AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9722		
Aircraft Registration	**ZS-BRV**	**Date of Accident**	10 July 2018		**Time of Accident**	1451Z	
Type of Aircraft	Convair 340/440		**Type of Operation**		Private (Part 91)		
Pilot-in-command Licence Type	Validated Australian PPL		**Age**	65	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	Total Flying Hours		18240.5		Hours on Type	63	
Last Point of Departure	Wonderboom Aerodrome (FAWB), Gauteng Province						
Next Point of Intended Landing	Pilanesberg Aerodrome (FAPN), North West Province						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
The accident occurred approximately 1 kilometre east of the N4 highway in Derdepoort industrial area, and approximately 5.78 kilometres to the east of FAWB Aerodrome. Geographical position was determined to be S26°67.031" E028°28.461" at an elevation of approximately 4095 feet above mean sea level (AMSL).							
Meteorological Information	Temperature: 19°C, Dew Point: 05°C, Wind Direction and Speed: 270° at 04 knots, Clouds Amount: 3500 feet, Pressure at Station Level: 1030 hPa						
Number of People On Board	2 + 17	**No. of People Injured**	18	**No. of People Killed**	1		
Synopsis							

On Tuesday 10 July 2018, at approximately 1439Z, two crew members and 17 passengers took off on a ZS-BRV aircraft for a scenic flight from Wonderboom Aerodrome (FAWB) destined for Pilanesberg Aerodrome (FAPN) when the accident occurred.

During take-off, the left engine caught fire, however, the crew continued with the flight. They declared an emergency by broadcasting 'MAYDAY' and requesting to return to the departure aerodrome. The crew turned to the right with the intention of returning to the aerodrome. However, the left engine fire intensified, causing severe damage to the left wing rear spar and left aileron system, resulting in the aircraft losing height and the crew losing control of the aircraft and colliding with power lines, prior to crashing into a factory building.

The footage taken by one of the passengers using their cellphone showed flames coming from the front top side of the left engine cowling and exhaust area after take-off. The air traffic control (ATC) on duty at the time of the accident confirmed that the left engine had caught fire during take-off and that the crew had requested clearance to return to the aerodrome. The ATC then activated the crash alarm and the aircraft was prioritised for landing. During the accident sequence that followed, one passenger (engineer) occupying the jump seat in the cockpit was fatally injured and 18 others sustained injuries.

The investigation revealed that during take-off, the left engine had caught fire and the crew had continued with the flight without securing the left engine as prescribed in the aircraft flight manual (AFM). The crew had then declared an emergency and attempted to return to the aerodrome, however, they lost control of the aircraft and collided with power lines prior to crashing into a factory building.

SRP Date	19 July 2019	Publication Date	01 August 2019

Reference Number	**:**	CA18/2/3/9722
Name of Owner/Operator	**:**	Rovos Rail
Manufacturer	**:**	General Dynamics
Model	**:**	Convair 340/440
Nationality	**:**	South African
Registration Marks	**:**	ZS-BRV
Place	**:**	Wonderboom Aerodrome
Date	**:**	10 July 2018
Time	**:**	1451Z

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 (CAR) 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 Investigation Division (AIID) was notified of the accident on 10 July 2018 at about 1510Z. The investigators went to Wonderboom Aerodrome on 10 July 2018. The investigators co-ordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and the relevant investigation procedures. The AIID of South Africa is leading the investigation as the Republic of South Africa is the State of Occurrence.

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

- *Accident – this investigated accident*
- *Aircraft – the Convair 340/440 involved in this accident*
- *Investigation – the investigation into the circumstances of this accident*
- *Pilot/s – the pilot/s involved in this accident*
- *Report – this accident report*

2. Photos and figures used in this report are taken from different sources and may be adjusted from the original 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 addition of text boxes, arrows or lines.

Disclaimer:

TABLE OF CONTENTS	PAGE NO

ABBREVIATION	DEFINITION
AFM	Aircraft Flight Manual
AGL	Above Ground Level
AMSL	Above Mean Sea Level
ATC	Air Traffic Control
ATNS	Air Traffic and Navigation System
ATPL	Airline Transport Pilot Licence
ATSB	Australian Transport Safety Board
AMIS	Aviation Management Information System
AMO	Aircraft Maintenance Organisation
CB	Cumulonimbus
CoA	Certificate of Airworthiness
CoR	Certificate of Registry
COT	City of Tshwane
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
DCA	Director of Civil Aviation
EHLE	Lelystad Airport
ELT	Emergency Locator Transmitter
EMS	Emergency Medical Services
FAPN	Pilanesberg Aerodrome
FO	First Officer
fpn	Feet per Minute
ft	feet
Kt	Knots
LAME	Licensed Aircraft Maintenance Engineer
NOTAM	Notice to Airmen
PPL	Private Pilot Licence
QNH	Query Nautical Height
QRH	Quick Reference Handbook
RPM	Revolutions per Minute
SACAA	South African Civil Aviation Authority
SAPS	South African Police Service
TCDS	Type Certificate Data Sheet
TCU	Towering Cumulus
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
WIS	Wing Inch Station
WBS	Wind Bulkhead Station

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 10 July 2018, Rovos Rail, the registered owners of the ZS-BRV aircraft, finalised and signed a sale agreement (of the said aircraft) with Luchtvaart Themapark Aviodrome (Museum), situated in Lelystad, approximately 67 kilometres north-east of Amsterdam in the Netherlands. According to Rovos Rail, between 7 and 9 April 2018, the Museum representatives came to South Africa to inspect the aircraft and its documentation.

1.1.2 The records indicated that the aircraft had been refuelled with 2100 litres of low lead (LL) 100 octane fuel. Prior to the flight of 10 July 2018, the aircraft had last been flown on 22 February 2018.

1.1.3 In preparation to ferry the aircraft to the Netherlands, it had to be painted, serviced, inspected and accepted by the museum representatives. The aircraft was painted and weighed in February 2017. It was also branded with the Dutch National Carrier colours—Martin's Air Charter—in December 2017. The aircraft was serviced and inspected on 6 July 2018. The representatives of the Luchtvaart Themapark Aviodrome were satisfied with both the aircraft's documentation and the maintenance performed.

1.1.4 On 6 July 2018 at 18115.1 airframe hours, the A, B and C maintenance checks were performed on the aircraft. The accident flight was the first flight after the above-mentioned maintenance. During the above-mentioned maintenance checks, the manifold pressure gauge, which is a dual indicator for the left and right engine, was removed, repaired and refitted to the aircraft. During repairs, it was discovered that the right engine valve on the gauge had carbon deposits. Both valves were cleaned before the manifold pressure gauge was reassembled and refitted to the aircraft on 6 July 2018.

1.1.5 According to the FAWB air traffic control (ATC), the crew filed their flight plan at approximately 1124Z with Johannesburg Briefing and indicated the estimated departure time as 1130Z. The ATC cleared the aircraft for take-off on Runway 29 with their flight plan being FAWB-FAPN-FAWB. The clearance was given without the knowledge that FAPN had issued a Notice to Airmen (NOTAM) barring the landing of fixed-wing aircraft as the runway was undergoing maintenance. This information was discovered by ATC post-accident. Prior to the flight plan, all 17 passengers were advised to sign the indemnity before boarding the aircraft. These passengers were citizens of four different countries — 12 South Africans, 1 Australian, 1 Zimbabwean and 3 Dutch.

1.1.6 Visual meteorological conditions (VMC) prevailed and the aircraft was operated according to the visual flight rules (VFR) as indicated in the flight plan. The weather conditions at the time of the accident were recorded as follows — wind 270° at 04 knots with scattered clouds at 3500 feet, QNH 1030 hPa and temperature at 19°C.

1.1.7 It should be noted that Pilanesberg Aerodrome was, at the time, closed for fixed wing aircraft as indicated in the NOTAM No. B0930/18, owing to the runway being under construction. At the time of take-off (1439Z), the NOTAM was already published by Pilanesberg Aerodrome, however, it appears that the crew members and FAWB ATC were not aware of it.

1.1.8 On Tuesday 10 July 2018, 17 passengers and two crew members met at FAWB at midday in preparation for a scenic flight[1]. Later that afternoon, a pre-flight briefing was conducted prior to the flight. The licensed aircraft maintenance engineer (LAME) connected the tug and towed the aircraft for a start-up and taxi. One of the passengers interviewed mentioned that the external ground power unit was connected to the aircraft upon which all passengers were requested to board the aircraft. The right engine was started first, thereafter, the assistant engineer disconnected the ground power unit and boarded the aircraft. The crew then started the left engine. The run-up checks were reported to have been unusually long by the aircraft owner representative. However, after all run-up checks were concluded, the crew made a request for taxi and take-off. The request was acknowledged by the ATC and granted before the aircraft was taxied to Runway 29 at 1430Z.

1.1.9 At approximately 1439Z, the aircraft took off with two crew members and 17 passengers for a scenic flight from FAWB destined for Pilanesberg Aerodrome (FAPN). The passenger manifest indicated that there were two Australian pilots and 17 passengers on-board, although one of the passengers (LAME) was seated on the jump seat with the crew at all times.

1.1.10 The aircraft entered Runway 29, accelerated and, at 50 knots (kts), the pilot monitoring (PM) stated that the left engine manifold pressure was low. After the V1 call, the aircraft rotated, and one of the passengers went to the flight deck and told the LAME that the left engine was on fire. This was evident on the flight deck GoPro video camera. This passenger was later identified as the assistant of the LAME. He confirmed during interviews that he had gone to the flight deck to alert the LAME of the left engine fire. He also stated that he had quickly gone back to his seat because he wanted to record the smoke and flames for troubleshooting when they return to FAWB. He further stated that he was surprised that the aircraft was losing height and could not sustain altitude.

1.1.11 The aircraft owner representatives also stated that this aircraft was not the first one they were exporting with the same LAME in charge of the operation of the engine controls during flight. The other aircraft, ZS-ARV, a similar type to ZS-BRV, was exported to Australia in 2016 and the same LAME was part of the crew that ferried it.

1 **Scenic Flight:** A flight conducted for the purpose of viewing something from the air. It does not include flights conducted for the purpose of flying training, carrying cargo from one place to another or moving passengers from one place to another, except as a stop-off during a scenic flight.

1.1.12 Standard communication was made to the ATC on FAWB frequency 118.35 megahertz (MHz), which included engines start-up and taxi to the run-up bay, just before entering the take-off runway. On review of the recovered GoPro video camera fitted to the empennage of this aircraft, it was evident that the aircraft was consistently drifting to the left and coming back to the centreline. Moreover, on review of the GoPro camera fitted in the flight deck, it was found that during taxiing, the PF (captain) was complaining about the stiffness of the rudder. During the pre-flight checks, the PF stated that the left engine's auto-feather light was not illuminating when tested. The LAME responded to the PF saying that the light bulb was inoperative.

1.1.13 During rotation, flames were seen on the top front side of the left engine cowling and exhaust area (Figures 2/3). The ATC stated that the aircraft continued in a north-westerly direction from the aerodrome over Bon Accord Dam at approximately 2 to 2.5 track miles and at the height of about 800 feet above ground level (AGL), indicating a rate of climb of 600 to 700 feet per minute (fpm). The ATC confirmed to the investigators that the left engine had caught fire and that the crew had broadcasted a 'MAYDAY', however, when the crew broadcasted 'MAYDAY', they did not indicate what the nature of their emergency was. This statement was confirmed by the recordings of the cockpit GoPro camera. At that point, the crash alarm was activated by the ATC and the emergency services were ready for dispatch. The crew indicated that they intended to land back at the aerodrome. The ATC advised the crew that all runways were available for the emergency landing. They were prioritised and were cleared to land. However, the aircraft kept on losing height.

1.1.14 Throughout the flight, the left engine was on fire. The cockpit GoPro video recording showed that the left engine's revolutions per minute (RPM) indicator was fluctuating and, later, the left engine's fire master caution light illuminated and an audible warning sound came on confirming that the left engine was on fire. The GoPro video recording also showed that prior to impact, the control wheel was being deflected to the right by the PF and he indicated that they had lost aileron control. He also requested the PM (first officer) for the rudder input.

1.1.15 The GoPro video recording further showed that the PF was not sure if they had retracted the landing gears as he could be heard asking the PM if the gears were retracted or not. Moreover, the video recording revealed that although the crew was informed of the left engine being on fire by one of the passengers, they were still not sure which engine was on fire. At no stage did the crew discuss or attempt to extinguish the fire in the left engine. As a result, the left engine fire extinguishing system was never activated and the left engine remained operating and on fire until the aircraft impacted the building.

Note: See below the procedure which the crew were required to follow after identifying that the left engine was on fire. The below procedure is an extract from the in-flight checklist:

i. Feather the propeller
ii. Pull the appropriate fluid shut-off "T" handle
iii. Close the heat source valves of the burning nacelle with the emergency

heat valve disconnect switch

iv. Place the cowl doors switch of the burning nacelle to the CLOSE position

v. Place the fuel shut-off valve switch of failed engine to the CLOSE position

vi. Place boost pump switch of the inoperative engine to OFF position

vii. With fire extinguisher selector on main, operate the appropriate fire switch. The main circuit breaker (CB) supply out light on the fire control panel should come on

viii. If the fire persists, place the fire extinguisher selector to reserve and operate the appropriate fire switch

Note: None of the above procedures was followed by the crew when the left engine caught fire.

Figure 1: The aircraft with black smoke trailing from the left engine/No 1 engine.

1.1.16 Melted metal debris from the left engine was seen coming out of the left engine exhaust and was found along the flight path by witnesses on the ground. The aircraft kept losing height and it first struck the power lines that spanned parallel to Sakabuka Street in Derdepoort industrial area, north of Pretoria, prior to colliding with a factory building and coming to rest facing 192 degrees magnetic. According to some of the passengers that were interviewed after the accident, one of the passengers had advised all other passengers to strap themselves and assume brace position. Thereafter, this passenger also seated himself on the left side of the aircraft and assumed brace position.

1.1.17 After the crash, passengers that were seated at the rear of the aircraft exited from the back using the rear exit doors, while the passengers seated on the right-hand side exited through an opening on the right-hand side of the fuselage. The passengers stated that it took approximately 15 to 30 minutes for emergency personnel to arrive at the accident site.

1.1.18 The accident occurred at approximately 5.78 kilometres east of FAWB. The South African Police Service (SAPS), the City of Tshwane (CoT) Emergency Medical Services (EMS) and the fire and rescue units were notified of the accident and responded promptly to assist and rescue the passengers at the accident site. The EMS used the Jaws of Life to free the PF and PM who were trapped in the cockpit. First aid was administered to the crew prior to them being airlifted to a hospital in Johannesburg. The other passengers were all transported by road to different hospitals around Gauteng Province.

Figures 2/3: Images of the left wing and engine taken from the cabin. The image circled in red (left) shows the fire trailing underneath the left wing. The one circled in yellow (right) shows fire emanating from the left engine (No 1) compartment with the cowl flaps in the open position.

1.1.19 The flight was conducted under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011, as amended.

1.1.20 The accident occurred during daylight conditions at a geographical position determined to be S26°67.031" E028°28.461" at an elevation of about 4095 feet above mean sea level (AMSL). See Google Earth map Figure 4.

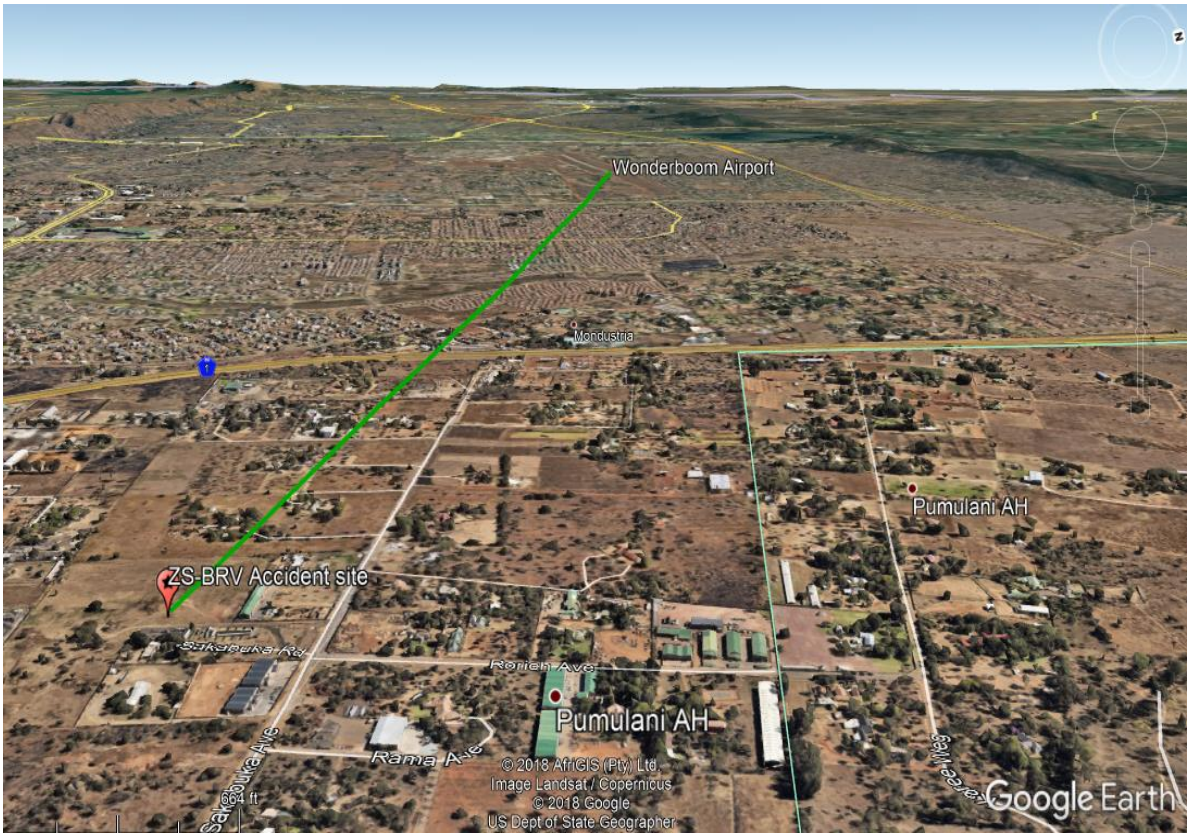


Figure 4: Google Earth map shows the aerodrome and the accident location.

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	1	-
Serious	2	-	2	4
Minor	-	-	14	4
None	-	-	-	-

Note: 'Other' on the table above refers to people who were on the ground at the factory building.

1.3 Damage to Aircraft

1.3.1 The aircraft was destroyed on impact. The in-flight left engine fire caused damage to the left wing and the post-impact fire caused damage to the right main gears and right engine. See Figure 5.

Figure 5: ZS-BRV wreckage as found at the accident site.

1.4 Other Damage

1.4.1 Damage was limited to the power lines that spanned parallel to Sakabuka Street, two commercial vehicles and the factory building. See Figures 6 and 7.

Figures 6/7: Two commercial vehicles that the aircraft collided with prior to crashing into the warehouse. The left image shows pieces of the left wing. The vehicle on the right sustained substantial damage to the freezer.

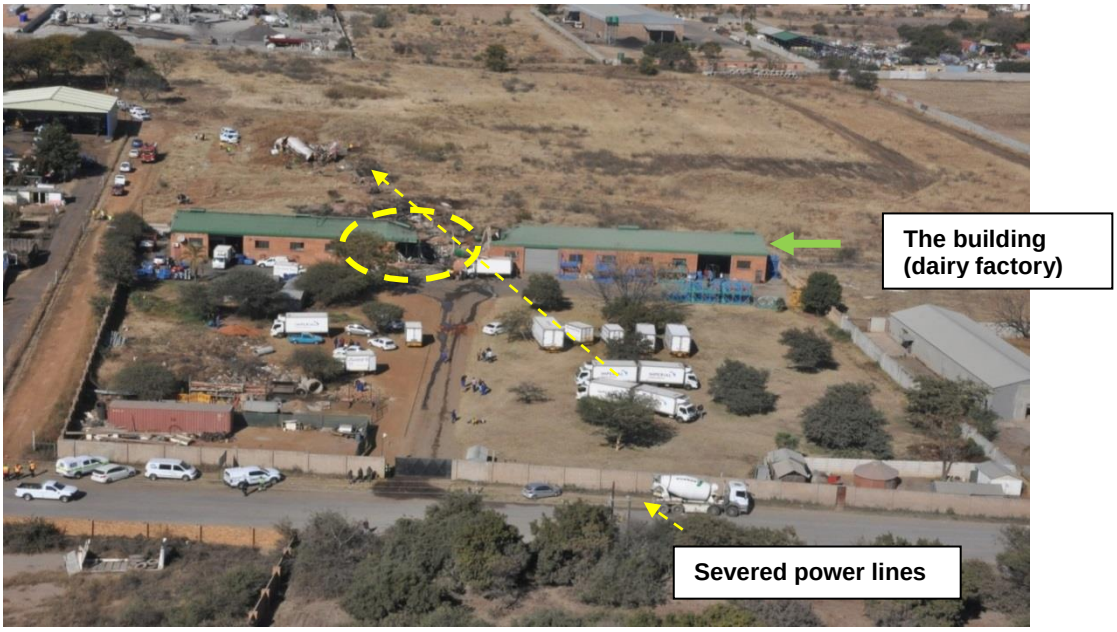


Figure 8: Reconstruction of the aircraft flight path and its final position. The picture shows damage caused to the factory building (circled in **yellow**) during the accident sequence.

1.5 Personnel Information

1.5.1 Captain or Pilot Flying (PF)

Nationality	Australian	Gender	Male	Age	65
Licence Number	**********	Licence Type		PPL	
Licence Valid	Yes	Type Endorsed		Yes	
Ratings	None				
Medical Expiry Date	11 December 2018				
Restrictions	Corrective Lenses				
Previous Accidents	Not known				

1.5.1.1 The PF had a valid Australian Air Transport Licence, Commercial Licence and Private Licence and he was type rated on the aircraft (Convair 340/440). However, the validation issued by the South African Civil Aviation Authority (SACAA) was for a Private Pilot Licence under visual flight rules (VFR) which was valid until 5 May 2021. According to the PF's logbook, the PF last flew the Convair 340/440 on 27 February 2017 and had flown 55.7 hours since 11 May 2016.

1.5.1.2 The PF's validation of his foreign licence, which was valid until 5 May 2021, was only limited to Single Engine Land aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This information is based on his foreign licence validation application and skills test report dated 9 May 2016.

1.5.1.3 The PF was not authorised to operate a South African registered Convair 340/440, as he had not done a skills test on a Convair 340/440 as required by CAR 2011, Part 61.01.13. See Appendix D.

1.5.1.4 The PF's Class 1 Airline Transport Pilot (ATP) medical expired on 11 June 2018. His Class 1 Commercial Pilot (CP) medical would have expired on 11 December 2018 and his Class 2 medical would have expired on 11 December 2018.

Flying Experience:

Total Hours	18240.5
Total Past 90 Days	58.8
Total on Type Past 90 Days	5.9
Total on Type	63

1.5.2 First Officer or Pilot Monitoring (PM)

Nationality	Australian	Gender	Male	Age	58
Licence Number	**********	Licence Type		PPL	
Licence Valid	Yes	Type Endorsed		Yes	
Ratings	None				
Medical Expiry Date	1 September 2018				
Restrictions	Suitable corrective lenses				
Previous Accidents	Not known				

1.5.2.1 The SACAA could not provide the investigation team with some of the supporting documents required for the issuance of the PM's validation of foreign licence in South Africa. However, the supporting documentation for the PF were made available to the investigation team. The investigation team was advised that some records were misplaced during the migration to the electronic business system.

1.5.2.2 The PM's Australian licence, issued on 13 November 2014, was validated by SACAA on 6 May 2016, with the expiry date of 5 May 2021. Among other documents considered by the SACAA for the issuance of the validation, they (SACAA) required a valid medical certificate and a valid foreign pilot's licence. At the time of application for validation of the foreign licence in May 2016, the PM had no rating for a Convair 340/440 in his Australian licence. He acquired the Convair 340/440 rating in 2017, post the validation issued by the SACAA. He last flew the same type of aircraft with the PF on 27 February 2017 and had accumulated 50.8 hours since 6 August 2016.

1.5.2.3 The PM's validation of his foreign licence, which was valid until 5 May 2021, was only limited to a Single Engine Land aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This information is based on his foreign licence validation application and skills test report dated 6 May 2016.

1.5.2.4 The PM submitted his initial skills test report with his application. The report indicated that the PM carried out his skills test on a Cessna 172. The PM completed 0.5 hours of briefing, 2.2 hours of flight time and 0.5 hours of debriefing. His flying experience was 2013 dual hours, 12 844 hours as the captain and had a total of 19 616 flying hours.

1.5.2.5 The PM was not authorised to operate a South African registered Convair 340/440 as he had not done a skills test on a Convair 340/440 as required by CAR 2011, Part 61.01.13. See appendix D.

1.5.2.6 The PM's Class 1 Airline Transport Pilot (ATP) and Commercial Pilot (CP) medicals were expiring on 1 September 2018, and his Class 2 had already expired on 1 July 2018.

Flying Experience:

Total Hours	Unknown
Total Past 90 Days	Unknown
Total on Type Past 90 Days	Unknown
Total on Type	Unknown

1.5.2.7 The PM's experience on the Convair 340/440 aircraft type could not be confirmed as his logbook could not be found. It is possible that it was lost at the accident site. The state that had issued the pilot's licence could not provide the investigation team with the PM's flying experience.

1.5.3 Licensed Aircraft Maintenance Engineer (LAME)

Nationality	South African	Gender	Male	Age	55
Licence Number	**********	Licence Type		LAME	
Licence Valid	Yes	Type Endorsed		Yes	
Ratings	A&C on the following: CONVAIR 340/440, CONVAIR CV-440/580, MCDONNEL DOUGLAS DC-3/C47 Series, MCDONNEL DOUGLAS DC-3 TP Series, MACDONNEL DOUGLAS DC-4/C54 Series, ALLISON 501-D13 (ENGINE), P&W PT6A Series, P&W R1830 and P&W R Series Engines.				

1.5.4 The Air Traffic Control (ATC)

Nationality	South African	Gender	Male	Age	28
Licence Number	**********	Licence Type		ATS	
Licence Valid	Yes				
Ratings	Aerodrome Control (AD) Approach Control (APP)				

1.5.4.1 The ATC's last proficiency check for Aerodrome Control (AD) and Approach Control (APP) was carried out on 2 June 2018 and expiring on 24 January 2019. The Air Traffic and Navigation System (ATNS) hired the ATC at FAWB control tower on 30 November 2015. His medical certificate was issued on 4 April 2018, with an expiry date of 20 April 2020 and without waivers or limitations.

1.6 Aircraft Information

1.6.1 The Convair 340/440 aircraft is an all-metal, low-wing, pressurised twin-engine, propeller-driven aircraft powered by two Pratt & Whitney R-2800-CB16 supercharged 18-cylinder radial engines with PR-58E5 carburettors. The engines and nacelles are installed on the wings, centred at about wing inch station (WIS) 150 and wing bulkhead station (WBS) 7. The nacelles are permanently attached to the wing and consist of three main portions: the power section, the nacelle body section and the nacelle after body section.

Figure 9: ZS-BRV picture taken on the apron prior to the accident, FAWB.

1.6.2 The Type Certificate (TC) of this aircraft is held by Transport Canada.

1.6.3 Flight deck Fuel System controls:

The aircraft's fuel system includes the fuel panel, fuel quantity indicators and fuel system warning annunciator lights. The fuel panel, which is located on the PF's overhead instrument panel, has an emergency 'power off' switch and three cover-guarded switches: two fuel tank shut-off valve switches and one fuel cross-feed valve switch. Figure 10 shows the overhead fuel panel of the Convair 340/440.

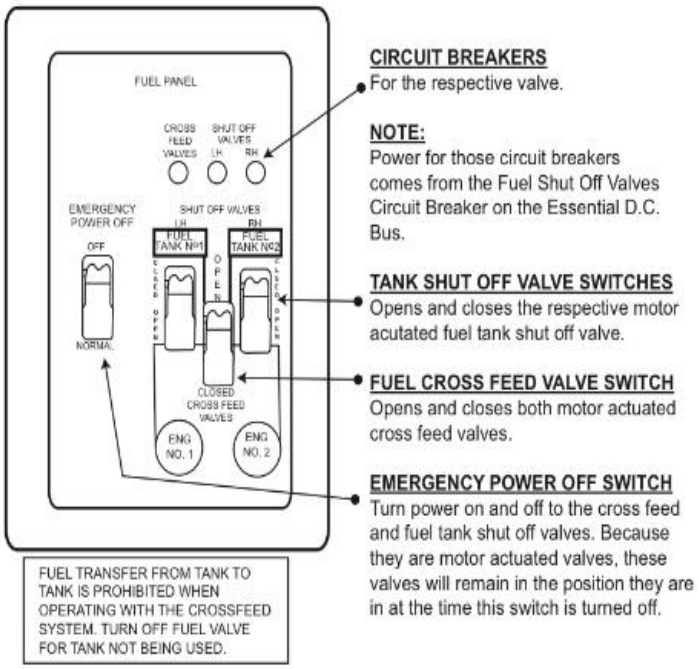


Figure 10: A Convair 340/440 overhead fuel panel.

Figure 11: The fuel panel as it was recovered from the accident site.

1.6.4 The aircraft comprises a unit nacelle that contains two distinct fire-detection systems: the unit detector (thermocouple type) system and the continuous loop detector system. The unit detector system consists of two independent overlapping fire detector circuits (identified as "A" and "B") from which thermocouples are distributed at strategic points in zone 1 (engine section), zone 2 (engine accessory section) and zone 3 (main landing gear wheel well). Whenever any of the thermocouple detectors of unit circuits "A" or "B" are exposed to a rapid rise in temperature, one or more of the four detector lights on the fire control panel will illuminate and the warning bell will ring intermittently. The four unit-detector lights are marked DET "A", No1 ENGINE, DET "B", No 1 ENGINE; DET "A", No 2 ENGINE and DET "B", No 2 ENGINE. Source: Convair 340/440 Flight Manual. See Figure 12.

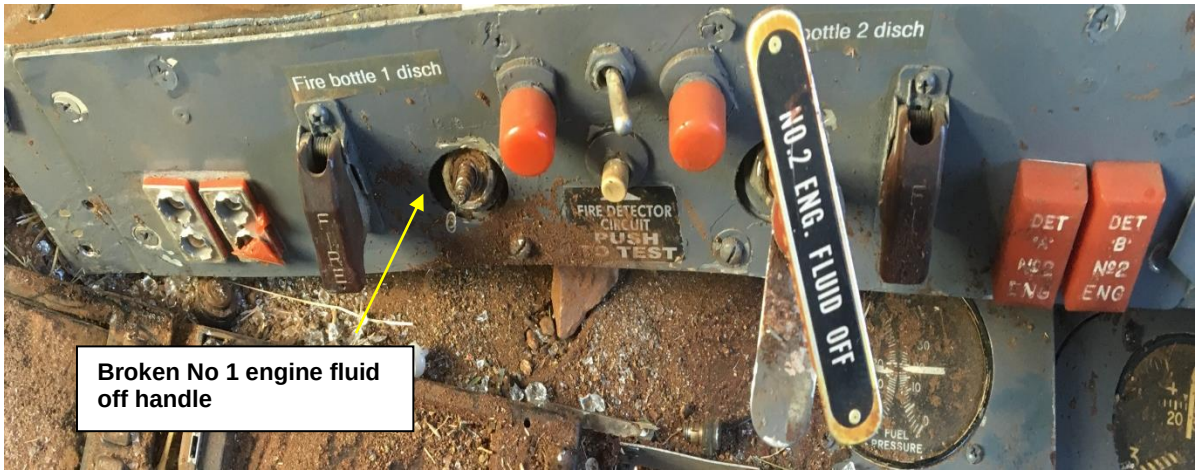


Figure 12: The engine fire extinguisher control panel showing all four unit-detector lights and a broken 'fluid off' handle.

1.6.5 The continuous loop detector circuit is routed in the augmenter bell-mouth and in a series of coils across the accessory vent duct in the engine shroud of each nacelle. If any portion of the detection wire is exposed to high temperatures, a circuit is completed to the fire control panel, causing one of the two continuous loop warning lights to illuminate and the fire warning bell to ring intermittently. This occurred in-flight for the No 1 engine, as can be seen on the video recording extracted from the cockpit GoPro camera that was mounted inside the cockpit on the door post. The continuous loop warning lights (one for each engine) are marked 'NO 1 ENGINE CONT DET' and 'No 2 CONT DET'. Illumination of any of the six detector warning lights, accompanied by an intermittent warning sound, is the indication to the crew of possible engine fire. Source: Convair 340/440 Flight Manual.

The in-flight checklist (refer to 1.1.15) should be used whenever the crew experience such a warning accompanied by sound.

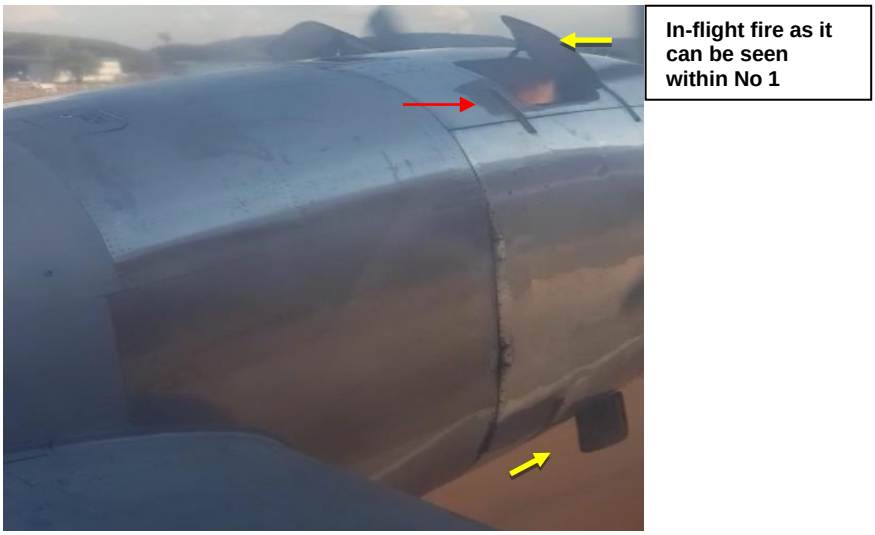


Figure 13: An in-flight captured photo of the No 1 engine cowl flaps in an open position.

Figure 14: The condition of the fire extinguisher bottles as found at the accident site. The gauge on the left-hand side reads '500psi' and the other gauge was unreadable and heavy, indicating that it contained the fire-extinguishing agent that was never used. This was an indication that both bottles were never discharged. In addition, two fire-extinguishing system discharge switches were in the 'off' and guarded position (refer to Figure 12 above), confirming that the crew neither activated nor discharged either of the fire-extinguishing systems.

Airframe:

Type	Convair 340/440	
Serial Number	215-54-2813	
Manufacturer	General Dynamics	
Date of Manufacture	1954	
Gross Weight	48 000 lbs	
Empty Weight	34 000 lbs	
Total Airframe Hours (At time of Accident)	18115.1	
Last A,B,C Checks (Hours & Date)	18115.1	6 July 2018
Total Hours Flown Since Last Maintenance Check	9 minutes	10 July 2018
Certificate of Airworthiness (Original Date of Issuance and Expiry Date)	16 August 2002	15 August 2018
C of R (Issue Date) (Present Owner)	18 December 2001	
Recommended Fuel Used	Avgas LL100	
Operating Categories	Standard - Part 91	
Type Certificate Data Sheet Holder (TDCS)	Kelowna, British Columbia (BC), Canada	

1.6.6 The maintenance records and Aircraft Maintenance Information System (AMIS) program that the aircraft maintenance organisation (AMO) used for tracking components and maintenance inspections were made available to the investigation team. The maintenance records revealed that the manifold pressure gauge had been removed, repaired and refitted to the aircraft in March and July 2018. The LAME, employed by the AMO, was responsible for the maintenance of the aircraft, except for the repair of the manifold pressure gauge which was outsourced to another maintenance organisation. The records indicated that the dual manifold pressure gauge valves were blocked by carbon deposits; and both valves were cleaned before the reassembling of the unit. The valves were inspected and refitted to the aircraft. The AMO responsible for the maintenance of the aircraft was initially issued with line maintenance approval for the Convair 340/440 aircraft, and later the SACAA issued the AMO with a letter authorising it to conduct full maintenance on the aircraft.

***Note**: 'Line maintenance' means limited maintenance performed during aircraft turnaround, route check or transit check, and is limited to defects rectification.*

1.6.7 The last maintenance performed on the engines was completed on 6 July 2018 and, during this maintenance, it was required that a compression test be carried out on each cylinder for both engine number 1 and 2. According to the maintenance records made available by the AMO to the investigation team, the AMO signed off the cylinder compression test as complied with.

Engine No.1:

Type	Pratt and Whitney R-2800 CB16
Serial Number	P37351
Hours Since New	Unknown
Hours Since Overhaul	109.1
TCDS holder	Pratt & Whitney Division

Engine No.2:

Type	Pratt and Whitney R-2800 CB16
Serial Number	P35954
Hours Since New	12148
Hours Since Overhaul	173.1
TCDS holder	Pratt & Whitney Division

1.6.8 Each engine is rated at 2500 shaft horsepower and drove through a reduction gearbox, a three-bladed Hamilton Standard constant speed, full-feathering automatic reversing propellers, fire detection and warning system, and an extinguishing system for the engines and nacelles. The engine exhaust from the 18 cylinders is routed to two manifold assemblies. Figure 9 shows the Convair 340/440 aircraft.

Propeller No.1:

Type	Hamilton Standard 43E60-565
Serial Number	N160891
Blade Numbers	R6895N-8
Blade Serial Numbers	N690513, N690514, N690515
Hours Since New	Unknown
Hours Since Overhaul	453.3

Propeller No.2:

Type	Hamilton Standard 43E60-565
Serial Number	N230744
Blade numbers	R6895N-8
Blade Serial numbers	738069, N732169, 738071
Hours Since New	Unknown
Hours Since Overhaul	453.3

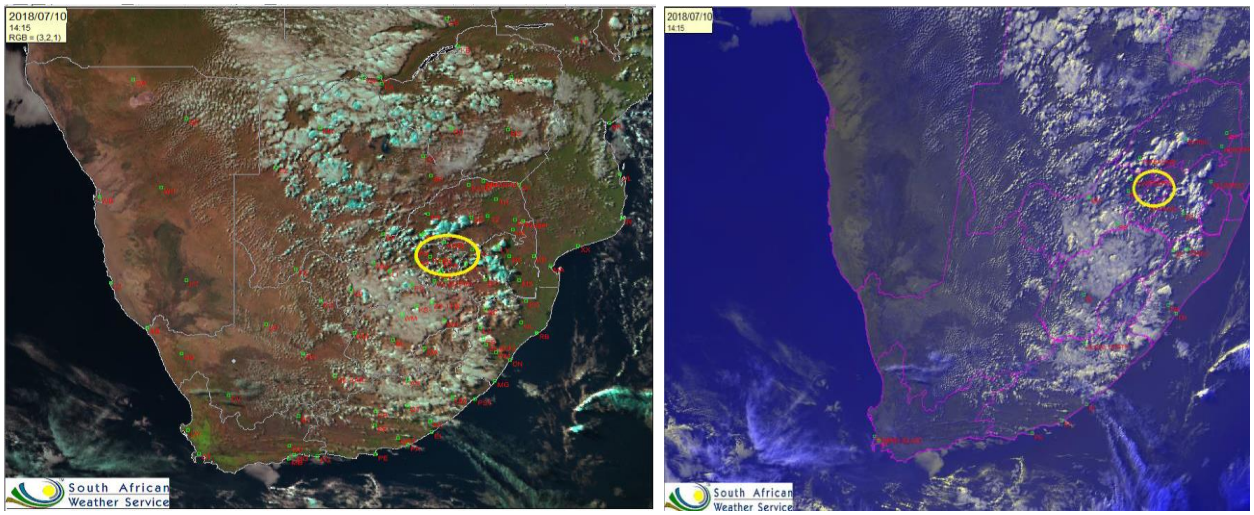
1.6.9 The propellers are of composite construction with 43E60-9 hubs and 6895A-8 blades. A minimum permissible cylinder head temperature is 260°C (500°F); minimum permissible oil-in temperature is 100°C (212°F); and minimum oil-in temperature is 40°C (104°F).

1.7 Meteorological Information

1.7.1 An official weather report was obtained from the South African Weather Service satellite image:

Wind direction	270°	Wind speed	4kt	Visibility	CAVOK
Temperature	19°C	Cloud cover	BKN	Cloud base	3500ft
Dew point	5°C	QNH	1030hPs		

1.7.2 The High Resolution Visible (HRV) satellite image observed showed scattered cumulus clouds at 1415Z, which can be identified by the thick cellular nature of the clouds in and around the accident site. The Day Natural Colours (DNC) satellite image also supported the presence of thick cumulus clouds with a cellular shape in and around the accident site. The cyan colour of the clouds suggested that the clouds had water particles in them. From a general view of the satellite images, it can be noted that the atmosphere was unstable as towering cumulus clouds can be observed around the accident site, however, no towering cumulus (TCU) or cumulonimbus (CB) clouds were observed over the accident site (See Figure 15/16). Analysis revealed that a surface high-pressure system with the support of an upper-level trough over central parts of the country contributed to the unstable nature of the atmosphere, which resulted in towering cumulus (TCU) and cumulonimbus (CB) development over central parts of the country. The geographic coordinates of the scene of the accident are indicated on the satellite images below.



Figures 15/16: Day Natural Colours (DNC) and High Resolution Visible (HRV).

1.8. Aids to Navigation

1.8.1 The aircraft was fitted with the following navigational aids:

i. 1 x Garmin GNS 530
ii. 1 x Garmin GNS 430
iii. 1 x RDR 2000 colour weather radar system
iv. 1 x Bendix King KN 64 DME
v. 2 x Bendix KR 87 TSO AFD
vi. 2 x Garmin GTX 327 transponders
vii. 1 x Garmin GMA 340 intercom system

1.8.2 There were no recorded defects on the navigational aids stated above.

1.9 Communication

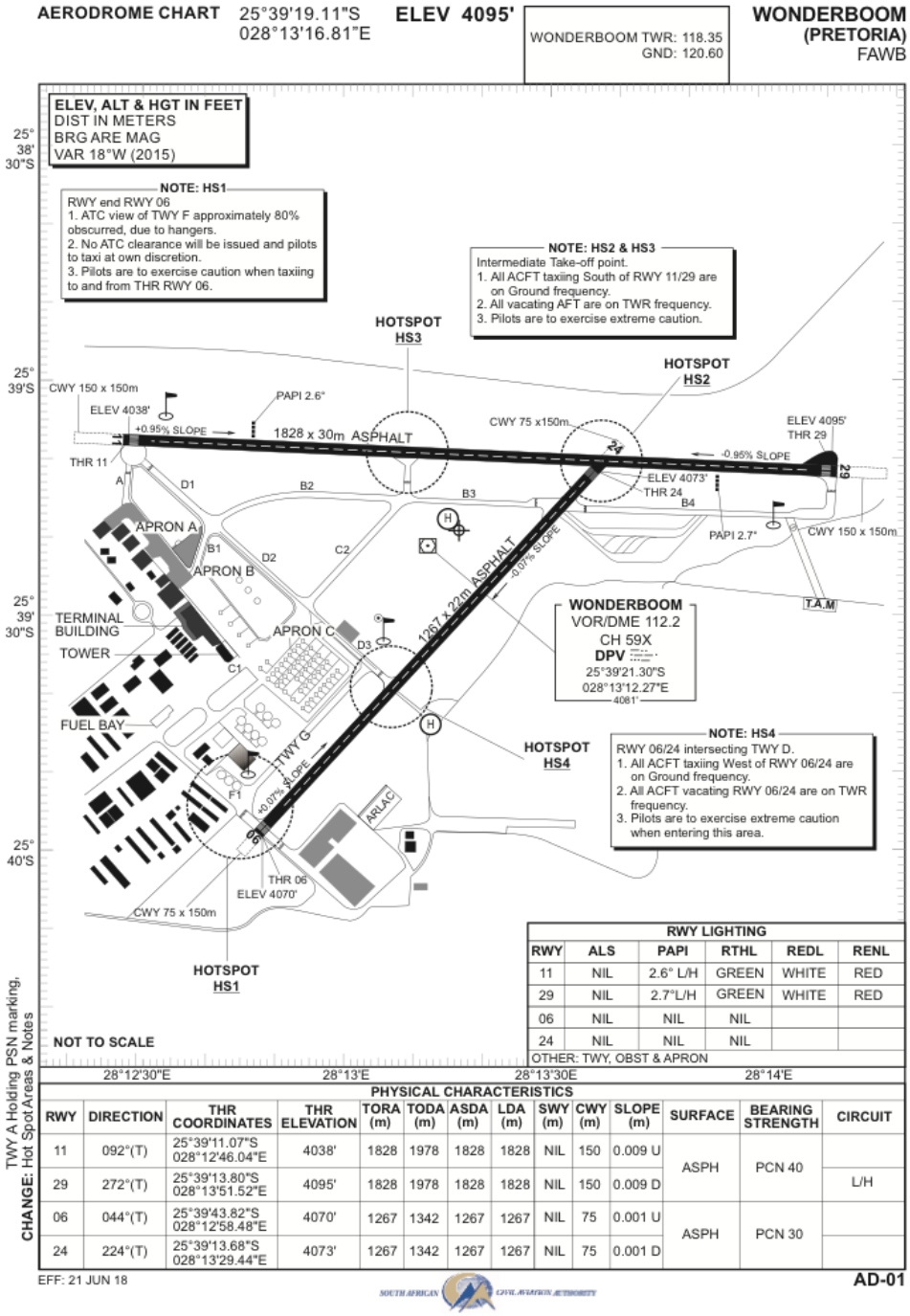
1.9.1 The aircraft was equipped with a very high frequency (VHF) radio. A 'MAYDAY' call was made, but the crew never communicated the type of emergency they were experiencing to the ATC.

1.9.2 There was good communication between the aircraft and the ATC. All communications between the ATC and the crew members were recorded by ground-based automatic voice recording equipment for the duration of the accident flight. The quality of the aircraft's recorded transmission was good. All VHF radios were serviceable. The communication between the ATC and the crew members has been transcribed and is attached as Appendix A of this report.

1.10 Aerodrome Information

1.10.1 Wonderboom Airport (FAWB)

Aerodrome Location	Pretoria North; Gauteng Province	
Aerodrome Coordinates	S25^{0}39'19.11" E028^{0}13'16.81"	
Aerodrome Elevation	4095ft	
Runway Designations	11/29	1828 X 30m
Runway Dimensions	06/24	1280 X 22m
Runway Used	29	
Runway Surface	Asphalt	
Approach Facilities	PAPI, VOR/DME	



RWY LIGHTING

RWY	ALS	PAPI	RTHL	REDL	RENL
11	NIL	2.6° L/H	GREEN	WHITE	RED
29	NIL	2.7°L/H	GREEN	WHITE	RED
06	NIL	NIL	NIL		
24	NIL	NIL	NIL		

OTHER: TWY, OBST & APRON

PHYSICAL CHARACTERISTICS

RWY	DIRECTION	THR COORDINATES	THR ELEVATION	TORA (m)	TODA (m)	ASDA (m)	LDA (m)	SWY (m)	CWY (m)	SLOPE (m)	SURFACE	BEARING STRENGTH	CIRCUIT
11	092°(T)	25°39'11.07"S 028°12'46.04"E	4038'	1828	1978	1828	1828	NIL	150	0.009 U	ASPH	PCN 40	
29	272°(T)	25°39'13.80"S 028°13'51.52"E	4095'	1828	1978	1828	1828	NIL	150	0.009 D			L/H
06	044°(T)	25°39'43.82"S 028°12'58.48"E	4070'	1267	1342	1267	1267	NIL	75	0.001 U	ASPH	PCN 30	
24	224°(T)	25°39'13.68"S 028°13'29.44"E	4073'	1267	1342	1267	1267	NIL	75	0.001 D			

Figure 17: FAWB Aerodrome chart.

1.11 Flight Recorders

1.11.1 The aircraft was neither equipped with a flight data recorder (FDR) nor a cockpit voice recorder (CVR), nor was it required by regulation to have it fitted to this aircraft type. The aircraft was installed with a GoPro video camera which recorded the flight deck voice and some aspects of the flight.

1.12 Wreckage and Impact Information

1.12.1 It was determined that the aircraft had approached the accident site in a southerly direction with the left wing in a low attitude. The aircraft first collided with electrical power lines that spanned parallel to Sakabuka Street in Derdepoort industrial area, north of Pretoria. The aircraft continued for approximately 88 metres, impacting the tree top with its left wing before impacting the two commercial vehicles and a building. The aircraft came to a stop when it impacted the ground.

1.12.2 This resulted in the left wing out-board section separating from the fuselage and the building severely damaged during the accident sequence.

1.12.3 The left wing in-board section caught fire during the accident sequence and continued burning until the fire was extinguished by emergency and fire personnel who arrived at the scene of the accident immediately after the crash. The fire-extinguishing bottles, the left propeller and left engine were found on the left side of the wreckage path at 156 metres, 160 metres and 172 metres, respectively. The right propeller was found to the right of the flight path at 168 metres. The left main gear assembly was located at 230 metres to the left of the flight path, while the main wreckage, right wing and engine were found 250 metres further on, where the wreckage came to rest facing 192 degrees magnetic. See Figures 18 to 26.

1.12.4 Figures 18, 19 and 20 illustrate the aircraft wreckage mapping and damage caused to the dairy farm building.

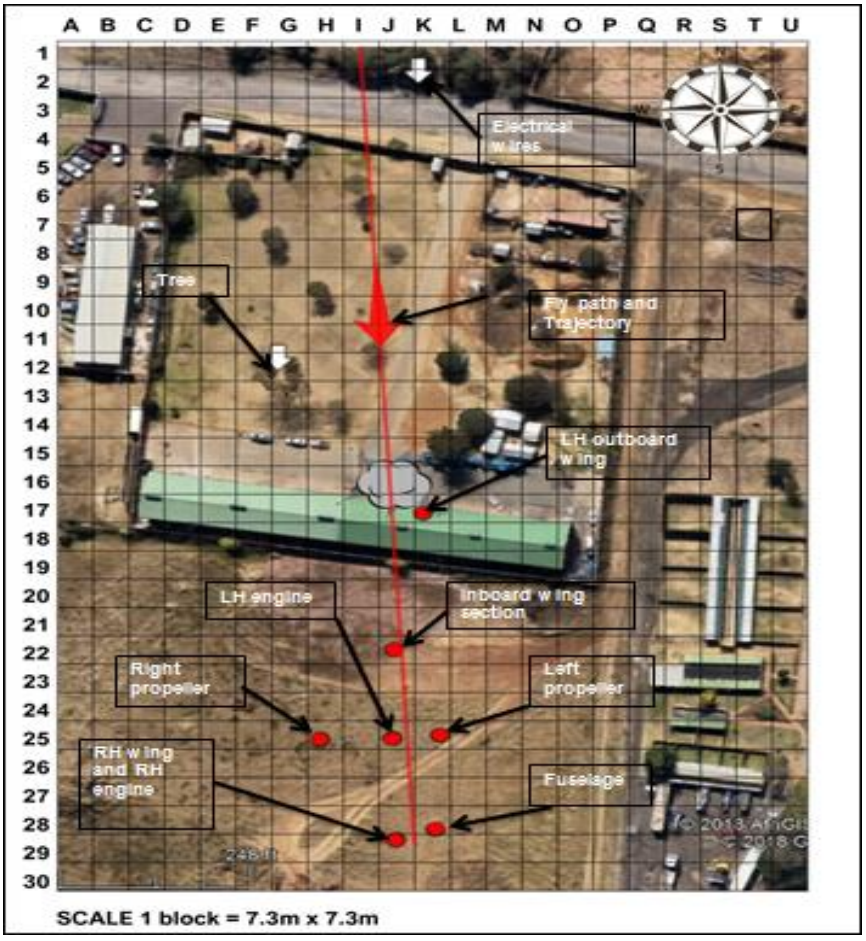


Figure 18: The aircraft wreckage mapping.

Figure 19: The nose, centre and aft section of the aircraft.

Figure 20: The left wing out-board section and part of the building damaged by the aircraft during the accident sequence.

The Aft Section (Empennage)

1.12.5 The empennage was separated from the mounts of the centre section. The empennage swung open to an angle of approximately 110° to the right and it was detached from the centre section. The vertical stabiliser exhibited damage on the leading edge. The right horizontal stabiliser was still intact. The left horizontal stabiliser separated as a result of impact with the building and was located at grid station L19. The day after the accident while the investigation team was examining the wreckage at the accident site, they heard a beeping sound coming from the aft section of the aircraft. It was later identified as an emergency locator transmitter (ELT) and it was switched off.

Figure 21: The aft section of the aircraft had separated from the fuselage.

The Engines and Propellers

1.12.6 The left-hand engine was located just behind the fuselage at grid station J25. The engine exhibited fire damage signatures near the carburettor. The accessory gearbox had broken off from the housing assembly. The left three-bladed propeller had broken off from the gearbox and was located at grid station K25. The first blade was missing, the second blade had disintegrated from the mid-section, while the third blade was fairly intact. The damage observed on the propeller blades was indicative of damage caused during the running of a low-powered engine. The exhaust tubes were still secured on the centre section of the wing. The exhaust exhibited damage caused by an in-flight fire and had signatures of overheating and discolouration.

Figure 22: The left-hand engine as it came to rest.

Figure 23: The left-hand propeller.

1.12.7 The right-hand engine was located near the leading edge towards the tip of the right wing. The engine exhibited signs of post-impact fire as observed on the scene. The right-hand propeller had broken off from the gearbox housing and was located at grid station H25. The propeller exhibited signs of damage caused when a rotating object struck an obstacle while at full power. The propeller only had one blade attached to it. The other two blades had broken off from the root. One of the propeller blades was located in the same grid station across grid station L24. The exhaust ducts were located near the right wing.

Figure 24: The right-hand propeller as it came to rest.

Figure 25: The right-hand engine as it came to rest with black soot indicating exposure to fire.

1.12.8 The images below show the damaged rear main spar and the aileron pulley attachment brackets because of the fire that came from the left engine. The pulley attachment brackets were found detached from the spar with slacked cables.

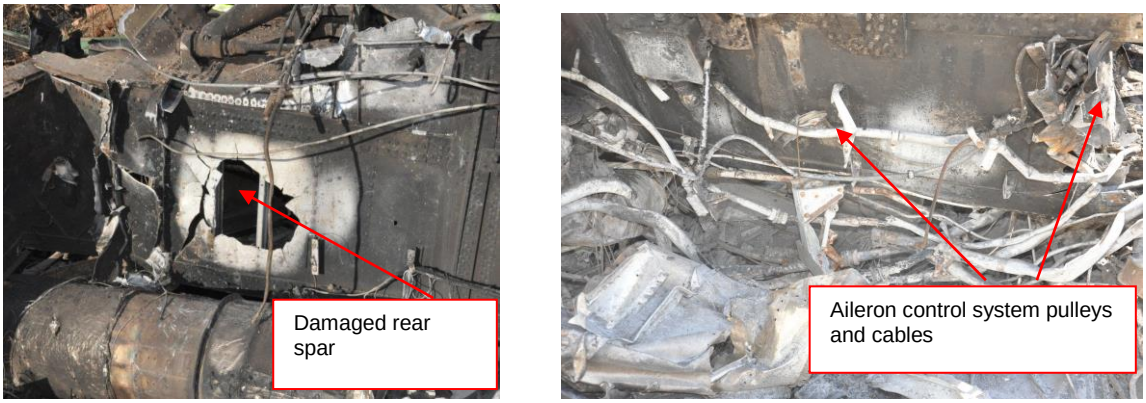


Figure 26/27: Images showing fire damage on the left-wing rear spar and pulley attachment brackets separated from the spar with its pulleys and the cables.

1.13 Medical and Pathological Information

1.13.1 Not applicable

1.14 Fire

1.14.1 The left engine caught fire during take-off and continued during the flight until the aircraft crashed.

1.15 Survival Aspects

1.15.1 The accident was considered not survivable due to the severe damage to the cockpit and empennage, and minor damage to the fuselage midsection where the passengers were seated. All seats in the aircraft were fitted with slip-through metal to fabric seatbelts. The seatbelts in the aircraft did not fail, although some had to be cut by medical personnel to rescue the crew and passengers.

Figure 28: The ER24/Netcare 911 helicopters at the accident site.

1.15.2 The emergency helicopters flew to the area of the accident approximately 30 minutes after the crash. The helicopters airlifted the PF and his wife, as well as the PM to a hospital in Johannesburg. The accident rescue personnel disturbed the cockpit area as they were rescuing the injured crew members, as well as when they were removing the body of the LAME who was fatally injured.

1.16 Tests and Research

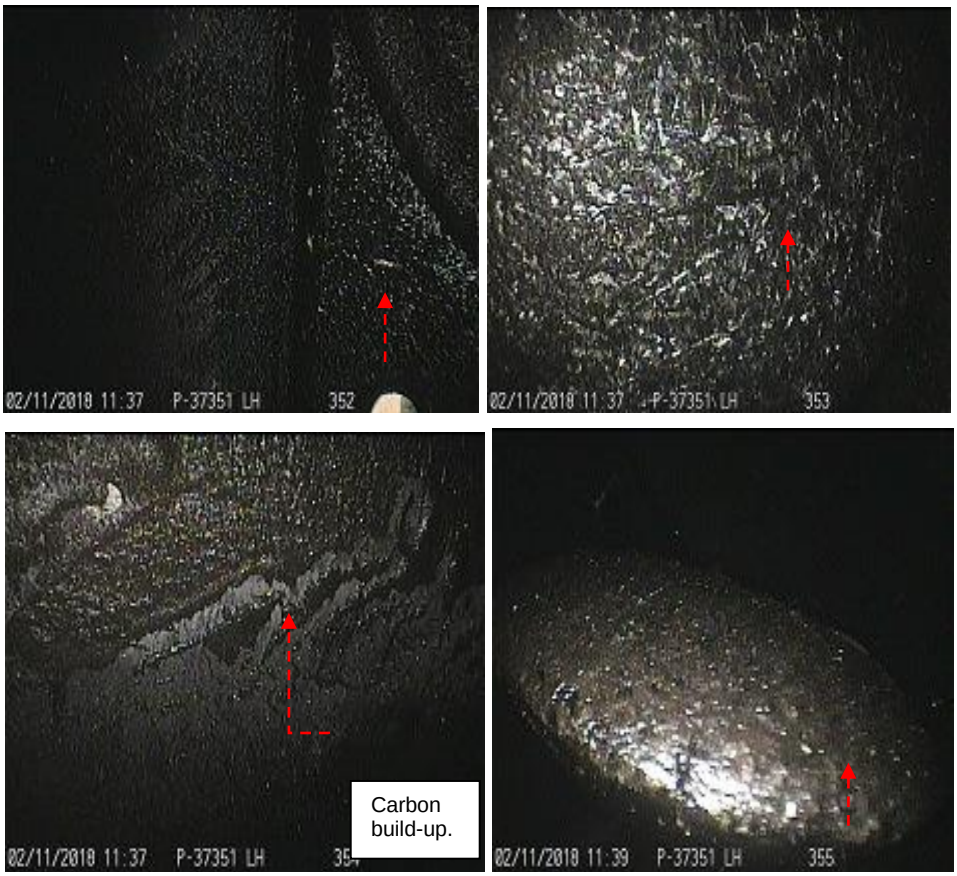
1.16.1 The fuel test report indicated the following: fuel density — 0.717; temperature — 16.5°C; density correction — -0.0029 and 0.7141; batch density — 0.7142 and difference (1) — (2) ± good. The test results revealed that the fuel was good and clean. Two aircraft were refuelled on the same day from the same tank that was used to refuel ZS-BRV and no anomalies were reported.

1.16.2 The fuel pumps, fuel control units and propeller control units from both engines were inspected and examined and no anomalies were observed during the inspection, which confirmed that there was no indication of malfunctioning prior to the accident.

1.16.3 Following the recovery of both engines and propellers from the accident site, the No 1 engine S/N P-37351 was subjected to a borescope inspection procedure. The borescope inspection found that cylinder No 13 had piston damage and carbon build-up on the valves. See images of the piston crown – Figures 29-32.

1.16.4 The inspection of the right engine (No 2) revealed no evidence of malfunctioning of the propeller, engine or engine accessories. Apart from the impact damage, the No 2 engine was found to be in normal operation prior to the accident.

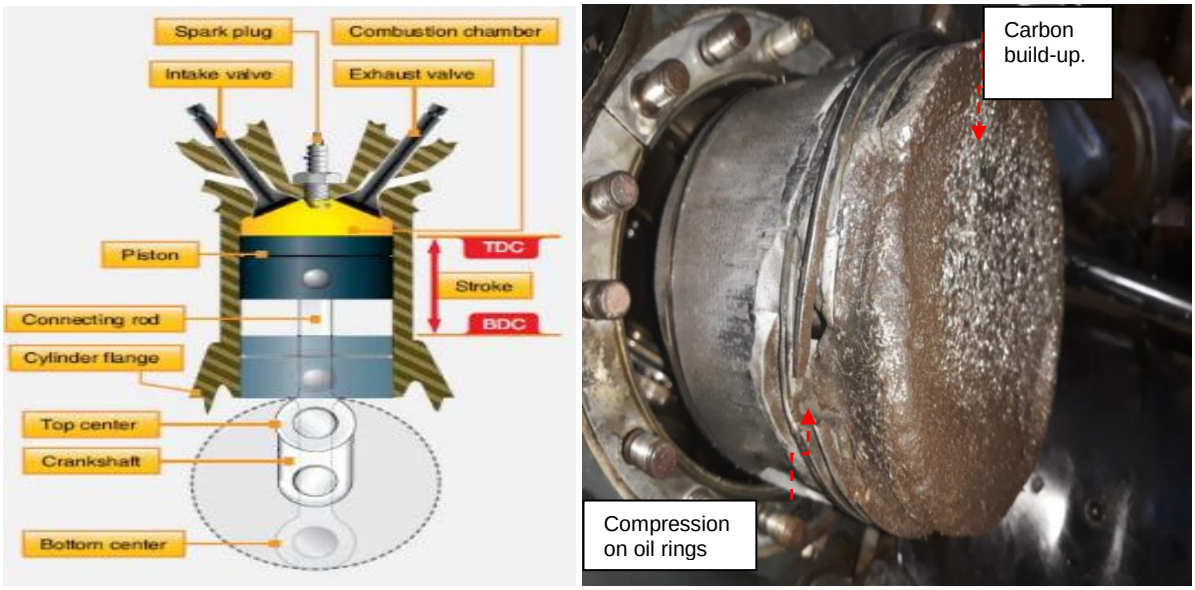
1.16.5 The focus was put on the No 1 engine due to the evidence which showed that the left engine had caught fire in-flight. The following information was extracted from the engine strip report.



Figures 29/30/31/32 Show the piston crown of cylinder No 13 taken during the borescope inspection.

1.16.6 No 1 engine examination:

The reduction gearbox forward housing separated from the engine. The No 1 engine single stage speed supercharger was inspected and no anomalies were detected. Both the magnetos were examined and were in normal condition and had satisfactory spark operation. The spark plugs were in normal condition and had satisfactory spark operation. The post-accident examination of the No 1 engine revealed damaged compression rings and oil ring packs on piston No 13, with evidence of hard carbon deposit on the piston crown. Further damage was noticed on piston No 7, which had a fractured exhaust valve head. The remaining 16 cylinders showed signs of proper combustion; carbon deposit found in the cylinders was normal. The pistons were in good condition with very little carbon build-up visible. See image below.

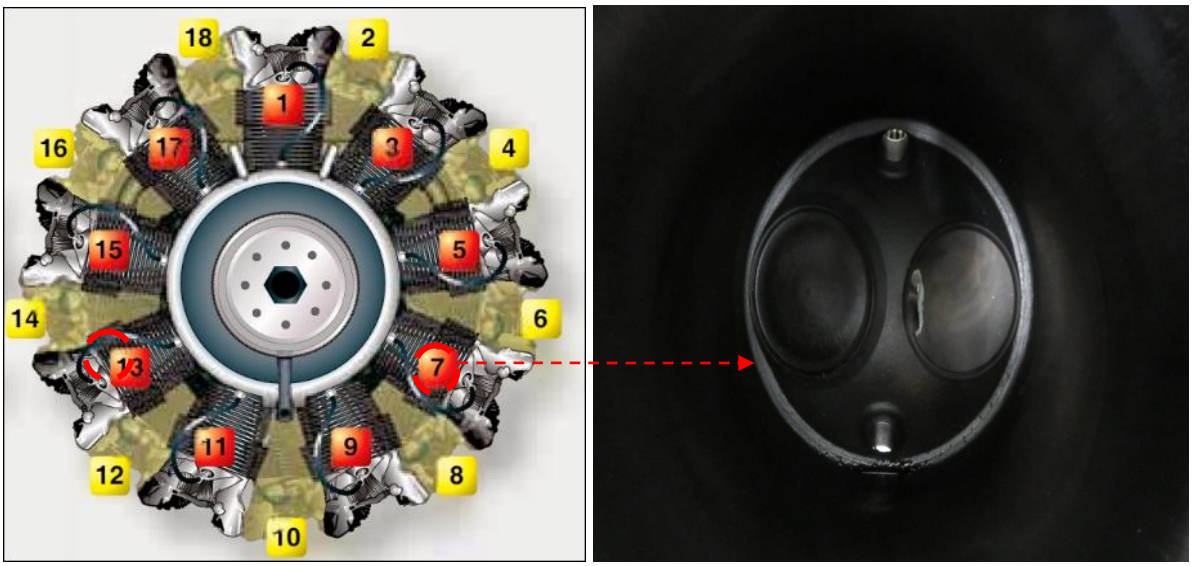


Figures 33/34: A sketch of components and terminology of engine operation and an image of the No 1 engine's cylinder No 13 piston displaying damaged compression and oil control ring packs and hard carbon on the piston crown.

1.16.7 The cylinder wall was smooth with no evidence of abrasion. None of the rings were broken on any of the 16 pistons. All the bearings were found to be in good condition and displayed evidence of adequate lubrication. All the connecting rods were found to be in good condition; the connecting bolts were properly secured. The crankshaft was found to be in good condition. A substantial amount of oil was still present in the engine. The oil pick-up in the sump was intact and free from any obstructions.

1.16.8 After the removal of the No 7 cylinder, the exhaust valve (P/N: 331107) head was found to be fractured. Further examination indicated that the inlet and the exhaust valves return springs and rocker arms were intact and in good condition. The No 7 cylinder cooling fins/plate (valve housing) had damage on the side wall.

See Figures 35/36/37/38/39 of the images taken during the engine teardown examination showing the damage caused by the fire on the No 7 cylinder.

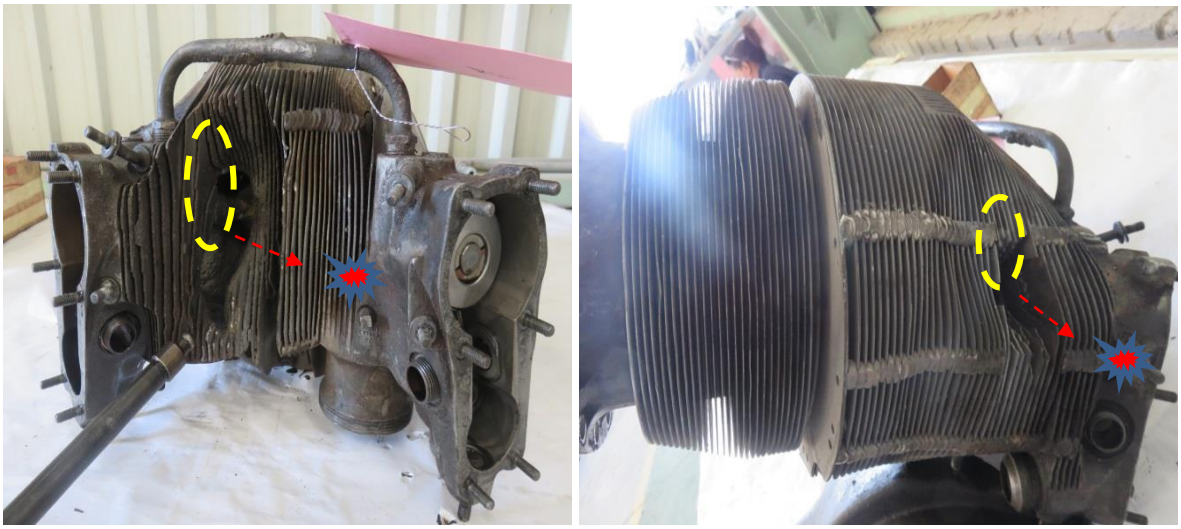


Figures 35/36: On the left is the 18 double-row, air-cooled Pratt and Whitney R-2800 radial engine and on the right is an image of the No 7 cylinder combustion chamber, showing a fractured exhaust valve head.

NOTE: The fuel/air mixture is ignited by the spark in the combustion chamber and commences burning as the piston travels towards the top dead centre (top of its travel) on the compression stroke. The ignited charge is rapidly expanding at this time, and pressure is increasing so that, as the piston travels through the top dead centre position, it is driven downward on the power stroke.

The intake and exhaust valve ports are located in the cylinder head, along with the spark plugs and the intake and exhaust valve actuating mechanisms. To prevent loss of power, all openings to the cylinder must close and seal completely on the compression and power strokes.

In this respect, there are three items in the proper operation of the cylinder that must be operating correctly for maximum efficiency. Firstly, the piston rings must be in good condition to provide maximum sealing during the stroke of the piston. There must be no leakage between the piston and the walls of the combustion chamber. Secondly, the intake and exhaust valves must close tightly so that there is no loss of compression at these points. Thirdly, and very importantly, the timing of the valves (opening and closing) must be such that the highest efficiency is obtained when the engine is operating at its normal-rated RPM. See Figure 33 for the engine operation.



Figures 37/38: Cylinder No 7 showing the hole where the fire escaped.

Figure 39: An image of the No 7 cylinder showing the fire damage on the exterior through the cooling fins and the plate.

1.16.9 Manifold pressure or engine vacuum in an internal combustion engine is the difference in air pressure between the engine's intake manifold and the earth's atmosphere. Manifold pressure is the effect of a piston's movement on the induction stroke and the choked flow through a throttle in the intake manifold of an engine.

The manifold pressure gauge traps air from the inlet manifold between the supercharger and the air inlet pipe. The following components are included in the operation of the manifold air pressure measurements: inlet air, carburettor air mixing box, carburettor, supercharger, inlet manifold, inlet pipes and cylinders. In this case, the supercharger provides additional pressure to the induction air to produce additional power, therefore, increasing the manifold pressure and forcing the fuel/air mixture into the cylinders. The higher the manifold pressure, the denser the fuel/air mixture and the more power an engine can develop (the fuel/air pressure is increased). Therefore, the supercharger, in effect, maintains sea-level manifold pressure to a higher altitude or can produce higher than ambient pressure fuel/air mixtures. Source: Department of Aerospace Indian Institute, Bombai, http://www.flight-mechanic.com/basic-engine-operating-principles/

1.16.10 The engine No 1 manifold pressure drop, as reported by the crew during the take-off roll, was the result of the No 13 cylinder damaged piston crown, piston rings and fractured No 7 cylinder exhaust valve head which subsequently caused backfiring.

1.16.11 The maintenance records revealed that the AMO recorded a defect of the "manifold pressure gauge stick on the No 1 engine". This defect was recorded on 26 February 2018 and was signed off as 'unit cleaned' as a method of rectification of the defect. On 5 May 2018, the same defect was recorded by the AMO and, again, signed off as 'repaired and refitted'. The manifold dual pressure gauge was removed twice (in March and July 2018) in a period of four months due to the left engine manifold pressure defect. In both cases, carbon build-up was found in the units.

1.17 Organisational and Management Information

1.17.1 The aircraft was operated as a private operation by Rovos Rail, which is the registered owner of the aircraft. At the time of the accident, the aircraft was engaged in a scenic flight.

1.17.2 The aircraft inspection programme comprises a service check and scheduled maintenance checks (A, B, C, D, E and F). The maintenance checks A through F were required to be performed at two-month intervals with a complete full cycle inspection of the airframe at every 12-month period.

1.17.3 The most recent inspection (A, B and C maintenance checks) conducted by the AMO was signed off as 'complied with' on 6 July 2018. The aircraft's total time at the point of inspection was recorded as 18115.1 total hours.

1.17.4 Records made available to the investigation team indicated that the AMO 1189 was audited on 13 September 2017. The scope of the audit was to determine whether the approval could be amended to include a Convair 340/440 aircraft in terms of the requirements stipulated in the Civil Aviation Regulations (CAR) Part 145 of 2011 as

amended. Below are the findings raised by SACAA during its audit of the AMO:

1.17.4.1 During the audit, the AMO could not demonstrate that it had adequate facility to support the maintenance activities applied for or produce a written facility agreement for the accommodation of Convair 340/440 aircraft in terms of CAR 2011, Part 145.01.8.

1.17.4.2 The AMO did not have a training programme aligned to the training requirements for certifying personnel on the Convair 340/440 aircraft in terms of CAR 2011, Part 145.01.11. See Appendix B and E.

1.17.5 The AMO was rated on category B (structural repairs and spray painting) maintenance for the aircraft detailed on the Operations Specifications issued by the SACAA. AMO 1189 submitted a corrective action plan to the SACAA notifying them that a hangar agreement was in place. In addition, a copy of a licensed aircraft maintenance engineer (LAME) who was responsible for the maintenance of a Convair 340/440 aircraft was submitted together with the hangar lease agreement.

1.17.6 The AMO informed the audit team that it had one licensed maintenance person, and that he was the only one in the country and that it had no other resources for the maintenance of the Convair 340/440 aircraft. The SACAA accepted the AMO's licensed maintenance person. The AMO was issued with A and C ratings limited to line maintenance on a Convair 340/440 aircraft. The AMO accepted the approved operations specifications (Ops Spec) with the limitation to performing only line maintenance on Convair 340/440 aircraft.

1.17.7 On 18 June 2018, the AMO sent another letter to the SACAA requesting to change its AMO approval on the Convair 340/440 from line maintenance to full maintenance, stating that the new hangar (Hangar 65, FAWB) could accommodate the aircraft for maintenance. Attached to the letter were the dimensions of the hangar and the floor plan which were 40m x 35m. On 22 June 2018, the AMO was granted a one-time authorisation to carry out full maintenance and release of the aircraft to service.

1.17.8 The Regulator (South African Civil Aviation Authority)

1.17.8.1 The SACAA carried out an audit at the AMO facility to ascertain if it could issue the organisation with an approval to conduct maintenance on the Convair 340/440 aircraft. During this audit, two non-conformances as stated above in paragraph 1.17.4.1 and 1.17.4.2 were raised with the AMO. The SACAA issued the AMO with a once-off approval letter, however, the letter did not specify the validity period of the approval; and the approval was for the AMO to perform full maintenance and the release of the Convair 340/440 aircraft to service.

1.17.8.2 The SACAA audit report highlighted findings that posed immediate safety threats and the findings required urgent remedial action by the AMO. The SACAA communicated to the AMO that an action plan to address the findings together with the manner in which they were closed or were intended to be closed was required within 14 days due to the nature of the findings. The audit report further stated that once the SACAA receive an action plan detailing the root cause, rectification and preventative actions taken, the requested amendment shall be recommended for approval to the Director of Civil Aviation.

1.18 Additional Information

1.18.1 Crew Resource Management (CRM)

Crew resource management or flight deck resource management is a set of training procedures for use in environments where human error can have devastating effects. Used primarily for improving air safety, CRM focuses on interpersonal communication, crew co-ordination, leadership and decision making in the flight deck of an aircraft. The training is designed to make problem solving in a flight deck much more efficient, thus, causing less distraction for the crew members. Extract from Big Sky Cabin Training Academy.

Management in the flight deck can be best described as team work among the crew members with the captain taking leadership and decision making. Work is equally distributed among the crew members to avoid one crew member having too many responsibilities. This exchange of information and continuous monitoring of each other's performance ensures a streamlined cockpit under normal and abnormal conditions.

Communication in the cockpit can be hampered by the following: unclear or ambiguous messages, background noises or impaired hearing, a disregard or misinterpretation of a message and arguments.

1.18.2 Flight Familiarisation

CRM training alone is inadequate if the crew does not conduct a familiarisation flight to practise what they have learnt in CRM. The results of not practising the skills learnt at CRM can lead to a decrease in communication, an increase in emotional conflict, an increase in wrong decision making and a lower probability of correcting a deviation from checklists or the desired flight path. The more CRM training, the less likely that the crew co-ordination will break down under a stressful situation, i.e. during an emergency. It would, therefore, be advisable for a crew to practise as a team to determine each other's duties in the flight deck during a normal flight or an emergency. This practise can be done in a form of a test flight or a familiarisation flight.

1.18.3 CAR 2011 Requirement

Maintenance of competency and skills tests

61.01.5 (1) Unless the holder of a pilot licence or rating maintains competency and recency by complying with the appropriate requirements prescribed in this part or part 62 and part 91, as the case may be, the licence holder shall not exercise the privileges granted by the licence.

(2) (a) The holder of a pilot licence shall not exercise the privileges of that licence unless he or she has successfully passed an initial licence skills test or a revalidation check in the same category of aircraft.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 General

From the evidence available, the following analysis was made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

2.2 Crew

2.2.1 The PF had a valid Australian Air Transport Licence, a Commercial Pilot Licence and a Private Pilot Licence; and he was type rated on the aircraft (Convair 340/440). However, the validation issued by the SACAA was for a Private Pilot Licence under visual flight rules (VFR). It was issued on 9 May 2016, with an expiry date of 5 May 2021. The PF's Class 1 & 2 aviation medical certificate was issued on 11 December 2017, with the expiration date of 11 December 2018. The PF last flew the Convair 340/440 on 27 February 2017 and had flown 55.7 hours since 11 May 2016. The PF had last flown the Convair 340/440 aircraft 17 months prior to the accident flight. No records could be found that indicated that the PF did comply with the skills test/competency check requirements as he had never flown the Convair 340/440 aircraft in the last 17 months prior to the accident flight. A competency check is required every 12 months.

2.2.2 The PF's foreign licence validation was only limited to a Single Engine Land aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This was based on his foreign licence validation application and skills test report dated 9 May 2016 and the validation was until 5 May 2021. However, at the time of the accident, the PF was operating a multi-engine aircraft which was not in accordance with the application submitted to the SACAA for a foreign licence validation.

2.2.3 The PM's Australian Air Transport Pilot Licence, issued on 13 November 2014, was validated by the SACAA on 6 May 2016, with the expiry date of 5 May 2021. Among other documents reviewed by the SACAA for the issuance of the validation, they required a valid medical certificate and a valid foreign pilot's licence. At the time of application for the validation of the foreign licence in May 2016, the PM's Australian Licence submitted to the SACAA had no rating for a Convair 340/440. He acquired the Convair 340/440 rating in 2017, post the validation issued by the SACAA; therefore, although he had acquired a Convair 340/440 rating post foreign licence validation by the SACAA, he was not authorised to operate a Convair 340/440 aircraft registered in South Africa. He last flew the same type of aircraft on 27 February 2017 and had accumulated 50.8 hours since 6 August 2016. No records could be found which indicated that the PM had complied with the skills test/competency check requirements as he never flew the Convair 340/440 aircraft in the last 17 months prior to the accident flight. A competency check is required every 12 months.

2.2.4 The PM's validation of his foreign licence was only limited to Single Engine Land aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This was based on his foreign licence validation application and skills test report dated 6 May

2016. The validation was due to expire on 5 May 2021. The aviation medical certificate had been issued to the PM with the expiration date of 1 September 2018 for Class 1, while Class 2 had already expired on 1 July 2018.

2.2.5 Neither the PF nor the PM were authorised to operate a South African registered Convair 340/440 as they had not done a skills test on a Convair 340/440 as required by CAR 2011, Part 61.01.13. Neither the PF's nor the PM's foreign licences validations included the Convair 340/440 as none of them applied for the validation of a Convair 340/440 aircraft. This information is supported by the SACAA application form number CA61-01-13 that was submitted for validation of their foreign licences.

2.2.6 The LAME had a valid Aircraft Maintenance Engineer (AME) Licence and was type rated on the aircraft (Convair 340/440). He was the only person qualified to work on the aircraft. There were no records to indicate when last the LAME had undergone a recurrent training/competency check as required by Part 145.01.11 of the Civil Aviation Regulations. The AMO could not provide the investigators with the training records of the LAME who was responsible for the maintenance of the Convair 340/440 aircraft. The LAME had misdiagnosed the manifold pressure defect by always removing the manifold pressure gauge whenever there was a left engine manifold pressure defect which was reported twice prior to the accident flight.

2.2.7 The ATC had an Air Traffic Services (ATS) Licence and was rated on AD and APP. The ATC's last proficiency check for the AD and APP were carried out on 2 June 2018 and would expire on 24 January 2019.

2.3. **The AMO**

2.3.1 The AMO 1189 was audited on 13 September 2017. The scope of the audit was to determine whether the approval could be issued to include a Convair 340/440 aircraft on the already existing AMO scope of work that had been approved by the SACAA. Following the audit, the SACAA approved the AMO and issued an approval to the AMO limiting the organisation to only perform line maintenance due to the AMO not having adequate facility to accommodate the Convair 340/440 aircraft and the AMO also did not have a training programme for the maintenance personnel. The AMO had only one person who was qualified and licensed to carry out maintenance on the Convair 340/440 aircraft.

2.3.2 The AMO sent a letter to the SACAA on 18 June 2018 requesting to amend its AMO approval on the Convair 340/440 aircraft from line maintenance to full maintenance capability, stating that the new hangar (Hangar 65, FAWB) could accommodate the Convair 340/440 aircraft for maintenance. On 22 June 2018, the AMO was granted a one-time authorisation by the SACAA to carry out maintenance and full release of the aircraft to service. The approval granted by the SACAA was based on the hangar lease agreement provided by the AMO. The AMO still did not address the finding raised in respect of the training programme as it had been highlighted during the audit of 13 September 2017.

2.3.3 The AMO had insufficient capacity in respect of maintenance personnel to properly maintain the Convair 340/440 aircraft as it only had one licensed Aircraft Maintenance Engineer (AME) who was responsible for the full maintenance including the last A, B and C maintenance checks carried out on the aircraft four days prior to the accident flight. Therefore, all duplicate inspection task(s) requiring a second licensed and rated AME on a Convair 340/440 were carried out by the same licensed LAME. There were no records to suggest that the organisation had a second qualified person for the purpose of duplicate inspections. This was in contravention of Civil Aviation Regulation Part 43.04.8.

Civil Aviation Regulation Part 43.04.8 states:

Duplicate inspections of flight and engine controls

(1) No person shall certify a control system component after the initial assembly, subsequent disturbance or adjustment of any part of such control system, unless—

(a) a duplicate safety inspection of the control system has been carried out; and

(b) the duplicate safety inspection is recorded and certified in the appropriate logbook or other maintenance record approved by the Director.

(2) A duplicate safety inspection authorised in terms of sub-regulation (1), shall consist of—

(a) an inspection by a person referred to in regulation 43.04.1 to certify the release to service of the control system after maintenance; and

(b) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM in excess of 5700 kg, as prescribed in Document SA-CATS 43; or

(c) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for helicopters with a MCM in excess of 3 175 kg, as prescribed in Document SA-CATS 43; or

(d) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM below 5 700 kg and helicopters with a MCM below 3 175 kg, as prescribed in Document SA-CATS 43.

2.3.4 The AMO 1189 outsourced the category 'W' (Avion/Electrical/Instruments/ Combination) rating maintenance to another organisation which had a category 'W' rating and personnel rated with a category 'W' rating. It was found that the personnel of the organisation that performed the category 'W' rating task on behalf of the AMO 1189 were neither trained on the Convair 340/440 aircraft nor its components. This was in contravention of Civil Aviation Regulation Part 145.01.11.

Civil Aviation Regulation Part 145.01.11 states:

(1) The holder of an aircraft maintenance approval shall establish and maintain a training programme for aircraft maintenance personnel in his or her employ.

(2) The approval holder shall ensure that aircraft maintenance personnel receive, as prescribed in Document SA-CATS 145—

(a) type- or model-specific training in respect of the aircraft or aircraft components for which the organisation has received maintenance approval;

(b) training to keep abreast of new technology developments and maintenance techniques; and

(c) initial and continuation training appropriate to their assigned tasks and responsibilities.

(3) The training programme, contemplated in sub-regulation (1), shall—

(a) include training in knowledge and skills related to human factors principles, including coordination with other maintenance personnel and flight crew; and

(b) be part of the organisation's manual of procedure.

(4) Initial and recurrent training may be provided only by the holder of an ATO approval issued in terms of Part 141, or by or on behalf of the original equipment manufacturer.

2.4 **The Regulator (South African Civil Aviation Authority)**

2.4.1 The SACAA approved the AMO and issued an approval limiting the organisation to perform line maintenance due to inadequate facility to accommodate the maintenance of the Convair 340/440 aircraft; furthermore, the AMO did not have the training programme for the maintenance personnel.

2.4.2 The AMO had only one LAME rated to carry out maintenance on the Convair 340/440 aircraft, however, the SACAA issued the AMO with a full approval to maintain and release a Convair 340/440 aircraft to service. Considering the limitations of the AMO in respect of the maintenance personnel, the SACAA should have considered that the AMO had only one LAME prior to the issuance of a full maintenance approval.

2.4.3 Neither the PF nor the PM were authorised to operate a Convair 340/440 registered in South Africa as they had not done a skills test on a Convair 340/440 as required by CAR 2011, Part 61.01.13. Neither the PF's nor the PM's foreign licences validation included the Convair 340/440 as none of them had applied for the validation of a Convair 340/440 aircraft. This information is supported by the SACAA application form number CA61-01-13 that was submitted for validation of their foreign licences.

2.5 **The Aircraft**

2.5.1 Prior to this accident, the aircraft was last flown on 22 February 2018 and had 18115.1 flying hours. It was then parked for five months before it was flown again on 10 July 2018. The aircraft was being sold and the contract indicated that the aircraft would remain on the RSA register under the registered owner's name until it was delivered to the new owners in the Netherlands. The new owners were to take delivery of the aircraft in the Netherlands.

2.5.2 The maintenance records revealed that on 26 February 2018, the AMO had recorded the defect of a manifold pressure gauge indication on the No 1 engine which was sticky. As a method of rectification, the manifold dual pressure gauge was removed, cleaned, sign off and refitted to the aircraft. On 5 May 2018, the same defect was recorded by the AMO and, again, the manifold dual pressure gauge was signed off as repaired and refitted. The manifold dual pressure gauge was removed twice (in March and July 2018) over a period of four months due to the left engine manifold pressure defect. During the engine inspection and examination, it was evident that the pre-existing damage on cylinder No 7 and cylinder No 13 were the cause of the left engine manifold pressure defect. The LAME misdiagnosed the manifold pressure indication defect by always removing the manifold dual pressure gauge whenever there was a left engine manifold pressure indication defect which was reported twice prior to the accident flight.

2.5.3 The engine No 1 manifold pressure drop, as reported by the crew during the take-off roll, was the result of a fractured No 7 cylinder exhaust valve head which subsequently caused backfiring. This explains the flames by the engine cowl flaps above the cowling.

2.5.4 During take-off, fire was seen on the top front side of the left engine cowling and exhaust area (Figures 2/3). The ATC stated that the aircraft continued in a north-westerly direction from the aerodrome over Bon Accord Dam at approximately 2 to 2.5 track miles and at a height of about 800 feet AGL, indicating a rate of climb of 600 to 700 feet per minute (fpm). The ATC confirmed to the investigators that the left engine had caught fire and that the crew had broadcasted a 'MAYDAY' call; however, when the crew broadcasted 'MAYDAY' they did not indicate the nature of the emergency that they were facing. This statement was confirmed by the recordings of the cockpit GoPro camera that was installed in the cockpit at the time of the accident. Although the left engine caught fire during the take-off roll, the crew continued with the flight and did not abort the take-off. Evidence obtained from the Gopro video camera installed in the cockpit showed the LAME giving the PM the quick reference handbook (QRH). However, the PM elected to ignore and not use the QRH for procedures to be followed during an emergency in-flight engine fire as was the case during this accident flight. This, therefore, explains why the left engine continued to be on fire until the aircraft impacted the ground.

2.5.5 Pilots flying multi-engine aircraft are trained to shut down the engine whenever an engine catches fire or whenever the crew suspects fire in the engine. The engine fire in-flight checklist required that the crew shut down the left engine that was on fire and that the left propeller be feathered. The PF and PM never followed the engine fire in-flight checklist and, as a result, the left engine that caught fire was never shut down or the propeller feathered. Post-accident examinations revealed that the left propeller had not been feathered prior to impact with both engines' settings consistent with engines at take-off or climb.

2.5.6 The aircraft continued with its take-off and climbed to 800 feet AGL (with the left engine still on fire and not secured) before turning right after being cleared by ATC to return to the aerodrome due to the emergency. At this stage, the crew were just observing the LAME who was continuously operating the engine controls and overhead panel switches. This is evident on the Gopro video camera that was installed in the cockpit. Crew resource management was not observed as none of the crew attempted to use the emergency procedures checklist to respond to the in-flight left engine fire.

2.5.7 The aircraft made another right turn (base leg) while losing height. It continued in that trajectory and the PF lost aileron control. This occurred due to the weakening of the left-wing rear spar because of fire damage that caused the attachment rivets of the aileron cables to melt, resulting in the cables being slack and, thus, loss of aileron control. The loss of aileron control led to the crew losing control of the aircraft and the aircraft colliding with power lines before impacting the factory building.

This resulted in the left aileron deflecting slightly up and a left roll. This left roll was exacerbated by the left engine operating at partial power loss due to cylinder No 7 and No 13 malfunctioning while the right engine was at full power. This caused a left yaw as a result of the asymmetric engines and required the PF to always make the right rudder input to correct the left yaw. See Appendix C. This resulted in the crew losing control of the aircraft.

2.5.8 The aircraft continued in that attitude while still losing height and impacted the electrical power lines (which were 30 metres high) before impacting trees in the factory yard, the vehicles parked outside the factory building and the factory building with its left wing. The aircraft damaged the factory building as it impacted the centre of the building. The in-board left wing had also separated and was found behind the factory building with its engine a few metres behind the left in-board wing. The right engine had also separated and was found a few metres to the left of the left wing's position. The aircraft continued for a few metres before impacting the raised ground and stopped at the point of impact. The aircraft broke in two places/points and there was evidence of fire damage on the right side. The right fuel tank still contained fuel which was drained a day after the accident.

2.5.9 The LAME was fatally injured, while the crew, two passengers and four other persons on the ground sustained serious injuries. The rest of the passengers and four other persons on the ground had minor lacerations.

2.5.10 The last maintenance on the engine completed on 6 July 2018, indicated that the AMO had conducted compression tests on all cylinders for both engine 1 and 2 in accordance with the prescribed maintenance schedule (AMS) J15/09/427. The damage found on piston crown cylinder No 13 and Cylinder No 7 during the engine teardown inspection showed that the damage had existed prior to the accident. This explains the manifold pressure defect that was recorded in March 2018 and on 6 July 2018 prior to the accident. This was a clear indication that not all the cylinders had been subjected to the compression tests as was required during the A, B and C maintenance checks completed four days prior to the accident.

2.5.11 The failure of the No. 7 cylinder exhaust valve led to the cylinder cooling fins overheating, thus, causing the failure of the cylinder housing.

2.5.12 The failure of the exhaust valve and its housing led to the continuous fire coming from the cylinder through the chamber in the No 7 cylinder, given that the engine operates at a fairly high RPM. That resulted in the front main spar weakening/flaking and the damage to the aileron pulley attachments failing because of the mounting rivets melting. The melting of the rivets resulted in the pulley attachments falling into the wing and slacking the aileron control cables, which caused the aircraft to roll to the left.

2.5.13 The fire started in the left engine and evidence showed that the No 7 cylinder was the one with the most damage and was the source of the left engine fire. The fire continued burning through a hole on the No 7 cylinder, causing damage to the front wing spar and the left aileron pulley attachment point, melting the attachment rivets. As a result, the left aileron control cables slacked and the aileron deflected slightly up. With the left engine operating at partial power due to damage and failure of cylinder number 7, the aircraft started rolling to the left. The opening of the left engine cowl flaps in-flight increased the intensity of the engine fire and the left roll.

2.5.14 Piston No 13 was found with carbon build-up, damaged piston crown and oil rings, indicating that cylinder No 13 was not operating effectively. The damage on the piston crown and oil rings would result in the loss of pressure in this cylinder and the left engine not operating at optimum power.

2.5.15 The left engine continued to operate at partial power with the propeller not feathered while the right engine was on full power. Moreover, a non-feathered propeller could induce a high parasite drag on an aircraft performance. The fact that the left engine propeller was never feathered is revealed in the GoPro video camera wherein the crew never discussed securing the left-hand engine.

2.5.16 The right-engine settings were generally consistent with the engine being at full power, which was operating normal, and the right propeller's pitch was consistent with a high rotation power setting.

2.5.17 Approximately five litres of fuel was drained from the right-wing tanks at the accident site and the fuel was sent for examination. The fuel was consistent with AVGAS 100LL, which was free from contamination. The fuel test report indicated the following: fuel density — 0.717; temperature — 16.5°C; density correction — -0.0029 and 0.7141; batch density — 0.7142 and difference (1) — (2) ± good. The test results revealed that the fuel was good and clean. Two aircraft were refuelled on the same day from the same tank that was used to refuel ZS-BRV and no anomalies were reported. Oil and water methanol samples were examined and found to be within specifications and without contamination.

2.6 **Weather**

2.6.1 The weather at the time of the accident was not a factor.

2.7 **ATS**

2.7.1 ATC services provided to the accident flight, including after the PF declared an emergency, were sufficient and were not a factor in the accident.

2.7.2 The investigation revealed that during take-off, the left engine caught fire and the crew continued with the flight without securing the left engine as prescribed by the aircraft flight manual (AFM). The crew declared an emergency and attempted to return to the aerodrome, however, they lost control of the aircraft and collided with power lines prior to crashing into a factory building.

3 CONCLUSIONS

3.1. General

From the evidence available, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusions heading:

- **Findings -** are statements of all significant conditions, events or circumstances in this Accident. The findings are significant steps in this Accident sequence, but they are not always causal or indicate deficiencies.
- **Causes -** are actions, omissions, events, conditions or a combination thereof, which led to this Accident.
- **Contributing factors -** are actions, omissions, events, conditions or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 The PF had a valid Australian Air Transport Pilot Licence, Commercial Pilot Licence and Private Pilot Licence and was type rated on the aircraft (Convair 340/440). However, the validation issued by the SACAA was for a Private Pilot Licence under visual flight rules (VFR), which was issued on 9 May 2016, and expires on 5 May 2021.

3.2.2 The PF's foreign licence validation was only limited to Single Engine Land aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This was based on his foreign licence validation application and skills test report dated 9 May 2016 and the validation was valid until 5 May 2021. However, at the time of the accident, the PF was operating a multi-engine aircraft which was not in accordance with the submitted application and validation issued by the SACAA.

3.2.3 The PM's Australian Air Transport Pilot Licence, issued on 13 November 2014, was validated by the SACAA on 6 May 2016, with the expiry date of 5 May 2021. Among other documents considered by the SACAA for the issuance of the validation, they required a valid medical certificate and a valid foreign pilot's licence. At the time of application for the validation of a foreign licence in May 2016, the PM's Australian Licence submitted to the SACAA had no rating for a Convair 340/440. He acquired a Convair 340/440 rating in 2017, post the validation issued by the SACAA, therefore, although he had acquired a Convair 340/440 rating post the foreign licence validation by the SACAA, he was not authorised to operate a Convair 340/440 aircraft registered in South Africa.

3.2.4 Both pilots last flew the Convair 340/440 aircraft 17 months prior to the accident flight, therefore, none of the crew complied with the 12-month competency check.

3.2.5 Neither the PF nor the PM were authorised to operate a South African registered Convair 340/440 as they had not done a skills test and/or competency check on a Convair 340/440 as required by CAR 2011, Part 61.01.13. Neither the PF's nor the PM's foreign licences validation included the Convair 340/440 as none of them had applied for the validation of a Convair 340/440 aircraft. This information is supported by the application form number CA 61-01-13 that was submitted to the SACAA for the validation of a foreign licence by both pilots.

3.2.6 The PM's validation of his foreign licence was only limited to SEL aircraft with the following aircraft types: C150, C172, C182 and PA 28 A/B. This was based on his foreign licence validation application and skills test report dated 9 May 2016, with the validation expiring on 5 May 2021. The aviation medical certificate had been issued to the PF with the expiration date of 11 December 2018.

3.2.7 The crew resource management (CRM) in the cockpit was found lacking due to the crew not using the in-flight engine fire checklist when they declared an emergency.

3.2.8 The aircraft was certified for a two-pilot operation, however, the engine controls were operated by a LAME who was also seated in the cockpit with the crew and was not rated on the aircraft as a pilot.

3.2.9 The AMO had limited resources in respect of maintenance personnel to properly maintain the Convair 340/440 aircraft as it only had one licensed Aircraft Maintenance Engineer (LAME) who was responsible for the full maintenance including the last A, B and C maintenance checks carried out on the aircraft four days prior to the accident flight. Therefore, all duplicate inspection task(s) required in terms of Civil Aviation Regulation Part 43.04.8 were carried out by the same licensed AME according to the maintenance records provided to the investigation team. There were no records which suggested that the organisation had contracted an AME who was rated on a Convair 340/440 or any person meeting the requirements of CAR Part 43.04.8 for the purpose of duplicate inspections. This was in contravention of Civil Aviation Regulation Part 43.04.8.

3.2.10 The LAME misdiagnosed the manifold pressure defect by always removing the manifold pressure gauge whenever there was a left-engine manifold pressure defect, which was reported twice prior to the accident flight.

3.2.11 The last maintenance on the engine completed on 6 July 2018 indicated that the AMO had conducted compression tests on all cylinders for both engine 1 and 2 in accordance with the prescribed maintenance schedule (AMS) J15/09/427. The damage found on piston crown cylinder No 13 during the engine teardown inspection showed that the damage had existed prior to the accident. This explains the manifold pressure indication defect that was recorded in March 2018 and on 6 July 2018 prior to the accident. This was a clear indication that not all cylinders had been subjected to the compression tests during the last maintenance check performed on the aircraft prior to the accident flight.

3.2.12 The AMO 1189 outsourced the category 'W' (Avion/Electrical/Instruments/ Combination) rating maintenance task to another organisation that had category 'W' rating and personnel rated with a category 'W' rating. It was found that the personnel of the organisation that had performed the category 'W' rating task on behalf of the AMO 1189 were never trained on the Convair 340/440 aircraft or its components. This was in contravention of Civil Aviation Regulation Part 145.01.11.

3.2.13 The aircraft had two crew members at the time of the accident, and 17 passengers on board. The PF, PM and two passengers were seriously injured; and the LAME who was seated on the jump seat with the crew was fatally injured, while the other 14 passengers sustained minor injuries.

3.2.14 Four persons on the ground sustained serious injuries and the other four had minor injuries.

3.2.15 The FAWB ATC stated that the crew had filed their flight plan at approximately 1124Z with the Johannesburg Briefing and had indicated the estimated departure time as 1130Z. The ATC had cleared the aircraft for take-off on Runway 29 with their flight plan being FAWB-FAPN-FAWB. The clearance was given despite a NOTAM issued by FAPN prohibiting the landing of fixed wing aircraft as the runway was undergoing maintenance and was closed.

3.2.16 After the 50kts call, the PM indicated that the left manifold pressure indication appeared to be low but the crew did not abort the take-off as the aircraft had not yet reached V1 speed.

3.2.17 The assistant engineer who was seated in the left-hand side of the cabin informed the crew of the left-engine fire. The master caution light illuminated, however, the crew never activated or discharged the engine fire extinguishing system or followed the quick reference handbook (QRH).

3.2.18 The AMO had only one licensed maintenance engineer to carry out maintenance on the Convair 340/440 aircraft, however, the SACAA issued the AMO with a full approval to maintain and release a Convair 340/440 aircraft to service. Considering the limitations of the AMO in respect of the maintenance personnel, the SACAA should have considered the AMO's limitations regarding maintenance personnel prior to the issuance of a full maintenance authorisation for the Convair 340/440.

3.2.19 The No 2 engine was inspected and examined and was found to have operated normally prior to the aircraft impacting the ground.

3.2.20 Approximately five litres of fuel was drained from the right-wing tanks at the accident site and the fuel was sent for examination. The fuel was consistent with AVGAS 100LL, which was free from contamination. The fuel test report indicated the following: fuel density — 0.717; temperature — 16.5°C; density correction — -0.0029 and 0.7141; batch density — 0.7142 and difference (1) — (2) ± good. The test results revealed that the fuel was good and clean. Two aircraft were refuelled on the same day from the same tank that was used to refuel ZS-BRV and no anomalies were reported. Oil and water methanol samples were examined and found to be within specifications and without contamination.

3.2.21 The No 1 engine S/N P-37351 was subjected to a borescope inspection procedure. Cylinder No 13 was found with piston damage and carbon build-up on the valve. The build-up of the carbon deposit seemed to have happened over time while the engine was being operated.

3.2.22 The reduction gearbox forward housing separated from the engine. The No 1 engine single stage speed supercharger was inspected and nothing abnormal was detected. Both the magnetos were examined and were in a normal condition and had satisfactory spark operation. The spark plugs were in a normal condition and had satisfactory spark operation.

3.2.23 The cylinder wall was smooth with no evidence of abrasion. None of the rings was broken on any of the 16 pistons. All the bearings were found to be in good overall condition and displayed evidence of adequate lubrication. All the connecting rods were found to be in good condition; and the connecting bolts were properly secured.

3.2.24 On removal of the No 7 cylinder, the exhaust valve (P/N: 331107) head showed fracture characteristics. Further examination indicated that the inlet and the exhaust valves return springs and rocker arms were intact and in good condition. The No 7 cylinder's external area showed signs of fire damage/passage from the combustion chamber where the burning and expansion of gases had commenced, to the exterior through the aluminium cooling fins/plate, and into the engine compartment.

3.2.25 The remaining 16 cylinders were removed. On inspection, they showed signs of proper combustion. Carbon deposits on the valves were found to be normal on this type of engine. The pistons were in good condition with very little carbon build-up visible.

3.2.26 The engine No 1 manifold pressure drop, as reported by the crew during the take-off roll, was the result of a fractured No 7 cylinder exhaust valve head, which subsequently caused backfiring. This explains the flames by the engine cowl flaps above the cowling.

3.3 Probable Cause/s

3.3.1 During take-off, the left engine caught fire and the crew continued with the flight without securing the left engine as prescribed in the aircraft flight manual (AFM). The crew declared an emergency and attempted to return to the aerodrome, however, they lost control of the aircraft and collided with power lines prior to crashing into a factory building.

3.4. Contributory Factors:

3.4.1 Pre-existing damage to the cylinder No 13 piston and ring pack deformation and, most probably, the cylinder No 7's fractured exhaust valve head that were not detected during maintenance of the aircraft.

3.4.2 Substandard maintenance for failing to conduct compression tests on all cylinders during the scheduled maintenance prior to the accident.

3.4.3 Misdiagnosis of the left engine manifold pressure defect as it was reported twice prior to the accident.

3.4.4 The crew not aborting take-off at 50kts prior to reaching V1; manifold pressure fluctuation was observed by the crew at 50kts and that should have resulted in an aborted take-off.

3.4.6 Lack of crew resource management; this was evident as the crew ignored using the emergency checklist to respond to the in-flight left engine fire.

3.4.7 Lack of recency training for both the PF and PM, as well as the LAME.

3.4.8 Non-compliance to Civil Aviation Regulations by both the crew and the maintenance organisation.

4. SAFETY RECOMMENDATIONS

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report; the AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2 Safety Recommendation/s

4.2.1 It is recommended to the Director of Civil Aviation (DCA) that the SACAA should consider reviewing the process of issuing foreign licence validation certificates to ensure that the validation is issued to the aircraft rating where the requirements of CAR 2011 Part 61.01.13 have been complied with.

4.2.2 It is also recommended that the DCA reviews the rating of the Convair 340/440 aircraft issued to the AMO 1189 as it does not meet the CAR Part 145 requirements in respect of sufficient maintenance personnel required to conduct safe maintenance.

4.2.3 It is recommended that the DCA reviews the issuance of the category 'W' rating to the AMO and aircraft maintenance personnel. During the investigation of the ZS-BRV accident, it was found that the category 'W' rated personnel who were performing work on the manifold pressure gauge were never trained or licensed on the aircraft type or aircraft components of the Convair 340/440 aircraft, and this was in contravention of CAR 2011 and SACATS, Part 145.01.11. It should be noted that the aircraft in question had a category 'W' rating defect on engine No 1 and this is the engine that caught fire during the take-off roll.

Note: All the above safety recommendations were issued to the Director of Civil Aviation on 9 October 2018 and were accepted by the Director of Civil Aviation for implementation.

4.2.4 It is recommended to the Director of Civil Aviation that the SACAA should consider evaluating the effectiveness of its Part 91 operation oversight programme, as well as ensure that Part 91 operations are conducted at the same level of safety as Part 121 and 135 operations.

4.2.5 It is recommended to the Director of Civil Aviation that the SACAA review large aircraft (aircraft above 5700kg) operated under Part 91 and ensure that the manufacturer's maintenance requirements are executed by qualified and rated maintenance personnel.

5. APPENDICES

5.1 Appendix A: Communication between ATC and ZS-BRV
5.2 Appendix B: Audit findings by the SACAA on the AMO
5.3 Appendix C: Asymmetrical Condition
5.4 Appendix D: Regulations CAR 2011, Part 61.01.13
5.5 Appendix E: Regulations CAR 2011, Part 145.01.12 and SA CATS 145.01.11

ZS-BRV	TOWER	Wonderboom Tower, Bravo Romeo Victor ready
TOWER	ZS-BRV	Zulu Sierra Bravo Romeo Victor good day, behind Charlie one seven two, short final approach runway two nine line-up and wait runway two nine
ZS-BRV	TOWER	Rodger behind the Cessna one seven two, on finals behind line up behind runway two nine Bravo Romeo Victor
TOWER	ZS-BRV	Bravo Romeo Victor proceeding traffic remaining in the right circuit runway two nine cleared take-off wind two four zero degrees six knots report boundary outbound, climb to 6000 feet
ZS-BRV	TOWER	We will report…ehhh…boundary airport…ehh…runway two nine cleared to take off and six thousand Bravo Romeo Victor
ZS-BRV	TOWER	Mayday, Zulu Sierra Bravo Romeo Victor engine fire left hand engine
TOWER	ZS-BRV	Bravo Romeo Victor, report on the right downwind runway two nine (siren in the background)
TOWER	ZS-BRV	Bravo Romeo Victor, report your intentions
ZS-BRV	TOWER	Yeah, standby
TOWER	ZS-BRV	Bravo Romeo Victor, runway two, correction runway two four is available for landing
ZS-BRV	TOWER	ehhh…negative. We on downwind standby
TOWER	ZS-BRV	Bravo Romeo Victor, circuit is clear, you can fly a tight base report final approach runway two nine, number one
ZS-BRV	TOWER	Bravo Romeo Victor we *gonna* try and track for a right base two nine

		standby
ZS-BRV	Unintentional	Click click…rudder. Give me right rudder
ZS-BRV	Unintentional	I'm trying…give me right rudder…help me with it
TOWER	ZS-BRV	Bravo Romeo Victor, runway two nine cleared to land surface wind is calm
ZS-BRV	TOWER	Cleared to land runway two nine, Bravo Romeo Victor
ZS-BRV	Unintentional	I can't, give me rudder…give me rudder
TOWER	ZS-BRV	Bravo Romeo Victor position?

-END-

Appendix B

[redacted] Date: 20September 2017

NON-CONFORMANCE # F 1:	Audit Date: 13 September 2017	M/F	F	O
At the time of the Audit the AMO could not demonstrate that they have adequate facility To support the maintenance activies applied for or produce a written facilities agreement for accommodation of CONVAIR CV-340 Aircraft. (SA CAR 145.01.8)			X	

ROOT CAUSE:
Awaiting Hangar Agreement

CORRECTIVE ACTION/S TAKEN:
Awaiting Hangar Agreement will forward to CAA by 28 September 2017

		CORRECTIVE ACTION TAKEN BY: (Signature & Stamp)	VERIFIED Done BY QA: (Signature & Stamp)
TARGET DATE:	21 September 2017		
CLOSE-OUT DATE:	28 September 2017	1	NGAQA 1

PREVENTATIVE ACTION/S TAKEN:
Hangar Agreement will be kept at Sport Plane Builders facility on file

NON-CONFORMANCE # F 2:	M/F	F	O
Training programme could not be produced for review in compliance with the training requirements for the certifying personnel on the CONVAIR CV-340 Aircraft. (SA CAR 145.01.11)		X	

ROOT CAUSE:
Mr Chris Barnard has been licensed to work on the CONVAIR series

CORRECTIVE ACTION/S TAKEN:
Mr Chris Barnard has been licensed to work on the CONVAIR series and licensed on the Type since 2000, Sport Plane Builders will send the copies of license by 28 September 2017.

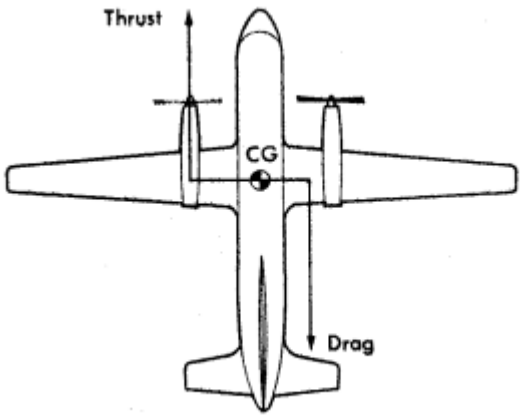
		CORRECTIVE ACTION TAKEN BY: (Signature & Stamp)	VERIFIED Done BY QA: (Signature & Stamp)
TARGET DATE:	21 September 2017		
CLOSE-OUT DATE:	28 September 2017	1	NGAQA 1

PREVENTATIVE ACTION/S TAKEN:
Mr Chris Barnard Personnel file with Licenses are kept at Sport Plane Builders facility

Appendix C

Asymmetrical Conditions

If a multi-engine airplane suffers engine failure when airborne, there are two immediate effects:
The initial effect is the yawing that occurs due to the asymmetry of the thrust line (see image below). The size of this initial yawing moment depends upon the engine thrust, the distance between the thrust line and the airplane's centre of gravity (CG), and the airplane's directional stability, which tends to oppose the asymmetric yawing moment. The yawing moment is also affected initially by the rate of thrust decay of the 'dead' engine and, ultimately, by its drag. In addition, the yaw is aggravated by the drag effect of the wind-milling propeller. The total moment can be very large, particularly when the airplane is at high power and low speed.
The second effect is roll, which occurs when the airplane continues to yaw towards the failed engine, resulting in a decrease in lift from the 'retreating' wing and a yaw-induced roll towards the failed engine. This roll is reinforced by the offset of the wings and the loss of the slipstream lift in airplanes with the propeller in front of the engine. This effect can be very pronounced, but it is well within the capacity of the ailerons to counter in all but the most abnormal cases outside design limits. It is important to understand that, although the yawing moment is the root cause of the problem, on those airplanes with considerable slipstream lift, it is imperative to counteract the roll with aileron in addition to controlling the yaw with rudder. If the yaw and roll are not corrected, the airplane will spiral into the failed engine.



http://www.cast-safety.org/pdf/5_asymmetric_flight.pdf

Appendix D

61.01.13 (1) The Director may recognise, through temporary validation or permanent conversion, on the conditions prescribed in this Part, pilot licences and ratings issued by an appropriate authority of a Contracting State if the standard of such foreign licence or rating is deemed to be equivalent to, or higher than, the South African licence or rating.

(2) (*a*) A person who holds a current and valid pilot licence issued by another Contracting State in accordance with ICAO Annex 1 to the Convention, may apply for a validation or conversion of such licence and associated ratings, for use on aircraft registered in South Africa.

(*b*) A foreign licence or rating shall only be validated or converted provided the minimum experience requirements for the issue of the applicable South African licence or rating have been met.

(3) Where the country of issue is not a Contracting State or does not comply with Annexes 1 and 6 to the Convention, then the foreign licence holder must undergo bridging training to the extent determined by the Director in individual cases and thereafter further assessment of competence to ensure compatibility with the relevant South African licensing standards.

(4) Before the Director validates or converts a foreign licence or rating for a commercial air transport operation or a PPL with Instrument Rating (PPL/IR), he or she must confirm the validity of the foreign licence or rating with the appropriate authority of the issuing Contracting State.

(5) Notwithstanding the provisions of subregulations (1) and (2), any applicant for the validation of a foreign licence or rating must undergo the appropriate skills test and—

(*a*) in the case of validation for use as a private pilot under VFR conditions (PPL/VFR), must—

(i) have attended a tutorial, conducted by at least a Grade III flight instructor at an approved Part 141 ATO on the differences in airspaces and terminology within South Africa;

(ii) have received a briefing on performance planning, taking into account the effect of density altitude; and

(iii) write an Authority approved examination in South African Air Law conducted by an approved Part 141 ATO; or

(*b*) in the case of validation for use as a private pilot under IFR conditions (PPL/IFR) must—

(i) have attended a tutorial, conducted by at least a Grade II flight instructor at an approved Part 141 ATO on the differences in airspaces and terminology within South Africa;

(ii) have received a briefing on performance planning taking into account the effect of density altitude; and

(iii) pass an examination on South African Air Law and Procedures at an approved Authority Examination Centre; or

(*c*) in the case of validation for use as a commercial pilot under VFR conditions (CPL/VFR) or as an airline transport pilot (helicopter) without instrument rating, must have passed an examination in South African Air Law at CPL level at an approved Authority Examination Centre; or

(*d*) in the case of validation for use as a commercial pilot under IFR conditions (CPL/IFR) or as an airline transport pilot (aeroplane) or as an airline transport pilot (helicopter) with instrument rating, must have passed an examination in South African Air Law and Procedures at an approved Authority Examination Centre.

Appendix E

Training and checking

145.01.11 (1) The holder of an aircraft maintenance approval shall establish and maintain a training programme for aircraft maintenance personnel in his or her employ.

(2) The approval holder shall ensure that aircraft maintenance personnel receive as prescribed in Document SA-CATS 145—

(*a*) type- or model-specific training in respect of the aircraft or aircraft components for which the organisation has received maintenance approval;

(*b*) training to keep abreast of new technology developments and maintenance techniques; and

(*c*) initial and continuation training appropriate to their assigned tasks and responsibilities.

(3) The training programme, contemplated in sub-regulation (1), shall—

(*a*) include training in knowledge and skills related to human factors principles, including coordination with other maintenance personnel and flight crew; and

(*b*) be part of the organisation's manual of procedure.