done because smoke was emitting from the gearbox vent, which he said was not uncommon for this type of engine. The dripping oil indicated that the original gasket had become brittle. The gasket that was changed was on the control (right) side. This change was done a few days before the accident. He further noted that there was no previous excessive oil consumption, so whatever was dripping was not enough to cause major alarm, so the gasket was changed. This was in contravention to the record from the engine logbook as highlighted in table 2 above.

On the day of the occurrence, when smoking was reported during take-off, he concluded that this was caused by residual oil remaining. By the time the helicopter returned to the landing pad there was no smoke, so the pilot was dispatched without any further checks. When questioned, the Engineering Manager was emphatic that no work was done on the vent orifice line which is on the left side. He reiterated that the gasket change was done on the right side.

The Engineering Manager identified the engineering Superintendent as his deputy, but this individual is not fully licensed on the helicopter. During personnel interviews, it was revealed that usually a group of four persons work on the helicopter. Two of these persons are employed as grade three Mechanics and are considered to be highly skilled and well trained on the helicopter, however they are not licensed.

1.6.3 Mass and Balance

The Pilot and two passengers were on board the helicopter. There was no cargo on board.

1.7. Meteorological Information

This accident occurred in daylight. There is no weather observation or recording facility in the vicinity of the accident location. The weather reported, at the time of the occurrence, was CAVOK.

1.8. Navigation Aids

The aircraft was tuned to the Timehri ADS-b

1.9. Communications

There were no reported communications difficulties.

1.10 Aerodrome Information

Not Applicable

1.11 Flight Recorder

This aircraft is not required by regulation to be equipped with a flight recorder.

1.12 Wreckage and Impact Information

Aircraft damage consisted of several cowling penetrations, inside to out in plane. The upper surface of the cowling exhibited thermal damage consistent with a post landing fire. A hole was observed in the rear slanted surface of the exhaust stack and material was petaled inward, consistent with debris striking the stack from the rear to the front.

1.13 Medical and Pathological Information

The pilot was not subjected to a medical examination.

1.14 Fire

The Air Traffic Controller on duty in the EFCIA Aerodrome Control Tower had advised the pilot that she observed heavy smoke coming from the helicopter's exhaust during the takeoff phase. This caused the pilot to return to the hangar. The ground crew carried out a ground check, while the aircraft's engine was running but found no cause for the reported smoke. The Engineering Manager explained that when he received the report that there was smoke coming from the helicopter exhaust, he concluded that this was caused by residual oil dropping onto the exhaust. The ground crew cleared the aircraft and it proceeded on its planned flight.

35 minutes later, during final approach, when the aircraft was at ~70ft AGL and preparing to land, the pilot heard a loud bang and lost power. The pilot performed an autorotational descent to the ground. After touchdown, the pilot extinguished a fire which had begun in the engine nacelle.

1.15 Survival Aspects

The pilot's seat, seat belt and shoulder harness were all intact. The passengers' seats and seat belts were intact. The pilot's skill in autorotating the aircraft safely to the ground, following the loss of the aircraft's engine, with no resultant additional damage or injury contributed to survival of the aircraft's occupants.

1.16 Tests and Research

1.16.1. Engine Examination

The engine was shipped to Keystone Turbine Services (KTS) in Coatesville, PA USA for further testing and examination. The engine exam was conducted on 05 February 2019 under the supervision of the NTSB. This section of the report is extracted from the Rolls Royce Report dated 03 June 2019.

During disassembly of the engine, the components listed in Table 3 were noted.

Table 3: Helicopter Components

Component	Serial Number	Part Number
Engine	CAE 895812	23004545
Gearbox	CAG 95826	23035178
Compressor	CAC 91900	23051643
Turbine	CAT 90518*	23035128
FCU	BR55192	23037146
PTG	BR 40920	23065125
Fuel Pump	T0191	6896822
Fuel Nozzle	Xxxxxx0345**	23077067
Bleed Valve	FF289258	23073353

*Data plate damaged. Information obtained from logbook entries.
**S/N illegible except last 4 digits

The N1 system turned with some scraping noises evident and the impeller was connected to the starter gear and turbine to compressor coupling. The N2 system was locked. Once the turbine was removed, the gearbox N2 geartrain rotated smoothly. The fuel system components were removed from the engine and a cursory examination of the fuel pump, fuel control unit, and power turbine governor revealed no anomalies. The input shafts were normal in appearance and no loose connections were noted during the disassembly. Several air and oil lines were fractured consistent with impact from exiting debris during the engine event. The fuel nozzle was bench tested and, although it passed specifications for fuel flow vs. pressure, it displayed significant pattern streaking at all test points.

1.16.2. Turbine

The exhaust collector displayed oil residue and debris around the exterior of the exhaust collector shaft tunnel. A carbon/oil residue was also noted within the No. 5 bearing air pressure line. There was no compressor vent orifice inserted in the compressor vent tube which regulates secondary air to the No. 2 and No. 5 bearing sumps.

The gas generator support was split open with metal petaled outward and displayed longitudinal cracking in several areas. The energy absorbing ring was bulged outward but remained intact. The No. 8 bearing was disintegrated, and the retaining plate was destroyed. The No. 8 sump area was void of any oil and displayed thermal signatures consistent with over temperature operation. The first stage nozzle exhibited localized cracking on the nozzle airfoils from 6 o' clock to 9 o' clock. The T1 wheel was disintegrated into multiple fragments and not fully recovered. The diaphragm from the second stage turbine nozzle was liberated and resting in the case. The T2 wheel stub shaft and turbine coupling were recovered with the wheel hub remaining on the shaft. One portion of the wheel web was recovered and the curvic teeth were smeared.

The power turbine support case was ripped outward from the 6 o'clock to 10 o'clock positions. Three of the four thermocouple probes were fractured, and substantial circumferential gouging was noted on the hub area. A section of the power turbine inner shaft was lodged in the hub, precluding inspection of the No. 6 bearing. The No. 7 bearing rolling elements were melted and flat and the sump was dry with no residual oil observed. The power turbine outer shaft displayed heavy coking on the outer diameter and the power turbine to pinion gear coupling was heat tinted but otherwise intact. The T4 wheel was undamaged but the fourth stage nozzle, T3 wheel, and third stage nozzle all displayed mechanical damage to the airfoils consistent with hard body impact. The outer combustion case was normal in appearance. The combustion liner exhibited cracking on the interior louvres from the 9 o'clock to 12 o' clock position. The interior lands on the fuel nozzle boss were worn flat from the 12 o' clock to 3 o'clock positions.

1.16.3. Compressor

The compressor module was normal in appearance externally. The impeller blades displayed some erosion and one blade had damage consistent with a minor FOD event. The spur adapter gearshaft bearing journal (which supports the No. 2 ½ bearing) displayed significant, uneven wear and was dry of oil while the No. 2 ½ bearing rollers were flattened. The No. 2 bearing was intact and rotated freely with some roughness noted.

1.16.4. Gearbox / Lubrication System:

Each of the external engine mounted oil lines were removed and flowed with non-pressurized oil, none were obstructed. The gearbox mounted fittings were removed, and the No. 8 bearing sump scavenge fitting was completely blocked while the No. 6/7 bearing scavenge fitting was significantly obstructed. The oil out fitting which provides pressurized oil from the gearbox to both turbine sumps was clear. The oil screen mounted in the turbine pressure line was black in appearance and not obstructed. The oil screen at the input to the gearbox mounted oil delivery tube retained some debris on the tip but was not obstructed.

The accessory gearbox was opened and none of the shafting or gears within the accessory gearbox displayed damage or disconnects. The oil pump was removed, and the input drive shaft was intact but could not be turned. The pump was disassembled, and debris was lodged in the turbine scavenge pump gears, preventing rotation. The debris appeared to consist of metallic and carbonized oil deposits. The oil pump gears were intact and displayed scoring on the teeth while corresponding scoring was noted on the pump housing within the gear pockets. The damage was consistent with the pump ingesting foreign debris during operation.

1.16.5. The Oil Pump

The oil pump was examined to verify basic mechanical functionality. The pump & gearbox housing were presented for examination in an uncleaned condition. The pump & housing components appeared visually normal following cleaning. with only random locations of oil coking in and around the pump housing cavities. Most of the components were lightly blackened in appearance and all exhibited an oily film on their surfaces. The gearbox housing was coated with a film of oil and also blackened in random areas. The only significant area of coking was around the interface between the pump and gearbox housing adjacent to the pump drive gear shaft. When rotated using an electric drill the oil pump demonstrated the ability to dispense oil through all of the open orifices, ports, and transfer tubes in the exposed gearbox housing. All available evidence suggests the oil pump was capable of moving oil throughout the internal gearbox oil system.

1.16.6. Materials Evaluation Report

The following components were returned to the Rolls-Royce Materials Laboratory in Indianapolis, IN for further analysis.

Table 4: Components received for Testing

Part Name	P/N
First Stage Turbine Wheel	M250-10227
Second Stage Turbine Wheel	M250-10658
Gas Producer Support Assembly	23073466
Power Turbine Support Assembly	M250-10097
Power Turbine Oil Sump Cover Assembly	23037449

Power Turbine Inner Shaft	23071313
Power Turbine Outer Shaft	23038136
No. 5 Bearing and Sump Sealing Components	M250-10106
Exhaust Collector	M250-10217

The results of the laboratory examination are as follows:

- The No. 8 bearing inner ring exhibited severe rub damage and deformation, and the aft half of the bearing inner ring was obliterated, indicating that the No. 8 bearing was not able to axially locate the gas producer turbine rotor.
- The Nos. 6, 7, and 8 bearings exhibited severe distress, including flat spots and small bearing rolling elements and deformation of the inner raceways, consistent with engine operation with insufficient lubrication.
- The first and second stage turbine wheels were fractured in overload. Rub damage grooves were found on the forward sides of the fragments of both wheels at radial locations corresponding to adjacent sump and structural features. The rub damage at these locations is consistent with damage that would occur if the No. 8 bearing ceased to axially locate the gas producer turbine rotor.
- Coked oil in the bore of the exhaust collector, on the outer diameter surface of the power turbine outer shaft, and on the No. 5 bearing aft side sealing components were consistent with an oil leak from the No. 5 bearing sump.

1.16.6.1. First Stage Turbine Wheel P/N M250-10227

The first stage turbine (HPT1) wheel was found fractured into several fragments, some of which were recovered during engine disassembly. All the airfoils were fractured and liberated; their fracture surfaces were smeared. The web fractures were mostly chordal, except for a singular approximately circumferential fracture that encapsulated the bore and curvic teeth platform; the entire circumference of the bore was intact in a single fragment of the hub. All the web fractures exhibited an interdendritic appearance consistent with overload. The leading-edge side stub shaft was fractured from the rest of the wheel and was recovered. Several of the fragments exhibited a circumferential groove, immediately outboard of the curvic teeth platform. The groove spanned approximately half of the outer diameter circumference of the hub fragment; the other half of the circumference was fractured inboard of the radial position of the groove. The groove was also present at the inboard edges of the fragments that were adjacent to the hub fragment (based on the partial reconstruction).

1.16.6. 2. Second Stage Turbine Wheel P/N M250-10658

The second stage turbine (HPT2) wheel was found fractured; one hub fragment and one rim and web fragment were recovered during engine disassembly inspection. The rim and web fragment had three airfoils that were not completely liberated, and the hub fragment still contained the trailing edge side stub shaft, turbine splined adapter, tie bolt nut and part of the turbine tie bolt. The web and airfoil fracture surfaces were rough, consistent with overload. The trailing edge side web fragment exhibited two bands of circumferential rub damage, one immediately inboard of the rim and another inboard of the balance weight land. The trailing edge side knife seal arm was obliterated. A rim crack extended approximately 0.208 inch from the rim surface into the web on the fragment. Rim cracks that did not extend into the web were found between several other airfoil locations along with smaller rim cracks.

1.16.6.3. Gas Producer Turbine Support Assembly P/N 23073466

The as-received condition of the gas producer turbine support assembly (GP support) showed that the first stage nozzle was still installed and parts of the No. 8 bearing, and sump components were still retained in the bore of the support. The aft half of the No. 8 bearing inner ring was obliterated, consistent with damage that would allow the gas producer turbine assembly to move forward and clash with adjacent static components, this was noted by the rub damage on the first and second stage turbine wheels. The No. 8

bearing sump forward rotating seal was fractured and deformed outboard over an approximately 45° span; the first stage nozzle support exhibited a gray discoloration over an approximately 180° arc centered around the fracture of the forward rotating seal. Backscattered electron SEM imaging and semi-quantitative EDS analysis of the discoloration revealed the gray discolored area exhibited relatively lower average atomic number and was rich in phosphorus relative to the base material, consistent with engine oil residue. The energy absorption ring exhibited rub damage around the entire circumference.

The GP support was sectioned to allow for removal of the components still installed in the bore. Two of the retained No. 8 bearing balls were destroyed or lost during the sectioning process. The aft half of the inner ring was missing entirely, and the intact portion of the inner raceway was smeared such that the raceway curvature was obliterated. The No. 8 bearing balls exhibited flat spots and the maximum diameter of each ball, measured using calipers, was less than the nominal component definition requirement of 0.2813 inch. The maximum measured diameter among the six balls was 0.242 inch. The missing aft half of the No. 8 bearing inner ring, small balls, and flat spots on the balls were consistent with insufficient lubrication during engine operation and the loss of the aft half of the inner ring indicates the bearing was unable to axially locate the gas producer turbine rotor. The No. 8 bearing sump seal, of which the stationary seal was cut at two approximately diametrically opposed locations to expose the seal running surfaces of both the rotating and stationary seal elements. Both elements exhibited smearing damage, and part of the forward end of the rotating seal was fractured.

1.16.3.4. Power Turbine Support Assembly P/N M250-10097

The as-received condition of the power turbine support assembly (PT support) was noted. The power turbine inner shaft was loose but lodged inside the bore of the PT support. The outer diameter surface of the hub exhibited corrosion damage and deposited labyrinth seal abradable material.

The aft side of the PT support hub exhibited severe rub damage which flattened the inboard and outboard walls of a secondary air plenum. An exemplar new PT support and schematic were used to indicate the rub damaged features of the in-use PT support hub. The PT support was diametrically sectioned and compared to a representative inner diameter view showing the Nos. 6 and 7 bearings and the labyrinth seal. The No. 7 bearing rollers were flattened and retained within the separator pockets, and the No. 6 bearing rollers fell out of the bearing during sectioning. The rollers exhibited flat spots. The aft end of the race was deformed outboard, which retained the shaft in the bore of the PT support. The severe damage to the bearings was consistent with insufficient lubrication during engine operation.

1.16.3.5. Other Components

The PT support oil sump cover assembly was inspected. The abradable seal surfaces were rubbed away. The power turbine outer shaft exhibited coked oil and blistered coating on the outer diameter surface. The No. 5 bearing and No. 5 bearing sump sealing components were inspected. The bearing exhibited rainbow coloration consistent with oil varnishing and heat tinting of the base metal. The No. 5 bearing seal was inspected. The stationary seal abradable surface exhibited rub damage, and the tips of the rotating seal exhibited deposited abradable and coked oil. The exhaust collector had coked oil in the bore.

1.17. Organisation

1.17.1. The Company Air Services Ltd.

Air Services Ltd (ASL) is one of the oldest aircraft operators in Guyana. The company acquired its Guyana Air Operator Certificate No. 001 from the Guyana Civil Aviation Authority in 2002. This AOC allows the company to do domestic; scheduled and charter, passenger and cargo operations. This company has thirty aircraft, comprising seven different aircraft types listed in its AOC, including two different types of helicopters.

The management structure includes the Accountable Manager. The Maintenance Manager, the Flight Operations Manager, and the Safety and Quality Manager. They all report to the accountable Manager.

The company acquired an Approved Maintenance Organisation (AMO) certificate No.003 issued by the GCAA in 2003 and carries out its own maintenance. The AMEL system is utilised as the basis for maintenance certification. Its main maintenance facility is co-located with its aircraft operations at EFCIA and includes hangar space, offices, and several specialized workshops. Base and line maintenance are done on airframes, engines, avionics, instruments and propellers for aircraft below 5700kg.

The management structure of the AMO includes the Accountable Manager, Maintenance Manager and Quality Assurance Manager.

The Maintenance Manager is responsible for the continued airworthiness of ASL's entire aircraft fleet and for the productivity and efficiency of the engineering department. This wide-ranging responsibility includes:

1. ensuring availability of sufficient competent personnel to plan, supervise, inspect and certify the work performed;
2. ensuring availability of tools, equipment and materials to perform tasks;
3. ensuring availability of technical data for all aircraft types and appliances;
4. responsible for implementation of training programmes;
5. monitoring industry trends and changing practices; and several other equally important tasks.

In addition to his management tasks, The Maintenance Manager is additionally expected function as base and line supervisor for the company's helicopters. In fact, he is the only person listed in the Maintenance Procedures Manual (MPM) who is fully licensed on the Bell206L4 helicopter. Thus, he is directly responsible for oversight of helicopter maintenance and is also responsible for oversight of the company's fixed wing aircraft maintenance. One other fully qualified rotorcraft engineer is contracted to provide dual signature for the helicopter where required.

The day-to-maintenance on the helicopter is done be three Technicians, all of whom had prior helicopter experience with the Guyana Defence Force. Their move from the GDF was largely influenced by the collapse of the Rotor Wing Section of the GDF. The technicians had acquired extensive technical training on the helicopter while employed by the GDF, but unfortunately none of the three technicians were type rated on the B206 helicopter.

The MPM details a three-shift arrangement per day and a schedule of five days on and two days off per week. Each shift consists of a supervisor engineer and mechanics as necessary. The supervisor engineer is signatory for the rectification of line defects and other maintenance tasks for the helicopters. With only one engineer, this requires the 24/7 presence of the engineer on the floor.

In addition to its own fleet of aircraft, the company also provides contracted maintenance service to other aircraft operators.

As investigations progressed it became very obvious that the available staff compliment was woefully inadequate to safely meet the mechanical requirements for the quantity of aircraft operated by this company.

1.17.2. Interview with The Company Engineers

On the day of the occurrence one technician and the Chief Engineer were on duty. The helicopter was pre-flighted and positioned on the taxiway by the Technician. This Technician said that he and the Pilot had a brief discussion before the Pilot did his pre-flight inspection. After this, the pilot and two passengers boarded the helicopter, and it took off. As is normal they watched the takeoff. Just as they were preparing to go back to the hangar, they noticed that the helicopter was turning back. When the helicopter landed, he and the engineer approached it and the pilot told the engineer that the tower reported smoke from the engine. He saw puffs of smoke coming from the engine, but it was not much.

The engine was not shut down, the engineer removed the right cowling. The engineer walked around the aircraft, looked at the engine and then told the pilot it was ok for the flight to proceed. He agreed that this could not have been an effective inspection, as the engine would have been too hot, but he was not involved in this decision. The engineer gave the pilot a thumbs up and the helicopter took off. Everything seemed to be normal with this departure. Later that afternoon, the engineer told him that the helicopter had an incident.

The technician does not have an engineer's licence, but he has done much training on the helicopter both locally and overseas in England and USA. This training was done while in the GDF. He has more than thirty years' experience as a mechanic. He is aware of the need for safety and he is always conscious of this.

He said that the decision to allow the helicopter to go was not up to him, as he was not licensed, and the engineer was the senior person. He agreed that a thorough examination should have been done. But he did not think that he had the authority to suggest that the aircraft should have been grounded at this time to facilitate a thorough examination.

During his interview, the Engineering Manager stated that he has oversight for all maintenance of all the company's aircraft. He reports to the accountable manager. He is type rated on the B206 and several fixed wing types. He stated that his job could be tedious, but his duties came about due to lack of sufficient qualified staff in the company.

The engineer was invited for a second interview, he confirmed that he personally did work on a seal a few days prior to the accident flight. He explained in detail that the line that was worked on was the line on the right side. The manager reiterated that he did not interfere with the vent orifice line, which is on the left side, viewed from the back of the aircraft. He said that no resizing was done. He confirmed that he did most of the things concerning the helicopter because he is aware of the concern for the detail."

Despite diligent searches, no worksheet pertaining to the work done on the gasket was found. Notwithstanding this, he said that the fact that there was oil dripping, means that the original gasket that was there had become brittle, so that gasket had to be changed. He concluded that the smoke observed was due to residual oil that got heated and started to smoke.

Based on the tear down report, which stated that the vent orifice was missing, and this resulted in all the damage to the engine. He was asked to explain this. He insisted that he never troubled the vent orifice, and it was never removed. It was also explained to him that the engine tear down revealed that there was high temperature silicone which required explanation for its removal. He stated that he did recall putting his hand in the exhaust, but he did not trouble the orifice. Further, his was more than a year before this accident. He did not do any resizing. He noted that a compressor was changed during 200hr work on the compressor. This would have required disassembly of the strut.

He stated that he had no concerns after the aircraft departed the second time as there was no smoke.

It was pointed out that the orifice could have been misplaced while work was being done on the day before the accident, but because there is no actual record of this work being done, it would be difficult to trace. The engineer then said that indeed the orifice could have fallen out by accident, this would account for the oil flowing incorrectly, resulting in oil starvation. He also mentioned the possibility that at the time of factory overhaul, a decision may have been made by the factory that there was no need for the orifice and thus it may have not been inserted at the time of overhaul. He promised to check with Rolls Royce about this possibility.

He said that he checked the engine when he got to the accident site and there was oil in it. He posited that the pilot did report a chip plug light and the pilot is expected to land right away, but he couldn't land right away due to the terrain, so he had to milk the engine. He posited that if the helicopter had landed in good time, this accident would not have happened. But he agreed that it was impossible for the pilot to land the aircraft. He believed that this compounded the situation. The engine is designed to fly a couple of minutes with no oil. So, the aircraft basically went over its limits, but the pilot had no control over this because he couldn't land on the treetops.

The other helicopter technicians were also interviewed. They agreed that their team was close knit and worked well together, however, the technicians did express some unhappiness with the restrictions that were place on them in relation to certain tasks. They however agreed that these were necessary because they were not licensed engineers.

1.17.2. GCAA

The Guyana Civil Aviation Authority has oversight responsibility for the company. The Authority does not have appropriately qualified field staff to provide oversight for the helicopter operations of this company.

The expansion of the company's fleet is approved by the Authority

2. Analysis

2.1. The Pilot

The pilot was properly qualified and experienced for the operation. There was no evidence of any pre-existing medical or behavioural conditions which may have adversely affected the pilot's performance during this flight.

2.2. Maintenance Staff

It was suggested that engineers and other ground staff could benefit from a simplified version of CRM in the interest of improved safety in the industry.

Concerns were expressed with the limited number of qualified maintenance staff in the company compared with the number of aircraft they own.

Too much responsibility was put on a single individual, to with the manager, who was expected to be responsible for both day-to-day maintenance oversight of thirty aircraft and general management of the entire maintenance department. It is unlikely that one individual can single-handedly perform these tasks efficiently and effectively

2.3. The Aircraft

2.2.1. Maintenance

The aircraft has a Certificate of Airworthiness which is valid until 5th December 2018.

The observed condition of the engine was consistent with damage sustained during a failure of the No. 8 bearing. The cause of the No. 8 bearing failure was over temperature operation due to oil starvation, the most likely cause of which was the missing compressor vent orifice.

The engine oil system design utilizes an orifice plate located in the end of the compressor vent tube where it enters the exhaust collector. This orifice plate is referred to as the compressor vent orifice. There are several different part numbers for this orifice plate with different orifice diameters. The proper size orifice is determined by measuring the back pressure and replacing the orifice until the correct pressure is achieved. The Rolls-Royce Operation and Maintenance Manual contains detailed instructions regarding this task, and several differently sized orifice plates are available for this purpose.

If the proper orifice size is not installed, the oil system will not perform to design specifications. If the orifice size is too small, the No.5 bearing seal pressure will be too high and potentially starve the No. 5 bearing of oil. If the orifice size is too large or missing, the seal pressure will be lower than design specification. This condition would result in excessive oil flow from the No. 5 bearing sump through the seal, into the exhaust collector shaft tunnel, and ultimately out of the engine through the exhaust gas path.

The chain of events leading to the engine failure and supporting evidence is listed below:

1. The compressor vent tube orifice is omitted. *Evidence*:
   - The vent tube orifice was found not installed at engine disassembly
2. Gearbox pressure is able to overcome the No. 5 bearing sump seal buffer pressure resulting in oil moving through the seal, into the exhaust collector shaft tunnel. *Evidence*:
   - Carbon build-up observed on the power turbine outer shaft
   - Carbon build-up observed in the exhaust collector shaft tunnel
   - Carbon build-up observed in the exhaust collector dead space on the OD of the shaft tunnel
   - Smoke observed by the airport tower at take-off on event flight
3. Oil exiting the system through the No. 5 bearing sump seal results in low oil system quantity. *Evidence:*
   - Low operating times between additions to the oil reservoir
   - Engine oil system quantity found low at landing site after event
4. Low oil system quantity results in oil starvation/deteriorating bearings. *Evidence:*
   - The observed condition of the turbine bearings at engine disassembly is consistent with oil starvation
   - Debris observed on the upper magnetic chip detector
   - Debris observed in the airframe mounted scavenge filter
   - Debris removed from the engine oil to airframe mounted scavenge filter bowl
   - Debris observed in the scavenge elements of the oil pump

- The “Engine Chips” light and indication of no oil pressure 5 minutes prior to engine shut down

5. The deteriorating No. 8 bearing allows forward translation of the gas generator turbine rotor resulting in contact between the static and rotating components. *Evidence:*
   - Rub indication observed on the aft power turbine support sump face
   - Rub indication observed on the T1 and T2 wheel forward sides
6. Turbine wheel rub results in T1 and T2 wheel burst and release of high energy debris and engine shut down. *Evidence:*
   - The observed condition of the turbine supports at engine disassembly
   - The observed condition of the T1 and T2 wheels

The Maintenance Manager’s statement that there was no indication of excessive oil consumption conflicts with the engine technical logbook records that indicate that the helicopter was consuming one quart of oil every five hours of flight.

2.2.2. Mass and Balance

The aircraft was not overloaded.

2.3. The Weather

This weather was not a contributary factor to this accident.

2.5. Survival Aspects

The seats and seat belts functioned satisfactorily.

2.6. The Company

Although company was certified for this operation. It is considered that the maintenance department does not have sufficient staffing that are suitably trained and experienced to carry out the required maintenance on this helicopter.

Major maintenance, done on the helicopter i.e., the changing of the gasket, was not recorded in the technical log. As noted in a previous accident report, the failure to ensure that records are accurately recorded in appropriate technical logbooks and other documents is now apparently a common practice in this organisation. Record keeping in the Aircraft Technical Logbook is generally unsatisfactory. The aircraft and engine cycles were not recorded. By not ensuring that the Technical Logs Records were accurately completed the company is in violation of GARs 9.1.4.9.

Further, it is not acceptable for the pilot to be verbally advised about work done without any substantiating record being properly documented.

The company should consider whether the qualified engineering staff listed in the company's MPM are able to provide enough maintenance coverage for the number and variety of aircraft operated by this operator. There is no doubt that the staff provided for helicopter maintenance is insufficient.

2.7. The GCAA

The Authority does not have enough skilled staff to provide the required oversight to this and other operators.

It is considered that the Authority needs to determine if the company's current maintenance staffing situation is sufficient to meet the demands of its present fleet. This should be taken into account when considering requests from the company to expand its fleet.

3. Conclusion

3.1. Probable Cause

Based on physical evidence, maintenance history, witness statements, and engineering analysis, the most likely cause of the engine failure was the absence of a compressor vent orifice. The missing orifice resulted in unintended oil loss through the No. 5 bearing seal which led to system level oil starvation and ultimately the failure of the No. 8 bearing. The failure of the No. 8 bearing, which is the thrust bearing for the gas generator rotor, allowed the rotor to move forward and the wheels to contact stationary components of the turbine. The interference of the rotating turbine wheels and static turbine components produced a rapid increase in temperature within the turbine wheels, exceeding the material capabilities and causing them to disintegrate.

3.3 Findings

3.3.1. The Pilot

1. The pilot was suitably qualified for the operation.
2. His last APC on type was satisfactorily completed on 14th April 2018.
3. The pilot was a contract employee of the company, but he was familiar with the operating conditions, of the company and the requirements for safely conducting the occurrence flight.
4. The pilot was able to make a proper assessment of the preliminary indicators of the pending failure and was able to take action to prevent a more disastrous situation from developing.

3.3.2. Maintenance Staff

1. The number of licensed maintenance staff did not meet the maintenance requirements for safe operation of the helicopter. The sole licensed engineer was assigned more tasks than is reasonable for one person. He was expected to oversee line maintenance and also carry a heavy load of management responsibilities.

2. the technicians were well qualified, but unfortunately had no incentive to move beyond the technician level.

3. The Maintenance Manager failed to meet his responsibility to advise the

Accountable Manager that the limited staff would adversely effect the safety of aircraft operations in the company.

3.3.2. The Company

1. The company holds an Air Operator Certificate and an Approved Maintenance Operator Certificate.
2. The quantity and variety of aircraft operated by the company, may exceed the capacity of its present operational management structure.
3. Maintenance service provided by the AMO was unsatisfactory.
4. The company does not have enough maintenance staff to meet its current fleet demand.
5. The daily and weekly roster of maintenance staff cannot be adequately covered by the existing staff.
6. The company needs to be more vigilant with regard to the record keeping in the aircraft technical logs. It is unacceptable that defects are not recorded in the technical log. The company should also ensure that engine cycles are recorded in the technical logbook.
7. There was no record of certain maintenance work done.

3.3.3. The Aircraft

1. The aircraft had a valid Certificate of Airworthiness.
2. The aircraft was not overloaded.
3. Maintenance work done on the aircraft was not properly recorded.
4. The observed condition of the engine was consistent with damage sustained during a failure of the No. 8 bearing. The cause of the No. 8 bearing failure was overtemperature operation due to oil starvation, the most likely cause of this was the missing compressor vent orifice.
5. The Nos. 6, 7, & 8 bearings and sump components of the engine exhibited distress consistent with operation with insufficient lubrication.

3.3.4. The GCAA

1. The GCAA should increase/improve its surveillance, checks and audits of this

company to ensure that the company's operations are in compliance with all approved manuals, especially as they relate to staffing issues.

2. The GCAA should consider if the company's present engineering staff can provide adequate coverage for this company's fleet. This is especially necessary if the company requests approval to increase its fleet.

4. Safety Recommendations

4.1. The Company

1. The company should consider employing/identifying type rated engineers for each of the aircraft types it maintains.
2. The company should carry out a staff needs assessment to determine if the present complement of staff can provide a safe level of maintenance service for its fleet.
3. The company should consider the need to provide its engineering staff with recurrent factory training for the more complex engines it operates.

4.2. The GCAA

1. GCAA should require the company to carry out a staff assessment to determine if the present staff complement can provide a satisfactory and safe level of maintenance to its current fleet,

2. The staff assessment should be completed and submitted to the Authority before the company is allowed to add any more aircraft to its fleet.