



AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/8706	
Aircraft Registration	ZU-BEX	Date of Accident	14 November 2009		Time of Accident	1022Z
Type of Aircraft	English Electric Lightning MK T5		Type of Operation		Commercial – Air Show	
Pilot-in-command Licence Type		Airline Transport	Age	46	Licence Valid	Yes
Pilot-in-command Flying Experience		Total Flying Hours	10993.0		Hours on Type	unknown
Last point of departure		Overberg – Test Flying and Development Aerodrome (FAOB)				
Next point of intended landing		Overberg – Test Flying and Development Aerodrome (FAOB)				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)						
Overberg – Test Flying and Development Aerodrome (FAOB) at GPS co-ordinates: S 34°31.232 E020°22.618						
Meteorological Information		Wind direction: 250° , Wind speed: 10 kts , Temperature: 20°C, Visibility: Good, Cloud cover: 5/8, Cloud base: 2500 ft.				
Number of people on board	1 + 0	No. of people injured	0	No. of people killed	1	
Synopsis						
<p>On Saturday morning, 14 November 2009, the pilot flew the EE Lightning aircraft in an air show at Overberg Test Flying and Development Aerodrome (FAOB). The pilot was the sole occupant on board the aircraft at the time. The pilot reported to FAOB ATC that he was experiencing a double hydraulic failure in flight. The pilot was cleared to return to the aerodrome and execute an emergency landing. The pilot lowered the undercarriage but experienced an undercarriage failure when the left side main gear not extend. The pilot attempted to correct the undercarriage failure situation with emergency gear extension procedures, but he was unsuccessful. Following the undercarriage emergency the pilot reported that it was becoming increasingly difficult for him to control the aircraft. The pilot opted to eject “bail-out” from the aircraft, but experienced an ejection seat failure. The pilot was trapped inside the aircraft when it impacted the ground at a high speed. The aircraft was destroyed in the ground impact sequence and the pilot was fatally injured in the process.</p>						
Probable Cause						
Uncontrolled flight due to double hydraulic failure.						
Contributory Factors						
<p>There was evidence found indicating that the aircraft was exposed to a pre impact fire in flight and the heat from the fire probably caused damage to the components or parts in the hydraulic system.</p> <p>The pilot experienced a double hydraulic failure (HYD 1 and HYD 2) in flight.</p>						
IARC Date				Release Date		

AIRCRAFT ACCIDENT REPORT

Name of Owner/Operator : Thunder City (Pty) Ltd.
Manufacturer : British Aerospace
Model : English Electric Lightning MK T5
Nationality : South African
Registration Marks : ZU-BEX
Place : Overberg – Test Flying and Development Aerodrome
(FAOB) at GPS co-ordinates: S 34°31.232 E020°22.618
Date : 14 November 2009
Time : 1022Z

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

Purpose of the Investigation :

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

Disclaimer:

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

1. FACTUAL INFORMATION

1.1 History of Flight

- 1.1.1 Thunder City Flying Company (Pty) Ltd trading as Thunder City was invited by South African Air Force (SAAF) to participate in a special air event (air show) at FAOB. Thunder City accepted the invitation and dispatched their ex-military aircraft to the venue. The English Electric Lightning MK T5 aircraft, with registration numbers ZU-BEX was one of the aircraft. The EE Lightning was refuelled at Cape Town International Aerodrome (FACT) uplifting sufficient fuel (7600 lbs) of fuel and a pre-flight inspection carried out where after it was certified airworthy for the next flight.
- 1.1.2 On Friday, 13 November 2009 at 1219Z, the EE Lightning was flown from FACT to Air Force Base Overberg Flying and Development Military Aerodrome (FAOB). The pilot accompanied by a passenger flew the aircraft in a commercial air transportation flight under visual flight rules (VFR) by day. A flight plan, which was filed at FACT Air Traffic Control (ATC) Centre, shows that the aircraft was cleared to do a vertical climb out to flight level – FL200 above the field and maintain heading on FL350 direct to FAOB. After an uneventful flight, at 1229Z the aircraft entered the controlled airspace of FAOB. The pilot reported his position to FAOB ATC and he was cleared to land on Runway 28.

Validation Flight Approval:

- 1.1.3 The pilot made a decision not to land but he instead asked for permission to straight away proceed with his validation flight. The SAAF Safety Officer approved this request. The Safety Officer evaluated the aerobatic display sequence of the validation flight. The Safety Officer found that the validation flight was satisfactory and it was approved. After the validation flight was completed, FAOB ATC gave clearance to the pilot to land on Runway 28. During the landing sequence on the runway, the brake parachute was deployed and brakes applied to bring the aircraft to a stop. The pilot back tracked and taxied the aircraft to the allocated parking bay at Apron B (bravo). There was no proof of a defect or malfunction reported after the validation flight.

Late afternoon flight:

- 1.1.4 Later that day the pilot flew the aircraft again in a late afternoon air show flight at 1728Z. The evening air show was an event for ticket holders of the wine tasting, auction and dinner charity function. The evening air show was described by those that witnessed it as being an “*amazing spectacle*”. The pilot was accompanied by a different passenger inside the aircraft during the evening air show. The pilot performed an aerobatic display using Runway 28 as a line reference and demonstrated the visual effects of the afterburner plume. He then returned to the aerodrome at 1748Z and landed the aircraft.

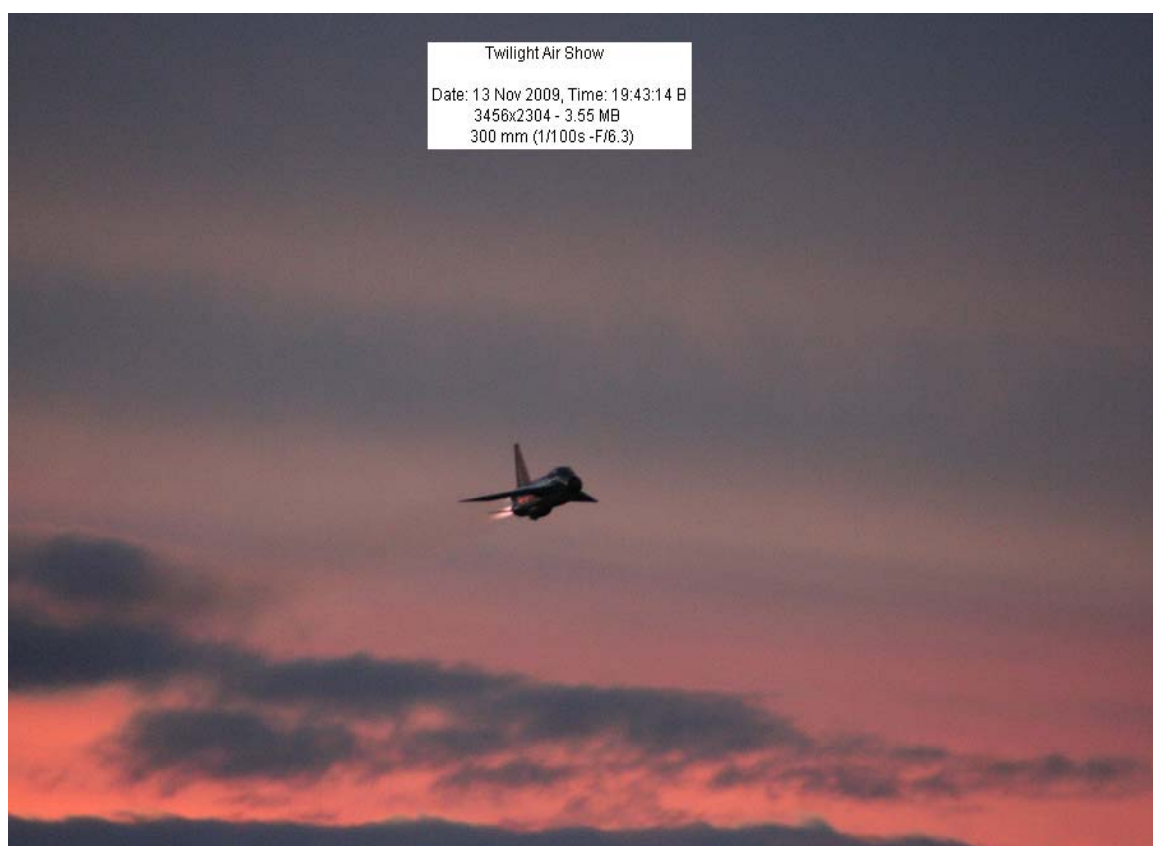


Figure 1, shows the EE Lightning aircraft flying in the evening air show at FAOB

1.1.5 The evidence shows that during the landing sequence the pilot applied maximum braking due to the brake parachute that was not deployed. The brake parachute was not installed after the previous landing of the validation flight due to certain spares not being available. The time when the aircraft came to a stop, the pilot back track and taxied to Apron B via “Echo” turning left into “Alpha” taxiways. In front of the crowd at Apron A (*venue of the wine auction and charity function*) the pilot decided to bring the aircraft to a stop and he performed the final **“show stopper”** of the day for the audience. The pilot lit engine #2 afterburner. Thereafter he proceeded to taxi to Apron B. During the taxi roll, approximately 100 meters from the point where the afterburners was lit. The pilot suddenly experienced an engine flameout condition and immediately reported to ATC that he was attempting a relight. The ATC observed a large flame followed by white smoke exit the engine exhaust. The flame and smoke situation was brought to the attention of the pilot. The pilot responded that he was **“going to shut it down”** – referring to the aircraft. The pilot realised it was not going to be possible to restart and taxi the aircraft back to its allocated parking bay . He requested assistance from ground personnel to tow the aircraft back to Apron B.



Figure 2, shows engine #2 afterburner being lit after the evening air show flight.

1.1.6 The passenger that flew with the pilot in the evening air show stated that he and the pilot were sitting inside the aircraft waiting to be towed. The aircraft could not be towed due to the ground equipment (tow bars) that did not arrive at FAOB. Thunder City’s ground crew personnel were still on the road driving from Cape Town to bring the ground equipment to FAOB. The pilot and passenger waited for a few minutes, before they decided to help each other to install the safety pins to their ejection seats and disembark the aircraft. The pilot went to the charity event where he joined his peers and the passenger was left with the responsibility to ensure the aircraft was towed to its allocated parking bay. The passenger had to borrow a tow bar for the task. No maintenance was carried out to determine the cause of the engine flameout and relight being unsuccessful. The aircraft was left outside overnight parked on Apron B.

- 1.1.7 On Saturday morning, 14 November 2009, the ground crew personnel gathered at Apron B to carry out line maintenance inspections (pre-flight) to prepare the aircraft for the air show. The aircraft was refuelled at 0800Z, uplifting sufficient quantity of fuel. After refuelling was completed, the aircraft started to leak fuel. The fuel leak was causing a large spillage on the apron. The Aerodrome Rescue and Fire fighting services (ARFF) were called out to the apron at 0818Z for fuel spillage containment. The ARFF personnel discovered that the EE Lightning was leaking fuel continuously. The ARFF personnel attempted to contain the fuel spillage using oclansorb and drip trays underneath the aircraft. The fuel containment measures taken were only temporarily, because the fuel was still leaking constantly. The ARFF personnel were convinced by Thunder City's ground crew personnel explaining to them that the fuel leak was a normal occurrence. The ARFF personnel reported the matter to the Fire Station duty room and returned to the station at 0838Z.
- 1.1.8 The aircraft was prepared and ready for the air show at 0940Z. According to the Air Show Flying Program, this aircraft was scheduled to perform its aerobatic display flight in slot #15 at approximately 1003Z. But the EE Lightning was moved up the list to slot #13 at approximately 0945Z. The change was due to another aircraft which was scheduled in slot #13 becoming unserviceable. The pilot was notified of the slot change and requested to prepare for the earlier take off. The pilot started up at 0945Z and taxied to Runway 28, lined up on the runway ready for takeoff. The ATC gave the take off clearance at approximately 0952Z and once airborne was handed over to a different frequency to communicate directly with the Safety Officer.
- 1.1.9 Approximately half way into the aerobatic display the pilot suddenly experienced an emergency situation at 1016Z. The pilot transmitted an urgency call "**PAN – PAN - PAN**" three times at 1017Z. The pilot reported that he was having a double hydraulic failure. The ATC took over communication and requested the pilot to report his position. The pilot reported that he was on a high final base leg for Runway 28. The ATC notified the pilot that the safety barrier net was raised on Runway 28 and ARFF personnel put on standby. When the runway was in sight, the pilot selected undercarriage down lowering it for the landing. The left hand side main landing gear remained retracted. The pilot decided to attempt a manoeuvre "blow down". This may be probably to follow the emergency undercarriage blow down procedure, which was by pulling the emergency selector and/or exposing the aircraft to "G" forces – shake the wings (side to side) to extend the gear. The pilot was not successful in attempting to lower the affected landing gear and it remained retracted.
- 1.1.10 The emergency escalated whereby the pilot experienced difficulty in controlling the aircraft. Shortly thereafter the pilot reported that he was going to eject. The ATC instructed the pilot to fly the aircraft to the air ground target (AGT) area, located on the eastern side of the aerodrome for the ejection. The aircraft position was over the sea and the pilot was attempting to steer it toward the AGT. The pilot reported that he was losing control of the aircraft and that he may have to eject. The time when the aircraft reached the AGT area, ATC observed that the aircraft was turning towards the crowd line and directed the pilot to turn more to the right in the direction of the AGT.

1.1.11 The pilot followed the instruction but reported that he was struggling to control the aircraft. The pilot was concerned about the safety of the spectators and requested information if the area below him was clear. The aircraft was descending in a nose down attitude towards the ground, rolling over toward the right, going inverted. The pilot attempted to eject from the aircraft, but experienced a problem with the ejection seat. The ejection seat did not eject as required. The pilot called out “*ejection seat failure - ejection seat failure*” before the aircraft impacted the ground.

1.1.12 The ATC was using binoculars to follow the movements of the aircraft and could not see the pilot ejecting from aircraft. A ball of dark smoke was emanating from the location of the accident site after the aircraft impacted the ground. The ARFF personnel were given instructions to fly and drive out to the AGT location of the accident site. The ARFF personnel was required to assist the pilot if found that he successfully ejected from the aircraft. The evidence shows that the aircraft exploded during the impact sequence. The area in which the debris was scattered was in a fan shape and determined to be approximately 37 000 square meters from the impact crater. The wreckage and vegetation was consumed by the post impact fire. The aircraft was destroyed and the pilot was fatally injured.

1.2 Injuries to Persons

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

1.3 Damage to Aircraft

1.3.1 The aircraft was destroyed during ground impact sequence and by post impact fire.



Figure 3, shows the impact area.

1.4 Other Damage

1.4.1 Some vegetation (trees and grass) was destroyed by the post impact fire.

1.5 Personnel Information

1.5.1 Pilot in command (PIC):

Nationality	South African	Gender	Male	Age	46
Licence Number	0270202070	Licence Type	Airline Transport		
Licence valid	Yes	Type Endorsed	Yes		
Ratings	Test Pilot Class 1, Flight Tests – Multi & Single Engine Piston, Instrument, MNPS/RVSM, Night Ratings.				
Medical Expiry Date	30 November 2009				
Restrictions	None				
Previous Accidents	None				

Flying Experience:

Note: Information obtained from pilot file dated 21 May 2009.

Experienced	Pilot-in-command	Co-Pilot	Dual	Total
Flying hours last 6 months	00.0	302.7	8.0	310.7
Flying hours last 12 months	00.0	502.7	8.0	510.7
Grand total flying hours	3719.8	6202.6	1070.6	10993.0
Instrument Rating				
Instrument flying hours last 6 months	00.0	118.0	00.0	118.0

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

1.5.2 The flying experience included in the table above comes from an “*Application for Initial or Revalidation of Commercial or Airline Transport Pilot licence*” document dated 21 May 2009. The pilot submitted the document to the SACAA when applying to renew his license. The record of flying experience was calculated by the pilot.

1.5.3 The pilot experience logbook could not be located during the investigation process. The dependants reported that the pilot used to keep record of his flying experience on his personal laptop computer. The laptop computer was unlawfully removed from the pilot house after the accident. The logbook and laptop was declared missing in the investigation. It was not possible to determine the total amount of hours, total hours on type and hours flown over the 90 day period prior to the accident, hence identified as unknown in the column above.

1.5.4 The pilot started his aviation career in the SAAF. He gained extensive flying experience on different types of military aircraft. The pilot was also performing duties as a test pilot while in the SAAF. The pilot resigned from the SAAF and commenced employment with a local commercial airline on 02 June 1997. He flew the Boeing B737 and B747 series aircraft, both as pilot in command (PIC) and co-pilot. The pilot had various types of aircraft endorsed on his license. On 31 August 2009, he resigned from the airline to further his flying career abroad. The pilot was a **“freelance pilot”** for Thunder City. He was flying freelance for the past 11 years. The pilot flew the ex-military aircraft for Thunder City. The flight which he normally flew was to participate in special air events (air shows). The pilot was appointed Safety Officer for the duration that he was flying for Thunder City.

1.5.5 Aero Club of South Africa (AeCSA): The pilot membership with the AeCSA was not renewed. Hence all the ratings included on the membership card expired during 2007. The result was that he did not hold a valid display rating at the time of this flight. As such he was not supposed to participate in the air show without a valid display rating. **(Appendix A, see attached copy of AeCSA membership card)**

1.5.6 *Maintenance Personnel Experience:* Thunder City AMO deployed four of their maintenance personnel to act as ground crew members at FAOB. Their duties were to provide line maintenance and technical support to the aircraft for the duration of the air show which was in accordance with maintenance away from base procedures. The maintenance personnel became relevant due to the role they played in performing maintenance on the aircraft.

1.5.7 Thunder City’s AMO approved manual of procedures (MoP) indicated that the organisation had a total number of 11 certifying inspectors on their list of certifying personnel. It was later discovered that 8 certifying inspectors resigned from the AMO and only 4 remained. See below personnel experiences of the four certifying inspectors:

1.5.7.1 *Certifying Inspector A:* The certifying Inspector started his aviation career in the SAAF. He resigned from the SAAF and started working for Thunder City AMO. The certifying inspector worked at Thunder City AMO for the past nine (9) years. His position in the organisation was appointed as a Licensed Engineer/Certifying Inspector. The certifying inspector had a valid aircraft maintenance engineer (AME) Licence. The information on his license included the following:

Nationality	South African	Gender	Male	Age	43
Licence Number	0272269069	Licence Type	Aircraft Maintenance Engineer (AME)		
Licence valid (issued) (expiry)	21 November 2009 22 November 2007	Type Endorsed	No		
Rating	Category A - Aerospatiale SA 330 series Category C – Engines fitted to rotorcraft for which Category A rating held. Note: Subject to valid company certificate being held.				

1.5.7.2 *Approved Person (AP) Certificate*: Certifying Inspector A was a member of AeCSA. He had a valid AP certificate issued on 13 February 2009. The AP certificate was valid until 28 February 2011. The AP certificate authorised him to carry out maintenance on Non Type Certificated Aircraft (NTCA) which included the ex-military EE Lightning MK T5 type aircraft.

1.5.7.3 *Thunder City AMO issued Company Authorisation*: Certifying Inspector A was last issued with a Company Authorisation Certificate on 28 February 2007. The certifying inspector was authorised to certify Certificates of Release to Service (CRS) relevant to the work carried out on the airframes, engines and associated systems on all Thunder City aircraft.

1.5.7.4 *Certifying Inspector B*: The certifying inspector also started his aviation career in the SAAF. The inspector resigned and started working for Thunder City AMO. He was employed by Thunder City AMO for the past 11 years. His position in the organisation was Certifying Inspector of Ejection Seats.

1.5.7.5 *Thunder City AMO Company Authorisation Certificate*: Certifying Inspector B was last issued with company authorisation certificate on 28 February 2008. He was authorised to carry out maintenance on Martin Baker Ejection Seats fitted on Thunder City aircraft.

Note: The Company Authorisation Certificate issued to the certifying inspector was not signed by Thunder City's Engineering Manager as required by the approved Manual of Procedures (MoP), however, the certifying inspector continued to exercise the privileges of the company authorisation which became invalid due to the anomaly.

1.5.7.6 Certifying Inspector B was never a member or issued with an AP rating by AeCSA.

1.5.7.7 *Certifying Inspector C*: The certifying inspector started his aviation career also in the SAAF. After resigning from the SAAF, he started working for Thunder City AMO. He was employed in the organization for twenty four months. His was responsible for electrical and instrumentation maintenance of Thunder City aircraft. The certifying inspector had a valid AME License with a Category W, Class W1 rating endorsement. The privileges of the license were to carry out aircraft electrical installation (direct and alternating) current only.

Note: There was no evidence showing that Thunder City AMO ever issued a Company Authorisation Certificate to Certifying Inspector C as required by their approved Manual of Procedures (MoP). The certifying inspector exercised the company authorisation privileges without it actually being issued.

1.5.7.8 Certifying Inspector C was never a member or issued with an AP rating by AeCSA.

1.5.7.9 *Certifying Inspector D*: The certifying inspector started his aviation career in South African Airways (SAA) from 1980 to 1990. After completing his apprenticeship, SAA gave him company authorisation to work on Boeing 747 aircraft. He resigned from SAA, worked for Air Mauritius and National Airways Corporation (NAC). Thunder City AMO hired him on 01 January 2009.

Note: Certifying Inspector D was not an AME License holder. He was also not issued with a Company Authorisation Certificate. His name was not on list of certifying inspector authorise to carry out maintenance of Thunder City aircraft.

1.5.7.10 Certifying Inspector D was not a member or issued with an AP rating by AeCSA.

1.5.7.11 Thunder City AMO had no proof that all the above identified certifying inspectors were ever exposed to any technical training on the airframe, engine and systems of the EE Lightning aircraft. They gained experience from working under supervision of other personnel. Certifying Inspector A was the most experienced on the type and acted in a supervisory role to the other airframe and engine certifying inspectors. Certifying Inspector C had no person of similar trade to supervise him on the aircraft. He was not familiar with the operation of the systems of the aircraft. **(Appendix B, see attached copies of company certification)**

1.6 Aircraft Information

Airframe:

Type	English Electric Lightning MK T5		
Serial Number	95011		
Manufacturer	British Aerospace		
Date of Manufacture	05 June 1969		
Total Airframe Hours (At time of Accident)	1739.0		
Last Annual Inspection (Date & Hours)	14 October 2009	1737.2	
Hours since Last Annual Inspection	1.8		
Authority to Fly (Issue Date)(Expiry Date)	(issue date) 26 October 2009	(expiry date) 12 October 2010	
C of R (Issue Date) (Present owner)	24 February 1997 Thunder City Aircraft Company (Pty) Ltd.		
Operating Categories	Commercial Authority to Fly (Part 96)		

Engine: #1

Type	Rolls Royce Avon 302C		
Serial Number	9932		
Hours since New	675.20	Cycles since New	Unknown
Hours since Overhaul	Not reached		

Engine: #2

Type	Rolls Royce Avon 302C		
Serial Number	11023		
Hours since New	543.0	Cycles since New	Unknown
Hours since Overhaul	Not reached		

1.6.1 From Wikipedia website:- *“The English Electric Lightning is a supersonic jet fighter aircraft of the Cold War era, remembered for its great speed and unpainted natural metal exterior finish. It is the only all-British Mach 2 fighter aircraft. The aircraft was renowned for its capabilities as an interceptor; Royal Air Force (RAF) pilots described it as **“being saddled to a skyrocket”**. The EE Lightning was used throughout much of its service life by the RAF and the Royal Saudi Air Force. The aircraft was a regular performer at air shows and was the first aircraft capable of super cruise. The EE Lightning was also one of the highest performance aircraft ever used in formation aerobatics. During the years of service in RAF, a number of EE Lightning aircraft were lost in accidents. The type was later phased out of service and some were sold to private owners. The EE Lightning aircraft was retired to museums, but three examples were maintained in a flyable condition at Thunder City in Cape Town, South Africa”*.

1.6.2 *United Kingdom (UK) Register*: According to the aircraft file, the EE Lightning aircraft was painted with registration numbers G-LTNG and last flown in the UK on 25 November 1976. The total time since new (TTSN) was 1596.55 hours, 2454 landings and 5566 cycles. The aircraft was sold to an owner residing in South Africa. The aircraft was then deregistered from UK Register of Civil Aircraft effective from 13 February 1997. The new owner took ownership of the aircraft in May 1997.

1.6.3 *South African Registration Process*: According to the certification file, there was a letter submitted to the National Department of Transport (NDOT) on 19 August 1996. The letter notified the NDOT of the owner’s intention to import the aircraft to South Africa. In a second letter dated 18 October 1996 the NDOT was invited by the owner to carry out a type acceptance inspection in order to allow that the aircraft be registered on the South African Civil Aircraft Register. The NDOT (Transport Ministry Office) received the letter but forwarded it to the relevant department (Inspectorate). The Inspectorate was requested to give recommendations to the Minister of Transport into the matter. On 21 October 1996, the recommendations were forwarded to the Transport Minister’s Office. Based on the recommendation the Minister of Transport approved that the aircraft may be imported and registered.

Note: The evidence shows that the owner had previously registered two Hawker Hunters, a Blackburn Buccaneer and English Electric Canberra aircraft which was also imported into South Africa. All three aircraft types were all involved in accidents before the request that G-LTNG be imported.

1.6.4 The exportation process was delayed by the UK Civil Aviation Authority (UK CAA). The UK CAA refused to issue a **Permit to Fly** to the owner. Without the permit to fly, the owner was not able to ferry the aircraft from the UK to South Africa. The UK CAA position was that the aircraft, which was classified as being a **“complex aircraft”** must be supported by its manufacturer. The situation was that the aircraft manufacturer – British Aerospace Systems (BAe) was no longer supporting the type. The UK CAA was enforcing their regulations and was not willing to compromise. The issuance of the permit to fly could not be resolved hence the owner requesting help from the NDOT.

- 1.6.5 Lines of communication were established between UK CAA and NDOT. The NDOT was of the opinion that the ex-military aircraft was relatively **“simple technology”**; provided that more complex equipment associated with the operational role of the aircraft (i.e. radar equipment, weapons systems and missile systems) to be removed or disabled. They believed strongly that if the identified equipment is removed from the aircraft, it may be safely classified as being **“intermediate”** rather than **“complex”**. The NDOT recommended that if the owner satisfies the requirements for organisation, supervision and management of maintenance engineering and flight operations, with necessary back up of spares ground equipment, engineering resources and qualified personnel. Only then will the aircraft be considered safe to operate in South Africa. **(Appendix C , see attached copy of communication between UK CAA and NDOT)**
- 1.6.6 The UK CAA Head of Applications and Certification Section responded to the comments made by NDOT and informing them that the ***in-service accident data of the English Electric Lightning type of aircraft demonstrated a safety record which is considerably worse than other similar ex-military aircraft issued with a permit to fly in the UK.*** The UK CAA did not change their decision about the issuance of the permit to fly. The two States Organisations (UK CAA and NDOT) came to a resolution that the aircraft would be disassembled, packed into a container and transported to South Africa.
- 1.6.7 *Certificate of Registration (C of R):* The aircraft was reassembled in South Africa on 21 October 1996. It was registered on the South African Civil Aircraft Register on 24 February 1997. The aircraft was then registered in the name of Thunder City, after Change of Ownership on May 1997.
- 1.6.8 *Certificate of Airworthiness (C of A):* The owner submitted an application for issuance of Certificate of Airworthiness (C of A) on 10 August 2000. The aircraft was then issued with an Experimental C of A on 31 August 2000. The aircraft operated in experimental category until 30 June 2003. The aircraft was re-classified as a Non Type Certificated Aircraft and the C of A status changed to Commercial Authority to Fly on 14 February 2005. The owner operated the aircraft commercially until the accident occurred.
- 1.6.9 *Annual Inspection:* The aircraft had an Annual Inspection (Check 1) on 14 October 2009. Thunder City AMO was requested to submit the annual inspection maintenance records for review. During the review process the following anomalies were identified:
- (i) There were no entries made on the job card to indicate that a pre-inspection of notable defects was carried out on the aircraft.
 - (ii) The work pack was not certified as required by the regulations. The maintenance supervisor did not certify the work pack as required by the Servicing Record: AP101B-1000-5B2. The same anomaly (supervisor not certifying maintenance) was recurring in the Change of Serviceability Log.
 - (iii) There was also no indication that any dual inspections were carried out during the Annual Inspection as required by applicable manufacturer service instructions.
 - (iv) The work pack was incomplete (pages missing).

1.6.10 *Certificate of Release to Service (CRS)*: The CRS of the aircraft was invalid. The evidence shows that the CRS was last issued 7 years ago on 31 December 2002. The CRS lapsed when the aircraft reached a total of 1672.0 airframe hours.

Note: The owner did not act in accordance with applicable regulation, to ensure that the CRS was validated for the prescribed calendar (12 months) and 100 hour flight time; or other time as approved by the Commissioner. The regulation also requires that the aircraft may only be considered airworthy if it has been issued with a valid CRS. (Appendix D, see attached copy of invalid CRS)

1.6.11 After the Annual Inspection was certified, Thunder City AMO submitted to the SACAA an application to renew the Authority to Fly. The SACAA issued a Commercial Authority to Fly on 26 October 2009. The Commercial Authority to Fly was expiring on 12 October 2010. The aircraft was flown on 30 October 2009. The pilot recorded 5 defects in the Change of Serviceability Log. Thunder City AMO corrective actions was the following:

Date	Hours	How found & by whom	Reason for placing unserviceable	Record of work carried out
30/10/09	1738.3	FLT by pilot	Engine #1 nozzles to be inspected uncommanded fluctuation in #1 AB. AT-FW Power	Deferred to next service (Check 2)
30/10/09	1738.3	FLT by pilot	Fuel venting overboard during taxi	Deferred to next service (Check 2)
30/10/09	1738.3	FLT by pilot	Gen cuts out at low r.p.m with associated low battery voltage	Deferred to next service (Check 2)
30/10/09	1738.3	FLT by pilot	Load background noise associated with generator Alt or inverter	Deferred to next service (Check 2)
30/10/09	1738.3	FLT by pilot	Fuel leaking into pitot/static system (leaking out of pitot probe)	Pitot static system drained

Table 1, shows the list of deferred defects in Change of Serviceability Log.

1.6.12 *Engine flameout*: On 13 November 2009, the engine #2 flamed out after the afterburner was lit. The pilot attempted to relight the engine, but he was unsuccessful. The ATC observed a large flame exiting the engine exhaust immediately followed by white smoke during the attempted relight. The pilot reported to ATC that he was shutting the aircraft down completely. The aircraft was standing on the runway for approximately 5 minutes, before the pilot attempted to restart. The pilot reported to ATC that external power was needed. The engine/s could not start and the aircraft had to be towed back to Apron B.

Note: The maintenance personnel, stating that they were not informed or logbook entries made of the engine flame out situation, as a result no maintenance or any sort of inspection carried out on the aircraft to determine the cause of the engine flameout.

1.6.13 *Double Hydraulic Failure:* On 14 November 2009 during the display flight, the pilot reported that he was experiencing an emergency situation related to the hydraulic system. The EE Lightning was experiencing a double hydraulic failure. The maintenance records of the aircraft were reviewed to determine if this was an isolated case or re-occurring defect:

- (i) According to the aircraft file, there was an incident related to a hydraulic failure which was previously reported on 15 May 2003. Thunder City AMO conducted its own internal investigation. The findings were that the aircraft experienced a hydraulic (HYD 1) indication. It was determined that the hydraulic (HYD 1) pump failed internally. The corrective action taken was to replace the unserviceable hydraulic pump and to carry out system checks in accordance with applicable maintenance procedures. The serviceable hydraulic pump, serial number: W7646 was fitted on the aircraft. The aircraft was certified serviceable and released to service.
- (ii) During the onsite investigation, the hydraulic pumps (Type: 220MK63, Serial Number: W7646) on engine #1 and (Type: 180MK70, Serial Number: W4407) on engine #2 was located. The identified hydraulic pumps separated from the engines during the ground impact sequence. The pumps were recovered from the accident site for testing.

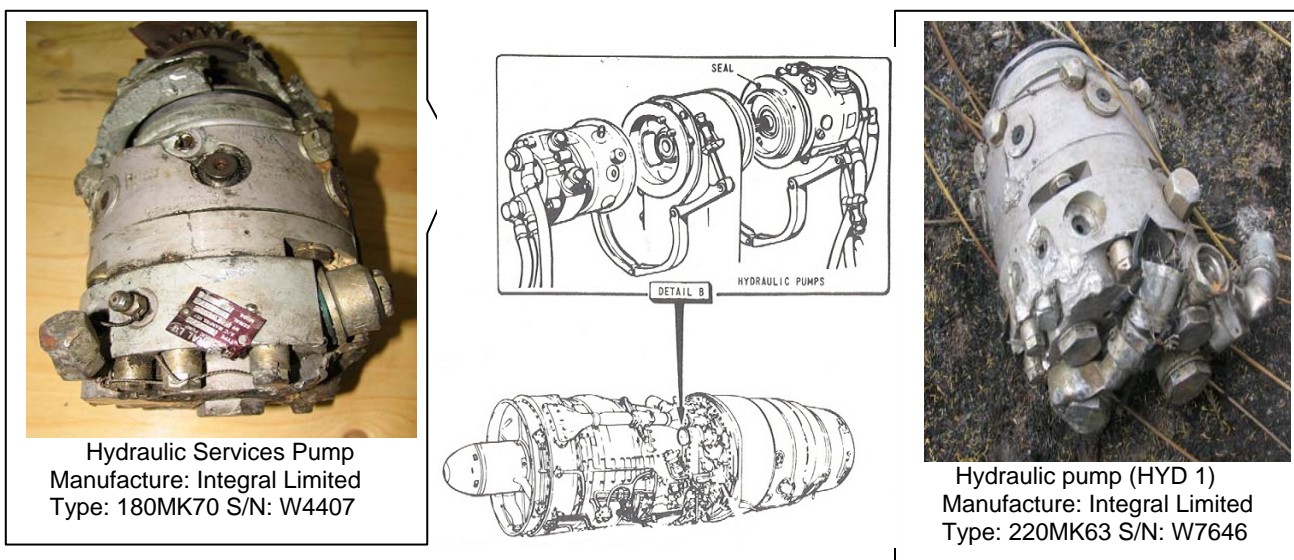


Figure 4, shows Hydraulic Services Pump and Hydraulic (HYD1) Pump.

- (iii) The hydraulic pumps identified above had no records of service life, overhaul status and repairs carried out prior to installation. The hydraulic pump (HYD 1 - S/N: W7646) was fitted to the aircraft on 16 May 2003. It was determined that the pump was operating for approximately 110.65 hours (1679.35 to 1790.00) until the accident. The other hydraulic pump (HYD 2 – S/N W4407) had the same anomaly of maintenance history not available.

(iv) The hydraulic pump (S/n W4407) identification does not appear in the Aircraft Maintenance Manual (AMM) as a listed hydraulic pump. The pump was identified in a component life extension document as being either engine #1 or #2 services pump which was introduced by modification 4774. The pump still had attached to it a part of the drive gearing from the engine. All flexible hoses had broken off. The presumption was that the flexible hoses were destroyed in the ground impact sequence. Both pumps appeared to be in compliance with the latest modifications.

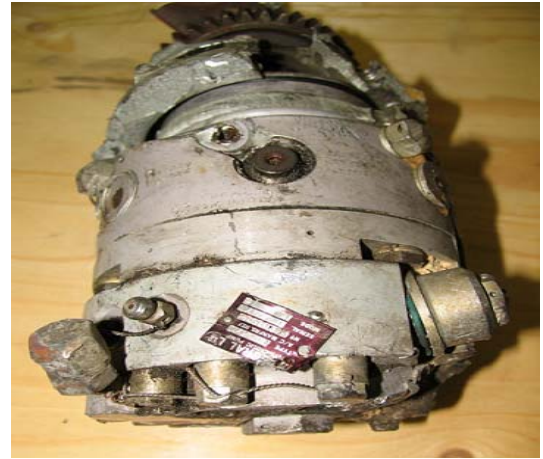


Figure 5, shows Hydraulic Pump.

(v) The hydraulic pump (S/N W7646) still had small pieces of flexible hoses attached to it. The bonded seals on the pump were supposed to have viton tape wrapped around to prevent a hydraulic oil spray in the event of a seal failure. The anomaly identified was that the pump seals did not have viton tape wrapped around. It is unlikely that the viton tape and wire locking was removed by the accident impact, particularly as the unions are relatively undamaged. This would suggest the viton tape had never been fitted.



Figure 6, shows hydraulic pump.

1.6.15 During the onsite investigation, there were aircraft components and parts found scattered on the accident site. The components and parts were from the fuel and hydraulic systems. Some of the component and parts had a black insulating tape wrapped around which was fastened by locking wire. The black insulating tape was wrapped around the connecting couplings as shown on the pictures below:

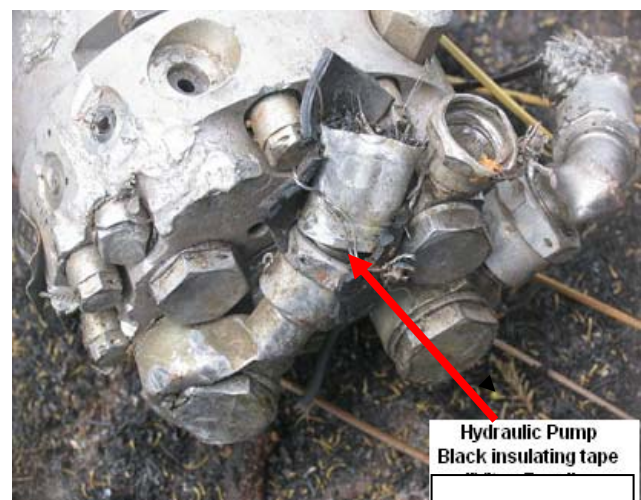


Figure 7 & 8, shows black rubber material wrapped around connecting couplings.

1.6.16 The black insulation tape which the aircraft manufacturer approved for use on the aircraft was called viton tape. The aircraft manufacture had the following comments about the use of viton tape in this regard:

(i) *“The black tape is fluorocarbon tape called Viton. The purpose of viton tape used on the aircraft was to prevent spraying mist of fluid in the event of bonded seal failure. It was standard practice to wrap all hydraulic joints containing bonded seals in the engine, inter and reheat bays with viton tape. The viton tape would ensure that the hydraulic spray mist would be contained, resulting in hydraulic oil leak dripping and find its way overboard through the fuselage drains. Thunder City AMO was required to comply with requirements of AMM, AP 101B-1005-1A, Section 3, Chapter 6, Para 43A, amended in November 1979 for guidance about use of viton tape”.*

1.6.17 The process of applying viton tape to components and parts was examined. Another Lightning (ZU-BBD) which was undergoing maintenance was used as an example to show the method of applying the viton tape. Photographs were forwarded to manufacturer for comment. The manufacturer responded as follows:



Figure 9, shows components from ZU-BBD.

Note: ***“The viton tape was wrapped around incorrectly and wire locking is not restraining the tape correctly.”***

1.6.18 Undercarriage Failure: On 14 November 2009 shortly after the double hydraulic failure was reported, the pilot selected undercarriage down to perform an emergency landing. The pilot realised that the undercarriage had also failed. The nose gear, right side main gear was extended and the left side main gear was retracted. The left side main gear was still retracted at the time of ground impacted.



Figure 10, shows the undercarriage failure.

Note: According to the Flight Reference Card, the Hazardous Landings Procedure (landing with Undercarriage in abnormal position) required the pilot's immediate action should be not to attempt to land and to abandon the aircraft.

1.6.19 According to the maintenance records, the undercarriage was last inspected during the Annual Inspection (Check 1). The undercarriage was examined and no defects were recorded.

1.6.20 *Double Flying Controls System Failure:* The aircraft became uncontrollable during flight. The control inputs made by the pilot in the cockpit were ineffective. The flight control system stiffened and became inoperative.

Note: According to the Flight Reference Card, when receiving HYD 1 and HYD 2 indications on the auxiliary warning panel (AWP); controls will stiffen and become inoperative. The pilot immediate action should be not to attempt to land with the double hydraulic failure indication, to use minimum control movement, establish 1g flight above 5000 ft above ground level (AGL), fly the aircraft with at least 70% power on each engine toward a suitable ejection area and prepare to abandon the aircraft.

1.6.21 *Ejection Seat Failure:* The pilot experienced an **ejection seat failure** during the flight. He attempted to eject meaning that the face-screen or seat-pan firing handles were pulled to activate the ejection sequence, but the ejection seat failed to eject.

Note: According to the Flight Reference Card, failure of the seat to eject requires that the pilot immediate response should be to pull the firing handle again. If this fails, to pull the other firing handle and retain grasp on handle. If seat still fails to eject, jettison canopy using normal operating handle.

1.6.22 According to the aircraft maintenance records, Martin Baker - Type 4BSB MK2 ejection seats were fitted in the aircraft. Both ejection seats – port side (S/N 45) and starboard side (S/N 64) were removed from the aircraft for bay maintenance on 8 September 2008. The ejection seats were installed into the aircraft again on 10 September 2008.

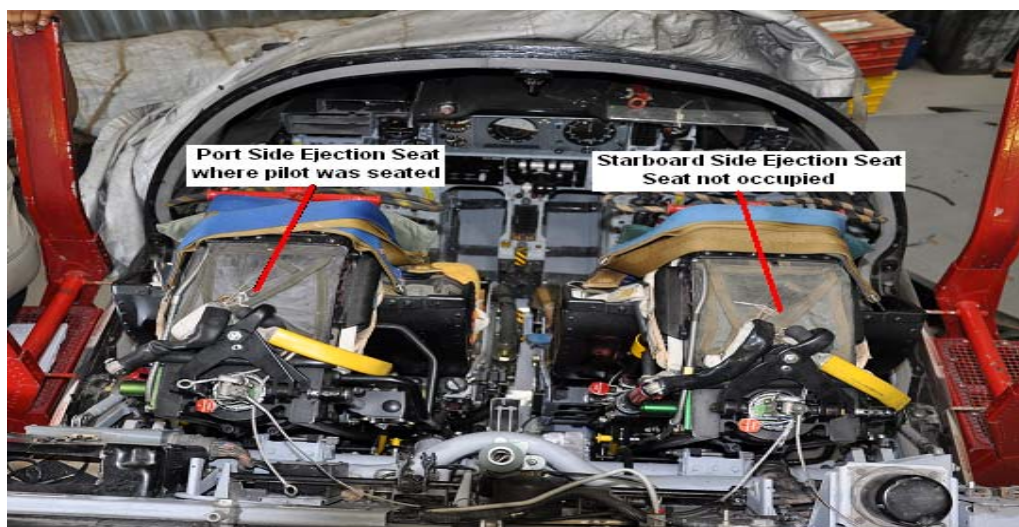


Figure 11, shows cockpit layout with ejection seats installed.

1.6.23 Thunder City AMO removed the ejection seats again on 16 February 2009. The purpose for the removal was to gain access to the cockpit floor space. The maintenance records do not identify the type of maintenance that was carried out inside the cockpit floor on the day.

1.6.24 The ejection seats were due for bay maintenance after 12 months. The evidence found indicated that the bay maintenance of the ejection seat was not carried out when it was due on 10 September 2009. The aircraft continued to operate in this condition with the ejection seat not maintained for duration of 49 days before Thunder City AMO issued an extension on 29 October 2009. An entry made in the flight requirements log stated the following: "Seats 30 day's extension" and "Post air show \pm 45 days".

Note: The bay maintenance of the ejection seats was important because according to the applicable aviation regulation regarding specialized equipment installed on ex-military aircraft – CAR, Part 24.01.2.D.3 (3)(4), stating that the equipment shall be maintained as far as possible to the standards used in the military service (RAF); and shall be maintained in accordance with the instruction manuals used whilst in military service, also complying with additional instructions (Maintenance Control Manual) issued by the Commissioner.

1.6.25 *Ejection System Explosive Cartridges:* The explosive cartridges installed on the port side ejection seat (that was occupied by the pilot) did not fire when ejection system firing handle was activated. The ejection seat did not eject due to cartridges not firing. The situation did not change (cartridges not firing) even after the aircraft impacted the ground. The cartridges were recovered from the accident site for further investigation.

(i) The evidence shows that Pretoria Metal Pressings (PMP) manufactured the cartridges locally during 2000 and 2001. A total quantity was 22 cartridges were purchased by Thunder City on 29 June 2000. Based on the date of manufacture, the evidence shows that the cartridges were between 8 to 10 years installed on the aircraft.

Note: According to the manufacturer, the install life cycle of the cartridges was 24 months (2 years) and 60 months (5 years) total life for uninstalled cartridges. The cartridges installed on the Lightning exceeded the identified required calendar time intervals, as such the cartridges in service life were considered to be expired.



Figure 12 & 13, showing cartridges recovered from accident site.

(ii) The aircraft explosives record card obtained from Thunder City AMO was as follows:

Type of Explosive Store & Location in Aircraft	Date of Filler	Lot Number	Quantity	Date of last Inspection	Date due for inspection	Details P/N
Seat Ejection Secondary (Main Gun)	03/01	002D	2	10/9/2008	09/2009	M826A1(MiL Spec) MBEU18601-1
Seat Ejection Secondary (canopy jettison)	06/00	001D	2	10/9/2008	09/2009	MBCJ 2028
Cart Seat Primary No 5 MK2	03/01	002D	2	10/9/2008	09/2009	MBEU32132-1
Cart Seat Ejection Droque	05/99	002D	2	10/9/2008	09/2009	M8216A1 MBEU28420
Cart canopy jettison MBCJ 440 (primary)	06/00	001D	1	10/9/2008	09/2009	M8218A1
Cart ejection seat Guillotine	06/00	001D	2	10/9/2008	09/2009	M8220A1 MBEU33663-1

Table 2, shows the maintenance information of the ejection seat cartridges.

1.6.26 The information in the table above shows that the cartridges were next due for inspection during September 2009. Thunder City AMO did not comply with the maintenance requirement. The aircraft maintenance documentation was inadequate as it did not identify the serial numbers of each cartridge and the seats they were fitted to. **(Appendix E, attach is a copy of explosive record card for the cartridges)**

1.6.27 *Canopy Jettison System:* There was a canopy jettison failure during the automatic ejection sequence. The canopy did not jettison from the aircraft when activated. The aircraft impacted the ground with the canopy still attached it.

Note: According to Flight Reference Card, if the canopy fails to jettison, operate emergency canopy jack release lever and pull up normal canopy unlocking handle. In the event of a failure in the automatic ejection sequence, the canopy has to be jettison manually, neither seat will eject until its firing handles has been pulled again.

1.6.28 According to aircraft maintenance records, the canopy was inspected and serviced during bay maintenance on 09 September 2008. The canopy jettison jacks (S/N 81 on the port side and S/N 7964 on the starboard side) and bypass valves were serviced. The work carried out was stripping, cleaning, inspecting, lubricating and assembling of the identified units.

1.6.29 The canopy was removed the last time from the aircraft on 16 September 2009. The canopy was removed so that the ejection seats may be removed. The maintenance personnel wanted to gain access to cockpit floor space to carry out maintenance. It is not known what maintenance they had to perform. After completing the maintenance, the ejection seats and canopy was installed again. There was no record of any other maintenance carried out on the canopy after the identified date.

1.6.30 According to servicing procedure SP102, in terms of AP101B-1000-5A3A (section 1) the canopy was supposed to undergo a “**Canopy Emergency Jettison Testing**”. The identified service procedure should have been performed at each ejection seat removal and fitment. There was no proof found over the past four years to show that the servicing procedure was complied with by the AMO.

1.6.31 Thunder City AMO was issued with an approved aircraft maintenance schedule (AMS) which included general instruction about maintenance requirements of the aircraft. The evidence shows that the Owner, Operator and AMO did not comply with the general instructions of the AMS.

1.6.32 *Fuel Status:* On 14 November 2009 the aircraft was refueled with Jet-A1 at FAOB. The quantity of fuel uplifted (**inside the wing tanks and ventral tank**) was 4063.56 pounds (lbs). The total quantity of fuel onboard the aircraft after refueling was 7630 pounds (lbs). The aircraft was flown for approximately 37 minutes (0945Z to 1022Z). Under normal flying circumstances the aircraft would have burned a quantity of approximately 4399.3 pounds (lbs) for the duration of the flight. In that case the estimated total quantity of fuel remaining onboard the aircraft would have been approximately 3230.7 pounds (lbs). However, given the fact that the aircraft had a fuel leakage the precise quantity of fuel onboard the aircraft at the time of ground impact could not be determined conclusively.

1.7 Meteorological Information

1.7.1 The weather conditions on the day of the accident were determined to be as indicated in the column below. The weather information was obtained from the South African Weather Services.

Wind direction	250°	Wind speed	10 kts	Visibility	Good
Temperature	20°C	Cloud cover	5/8	Cloud base	2500 ft
Dew point	08°C				

1.8 Aids to Navigation

1.8.1 The aircraft was flown at a military aerodrome. The following radio navigation and landing aids were available at the aerodrome:

- (i) Non-directional radio beacon (NDB) - OB: frequency 427.5 kHz.
- (ii) Very high frequency omnidirectional radio range (VOR) - OBV: frequency 115.4 MHz.
- (iii) Instrument landing system (ILS) LOC - OBI: frequency 110.9 MHz.
- (iv) Instrument landing system (ILS) GP: frequency 330.8 MHz.
- (v) Runway centrelines and identification markings.

1.8.2 All the above identified aids to navigation were in a serviceable condition.

1.8.3 The aircraft had an integrated flight instrument system (IFIS) which derives its information from the dynamic reference system, air data system, Tacan, ILS and UHF coupling units. These were standard navigational equipment which was approved for the aircraft type. There was no proof found of a defect or malfunction experienced with the navigation equipment. In the absence of information stating otherwise, the navigation equipment was considered to be in a serviceable condition at the time of the accident.

1.9 Communications.

1.9.1 The aircraft was operated from an unlicensed military aerodrome. The aerodrome communication facilities were military air traffic control (ATC) services. According to the Aeronautical Information Publication (AIP), the normal working hours of the FAOB ATC was from 0430Z to 1530Z. The ATC communication facilities were Approach (119.8 MHz), Tower (119.8 MHz) and Ground (119.8 MHz). The ATC did not report any defect or malfunction experienced with the communication equipment prior to and during the air show. The communication equipment was in a serviceable condition.

1.9.2 *Communication between ATC and pilot:* The ATC was the primary location of communication during the air show. The ATC broadcasted to the aircraft using frequency 119.8 MHz. After take-off and during the display, the pilot was handed over to the Safety Officer on frequency 120.8 MHz. The ATC was monitoring the communication between the pilot and Safety Officer. Half way through the pilot aerobatic display, he broadcasted on frequency 119.8 MHz to report an emergency. The pilot made an urgency call "PAN – PAN -PAN" three times and notified ATC that he was experiencing a double hydraulic failure. The ATC cleared the pilot to return to the aerodrome for the emergency landing. The pilot could not land due to an undercarriage failure. The undercarriage failure resulted in a decision whereby ATC instructed the pilot to fly to AGT area on the eastern side of the aerodrome. The communication between ATC and the pilot ended when the pilot indicated that he was experiencing an ejection seat failure. The communication was reviewed in the investigation and no anomaly identified.

1.9.3 *Communication between the Safety Officer and pilot:* The Safety Officer was the secondary location of communication for the duration of the air show. The Safety Officer broadcasted to the pilot on frequency 120.8 MHz. There were no anomalies identified with the communication.

1.9.4 *Communication between the ATC and Aerodrome Rescue Fire Fighting (ARFF):* The ATC broadcasted to ARFF to inform them of the emergency. The ARFF personnel (air and ground teams) were then instructed to standby until further notice. The ATC ended up giving instructions to dispatch to the accident site. The ARFF personnel reported the accident information back to ATC. The ARFF personnel then returned to the aerodrome to resume their duties in the air show. (**Appendix C, see copy of transcript**)

1.9.5 *Aircraft Equipment:* The aircraft was equipped with VHF radio communication equipment which was approved for the type. In addition to the VHF radio equipment, the pilot could communicate with the ATC by means of microphone. There was no record of a defect or malfunction experienced with the communication equipment installed in the aircraft. The communication equipment of the aircraft was serviceable.

1.10 Aerodrome Information

Aerodrome Location	Air Force Base Overberg – Test and Flying Development Aerodrome (FAOB)	
Aerodrome Co-ordinates	S34°3329.22 E020°1456.84	
Aerodrome Elevation	52 Feet	
Runway Designations	35/17	28/10
Runway Dimensions	3115 x 46	2111 x 40
Runway Used	28	
Runway Surface	Asphalt	
Approach Facilities	NDB, ILS, VOR.	

1.10.1 FAOB is an unlicensed Military Aerodrome. The SAAF was managing the operations at the aerodrome. According to the AIP, permission must be obtained from the Officer Commanding prior to flying or landing at the aerodrome. The operating hours during week days MON-FRI: 0545Z to 1415Z. If services are required after the normal operating duty hours, the necessary arrangement should be made with the Air Force Operations Department at the aerodrome.

1.10.2 The aerodrome had handling services and facilities available. The services included cargo handling and refuelling of aircraft. The aerodrome does not have hangar space and repair facilities available for visiting aircraft. In cases of emergency inside and around the premises of the aerodrome, all search and rescue activities performed by FAOB ARFF personnel will be under the coordinating direction of the SAAF.

1.10.3 The aerodrome was the venue of the air show. Several military and civilian registered aircraft was expected to make use of the aerodrome during this period. The SAAF provided parking to the visiting aircraft and assist as far as possible. The parking space of the Lightning was also on Apron B, opposite the main taxi way (alpha) in front of the hangar. There were no hangar or repair facilities available. Apron B was also used for line maintenance on the aircraft.

1.10.4 The air show attracted a substantial number of spectators to the aerodrome. The SAAF divided the aerodrome into special demarcated crowd control sections. The main viewing point was from taxiway (bravo). Other areas which was not used in the air show were restricted and under the protection of the military security personnel.

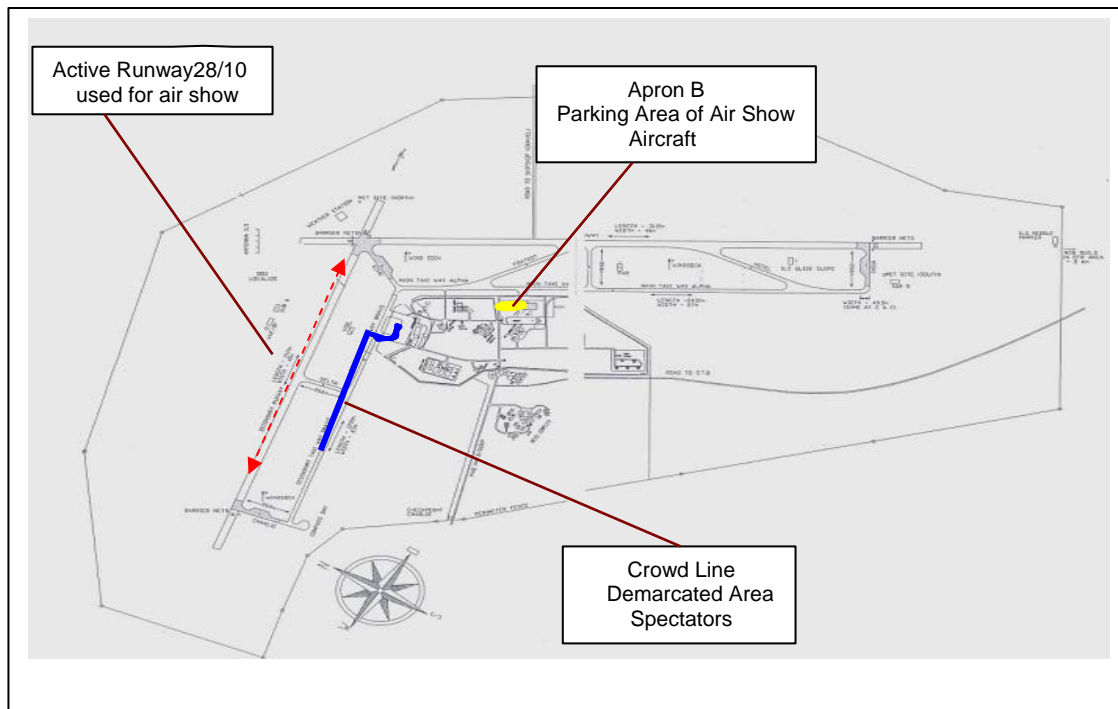


Figure 14, shows areas used for the air show.

1.11 Flight Recorders

- 1.11.1 The aircraft was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR) and neither was required by regulations to be fitted to this type of aircraft.
- 1.11.2 The Radar Equipment of the aerodrome was not in use at the time of the accident. It was not possible to obtain any information from the radar.

1.12 Wreckage and Impact Information

- 1.12.1 The location of the impact crater was at GPS co-ordinates: S34°31.232 E020° 22.618 on the eastern side of FAOB.
- 1.12.2 During the on-site investigation, the accident site and wreckage were examined to determine if any structural failure attributed to the cause of the accident. According to the wreckage and ground impact marks, it was evident that the aircraft impacted the ground in a nose pitched-down attitude. The impact angle was fairly high and at high velocity. The aircraft dug a deep hole **“impact crater”** and the fuselage followed the nose into the hole. The soil that was originally inside the hole, splashed out and formed a rim around the crater.

1.12.3 Because the aircraft impacted the ground at an angle, it caused the soil to pile up in the direction it was moving. On impact, the aircraft broke up and bulk of the debris was distributed in a random fashion away from the impact crater. The degree of break-up and destruction of the wreckage gave a clear indication of the impact heading and sequence. The impact information indicated that the aircraft was flying in north-westerly direction, almost parallel to Runway 35/17, losing altitude and rolling inverted to the right when it impacted with the ground.



Figure 15, shows accident site and wreckage distribution.

1.12.4 The flight path of the aircraft, prior to it impacting the ground was north westerly in the direction of the air ground target (AGT) area. After the aircraft impacted the ground, the debris was distributed in a fan-shape pattern from the impact point – crater.

1.12.5 The ground impact marks were examined to determine the impact attitude and angle of the aircraft.

(i) *Impact Attitude:* The pitch was in a nose pointing down and the bank angle (rolling) to the left. The information of impact scars and debris around the crater indicated that the bank angle was less than ninety (90) degrees when impacting the ground.

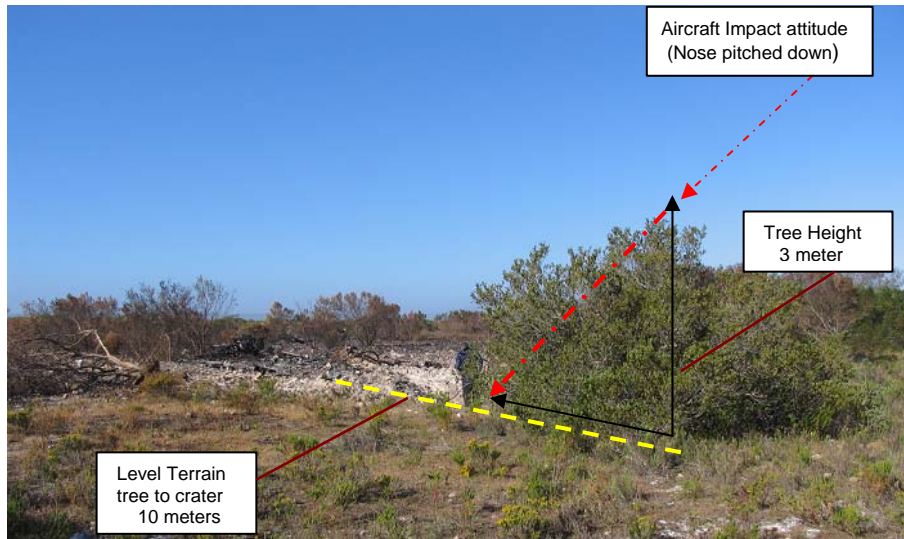


Figure 16, shows the measurements used to determine impact angle.

- (ii) *Impact Angle:* The impact angle was determined by using the aircraft pitch attitude with respect to the flight path. The terrain and elements (trees) close to the crater was used in a calculation to determine impact angle. The information of tree height and distance from the crater was measured and used in a mathematical formula. The impact angle was then determined to be approximately 17° (degrees).

1.12.6 The aircraft entered into a right turn prior to it impacting the ground. The outer wing (right side) was raised slightly higher than the inner wing (left side). The nose impacted the ground which resulted in the fuselage to disintegrate. The debris were found scattered over a large area (approximately 36 700 square meters - m²).

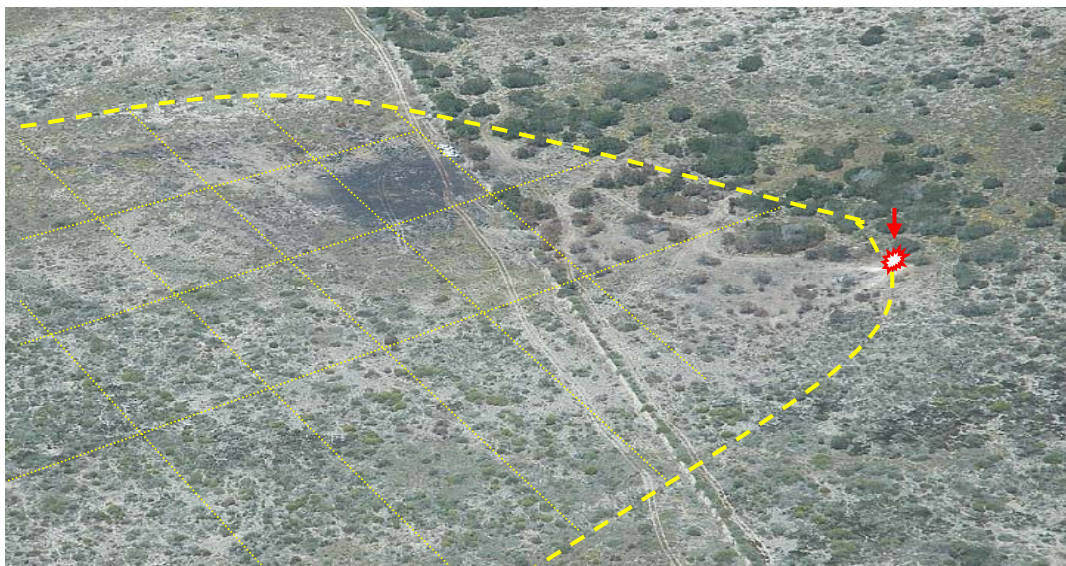


Figure 17, shows the aerial photo of accident site, wreckage distribution area (Approximately 36700 square meters (m²)).

1.12.7 *An inventory of the wreckage distribution was as follows:*
(See below table which indicates locations of debris)

Aircraft Component	Distance from Crater (meters)	Heading from Crater (degrees)	GPS co-ordinates
1. Engine No.2	16 m	0	S34°31.1323 E020°22.3727
2.Vertical (fin) Stabiliser	16m	0	S34°31.1323 E020°22.3727
3. Port side wheel	14 m	71°	S34°31.1353 E020°22.3764
4. Port Wing	20 m	99°	S34°31.1384 E020°22.3790
5. Nose Gear	89 m	36°	S34°31.1142 E020°22.3921
6.Horizontal Stabiliser	114m	59°	S34°31.1184 E020°22.4095
7. Engine No.1	191m	42°	S34°31.1095 E020°22.4047
8. Starboard Wing	197m	59°	S34°31.1047 E020°22.4378
9. Starboard Main Gear	270m	66°	S34°31.1019 E020°22.4680

Table 3, show locations where major components were found after break up.

1.12.8 The wreckage distribution information in figure 4 above and a picture was overlaid on Google Earth. See below wreckage distribution:



Figure 18, a Google earth picture showing the wreckage distribution

1.12.9 *Aircraft Systems*: The aircraft systems (mechanical, electrical, hydraulic, pneumatic and fuel) were destroyed in the accident. The debris of the aircraft systems were

scattered around the accident site.

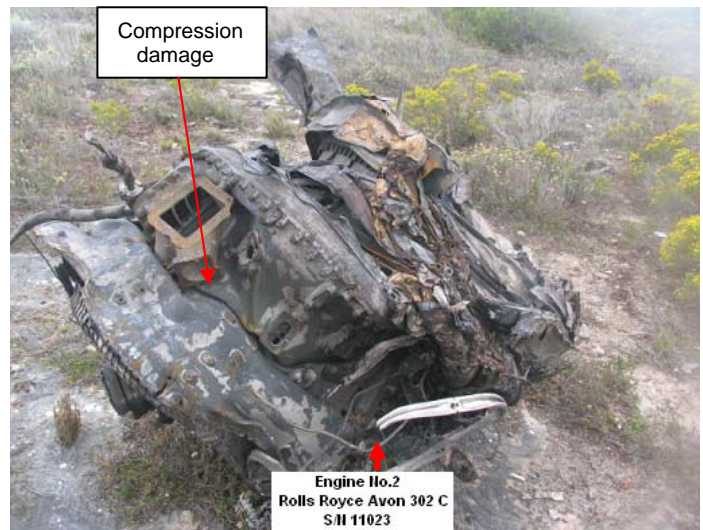
- (i) **Hydraulic System:** The reservoirs of the hydraulic system were destroyed in the accident. The hydraulic pumps separated from their installation points on the engines accessory drives. Only the power flying control unit and two engine-driven pumps (HYD1 and Services pump) was found at the accident site. All the identified hydraulic components were exposed to impact and post impact fire damage.
- (ii) **Fuel System:** The three fuel tanks (2xwing and ventral) were destroyed in the accident. All the components and parts (pumps, pressure valves and fuel lines network) were destroyed by impact and fire damage. The debris of the fuel system was scattered around the accident site. The indication was that the fuel spillage contributed to the fire damage.
- (iii) **Pneumatic System:** The pneumatic system (pressurisation, anti-icing, fire extinguishing and oxygen) were destroyed in the accident. Several pressurised containers from the identified pneumatic systems were found to have exploded. The evidence shows that the ensuing post impact fire was potentially aggravated by the pressure containers exploding.
- (iv) **Electrical System:** The electrical system (electronic equipment) of the aircraft was destroyed in the accident. The debris of electronic equipment was found scattered around the impact crater. The electrical wiring was exposed to excessive heat, which was applied externally. The nature and type of discolouring on the wiring was confirmation of this fact. The insulation of the wiring was severely burned in the post impact fire.

1.12.10 *Undercarriage:* The undercarriage was also destroyed. There was proof found showing that the nose and starboard side main landing gear were extended and port side main landing gear was retracted when the aircraft impacted the ground. The undercarriage was destroyed in the impact sequence and post impact fire.

1.12.11 *Engines:* The two engines were also destroyed. The engines sustained impact and post impact fire damage. Both engine casings showed gross evidence of failure. The accessory components separated from the engines and scattered on the accident site.

- (i) There was evidence of compression and torsion damage caused to the engines. The compression damage was as a result of high impact force. The torsion damage was as a result of sudden stoppage during operation. The rotor segments in the compressor and turbine sections showed evidence of rotational interference with the casing, the blade tips were ground down and rotational scoring on the inside of the casing. The implication was that the rotor shaft showed evidence of it shifting axially.
- (ii) The indication was that the engines were under power at the time of ground

impact. The pilot did not report any information that suggested he was experiencing any engine problems at any time during the flight. Both engines separated from the airframe during the impact sequence.



Figures 19 to 22, shows engine damage.

1.12.12 *Ejection Seats*: Both ejection seats were destroyed in the impact sequence. The evidence found showed that the ejection seats had not ejected. The debris of the ejection seats was scattered on the accident site (approximately 38 to 185 meters).

1.12.13 *Main Guns*: The main gun units separated from the ejection seats. The evidence of the main gun units showed that they did not extend, which also indicated that the ejection seat failed to eject. The first (#1) main gun display bending damage in the middle and the second (#2) main gun was flattened. Both main gun units were exposed to high impact forces. The cartridges (x4) fitted to the main gun units separated during the impact sequence. The cartridges were found scattered on the accident site. The cartridges were recovered and inspected and the evidence showed that the cartridges did not fire (explode) as was required in order to have

activated the ejection seat.



Figure 23 & 24, shows main gun unit.

1.12.14 Fragments of the pilots flying suite (dark blue in colour) were found amongst the some of the ejection seat debris which was approximately 88 meters from the impact crater. The ejection seat debris was determined to be that of the port side ejection seat parachute and survival pack. Once the port side ejection seat debris was identified, it was easy to conclude that the other debris was that of the starboard side ejection seat. This fact was supported by the various straps which were fastened to the harness quick release fitting.



Figure 25 & 26, shows debris of ejection seat survival pack.

1.12.15 *Ejection Seat debris distribution was as follows:*



Figure 27, showing the distribution of ejection seat components.

Ejection Seat Component	Distance from Crater (meters)	Heading from Crater (degrees)	GPS co-ordinates
1. Unknown Item A ejection seat	38 m	348°	S34°31'.1253 E020°22.31678
2. Cartridge	59m	339°	S34°31'.1192 E020°22.3628
3. Pilot in Command (PIC) Ejection Seat	88 m	6°	S34°31'.1090° E020°22.3751
4. Ejection Seat Harnesses	119 m	11°	S34°31.0993 E020°22.3802
5. Main Gun Telescopes	125 m	348°	S34°31.0976 E020°22.3610
6. Ejection Seat not used	148m	7°	S34°31.0910 E020°22.3779
7. Ejection Seat Adj Mechanism	156m	5°	S34°31.0866 E020°22.3763
8. Cartridge	185m	9°	S34°31.0779 E020°22. 3831

Table 4, shows the ejection seat debris and distribution area.

1.12.16 *Canopy*: The canopy of the aircraft failed to jettison during the flight. The evidence found indicated that the aircraft impacted the ground with the canopy in the closed position. The canopy was destroyed by impact and the post impact fire damage. Debris (pieces of Perspex) of canopy was found approximately 10 meters from the crater. The debris was toward the left side of the crater.

1.13 Medical and Pathological Information

1.13.1 The medico-legal post-mortem examination of the pilot was performed by the Department of Health: Western Cape Forensic Pathology Services on 16 November 2009. The post-mortem report concluded that due to multiple disintegrated human remains found, it was unable to determine the cause of death by autopsy alone.

1.14 Fire

1.14.1 *Fire in flight.* There was photographic evidence which shows that the aircraft was having an in flight fire. The tail section was burning during the flight. The photograph was taken by a spectator which attended the air show. The photograph was then forwarded to the aircraft manufacturer for expert opinion. The aircraft manufacturer looked at the properties of the digital photos, to ascertain the sequence in which they were taken.



Figure 28, shows fire in flight.

1.14.2 *Post Impact Fire:* Based on the evidence of the tail section being on fire; it can be seen that there was already a source of ignition for the post impact fire. The time the aircraft impacted with the ground, there was an explosion followed by a huge cloud of smoke rising from the location of the accident site. The ARFF personnel arrived on the accident site, there was post impact fire burning. The indication was that the flammable liquids carried onboard the aircraft contributed to the ferocity of the post impact fire. The post impact fire also contributed in the destruction of the aircraft.

Figure 29, smoke emanate from accident site.

1.14.3 The accident occurred in a bush type of terrain. The vegetation ignited and started burning spontaneously. The area covering a distance of approximately 17000 square meters (m) was exposed to the fire damage. The fire had to be extinguished by ARFF personnel.

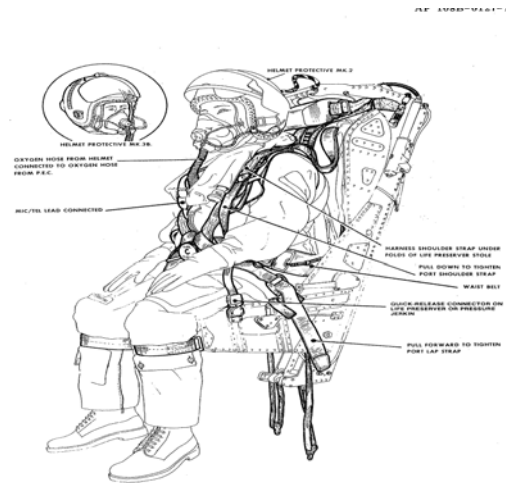


1.15 Survival Aspects

1.15.1 The accident was considered to be not survivable under any circumstances. The aircraft impacted the ground at a very high angle and velocity. The deceleration forces transmitted to the pilot exceeded that of human tolerance. The aircraft was destroyed during the ground impact and post impact fire.

1.15.2 Factors that eventually influenced the survivability:

- (i) Factor #1 – Although the pilot experienced a double hydraulic system failure in flight, he still had some control of the aircraft. He then decided to lower the undercarriage for the emergency landing. He was cleared to land and the ARFF personnel put on standby waiting for his arrival. The pilot realised that the left main landing gear did not extend, which prevented him to land. Fearing for the safety of the spectators at the air show, he turned the aircraft away from the aerodrome to attempt emergency gear extension manoeuvre. The situation was aggravated to a point where the pilot later was unable to control the aircraft. In order to survive the flight, the pilot had to eject from the aircraft.



- (ii) Factor #2 - The aircraft was equipped with Martin Baker 4BSB MK 2 type ejection seats. The ejection seats of the aircraft had the necessary survival equipment (Main Parachute, Survival Pack and Oxygen Supply) needed in the event of the pilot ejecting from the aircraft. It was very important that the ejection must be in a serviceable condition.
- (iii) Factor #3 - The pilot had appropriate flying clothing on for this type of operation. He was sitting in the port side ejection seat and properly restrained with the ejection seat safety harnesses and straps. The pilot was wearing a protective helmet and oxygen mask. The ejection seat on the starboard side of the aircraft was not occupied and the safety harnesses and straps were fastened.

Figure 30, shows pilot sitting position in ejection seat.

- (iv) Factor #4 – Both ejection seats of the aircraft each had five safety pins to preventing them from being activated inadvertently. The safety pins on the port side ejection seat were removed to arm the seat. The pilot was required to pull either one of the two firing handles provided on the ejection seat to activate the ejection sequence. The pilot reported an ejection seat failure, assuming that he pulled both firing handles. The pilot realised that the seat was not ejecting which posed a life threatening situation for him as he was trapped inside the cockpit.

- (v) Factor #5 - In case of an automatic ejection activation failure, the pilot had another option of activation of the system manually. The alternate means of activation of the ejection system required that the pilot attempt to open the canopy by means of levers inside the cockpit to unlock the canopy manually. Though it could not be conclusively determined, the possibility exists that the pilot probably attempted to open the canopy manually also, but he was not successful. The aircraft ended up impacting the ground with the canopy closed.
- (vi) Factor #6 - The tail section of the aircraft was burning during the flight. The area of the fuselage where the fire was observed had hydraulic equipment which was critical to the safety of the aircraft. The aircraft was equipped with a fire detection system to warn the pilot when fire erupts in the affected area. The pilot did not call a fire emergency, which suggested that he was not aware of the fire situation. It is possible that the fire detection system was inoperative or not even installed. The issue of the fire in flight was a serious factor which influenced flight safety and survivability. If the pilot knew about the in flight fire, he may have **“bailed out”** from the aircraft earlier or handled the situation differently.

1.16 Tests and Research

1.16.1 *Accident History*: The manufacturer – British Aerospace (BAE System) assisted with the investigation. BAE systems provided a summary of EE Lightning accident history while operated by the Royal Air Force (RAF). According to the accident history, the RAF indicated that the in-service experience of the EE Lightning was that the in flight fires occurred as a result of fuel coupling failure which contributed to the fuel leakage. The accident history in the table below:

Aircraft Registration	Mark	Date	Brief Summary
Xxxxxxx	F6	15/07/86	RHT 1 & RHT 2 warnings. Airborne inspection noted white smoke from lower (Number 1) jet pipe and rear fuselage appeared to be melting. Pilot ejected. Investigation concluded a fuel leak in Zone 3 had ignited causing catastrophic damage.
Xxxxxxx	F6	08/11/84	RHT 1 & RHT 2 warnings. Airborne inspected noted white smoke from the lower jet pipe and flames from the starboard fuselage. Pilot ejected with reports of FIRE 1, RHT 1, RHT 2, GEN, AC, TURB, OIL 2, FUEL 2, PUMPS S, TTC 2 and HYD warnings. Wreckage not recovered.
Xxxxxxx	F6	23/07/81	RHT 1 & RHT 2 warnings. Controls became ineffective before airborne inspection could be performed and pilot ejected. Pilot of a Lightning that was en route to provide airborne inspection reported a white fluorescent plume from the rear of the abandoned aircraft. Wreckage partially recovered and investigation established evidence of a major rear fuselage fire.
Xxxxxxx	F6	29/10/74	RHT 1 & RHT 2 warnings. Rear fuselage fire and pilot ejected. No additional information.
Xxxxxxx	F3	13/02/74	RHT 1 & RHT 2 warnings. Rear fuselage fire and pilot ejected. No additional information.
Xxxxxxx	F6	03/04/73	Number 1 engine fire. Pilot ejected. No additional information.
Xxxxxxx	T4	14/12/72	FIRE 1 & FIRE 2 warnings followed by an explosion. Crew ejected. No additional information.
Xxxxxxx	F3	07/08/72	Flames and stiffening controls. Pilot ejected. No additional information.
Xxxxxxx	F6	30/09/71	RHT 1 warning and stiffening controls. Pilot ejected. No additional information.
Xxxxxxx	F3	08/07/71	RHT 1 & RHT 2 warnings accompanied by smoke. Pilot ejected. No additional information.
Xxxxxxx	F6	26/05/71	Fire and loss of control. Pilot ejected. No additional information.
Xxxxxxx	F3	10/05/71	RHT 1, RHT 2 and FIRE 1 warnings. Controls stiffened and pilot ejected. No additional information.

Xxxxxxx	F6	28/04/71	Fire warning. Pilot ejected. No additional information.
Xxxxxxx	F3	25/01/71	Fire warning. Pilot ejected. No additional information.

Table 5, shows the accident history of the EE Lightning type.

1.16.2 The aircraft manufacturer could find only one incident which was suspected to have been due to aeration of the hydraulic system. It was a known problem (air entering the system) and hours were spent de-aerating each hydraulic system to ensure as much entrained air as possible was removed from the system. This was achieved by running the hydraulic systems through a de-aeration rig that had a vacuum applied above the oil.

1.16.3 *Refuelling History*: There was proof found that fuel was leaking from ZU-BEX. To determine the extent of the fuel leak, the fuel uplifts records was reviewed in the investigation. The fuel uplift record below has information of EE Lightning refueling done from 5 February 2009 to 13 November 2009. The fuel uplifts information in the column below was used in a calculation, which aim was to determine the actual fuel status over the identified interval. The fuel quantity is in liters.

Date	Receipt	Type	Registration	Quantity
05-Feb-09	0361150	FUELLING	JETA1 ZU BEX	3,225
20-Feb-09	0510126	FUELLING	JETA1 ZU BEX	3,783
06-Mar-09	0651171	FUELLING	JETA1 ZU BEX	3,370
09-Mar-09	0681179	FUELLING	JETA1 ZU BEX	3,048
16-Mar-09	0751129	FUELLING	JETA1 ZU BEX	3,618
14-Apr-09	1041128	FUELLING	JETA1 ZU BEX	3,543
23-Sep-09	2661162	FUELLING	JETA1 ZU BEX	3,406
24-Oct-09	2970144	FUELLING	JETA1 ZU BEX	2,980
28-Oct-09	3010174	FUELLING	JETA1 ZUBEX	3,214
13-Nov-09	3170112	FUELLING	JETA1 ZU BEX	3,408

Table 6, shows the fuel uplifts of ZU-BEX from 05 February 2009 to 13 November 2009.

1.16.4 The fuel uplifts information in the table below show that ***the information of fuel status of the EE Lightning was calculated incorrectly***. There was an anomaly identified between the operator entry fuel uplifted and actual fuel uplifted. The margin of correction between operator entry of fuel remaining prior to uplift and actual fuel remaining prior to uplift was also a cause of concern in the investigation. The possibility does exist that the anomaly may be as a result of the fact that Thunder City AMO was not sure of the fuel quantity remaining onboard the EE Lightning. Also, it is the opinion of the investigator that the entry made of remaining fuel was an estimated amount. If the latter is true, the problem may be one of the two scenarios experienced with the EE Lightning:

- (i) The fuel gauge/s was not serviceable during the identified interval.

- (ii) Fuel leak from the EE Lightning which was not properly contained.

Date	Operator Entry fuel (Total Quantity)	Actual Fuel Uplifted (Fuel Bay FACT)	Operator Entry (Fuel Uplifted)	Flying Time	Actual Fuel Remaining Prior to fuel uplifted (Fuel Bay FACT)	Operator Entry Fuel Remaining to refueling	correctio n
05 February 2009	7630 lbs	5676.00 lbs	unknown	40 min	1954.00 lbs	unknown	unknown
20 February 2009	7630 lbs	6658.08 lbs	6695.0 lbs	30 min	971.92 lbs	1000 lbs	±65 lbs
6 March 2009	7630 lbs	5931.20 lbs	5964.0 lbs	30 min	1698.80 lbs	2400 lbs	±734 lbs
09 March 2009	7630 lbs	5364.48 lbs	5394.0 lbs	50 min	2265.52 lbs	unknown	unknown
16 March 2009	7630 lbs	6367.68 lbs	6400.0 lbs	30 min	1262.32 lbs	unknown	unknown
1 April 2009	7630 lbs	unknown	6264.0 lbs	45 min	unknown	1366 lbs	±0
14 April 2009	7630 lbs	6235.68 lbs	unknown	40 min	394.32 lbs	unknown	unknown
20 July 2009	7630 lbs	unknown	5933.0 lbs	35 min	unknown	1800 lbs	±103 lbs
23 September 2009	7630 lbs	5994.56 lbs	6028.0 lbs	40 min	1635.44 lbs	1600 lbs	±35 lbs
24 October 2009	7630 lbs	5244.80 lbs	5274.6 lbs	40 min	2385.20 lbs	unknown	unknown
28 October 2009	7630 lbs	5656.64 lbs	5688.0 lbs	30 min	1973.36 lbs	unknown	unknown
13 November 2009	7630 lbs	5998.08 lbs	6030.0 lbs	30 min	1631.92 lbs	1400 lbs	±232 lbs

Table 7, shows the aircraft fuel uplifts calculation aimed at determining the actual fuel status.

1.16.5 *Fuel Gauge/s*: The cockpit of the EE Lightning was destroyed in the accident. It was not possible to determine if the fuel gauge/s were in a serviceable condition. No defect or malfunction experienced with the fuel gauge/s was reported by the pilot during the flight and on the ground.

1.16.6 *Fuel Leak*: The ARFF received a report that the EE Lightning was having a fuel leak. The ARFF dispatched personnel to the scene of the fuel leak at 0818Z, with the objective to contain the spillage. The ARFF personnel described the fuel leak as follows: ***“EE Lightning is continuously messing fuel and it’s going to require a lot of oclansorb to contain the spill. The fuel leak is contained for now but will not be for long as the lightning is constantly leaking fuel”***. The ARFF decided to return to base at 0850Z not being successful in stopping the fuel leak:

- (i) The parking bay of the EE Lightning was inspected during the investigation. There was proof found of liquid stains of an unknown substance which was leaking from the EE Lightning. The EE Lightning left trails of liquid stains on the apron following the direction the aircraft was taxiing to the runway. Below is proof of trails of liquid stains.



Figure 31 & 32 was taken on 15 November 2009. The figures show trails of liquid stains on apron and taxiway.

1.16.7 Thunder City AMO was visited during the investigation. There were other EE Lightning aircraft found parked inside the hangar. Specific attention was given to one of the aircraft parked in the centre of the hangar. The aircraft had containers placed underneath the wings to capture fuel leaking from different zones of the airframe. The fuel leaking was considered to be quite substantial. Reference is made to the fuel leak situation at FAOB which the ARFF personnel could not contain.



Operator Facility
Lightning aircraft parked inside hangar showing fuel leaking into containers below the aircraft.

Figure 33, show fuel leaking from another EE Lightning at AMO.

1.16.8 Photographs below shows proof of fuel leaking from the EE Lightning both on the ground and in flight were submitted to the SACAA during the investigation. The photographs were forwarded to the aircraft manufacture – BAE Systems. BAE Systems looked at the properties of the photographs. It was determined that the advanced properties of the photographs were from two different cameras (**Nikon D90 and Canon EOS 450D**). However, assuming that the cameras times were set correctly, the bright spots that appear on the photos were not visible due to the capturing time difference.

1.16.9 The photographs below show proof of atomised fluid or smoke from the rear fuselage of the EE Lightning. There are two separate trails of the atomised fluid. The one trail appears to emanate from an area slightly aft of the ventral tank with the other (possibly) from the interface between fuselage and the lower reheat jet pipe exit.

(Appendix F, see attached aircraft manufacturer copy of report about in flight fire and fuel leaking from ZU-BEX)



Figure 34 & 35, show proof of atomised fluid from the tail section of EE Lightning.

1.16.10 The aircraft manufacturer also commented on the deferred defects related to the fuel leak:

- (i) Fuel leaking into pitot/static system (leaking out of pitot probe): *Fuel leaking into pitot/static system - the most serious problem. This is indicative of a fault in a fuel valve; however, fuel in the pitot static system will also prevent correct operation of the aircraft instruments and flying control feel system. Although not a common occurrence, it can occur by internal failures in components in the fuel venting system, either an Inward-Vent Valve Diaphragm, a Float Control Valve Diaphragm, an Outward Vent Valve Diaphragm accompanied with fuel in the vent pipe or by a leak in an Inward Vent Valve NRV. All of these components are connected to the pitot/static system and are installed in each integral wing tank. Extract from the Aircraft Maintenance Manual Sect 7 Chap 5 that states:*

Note: *"The main system provides the pitot and static pressures required to operate the pressure switches, transducers, feel simulator and altitude and air speed unit. The pressures are taken from a pressure head, extended on a probe located under the nose air intake. In addition, the head provides two sources of static pressure, one of which supplies the instruments and the other which serves the fuel venting system."*

- (ii) Fuel venting overboard during taxi: *Venting is an indication of a fuel valve failure somewhere within the system. Isolation of such failures could result in protracted technical investigation to identify which valve(s) had failed. Venting could be caused by any of around 20 different faults in various valves and components. Fuel leaking from a fuselage overboard drain would indicate a failure within an engine, interpipe or reheat bay and would result in immediate investigation and rectification. Fuel venting overboard during taxi, would result in immediate sortie cancellation as there was no guarantee it would stop once*

airborne. As the EE Lightning was not capable of carrying a great fuel load, any loss was considered critical.

Note: According to the Aircrew Manual Part 1 Chap 2, “Abnormal venting from any other source (previous sentence refers to over wing tanks) while taxiing is to be checked by a servicing specialist prior to flight”.

- (iii) *External fuel leakage was a common problem on all marks of EE Lightning. Leaks generally came from the integral leading edge and main wing tanks and ventral tank. The source of the leak indicated rectification/maintenance activity. Structural leaks were generally acceptable and rectification was deferred until the next suitable maintenance activity was available. However, such leaks were normally classified as stains, seeps or weeps. When such a leak developed into a regular drip, the aircraft would be grounded until the problem had been rectified. Leaks from the fuel system pipework, valves and in-flight refuel probe were not acceptable; any leak from a fuselage overboard drain would indicate a failure within an engine, interpipe or reheat bay and would result in immediate investigation and rectification.*

1.16.11 A concern was raised that incorrect procedures were followed to light the afterburners on the ground. The aircraft manufacturer comments below stipulated afterburner lighting procedure during maintenance activity was as follows:

- (i) *“The RAF required the aircraft to be on a de-tuner, with double, spigotted, steel chocks (the spigot was approx 18 inches long, inserted into a steel tube in the concrete) which were also chained together. There were maximum times that the engine could be in reheat. Double reheat runs were only carried out by Propulsion tradesmen and again had strict running times. After coming out of reheat the engine had to be run for a minimum time (approximately 3 minutes) to ensure that any fuel in the hot streak (ignition) system was evaporated/burnt off to prevent jet pipe fires due to unburnt fuel accumulations. The early shut down of an engine post reheat run would invariably require the use of a fire extinguisher”*

1.16.12 The EE Lightning suffered a double hydraulic failure. According to the Aircraft Maintenance Manual (AMM), AP101B-1003, 5 and 6-15A, Part 1, Chapter 4:

- (i) *The EE Lightning has three hydraulic systems (services system, No. 1 controls and No.2 controls systems) as indicated below.*

Services System	No.1 Controls	No.2 Controls
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Undercarriage Wheelbrakes Airbrakes Flaps Feel System Canopy Nose wheel centring and anti-shimmy Autostabiliser actuators Guided weapons pack	Aileron Primary Flight Control Unit PFCU (outboard) Tailplane PFCU (right) Rudder PFCU (forward piston) Brake parachute doors Undercarriage emergency lowering	Aileron PFCU (inboard) Tailplane PFCU (left) Rudder PFCU (aft piston)
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Table 8, shows the three hydraulic systems.

- (ii) *Hydraulic power is provided by four engine-driven pumps. Two of the pumps jointly power the services systems and other two pumps supplying power to the controls systems: (No. 1 and 2 engine pumps serving the No.1 and 2 control systems respectively). There is a hand pump for ground operations of the services systems behind an access panel on left side of fuselage. The pumps draw fluid from three main reservoirs, one to supply the services system and one each for the No.1 and 2 controls systems. An auxiliary reservoir in the No.1 control system provides additional fluid for emergency undercarriage lowering. The services system has four accumulators and each control systems have two accumulators.*
- (iii) *The aircraft are equipped with a hydraulic gauge which is marked “**Services Pressure**” positioned to the right of the strip speed display. The normal pressure reading is 3000±250 PSI. When a service is selected which has a high fluid demand, the reading falls rapidly and then gradually recovers. Failure of the services system is indicated when the gauge falls to, and remains at, zero in the red sector of the gauge. A pressure switch is fitted in the delivery lines of both the No 1 and 2 controls systems. If the line pressure falls below 1750 PSI the switch closes and a HYD 1 or HYD 2 warning, as appropriate will be lit on the AWP. If both switches close an additional HYD warning on SWP comes on and the attention-getters operate.*
- (iv) *Hydraulic System Management: During the external inspection, check that the hydraulic pump handle is securely stowed and that the eight accumulator skin gauges are showing the correct nitrogen pressure. After starting No 1 engine, check the services pressure is 3000±250 PSI and the flying controls for full and free movement. Before take-off again check that the services pressure is correct and makes another full and free controls check, ensuring that the HYD, HYD 1 and HYD 2 warnings are all out. During flight, periodically check the services pressure and that no hydraulic caption are lit.*
- (v) *The hydraulic fluid type used in the aircraft was determined to be Aeroshell Fluid 41. The identified hydraulic fluid was a mineral oil based “super clean” hydraulic fluid containing an oxidation inhibitor and non-zinc anti-wear additive. The hydraulic fluid was dyed red for identification and leak detection purposes. The hydraulic fluid was suitable for use in very low temperature flow properties are desired, synthetic rubber seals are in use. The hydraulic fluid was not recommended for use with natural rubber seals. The hydraulic fluid used in the aircraft was determined to be satisfactory.*

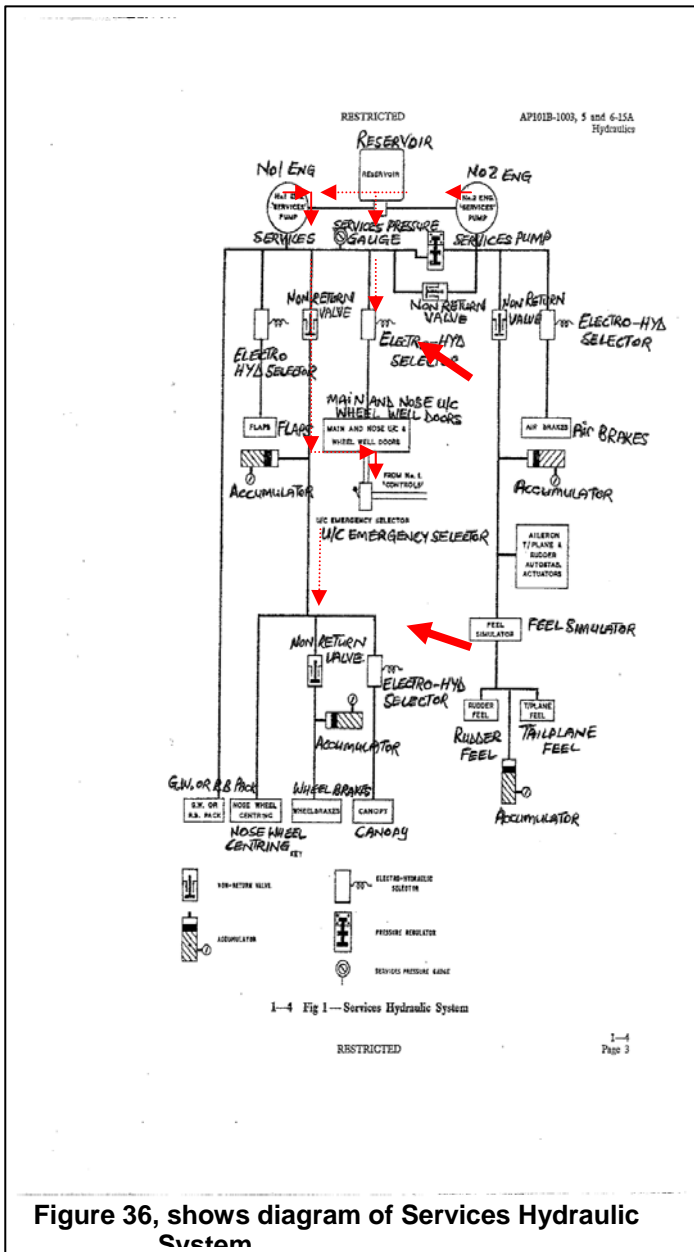


Figure 36, shows diagram of Services Hydraulic System

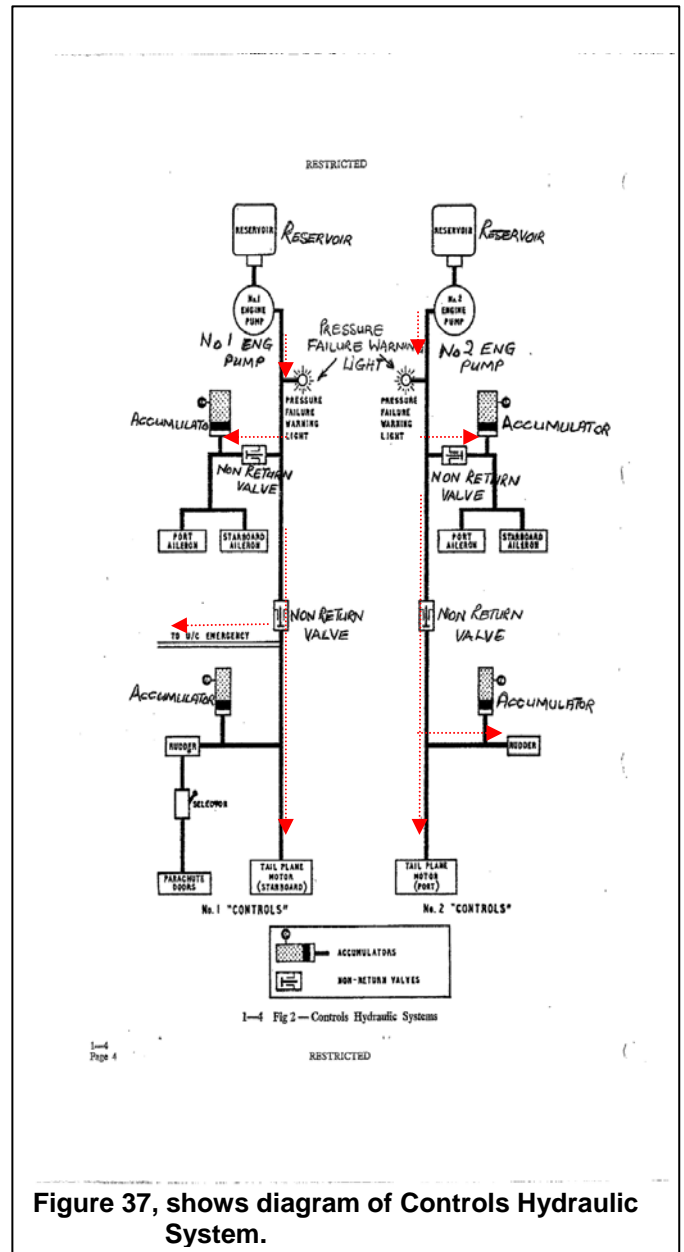


Figure 37, shows diagram of Controls Hydraulic System.

1.16.12 The emergency procedures after experiencing a double hydraulic system warning in the cockpit, is to make minimum use of the flight controls until one HYD warning extinguishes or operational reasons dictate otherwise. The pilot is not to attempt to land with a double HYD failure indication and to eject if control of the aircraft cannot be maintained. The manufacturer submitted a report which explains their comments into the hydraulic failure.

(Appendix G, attached find copy of manufacturers report)

1.16.13 According to the AMM, the undercarriage operation is through a two-position lever control. The lever enters a gate in both up or down position after selection. A solenoid is energised which operates a valve that directs hydraulic fluid to appropriate ends of jacks. Through this action the landing gear becomes extended.

(i) The undercarriage has three red and three green lights corresponding to the

three undercarriage legs. When undercarriage are down and locked the three green lights lit, and when locked up, all lights are out. The red light will come on when corresponding leg are neither up nor down. The emergency lowering system is mechanical whereby hydraulic power comes from #1 controls system. Emergency lowering of undercarriage is slow (approximately 70 seconds long) and it is recommended that emergency selection is made in good time and flying control demands are kept to a minimum.

- 1.16.14 A fire in the interpipe or reheat bays would affect several major hydraulic components including the reservoirs, which were of the rubber bladder type, accumulators, selectors (invariably with bonded seals on their connecting faces) and the tailplane and rudder powered flying control units (PFCU). Also the brake parachute selector and door operating jack are situated in the rear fuselage and are powered by the No.1 controls system. A fire in this region could quickly compromise the seals in the jack and selector valve.



Figure 38 & 39 shows in-flight fire.

- (i) Below figure, description of hydraulic components located in rear fuselage which integrity would have been affected by the fire.

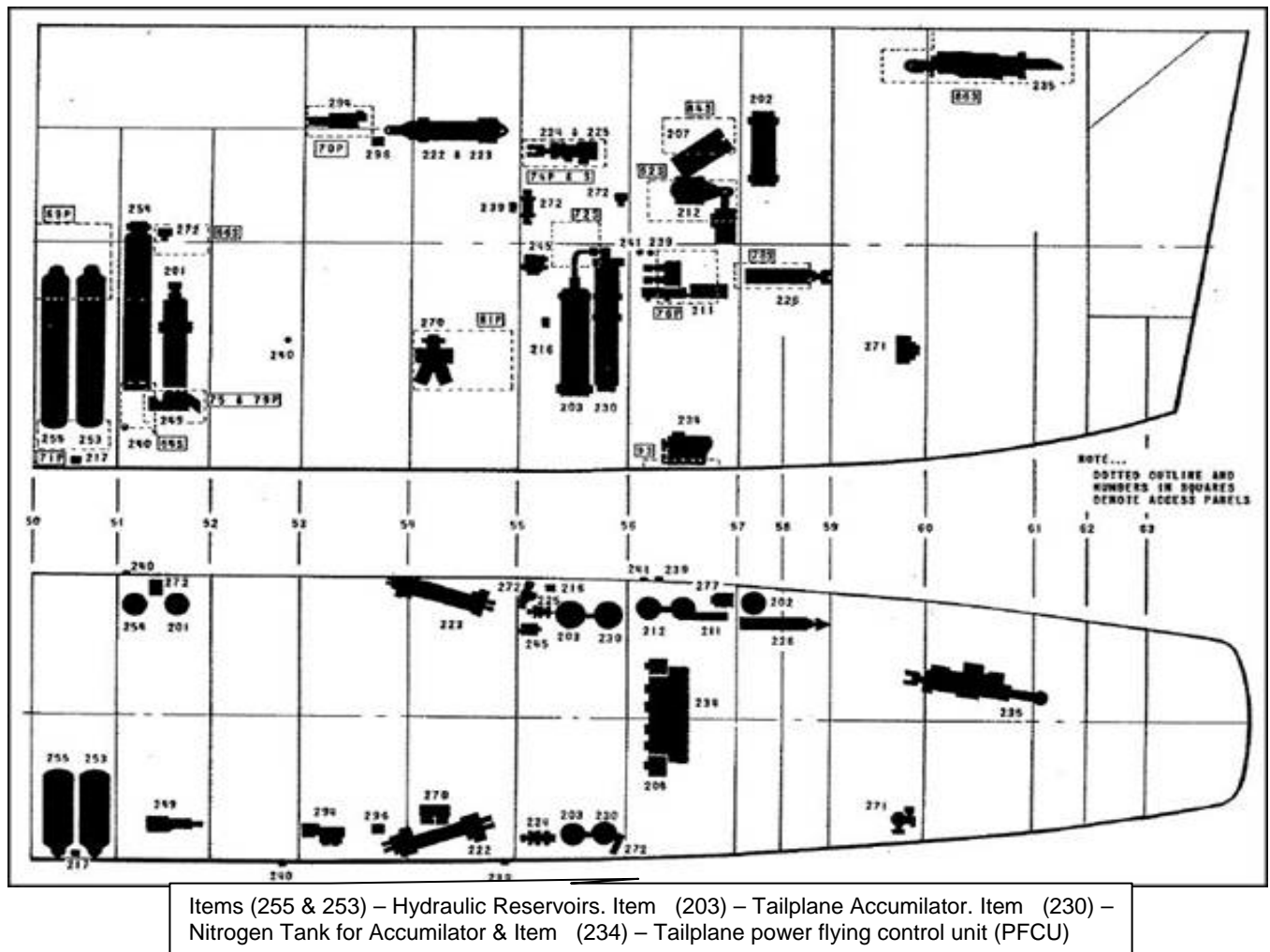


Figure 40, shows lightning hydraulic components in tail section.

1.16.15 In the case of ZU-BEX, there was proof of a tail pipe fire with flames visible at both tailplane spigots and inside the rear fuselage aft of the ventral tank fairing. An intense fire of this nature would lead to loss of the integrity of the hydraulic supplies to the PFCU and as described above the brake parachute selector would also be within the area of fire. With the loss of both control systems the pilot would experience stiffening flight controls, although the services system could remain unaffected depending how far forward the fire had originated or had spread.

1.16.16 According to the AMM, the canopy operates from the services hydraulic system. The canopy is normally opened and closed by the CANOPY operating control – on left side of the pupil's seat pan (i.e. the left hand seat). A lever having a three position toggle switch is used to open or close the canopy. To open the canopy, pull the lever up which unlocks the canopy and selecting the spring loaded toggle switch to open, enables hydraulic pressure to the canopy jack to open the canopy. During canopy operation an electric buzzer sounds to give audible warning of canopy movement will go on.

- (i) On demand for ejection, the canopy is jettisoned by pulling up the CANOPY JETTISON handle which will activate via a connecting rod and connecting link cable system, the primary cartridge inside the canopy jettison firing unit/breech. The cartridge releases a gas which flows via the connecting lines towards the port – and starboard seat by-pass valve. The gas pressure forces the piston upward, causing the piston crown to impact the canopy hook release mechanism and force the corresponding side's primary and secondary locks into the unlock positions. The gas pressure then follows the pipeline towards the high velocity canopy jettison jacks secondary cartridge firing pin units. The secondary cartridge fires and exerted gas pressure forces the high velocity canopy jacks upward to push the canopy into the air stream for separation. The canopy release from the main fuselage and activates the two Martin Baker ejection seat main cartridges by means of a cable connection.

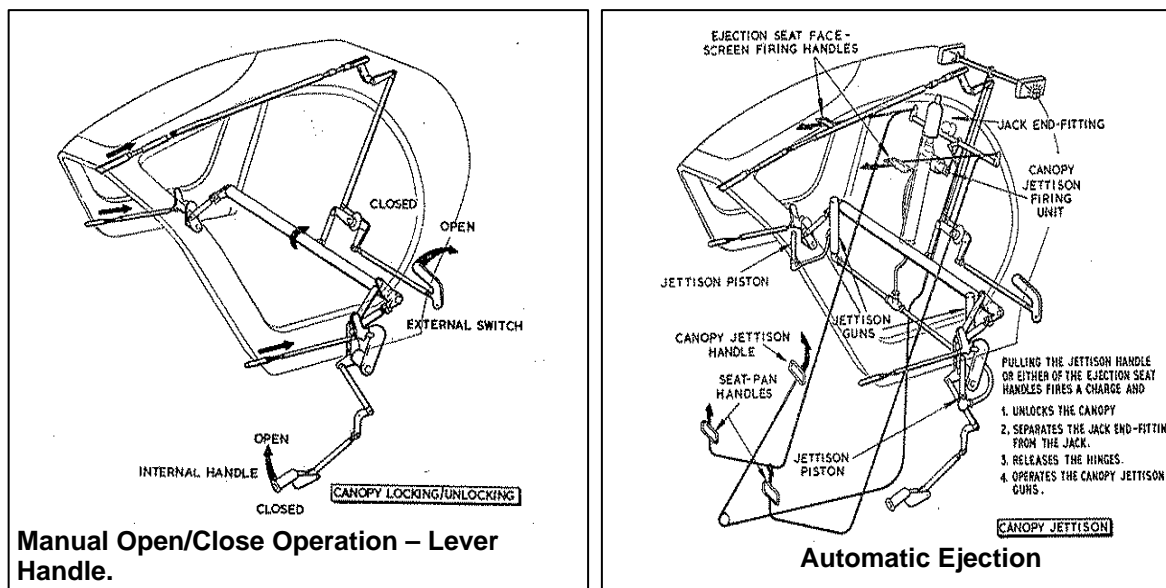


Figure 41, shows type of canopy installed on the lightning aircraft

- 1.16.17 In flight the aircrew is required to follow applicable FRC procedure. Canopy jettison emergency procedures: If, in the event of a failure in automatic ejection sequence, the canopy has to be jettisoned manually.

1.16.18 Canopy Teardown Examination: The canopy debris which was recovered from the accident site was taken for metallurgical examination. The findings and conclusion of the examination were as follows:

- (i) *Taking into account the dynamics as well as the immense energy released during a high velocity, high angle impact, it should be understood that more than one possible scenario may be applicable. Derived from the investigation results, the following are considered to be the most probable cause contributing to the failure of the ejection system.*
- (ii) *Smear sample evidence points toward the firing of all three cartridges, most probably following the activation of the ejection seat firing handle by the pilot in flight. On firing of the primary cartridge, the exerted gas pressurized the pipeline en route to the port and starboard by-pass valves via the connected T-piece. Following the starboard line, the impact evidence on the bypass valve piston crown indicates that the starboard side canopy unlocking system was activated.*
- (iii) *The primary starboard canopy hook found in the 'fully open' position confirmed this. The activation of the starboard by-pass valve allowed the gas pressure to fire the secondary cartridge in order to activate the starboard high velocity canopy jack. Evidence proved that the jack had limited upward travel resulting in the exploding of the jack sleeve due to the emitted gas pressure from the secondary cartridge. The canopy frame that was still partially in position most probably restricted the upward movement of the starboard jack.*
- (iv) *Following the portside line, the smear sample results revealed notably lower evidence of explosive residue (compared to the same starboard side positions) up to the secondary cartridge. Closer inspection of the port side exit line from the T-piece revealed that the feed line was 'pulled' from the relevant ferrule. Taking into account that none of the other retrieved pipeline/ferrule combinations showed similar signs (in most cases the pipeline/Ferrule combination proved to be strong enough to fracture the attachments rather than being separated), this combination raised concerns.*
- (v) *The evidence points toward the pipeline being 'pulled' from the ferrule leaving behind the 'skimmed' off pipe material. The exact cause for this failure could not be determined conclusively and may be due to incorrect fitment causing it to fail under the gas pressure, incorrect pipeline type/material (this line could not be located), pre-accident damages to the line or other. The disconnecting of this line would have deprived the remainder of the port side system of full gas pressure. The absence of indentation marks on the port side by-pass valve piston crown combined with the port side canopy hook found in the 'locked' position seems to confirm this. Although the evidence prove that the port side secondary cartridge did in fact fire, the orientation of the firing pin mechanism towards the impact angle may have caused the firing thereof on impact.*

1.16.19 The full technical report which include detailed information about the examination of the canopy components and parts are attached to the accident report.

(Appendix H, metallurgical report of canopy components and parts)

1.17 Organizational and Management Information

1.17.1 Aero club of South Africa (AeCSA): The AeCSA was the designated body, charged with the responsibility to do oversight on special air events (air shows). The SACAA determined that the management responsibilities, processes and procedures at air shows, particularly with regard to flight operations were not clearly understood by the aviation industry. In order to define the guidelines, the SACAA issued an Aeronautical Information Circular (AIC 19.1) which included general management conditions, rules and requirements for special air events. The AIC gave the AeCSA powers to approve organisers of special air events for each particular event. This particular special air event was organised and managed by the SAAF and the AeCSA was not involved. Though not directly involved with the air show, the AeCSA was fully aware of the air show calendar and had the option to be present or play a less significant role if interested.

1.17.2 *South African Air Force (SAAF):* The SAAF is one of the armed services of the South African National Defence Force (SANDF). The SANDF is a State Military Institution, thus the standards and recommendations set out in International Civil Aviation Organisation (ICAO), and requirements set out in South African Civil Aviation Act and Civil Aviations Regulations (CAR's) are not applicable to the SAAF unless under the following circumstances: ***“(a) aircraft belonging to the South African National Defence Force; or (b) aircraft for the time being in use exclusively by the South African National Defence Force, where such aircraft are in flight through controlled airspace or in use at non-military aerodromes and heliports” according to the relevant Government Notice.*** Hence, the SAAF was not required to comply with AIC 19.1.

1.17.3 The SAAF was the organiser of the special air event and the role of management was solely their responsibility. Their purpose was to ensure that proper management takes place; that processes and procedures are complied with by all the participants, in particular with the flight safety operations requirements. Below are a few examples of universally used basic requirements which the SAAF had to ensure:

- (i) The SAAF responsibility to appoint a qualified individual as safety and show box officer to carry out safety oversight of the special air event.
- (ii) Due to civilian aircraft participating in the air show, the SAAF responsibility was to ensure that the civilian display candidates complied with flight operations and the display requirements prescribed by their respective authorities.
- (iii) The SAAF to ensure that the venue of the air show with regard to its suitability; qualifying safety audit of airside operations pertaining to the proposed special air event.

- 1.17.4 The experience acquired by the SAAF empowered them to successfully arrange and manage the special air event. The level of their experience was tested during the time of emergency and occurrence. The SAAF acted promptly without unreasonable delay to the emergency situation and their ATC as well as search and rescue performance was found to be adequate. The SAAF willingness, at the request of the SACAA provided necessary resources and technical assistance in the investigation resulted in reduced expenditure and time. The SAAF contributions made during the onsite investigation process should be commended.
- 1.17.5 There was proof that the safety and show box officer was appointed on Tuesday, 10 November 2009 and he only arrived at FAOB on Thursday, 13 November 2009 during lunch time. According to the safety and show box officer, immediately when he arrived the first activity to do was validations. The validation of the EE Lightning aircraft was done while the pilot was carrying a passenger. The pilot did not have a valid display rating at the time of validation and during the air show. The safety and show box officer was not aware of both identified anomalies, however, there was evidence found of similar anomaly with other candidates. This information indicates that the SAAF did not ensure compliance by candidate with flight operations and display requirements.
- 1.17.6 *The Operator – Thunder City:* Thunder City Flying Company (Pty) Ltd trading as Thunder City had a valid Class III Air Service license, Number G820D issued in terms of Act 115 of 1990 on 20 April 2005 and a valid Air Operating Certificate (AOC) Part 96, issued on 21 October 2009 and expiry date 13 June 2010. The registration, ZU-BEX was authorised for utilization. Thunder City was authorised to perform commercial air operations, as defined in their operations specifications and in accordance with the operator's operations manual of procedures.
- 1.17.7 Thunder City operations were reviewed to determine if the organisation had complied with applicable regulatory requirements during the air show. The evidence found indicated that two types (Buccaneer and EE Lightning) aircraft of Thunder City participated in the air show. Thunder City ability to properly manage the operations of aircraft and pilot flying were inadequate. The SACAA conducted a renewal audit at Thunder City on 4 April 2009 and highlighted safety and quality was a problem inside the organisation. It was determined that Thunder City had no safety and quality policy in place, thus requested to do the necessary rectification actions within 90 days. There was no proof that Thunder City complied with the conclusion of the AOC audit report. Thunder City continued to operate without rectifying the audit findings.
- 1.17.8 Thunder City authorised that a passenger be carried onboard the EE Lightning for the flight from FACT to FAOB. Apart from the copy of "Indemnity" contract signed by the passenger, there was no proof that a passenger ticket was issued. Thunder City did not act in accordance with applicable regulation when transporting passengers between two independent destinations. During the twilight event air show, another passenger was carried onboard the aircraft without indemnity contract signed or passenger ticket issued. Thunder City did not apply their operations policies and procedure consistently which was one of the audit findings.

1.17.9 Thunder City had its own aircraft maintenance organisation (AMO) trading as Thunder City Aircraft Company (Pty) Ltd. Both organisations (Operator and AMO) were headed by the same Accountable Manager. The method of compliance in terms of management coordination between the two organisational structures showed that there was no management reviews. This resulted in ineffective management decision making in both organisations. The Accountable Manager did not comply with the corporate commitment agreement which was in contravention of the applicable regulations.

1.17.10 *Aircraft Maintenance Organisation (AMO)*: Thunder City AMO had a valid Aircraft Maintenance Organisation Approval Certificate Part 145 issued on 01 April 2009. The AMO Approval Certificate was valid until 31 March 2010.

1.17.11 According to the Management Corporate Commitment Statement accepted and approved by the Accountable Manager, Thunder City was to comply with all Civil Aviation Regulations and the approved Company Manual of Procedure. In order to determine if the AMO management complied with their commitment, the following issues were identified:

- (i) The AMO was required to appoint a person responsible for Quality Control who will be responsible for matters affecting airworthiness and aviation safety. The evidence found showed that the AMO did not have a Senior Person (Quality Manager) or Group of Senior Persons (Quality Inspectors) nominated to be accountable for the Quality Control System. The result was that the Quality Control activities were inadequately implemented. The AMO maintenance processes were negatively affected by the situation. The effects caused were the following;
 - (a) The AMO was required to have available sufficient number of personnel to inspect and certify the maintenance activities. The AMO did not comply with the requirement. The evidence found showed that the names of maintenance personal (certifying inspectors) listed in Part 1; List of Certifying Personnel of the manual of procedure (MoP) was not a true reflection of the individuals employed. Some of the personnel which are still reflected on the list resigned from the AMO. The MoP was not amended to reflect correct information about number of personnel employed by the company.
 - (b) The AMO was required to ensure that personnel in all technical departments are of sufficient number, experienced and have been given appropriate authority to be able to discharge their allocated responsibilities. To ensure there is full and efficient coordination between departments and within department in respect of airworthiness matters. Also, the AMO had to ensure that all maintenance personnel received initial and continuation training which was appropriate to the assigned tasks and responsibilities. Added too was that the AMO had to keep up to date all relevant documentation pertaining to the maintenance personnel. But the evidence found showed that the identified requirements were not complied with; and that the same non-compliances were identified in past audit findings.

- (c) The AMO was not receiving any technical support from the aircraft manufacturer. The result was that the AMO became solely responsible for the aircraft airworthiness. The type was declared obsolete during 1976 by the manufacturer, which meant that a whole lot of surplus spare parts became available. Thunder City purchased all the spare parts which they could obtain from the RAF and kept them in their storage facility. Majority of the parts in the stores were determined to be beyond their shelf life limit. The AMO procedure was to carry out a visual inspection of the parts to verify serviceability prior to fitting. There was stores control problems (e.g. tools missing and aircraft parts not issued through the store system) which the AMO clearly had difficulty to adequately manage.
- (d) Thunder City AMO hangar and out building space was shared with a Boat Manufacturing Organisation. The consequence of the scenario was that boats were parked next to the aircraft inside the hangar. Thunder City MoP was not amended to reflect this information.
- (e) The organisation was using an office space to carry out ejection seat maintenance. The AMO did not have a work shop intended for the purpose. A hazardous condition was identified where a number of explosive cartridges were stored in a steel cabinet due to lack of appropriate facilities approved for storage of explosives. The AMO could not produce documentation issued by appropriate Law Enforcement Agencies which authorises them to have the number of explosives. The MoP did not have relevant procedure of handling and storage of dangerous goods.
- (f) Some of the aircraft parked inside the hangar had fuel leaks. The fuel was leaking continuously. The AMO had no option but to put containers underneath the aircraft to capture the fuel. A hazard was identified with the contained fuel was left standing overnight, posing a possible fire risk.

1.17.12 The AMO management also committed themselves that the organisation will not release the aircraft to service if the defects that affect the airworthiness of the aircraft are rectified and certified. In order to assist the AMO to comply with their commitment, an aircraft maintenance schedule (AMS) was prepared by the AMO. The AMS was developed to ensure as far as possible in light of information and experience available, that the aircraft is effectively maintained in an airworthy condition by scheduling the maintenance to be done during its operational life with a programme of inspections and overhauls based on normal operational usage of the aircraft. However, in case of a defect affecting the airworthiness of the aircraft where rectification was not possible due to lack of parts, etc. The AMO has to receive prior approval from the SACAA before the aircraft, engine, module, component or equipment is released to service. There was evidence found showing that the AMO did not comply with certain requirements of the AMS. The following are identified:

- (i) Thunder City's decision to authorise that the aircraft be operated with deferred defects. The canopy system inspections which was not carried out. The ejection seats maintenance that was extended to a later date, to allow sufficient time to participate in the air show. The explosive cartridges of the ejection seats which life cycle had expired but were extended to accommodate the aircraft participating in the air show. The aircraft being operated with an invalid Certificate of Release to Service (CRS) due to it expiring.

1.17.13 The Accountable Manager, Management Personnel, Certifying Inspectors and all other role player involved employed by Thunder City AMO were displaying poor management and workmanship qualities. All the parties were equally responsible for ensuring that the aircraft was appropriately maintained in accordance with applicable regulations. They all neglected to identify, analyse and prevent unsafe conditions in the organisation.

1.17.14 *South African Civil Aviation Authority (SACAA)*: The SACAA are the custodian of the Civil Aviation Regulations and its mandate is to control and regulate civil aviation in the Republic; to oversee the functioning and development of the civil aviation industry; and in particular to control, regulate and promote civil aviation safety and security. In order to effectively and efficiently carry out this mandate, the Chief Executive Officer (CEO) and Commissioner for Civil Aviation (CCA) designated persons with necessary qualifications, powers and duties in the service of the authority as Inspectors or Authorised Officers. The Inspectors and Authorised Officers were charged with the responsibility to do oversight activities to ensure compliance to applicable regulations. In order to exercise proper control of the oversight activities, the SACAA was maintaining a register which included the information of organisations, aircraft and personnel operating in the Republic. Thunder City (Operator and AMO), the aircraft (ex-military) and all the personnel involved with operations information was also kept on the register.

1.17.15 According to the operators file, the SACAA and Thunder City's association started in November 2004 through an application to issue Part 96 - Operating Certificate. Thunder City was audited to determine if the organisation was in compliance with applicable regulation prior to issuance of the Operating Certificate. The SACAA approved Thunder City to operate and conducted oversight (audits) annually to evaluate the level of compliance. No records (audit reports and operating certificates) could be found to show that audits were carried out over three years from 2006 to 2008. The missing documents affected the investigation negatively, because it was no longer possible to determine the trend of circumstances that influenced Thunder City's level of compliance to deteriorate. There was also no proof that any surveillance inspections were carried out on the organisation during this period. The SACAA conducted a renewal audit on 4 April 2009 and during this audit identified a few non-compliances. The Quality Assurance and Safety Policies, Procedures and Systems were found to be not in place. The SACAA observation was that the findings were "**minor non-compliances**" and recommended that the AOC be renewed. Further instructions were to schedule a follow up inspection within 90 days to ensure that the necessary rectification actions have being implemented by Thunder City. However, within 28 days after issuance of the Operating Certificate, the accident occurred.

- 1.17.16 The SACAA audited Thunder City's operation in accordance with Part 135 (Air Transport for Small Aeroplanes) requirements, but Thunder City operation was Part 96 (Commercial Operation for Non-Type Certificated Aircraft). Due to the unique nature of the aircraft and operational requirements, the SACAA could not make a clear decision which of their departments should be responsible for oversight. Also, the SACAA did not have any written procedures to give guidance as to who should perform oversight duties at Thunder City. The situation unfolding was that the required oversight duty was moved between different sections within Flight Operations Department. The indecision of the SACAA led to Thunder city not being audited for a period of approximately three years.
- 1.17.17 According to the AMO file, the SACAA conducted a total of eight audits which was usually done before the anniversary date of the AMO Approval Certificate. The SACAA audited the AMO to determine whether the approval certificate could be renewed in terms of the requirements of applicable regulations. Over and above the audits, the SACAA also conducted **Surveillance Inspections** at Thunder City. After the audits and surveillance inspections were carried out, the SACAA produced audit reports which included findings categorised under the following headings: "**Severe, Major and/or simply identified as findings**". Thunder City was given time to rectify the identified findings within seven to thirty working days depending on the severity of the finding. Thunder City complied and produced an action plan, explaining in writing what actions being taken to correct the findings. There was no follow up audit conducted to verify that the corrective actions were actually implemented.
- 1.17.18 The evidence shows that the SACAA audit report findings which were raised against AMO operations were never rectified. A trend was starting to develop due to the same findings re-occurring every year. There were findings suggesting that the Quality Control Systems was not implemented. The result was that the AMO procedures were not complied with. The SACAA had enough information in the form of audit findings, which was collected over eight years, forewarning them of the hazards. The SACAA did not use the information to curb the potential risk factors endangering the AMO operation.

1.18 Additional Information

- 1.18.2 According to the MoP, work carried out away from base at another airport in the Republic of South Africa shall only be performed at CAA approved AMO's or facilities. Thunder City AMO shall timeously notify the CAA in writing of its intention to carry out the maintenance prior to commencement. There was proof found that the AMO did not comply with identified requirement of approving maintenance away from base.
- 1.18.2 The aircraft was destroyed in the accident. The destruction was caused by ground impact and fire damage. The debris was scattered around in a fan shape covering an area of approximately 37000 square meters (m²). The vastness of the accident site had its own challenges, but not as much as the risk identified involving exposure to radiation. The area first had to be tested by a radiologist to determine level of

radiation before approval was given to commence with the investigation. However, there was a point of caution that the debris should be handled with necessary care.

1.18.3 The air show was stopped temporarily after the accident occurred. All the aircraft on the Flying Programme still waiting to perform displays were recovered and those on start for slots were told to shut down. The primary concern at the time was to focus on the search and rescue operation. After the post impact fire was extinguished and determined that the pilot did not survive the accident. The air and ground search and rescue teams returned back to the aerodrome to resume their duties in the air show.



The
SAAF

decided to continue with the air show and the rest of the aircraft which were still holding slots on the program completed their displays. The pilot was honoured by his peers in a ***“missing man display”*** formation flight.

Figure 42, shows “missing man display” flown on the day.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 The English Electric Lightning MK T5 aircraft, serial number 9501 was manufactured in June 1969 by British Aerospace Systems (BAE). The aircraft was registered and operated in military operations by the Royal Air Force (RAF) of United Kingdom (UK). The RAF operated the aircraft for duration of 7 years before it was removed from service. The aircraft flew its last flight on 25 November 1976, having accumulated total time since new 1596.55 hours, 2454 landings and 5566 cycles at the time. For 21 years from 1976 to 1997, the aircraft was on the ground not flying until sold to a private entity from South Africa. After the sale of the aircraft, the new owners deregistered it from the United Kingdom (UK) register.

2.2 The new owner's intention was to export and register the aircraft on the South African Civilian Aircraft Register. After registration the owner intended to operate the aircraft in accordance with requirements of "LS1" experimental operating category in the civilian environment. The UK Civil Aviation Authority was not in favour of the idea that the aircraft will be operated in the civilian environment. Thus, the UK CAA refused to issue a permit to fly on the grounds that the safety record of the EE Lightning aircraft was considerably worse than other similar types of ex-military aircraft and also the fact that it was no longer supported by the manufacturer – BAe. On the basis of this evidence, the UK CAA stance was that as a regulator they would not be discharging their responsibility including that to the public, if they were to permit the aircraft to be operated for non-military purposes in a civilian environment. The owner was left stranded, because without a valid permit to fly, it was not possible to export the aircraft on a ferry flight. The aircraft had to be disassembled and shipped from the UK to South Africa.

2.3 The permit to fly hindrance did not discourage the owner from his ultimate mission to have the aircraft registered and operating in the civilian environment. The owner continued with the registration process with South Africa. A requirement was that a type acceptance process be followed before the aircraft could be registered. As such, South Africa's Directorate of Civil Aviation (DCA) [now known as South African Civil Aviation Authority – SACAA] came to the party. The UK CAA then wrote an official letter to the owner which was handed to the DCA, notifying them of the in-service accident data and safety record concerns which they had with the aircraft if allowed to operate in the civilian environment. The DCA was not convinced that the in-service accident and safety record of the type was critical, which can be seen by their response stating that their opinion is the EE Lightning ex-military aircraft was a relatively "simple technology" aircraft, provided with complex equipment that needed to be removed or disabled. With the complex equipment removed, the aircraft could be safely classified as being "intermediate" rather than "complex". Based on this

perception, the owner was advised that if he satisfied the requirement of removing the complex equipment and complying with additional requirements like establishing an organisation, supervision and management of maintenance engineering and flight operations, have necessary back up of spares and ground equipment, have engineering resources and qualified personnel. The aircraft will be registered and considered safe to operate in South Africa.

2.4 There was only one more barrier in the process flow to have the aircraft registered. The barrier was that the Minister of Transport had to make the final decision into the matter. The Minister relied heavily on supporting information and recommendations from the DCA before actually approving the registration of the aircraft. Evidence of a letter addressed to the Minister shows a recommendation that the aircraft must be imported and registered, but nothing was written about the UK CAA concerns. After the Minister approved, the aircraft was imported and registered. The alarming thing was that the same owner previously imported several other ex-military aircraft to South Africa. All those aircraft were involved in accidents which was exactly what the UK CAA gave warnings about.

2.5 Throughout the type acceptance process, the Conventional Arms Control Authority was not participating. The Conventional Arms Control Authority was excluded which were against the Arms Control Act (Act 41 of 2002). It resulted in a situation where the aircraft was not registered, the owner issued with necessary authorisation and regular inspections carried out by the Arms Control Authority. The notable impact was that the ex-military aircraft were in civilian hands, and that the authority charged with the oversight responsibility was not involved in its operation.

2.6 Now after 12 years that the aircraft was operating in the civilian environment. , the aircraft was involved in a tragic accident. The tragedy was that the preliminary findings shows that the factors which the UK CAA was concerned about may have played a role in the accident occurring. identified during the early stages of the investigation determined some of the factors to be since importation and registration of the aircraft in South Africa. During the investigation process, the UK CAA was requested to submit history of accident and incident information of the EE Lightning type aircraft. The accident and incident information showed that the EE Lightning type especially marks (F3, F6 and T4) in-service life was tainted with reports of fuel coupling failure defects. The defects contributed in fuel leaks that resulted in in-flight fires which caused catastrophic damage to the aircraft. All the accidents and incidents took place between 1971 and 1986. The DCA chose not to use the accident and incident information to their advantage those years ago when informed by the UK CAA. If they did listen to the UK CAA perhaps their decision to recommend importation and registration would have been different.

2.7 Shortly after the aircraft arrived and reassembled in South Africa. It was registered on the Civil Aircraft Register. The aircraft was issued with an experimental certificate of airworthiness and operated in "LS1" category the way which the owner had hoped it would be. The "LS1" regulations were amended, bringing in a new requirement that all

ex-military aircraft be classified as Non Type Certificated Aircraft (NTCA). The result was that the aircraft was issued with another different form of flying authorisation which was a Commercial Authority to Fly. The authority to fly authorised the owner to utilise the aircraft for commercial air transportation flights. The aircraft was to be operated in an approved aviation organisation in accordance with applicable regulation. The approved aviation organisation was Thunder City Flying Company (Pty) Ltd trading as Thunder City.

- 2.8 A few months after the aircraft was registered; the South African Civil Aviation Industry was undergoing a significant change with the formation of the South African Civil Aviation Authority (SACAA) on 01 October 1998. The SACAA mandate was to control and regulate civil aviation in the Republic; to oversee the functioning and development of the civil aviation industry; and in particular to control, regulate and promote civil aviation safety and security. To carry out this mandate, a Chief Executive Officer (CEO) and Commissioner for Civil Aviation (CCA) [*now Director of Civil aviation (DCA)*] and designated persons with necessary qualifications, powers and duties in the service of the authority as Inspectors or Authorised Officers were appointed. The Inspectors and Authorised Officers were then given powers to do oversight and ensure compliance to applicable regulations. Hence the SACAA became the new custodian of the Civil Aircraft Register which included the registration numbers of the EE Lightning aircraft (ZU-BEX).
- 2.9 The SACAA was responsible to carry out oversight on the maintenance and operations activities of the aircraft. The Flight Operations and Airworthiness Departments had drawn up an oversight programme which included functions like audits, surveillance and ramp inspections. The Flight Operations Department conducted oversight on Thunder City Air Operators. The Airworthiness Department conducted oversight on Thunder City AMO. The Operator and AMO were audited annually for the past 7 years since 2004 with the aim to determine their level of compliance to applicable regulation. In some cases surveillance inspections were carried out to verify the organisations willingness to comply with the regulations. After the identified inspections were carried out, reports were drafted and presented to Thunder City.
- 2.10 Thunder City's level of compliance was always and remained a challenge for the SACAA. There were two prominent findings which reoccurred in every audit and surveillance inspections. The findings were that the **quality** and **safety systems** were not implemented in the organisation. The quality and safety systems were very important programs. Implementation of the systems was a mandatory regulatory requirement. Organisations which did not implement the systems were acting in contravention of the regulations. Thunder City promised in their action plans to correct the situation, but did nothing.
- 2.11 The SACAA Flight Operations and Airworthiness Departments were aware of the problems in Thunder City. The identified departments had over the years raised a list of findings against Thunder City. The organisation was never held accountable for non closure of audit findings. The SACAA continually renewed the approval certificate/s of Thunder City. In the mean time the quality and safety record of the organisation was fast deteriorating drastically. It was a potentially dangerous situation

developing. The information of the situation with Thunder City was never highlighted to the Commissioner for Civil Aviation (CCA) [now Director of Civil Aviation].

- 2.12 Thunder City continued to maintain and operate the aircraft as usual without due consideration for the regulations. Until the time when the South African Air Force (SAAF) was hosting a special air event (air show) held at Air Force Base Overberg Flying and Development Military Aerodrome (FAOB) on 14 November 2009. The SAAF had invited Thunder City to bring their ex-military aircraft to participate in the air show. The air show programme included both military and civilian aircraft participating in the air show. A number of military aircraft that was going to participate was belonging to the SAAF. The civilian aircraft was privately owned by corporations and approved aviation organisation.
- 2.13 Thunder City was an approved aviation organisation. Three ex-military aircraft of Thunder City was dispatched to the air show. The English Electric Lightning MK T5 supersonic fighter jet with registration number ZU-BEX was one of the aircraft. The pilot accompanied by a passenger flew the aircraft from FACT to FAOB on 13 November 2009. It was a commercial air transportation flight. The pilot did not report any defect or malfunction experienced with the aircraft during the flight. It was considered to be an uneventful flight.
- 2.14 After the aircraft entered the airspace of FAOB, the pilot decided that he was not going to land and broadcasted to the ATC requesting permission or approval to continue with the validation flight. The validation flight was to validate the aircraft to perform in the air show on 14 November 2009. The ATC had to discuss the pilot's request with the Safety Officer. The air show activities, which also included the approval of validation flights was the responsibility of the Safety Officer. The Safety Officer approved the pilot to continue with validation flight. The Safety Officer then evaluated the validation flight and found it to be satisfactory. The aerobatic display was approved for the air show. The pilot landed the aircraft after the validation flight was completed.
- 2.15 The evidence shows that the Safety Officer only arrived at FAOB on 13 November 2009. The Safety Officer arrived a few minutes before the aircraft. The Safety Officer was a last minute replacement for another person. Due to other commitments, it was not possible for the Safety Officer to immediately take over the responsibility or travel to FAOB. The Safety Officer realised that time was going to be a critical factor and immediately proceeded to approve the validation flights. The rest of the activities he was entrusted with, which fell within his scope of responsibility, waited until after the validation flights were approved. This was clearly not an ideal situation and it could have resulted in an unsafe condition.
- 2.16 A passenger was carried on board the aircraft during the validation flight. The Safety Officer stated that he was not aware a passenger was carried on board the aircraft. A flight plan was filed which indicated the number of occupants. FAOB received a copy of the flight plan. It is not common practice for flight crew members to report the number of passengers carried on board prior to landing at an aerodrome. There was

no expectation that the pilot should make an announcement of the passenger, unless if the information was specifically requested. FAOB ATC and Safety Officer both did not ask if a passenger was carried on board the aircraft prior to the validation flight. The pilot was acting in contravention of applicable regulations, when he carried a passenger on board the aircraft during the validation flight.

2.17 The flight from FACT to FAOB was a commercial type of flight. Thunder City was supposed to have issued the passenger with a valid air transportation ticket. The evidence shows that a passenger ticket was never issued. The aircraft was flown in an evening air show with a passenger. The passenger was one of Thunder City's maintenance personnel. No evidence of maintenance related event could be found to corroborate the reason for his presence on board the aircraft. As such it was determined that the passenger was supposed to be issued with a passenger ticket. All the identified passenger related issues was found to be not in compliance with applicable regulations. Thunder City blamed the pilot for the passenger non-compliances. Thunder City's position of blaming the pilot for the passenger ticketing issue was not acceptable. The issuance of passenger tickets was not the responsibility of an individual but the function of the organisation. Hence the organisation, not the pilot, was supposed to ensure that the passenger tickets were issued in accordance with applicable regulations.

2.18 The evening air show was flown in night time conditions. Aircraft operating under NTCA requirements was not permitted to be flown by night. This was non-compliance in terms of the applicable regulations. Thunder City's position about the evening air show was that the flight had not being authorised. The evidence shows that the Accountable Manager of Thunder City witnessed the evening air show. The Accountable Manager insisted that the evening air show was an unauthorised utilisation of the aircraft. The pilot's actions in this regard could be construed as taking the aircraft without obtaining permission. Irrespective of the above, Thunder City still allowed the pilot to continue flying the aircraft in the air show the following day.

2.19 The SAAF arranged for a wine auction and tasting event on the evening before the air show. A special evening air show was arranged which coincided with the wine auction and tasting event. The EE Lightning was a participant in the evening air show. There was no evidence of the EE Lightning performing a validation flight for the evening air show. The SAAF and Thunder City were asked about the EE Lightning participating in the evening air show. Both organisations responses were found to be inconclusive. It appears that the duties and responsibilities of the Safety and Air Show Box Officer were not considered during the evening air show.

2.20 The aircraft took off without a brake parachute installed. The pilot was aware of this fact, but still decided to continue with the flight. The brake parachute was important in the operation of the aircraft, especially during landing sequences. The brake parachute was invariably an integral part of the aircraft to ensure safe landing. The

implication of not having a brake parachute installed may affect the safe operation of the aircraft. There is no airworthiness limitation against flying without it, but the possible risks factors outweigh any decision to operate the aircraft without it. The aircraft may sustain other defects and/or damage as a result of the brake parachute not being deployed.

2.21 The FAOB ATC observed fire sparks coming from the right side undercarriage during landing after the evening air show. The fire sparks was an indication of the wheel-brakes heated to an undesirable temperature. The ATC notified the pilot of the fire sparks coming from the wheel-brakes. The response of the pilot indicated that he was not too concerned about the wheel-brakes situation. He continued to taxi the aircraft regardless of the risk that damage to the brakes and tyres may occur. A runway of sufficient length was needed to compensate for the aircraft's increased landing roll. Also, the pilot was required to be very careful not to put heavy demand on the wheel-brakes. Based on the fact of the fire sparks and comment which the pilot made suggesting that the wheel-brakes were "just hot" indicates that heavy demand was put on the brakes. The aircraft was exposed to the risk of a runway excursion – overrun, brake lockup, skidding, tyre burst, flat spots or even veering off the runway.

2.22 After landing and during the taxi roll back to the parking bay, the pilot stopped the aircraft. The pilot informed ATC about his intention to light the afterburner. Only engine #2 afterburner was lit due to the risk of too high engine power which requires excessive use of brake, risking overheating of the brakes especially since the aircraft came to a stop. Another factor could be that engine #2 was further to the rear of the aircraft, thus reduce the risk of the other engine #1 being overheated. Also, the pilot probably decided not to light engine #1 afterburner due to the deferred defect of the nozzles that was causing uncommanded fluctuation in afterburner aft and forward power ratio. There were reports suggesting that engine #2 afterburner was lit for minimum (± 3 seconds), however, the evidence shows that the afterburner was lit for approximately 27 seconds. The usage of the afterburner on the ground would result in high fuel consumption and high temperature which could contribute to unexpected failures. After the afterburner was lit successfully, the pilot continued to taxi back to the apron.

2.23 Under normal circumstances, a pilot would light the afterburners when the aircraft is airborne. If the afterburners were to be lit on the ground, it would be done by maintenance personnel who had appropriate training with relevant experience. The important thing to remember would be to follow applicable maintenance procedures when lighting the afterburners on the ground. For this reason, Thunder City criticised the pilot's actions regarding the afterburner issue. In fact there are no procedures for the pilot empowering him to light the afterburner on the ground in the Flight Reference Card. The pilot did not comply with aircraft manufacturers requirements and thereby compromised the safe operation of the aircraft.

- 2.24 After the afterburner was lit, the aircraft started to taxi back to the apron. The pilot suddenly experienced an engine #2 flameout. The flameout took place a few seconds after the afterburner was cancelled. The passenger stated that the pilot throttled back too far and inadvertently shutdown the engine. However, under normal circumstances, to pull the throttle lever fully back would not cause the engine to shutdown. A stop at the IDLING position prevents rearward movement of the throttle lever; to select HP COCKS OFF the SHUTDOWN lever at the rear of the throttle box must first be pressed forward.
- 2.25 The aircraft was parked outside on the apron overnight. The next morning at 0810Z, the aircraft was refuelled and uplifted sufficient fuel for the flights during the air show. Approximately 0818Z, the ARFF personnel was called out to the apron to contain a fuel leak. When the ARFF personnel arrived at the apron, they realised that the EE Lightning was leaking fuel. There were fears that the quantity of fuel leaking from the aircraft on the apron was a fire hazard and could cause damage to the surface of the apron. The ARFF personnel experienced difficulty to contain the fuel spillage on the apron, because the fuel was leaking continuously from the aircraft. It took the ARFF personnel approximately 30 minutes to attempt to contain the fuel spillage of the aircraft. The ARFF personnel reluctantly left the apron at 0850Z, not convinced that the measures which they put to contain the fuel leak will be sustainable. The ARFF personnel had other important commitments in the air show which they had to attend to. They were reassured by Thunder City maintenance personnel that it was a normal occurrence for the EE Lightning type aircraft to have a fuel leak. A fully refuelled EE Lightning left in a hot sun would start to vent from the wing vent valves or flap tank relief valves as the fuel expanded. The perception of the maintenance personnel was justified, based on the evidence of fuel leak scenario that was observed from a similar type aircraft parked inside the hangar at Thunder City. It was determined that the maintenance personnel were confirmation bias about the fuel leak problem. Their attitude toward the situation most probably resulted in the reason why they did nothing to investigate the casual factors of the fuel leak. No attempt was made to determine the quantity (how much), duration (how long) and cause (what) the fuel leak on the apron.
- 2.26 The first defect of fuel leaking in the pitot/static system. The fuel was leaking out of pitot probe. The aircraft manufacturer stated that the fuel leak from the pitot/static system was a serious problem, which was indicative of a fault in a fuel valve which probably occurred as a result of internal failures of the components connected to the pitot/static system in the fuel venting system. Thunder City AMO made an entry that the pitot/static system was drained. Draining the pitot/static system was only a temporarily measure to remove the obvious visible problem. The maintenance requirement was to carry out intensive and protracted inspection on the pitot/static system to locate the source of the fuel leak. There was no inspection carried out on the aircraft to determine the cause of fuel leak from the pitot probe.
- 2.27 The second defect of fuel venting overboard during taxi. A defect of this nature was an indication of a fuel valve failure within the fuel system. The solution was to carry out an inspection on the aircraft and identify the fuel valve/s that failed. The aircraft obviously need to stay on the ground until the defective fuel valve/s been identified and required repairs carried out prior to releasing it back to service. If a similar defect was reported in the RAF, the reaction was cancellation of the flight due to the concern which was that there is no guarantee that the defect will stop in flight. Again as before with the pitot/static system, no inspection was carried out on the aircraft to determine the cause of the defect. The defect was deferred to the next service and the aircraft

was released to service.

- 2.28 The third defect of nozzles that were causing uncommanded fluctuation in the afterburner. When the afterburner is selected the nozzles opens to intermediate and maximum position. The effect could be that the nozzles remain open after afterburner cancelation. The result would be accumulation of unburned fuel in the hot streak (ignition) system and lead to fires in the jet pipe. It was important that a defect of this nature should be rectified in case of uncommanded nozzle change at a critical stage in flight. Also just as it was the case with the other two defects, no inspection was carried out on the aircraft to determine the cause of the defect.
- 2.29 All three defects were closely related. The most critical one out of the three was that of fuel leaking from pitot/static system. It is critical because the components in the fuel venting system were installed in each integral wing tank. It may well be that either one or a combination of the three defect contributed in the aircraft having the fuel leak. The fuel leak problem was never resolved because it continued. An undetermined quantity of fuel was leaking from the aircraft while taxiing from the apron and also during the flight. The evidence of the liquid fluid trails shows fuel leaking from multiple areas on the aircraft. The aircraft manufacture analysed all the fuel leak information which was identified in the investigation and determined that fuel was leaking from the reheat bay, forward engine bay and main engine bay vents.
- 2.30 The pilot had a valid Airline Transportation Pilot License (ATPL) and the aircraft type rating was endorsed on it. He also had a valid Class 1, Aviation Medical Certificate with no waivers. The pilot did not have any medical condition which prevented him from flying the EE Lightning aircraft. The pilot was employed by the SAAF, then SAA and also freelancing for Thunder City. His piloting experience is shown by the amount of flying hour which he accumulated in the aviation industry. The time that the pilot was still employed in the SAAF, he was stationed at FAOB and flew the military aircraft as a test pilot. It was concluded that the pilot was familiar with the SAAF operations procedures and he was well known by FAOB personnel.
- 2.31 The pilot experienced an engine/s flamed out condition with the aircraft. The pilot responded by using the words "that's right" basically acknowledging that he was aware of the flame out. The ATC saw a large plume of smoke coming from the aircraft which the pilot said was as a result of the relight. The passenger who was in the aircraft at the time submitted a statement describing the events pertaining to the flight. The statement was compared to ATC recordings and it was found that the sequences of events as told by the passenger did not follow the time line of the ATC recordings. The passenger stated that the engine flame out was induced by the pilot. The pilot allegedly pulled back too far on the engine throttle lever/s and inadvertently went to engine shut down instead of Idle. Also, that the relight was unsuccessful due to the reason of not having enough battery power to get the engine/s to start.
- 2.32 The ejection seat did not eject from the aircraft. The pilot attempted to eject but he

was unsuccessful. The ejection seat was determined to be the last line of defence built in the aircraft for the purpose of safeguarding the pilot throughout the escape, survival, location and recovery phases. It was vitally important that every facet of the ejection system from the initiation escape path clearance, ejection sequencing, stabilisation, life support, parachute deployment to be in a perfectly working and serviceable condition. The ejection seat was the most effective way of emergency escape for the pilot.

2.33 Thunder City's AMO was charged with the legal responsibility to ensure that the aircraft ejection system was always maintained in a serviceable condition. In order to fulfil the identified responsibility effectively, the AMO was required to comply with the aircraft manufacturer's requirements and applicable regulations.

- (i) According to the AMM (AP101B-1000-5A1), the requirement was that the ejection seat bay servicing life inspection should be carried out annually. The AMO did not comply with the identified bay servicing life inspection requirement. The evidence found indicated that the ejection seat was not serviced before or on the due date which was on the 10th of September 2009. The AMO management granted a 30 days extension intended not to carry out the bay servicing life inspection. The day on which the 30 days extension was granted was after duration of 49 days already have gone past. Only then was a defect entry to "snag" the ejection seat made in the flight requirements log. The AMO management realised that the 30 days extension interval had expired and they could not fly the aircraft without taking corrective action. So, they decided to give another 45 days extension. The additional 45 days extension was going to be until 12 December 2009. The extensions were granted without consulting with the regulator as required by approved AMS and applicable regulation. In terms of the MoP, the AMO was also not authorised to grant extensions. The aircraft was parked inside the hangar for duration of 66 days from 10 September to 13 November 2009. The aircraft was flown on four (4) occasions during the 66 days and each flight lasted for 30 to 40 minutes. Under normal circumstances the AMO took approximately 40 man hours (5 working days) to complete the ejection seat bay servicing. In the past the bay servicing was carried out during the annual inspections. The last annual inspection was certified on 14 October 2009. It was strange to note that when reaching the date of annual inspection, the ejection seat bay servicing was still not carried out. However, both extensions were approved not taking into account that the ejection seats might potentially develop a critical life threatening latent defect in the identified period. Based on the identified information of the days and time required for the ejection seat bay servicing, annual inspection and the 66 days the aircraft was on the ground. It is the opinion of the investigator that the AMO had more than enough time to carry out the required ejection seat bay servicing inspection.
- (ii) The ejection seats explosive cartridges were found to be overdue at the time of the accident. The install life and shelf life interval of the cartridges expired. The evidence found indicated that the cartridges were installed on the ejection seat for approximately 8 to 10 years at the time of the accident. The install life was approximately 5 to 8 years overdue and well over the total in service life limit. The anomaly of the cartridges was discussed with the manufacture – Pretoria Metal Pressing (PMP), focusing on the issues of attempting to address the worst case scenarios in terms of the cartridges going off "exploding" during initiation. A few was under discussion, but the significant one was most

probably affecting the discharge time. Implying that the sequence of ejection will be delayed slightly. The AMO management was of the opinion that the SACAA granted an approval to extend the cartridges install life to 10 years. However, they were not able to or in a position to show proof in the form of an official letter or certificate that the SACAA ever issued such an approval. The manufacturer - PMP of the cartridges was dumb struck by the revelation of the situation. The manufacturer - PMP was of the opinion that the cartridges found installed on the ejection seats was supposed to be replaced with new serviceable cartridges at the time when they became calendar and time expired. It was very important that the cartridges supposed to be in a serviceable condition. The life of the pilot and any other occupant (passengers) carried onboard the aircraft depended on the serviceability status in terms of having a safe ejection sequence.

- (iii) The ejection seat parachute assembly and personal survival pack was also no exception to the rest. The evidence found also indicated that the two items bay servicing inspection was not complied with by the AMO. Both items was last inspected on 10 August 2008. The “long and short” of the ejection seat not ejecting scenario was that the ejection seats were unserviceable and the AMO did not comply with the applicable regulations in Part 24.01.2 (1)(c), which stating that “Before a non-type certificated aircraft is considered to be airworthy it shall have no known condition which could make the aircraft unsafe for flight”.

2.33 The ATC received an emergency communication from the aircraft. The pilot reported an urgency condition, suggesting that he was threatened by grave and immense danger and in need of immediate assistance. The pilot was experiencing a double hydraulic failure condition which was an operating efficiency impaired to the extent that an emergency landing was likely to follow. Instead of making a distress call “MAYDAY”, the pilot elected to make an urgency call “PAN-PAN-PAN” spoken three times. Thereafter he maintained contact (initially 6 seconds interval) with ATC updating them on the status of the situation. The underestimation of the seriousness of the problem “DOUBLE HYDRAULIC FAILURE” was probably the reason why the pilot decided to make the urgency but not distress call.

2.34 The underestimation of the seriousness of the problem resulted in a 5 minute time delay between (10:17 to 10:22) before the pilot eventually decided to take aversive action and activate the ejection seat to eject. The time delay was a critical factor between life and death. Giving the pilot a benefit of the doubt, especially in light of his experience as a test pilot, it is possible that he probably believed that the threat of danger was not that serious. It is the opinion of the investigator that the pilot probably thought he was having the situation under control at the initial stage of identifying the emergency. However, the time element was always going to be a crucial factor for him.

- 2.35 The requirement of the Flight Reference Card (FRC) states - ***“When receiving HYD1 and HYD2 indication, the immediate action to take should be not to attempt to land with double hydraulic failure”*** The pilot did not comply with the instruction. He instead made a decision to lower the undercarriage to land. The unexpected then happened which probably caught him by surprise when the left side main gear remained retracted. The left side main gear issue prevented him from landing. In an attempt to save the situation, he decided to “blow down” the main gear. It may be probably to follow the emergency undercarriage blow down procedure, which was pulling the emergency selector and/or exposing the aircraft to “G” forces – shake the wings (side to side) to extend the gear. The investigation could not conclusively determine which one of the two emergency undercarriage blow down procedures was executed. The blow down scenario took him approximately 97 seconds between (10:18:17 to 10:19:54). The pilot was determined and became fixated in solving the undercarriage problem. The time factor was slowly starting to work against the pilot. All he needed to do was to adhere to the FRC instruction stating- ***“landing with undercarriage in abnormal position, requires an immediate action not to attempt to land and to abandon the aircraft”***.
- 2.36 There was still the other factor like the inextinguishable in flight fire which was reaching or already at a self sustaining temperature and fast reducing any chance for the pilot to land, ditch and/or evacuate from the aircraft. This was the time when the pilot should have taken the item of the Flight Reference Card (FRC) ***“When receiving double (HYD1 & HYD2) hydraulic failure indication, not to attempt to land but prepare to abandon the aircraft”*** very seriously.
- 2.37 At no stage during the pilot’s communication with ATC did he report a fire on board the aircraft. The ATC recordings did not indicate any alarms sounds in the background during the communications with ATC indicating a fire warning alarm.

3. CONCLUSION

3.1 Findings

Personnel

- 3.1.1 The pilot had a valid Airline Transportation Pilot License (ATPL) and the aircraft type rating was endorsed on it.
- 3.1.2 The pilot had a valid Class1 Aviation Medical Certificate with no waivers and he had no medical condition which may have prevented him from flying on the day.
- 3.1.3 The pilot was flying as a free lance pilot and he was appointed as safety officer of the operator of the aircraft.
- 3.1.4 The pilot did not have a valid Aero Club Membership. His aerobatics display rating had expired when participating in the air show.
- 3.1.5 The pilot was carrying a passenger onboard the aircraft during the validation flight

which was against the applicable regulation.

- 3.1.6 The pilot flew the aircraft during night time conditions in an evening air show, carrying a passenger and both action were not in accordance with applicable regulation.
- 3.1.7 The action by the pilot to light the afterburner on the ground was against the aircraft manufacturer requirements.
- 3.1.8 The pilot did not adhere to the Flight Reference Cards, when dealing with the emergency situation during the flight.
- 3.1.9 The investigation determined that the pilot was not aware the aircraft having a fire during the flight.
- 3.1.10 The pilot were fatally injured in the accident.
- 3.1.11 The investigation determined that the maintenance personnel did not have appropriate documentation which authorised them with the privilege to carry out maintenance on the aircraft.
- 3.1.12 The investigation determined that the maintenance personnel did not have sufficient experience and lacked the necessary training to carry out maintenance on the aircraft. Their actions and statements indicated that their knowledge and understanding of the aircraft systems was inadequate.
- 3.1.13 The investigation determined that defects were deferred by the maintenance personnel which was not in accordance with manufacturers requirements and applicable regulations.

- 3.1.14 The investigation determined that the maintenance personnel was aware of the fuel leak and spillage caused on the apron but they did not carry out an investigation into the cause of fuel leak.

Aircraft

- 3.1.15 The aircraft was operating in the United Kingdom Royal Air Force (RAF) since new until 25 November 1976 before being deregistered and imported to South Africa.
- 3.1.16 The aircraft was registered in South Africa and operated under LS 1 which is experimental/recreation operation category.
- 3.1.17 The aircraft operated under LS 1 category for duration of three years until being re-classification on 14 February 2005 to Non Type Certificated Aircraft (NTCA) and issued with a Commercial Authority to Fly which was in accordance with applicable regulations.
- 3.1.18 The aircraft was operated commercially for duration of four years until on the day of

the accident.

- 3.1.19 The aircraft was maintained by an approved aircraft maintenance organisation (AMO) whom carried out and certified the last Annual Inspection on 14 October 2009.
- 3.1.20 The aircraft documentation was reviewed during the investigation process and determined that the certificate of release to service (CRS) was invalid due to it being expired.
- 3.1.21 The maintenance documentation of the aircraft was reviewed during the investigation process and a number of anomalies were identified with the way in which entries were made and certifying thereof.
- 3.1.22 The maintenance processes were not in accordance with the manufacturers requirements and/or applicable regulations.
- 3.1.23 A list of five defects were raised against the aircraft which was subsequently deferred by the AMO and found to be not in accordance with applicable regulations.
- 3.1.24 The aircraft was refuelled at FAOB uplifting sufficient quantity of fuel for the flight.
- 3.1.25 The aircraft had no previous accident history, but was involved in one incident which was related to a hydraulic failure where it was determined that the hydraulic (HYD 1) pump failed internally.

Ejection System

- 3.1.26 The pilot reported that he was experiencing an ejection seat failure during the flight in the air show.
- 3.1.27 The investigation determined that the ejection seats and ejection system did not undergo annual maintenance inspection as required by aircraft manufacturer and applicable regulations.
- 3.1.28 The investigation determined that the ejection seats and ejection system was unserviceable due to all the cartridges fitted were expired.
- 3.1.29 The expired cartridges were granted an extension by the AMO without obtaining prior approval from the Commissioner of Civil Aviation (CCA).
- 3.1.30 The evidence found during the metallurgical examination to determine the cause of canopy jettison failure was due to the failure of the port side canopy release mechanism which left the canopy in a partially open position.

- 3.1.31 The evidence found during the metallurgical examination to determine the cause of the failure of port side canopy release mechanism was due to the port side feed line being pulled out under gas pressure from the relevant ferrule.
- 3.1.32 The exact cause of the pipeline/ferrule installation failure could not be determined conclusively in the investigation process.
- 3.1.33 The evidence shows that the disconnected pipeline deprived the port side canopy release mechanism system of full gas pressure.
- 3.1.34 The evidence shows that the port side secondary cartridge did in fact fire, the orientation of the firing pin mechanism toward the impact angle may have caused the firing thereof on impact.
- 3.1.35 The evidence shows that the failure of the canopy release system would have left the ejection seats inoperative, thus resulting in the pilot being unable to eject from the aircraft during the flight.

Engine/s

- 3.1.36 The evidence shows that engine #2 flamed out during lighting of the afterburner after landing on the day before the air show.
- 3.1.37 The evidence shows that the aircraft manufacturer requirements for lighting afterburner on the ground were not adhered to and thus may have resulted in accumulation of fuel in the hot streak ignition system which further could have resulted in a risk of having a jet pipe fire due to the unburned fuel accumulation.
- 3.1.38 There was no evidence found to show that the engine #2 flame out was reported through relevant channels, hence there was no action taken by maintenance personnel to determine the cause of the flameout.
- 3.1.39 Ultimately, the actual cause of engine #2 flame out could not be conclusively determined in the investigation.
- 3.1.40 A deferred defect related to uncommanded nozzle movement on engine #1 was raised which according to the aircraft manufacturer should have been rectified before the next flight was undertaken, due to uncommanded nozzle change at critical stage of flight.
- 3.1.41 The engine of the aircraft was no longer being supported by the engine manufacturer due to the aircraft being obsolete.

Fuel System

- 3.1.42 There was evidence of a fuel spillage being reported to FAOB ARFF on the apron where the aircraft was parked.
- 3.1.43 The fuel spillage which was reported to FAOB ARFF was determined to be as a result of an observed fuel leakage from the aircraft.
- 3.1.44 The fuel was leaking continuously from the aircraft, hence the fuel spillage on the apron could not be completely contained by FAOB ARFF.
- 3.1.45 When the aircraft started to taxi away from its parking bay, there was trails of fuel stains which followed the direction of the aircraft taxiing to the runway.
- 3.1.46 Based on the photographic evidence which was forwarded to the aircraft manufacture, their position was from where the aircraft was parked, during taxi and take-off run indicates that there was a substantial fuel leak from within the fuselage or ventral tank to fuselage interface.
- 3.1.46 The investigation determined that the fuel leak was from multiple areas on the aircraft, which was identified to be from the reheat bay, forward engine bay and main engine bay vents.
- 3.1.47 The evidence shows that the deferred defect related to fuel venting overboard during taxi required immediate cancellation of flight, to determine the source of the leakage because there was no guarantee that the fuel leak will stop during flight. (in accordance with the Air Crew Manual, Part 1, Chapter 2).
- 3.1.48 The investigation determined that the fuel venting overboard problem continued during the flight. The evidence of fuel venting can be seen by the two separate trails of atomised fuel emanating from the fuselage slightly aft the ventral tank as well as the interface between the fuselage and lower reheat jet pipe exit.
- 3.1.49 The investigation determined that the fuel status of the aircraft was affected by the fuel leakage problem, whereby errors were identified with fuel quantity values, showing unaccounted unburned fuel missing from the aircraft.
- 3.1.50 The evidence of accident history of the EE Lightning aircraft which was provided by the aircraft manufacturer shows that fuel coupling failures contributed to fuel leakage and the cause of in-flight fires resulted in the loss of the aircraft involved in the accidents.
- 3.1.51 Ultimately, the actual cause of the fuel leak could not be determined conclusively in the investigation due the level of destruction to the aircraft during the impact sequence.

Hydraulic System

- 3.1.52 The pilot reported to FAOB ATC that he was experiencing a double hydraulic failure during the flight.
- 3.1.53 The investigation determined that when the double hydraulic failure occurred, an indication will be observed with HYD 1 and HYD 2 warning on the AWP and additional HYD warning on the SWP with attention-getter.
- 3.1.54 The undercarriage of the aircraft was extended after the double hydraulic failure with the intention to return to FAOB for an emergency landing.
- 3.1.55 There was an undercarriage failure experienced during the flight, whereby the port side main landing gear remained retracted.
- 3.1.56 The pilot reported that he was losing control of the aircraft after the emergency was declared.
- 3.1.57 The investigation determined that the cause of the aircraft becoming uncontrollable was as a result of the hydraulic failure, which affected the operation of the flight control system of the aircraft.
- 3.1.58 The investigation determined that the integrity of a number of significant hydraulic components were compromised by the in-flight tail pipe fire, which probably resulted in the double hydraulic failure.
- 3.1.59 The investigation determined that in case of a double hydraulic failure, the requirement is not to attempt to land, to use minimum control movement, to establish 1g flight above 5000 ft AGL, to fly with at least 70% engine power toward a suitable ejection area and prepare to abandon the aircraft which was not complied with.
- 3.1.60 There was no defect or malfunction reported about the aircraft hydraulic system prior to the flight, hence the hydraulic system was considered to be in a serviceable condition before and during the flight.
- 3.1.61 Ultimately, the actual cause of the hydraulic failure could not be conclusively determined in the investigation due to the level of destruction to the aircraft in the impact sequence.

In-flight Fire

- 3.1.62 Copies of photographic evidence were obtained from several spectators at the air show which indicate the aircraft having a tail pipe fire in-flight.
- 3.1.63 The photographic evidence was analysed during the investigation process and the analysis concluded that the bright spots identified on the rear fuselage depict areas on the aircraft where flames emanated from the starboard rear fuselage around the tailplane, aft of the ventral tank and forward of the lower reheat jetpipe exit.

Management

- 3.1.64 The operator did not issue passengers tickets as required by applicable regulations.
- 3.1.65 The operator authorised that the aircraft be flown between two independent destinations which was not in accordance with applicable regulations.
- 3.1.66 The operator's quality and safety systems were audited and anomalies concerning implementation were identified which shows that the two systems were not in compliance with applicable regulation.
- 3.1.67 The ATC controller and show box officers were licensed and rated to provide the service during the air show.
- 3.1.68 The ATC provided prompt and effective service to the pilot during the emergency.
- 3.1.69 The ATC was pro active in notifying the ARFF in advance to provide assistance to the pilot in the event the pilot ejected from the aircraft.
- 3.1.70 The ATC directed the pilot away from the spectators during the emergency.
All the aerodrome approach aids were operating normally at the time of the accident.

Safety Oversight.

- 3.1.71 The SACAA audit and surveillance safety oversight programme design does not adequately address the diverse and complex nature of the aircraft.
- 3.1.72 The SACAA audit and surveillance safety oversight programme identified that the quality and safety systems as problem areas, however, the oversight program was ineffective in producing sufficient and timely measures of improvement.
- 3.1.73 The SACAA oversight monitoring program was ineffective in identifying and making the operator to correct deficiencies.
- 3.1.74 The SACAA did not have relevant skilled, trained and/or experienced inspectors to carry out inspections on this type of aircraft.
- 3.1.75 The UK CAA refused to issue the aircraft with a permit to fly due to the in-service accident history which demonstrates a safety record considerably worse than other similar ex-military aircraft.
- 3.1.75 The UK CAA's refusal not to issue the permit to fly to the aircraft subsequently resulted in an situation where it was prevented from flying in their airspace and had to be disassembled for shipment to South Africa.

3.1.75 The UK CAA notified the South African Aviation Authority (DCA at the time) in a letter of the safety concerns they had with the idea of operating the aircraft in a civilian aviation environment. The safety concerns of the UK CAA were overruled and aircraft was imported, registered and operated in civilian aviation environment in South Africa.

3.2 Probable Cause/s

3.2.1 Uncontrolled flight due to double hydraulic failure.

Contributory Factors

3.2.1 Defects related to fuel leakage not rectified but incorrectly deferred until next annual inspection.

3.2.2 External fuel leakage occurred on the ground at parking bay, taxi and take-off run.

3.2.3 Aircraft not grounded or rectified after evidence of fuel leak discovered prior to next flight.

3.2.4 Overboard fuel venting from the fuselage during the flight.

3.2.5 Pre-impact fire starting as a result of fuel ignition in jet pipe.

3.2.6 Pre-impact fire during the flight and the heat cause damage to the components and/or parts in the hydraulic system.

3.2.7 Double hydraulic failure (HYD1 and HYD2).

3.2.8 Undercarriage malfunction, causing that the left hand side main landing gear (MLG) not to extend which affected an emergency landing being executed.

3.2.9 Pilot in command (PIC) not adhering to FRC's.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that the Commissioner for Civil Aviation (CCA) should through the relevant certification department in the CAA; re-evaluate the applicable regulatory requirements of airworthiness status of all the ex-military aircraft currently on the Civil Aircraft Register which is maintained in accordance with CAR Part 24 and operated commercially in accordance with CAR, Part 96. Specific focus on:

- (i) The issue of technical support in the form of supplying serviceable components and parts.
- (ii) Availability of relevant maintenance documentation and tools and equipment to do proper maintenance on the aircraft.

- (iii) Appropriately trained, qualified and/or competent maintenance personnel.
- (iv) Appropriate facilities available.

4.2 It is recommended that the South African Air Force (SAAF) should include in their Air Show Manual of Procedures a procedure which requires that all Operators and/or Owners invited to an air show arranged by the SAAF should have in their possession valid documentation prior to them being allowed to participate in the air show:

- (i) Valid RAASA or Aero Club membership.
- (ii) Valid Pilot License with aerobatic aircraft type rating endorsements on it.
- (iii) Valid aerobatic ratings.

4.3 It is recommended that the Director for Civil Aviation (DCA) should discontinue the ineffective and insufficient current arrangement implemented within the SACAA geared to conduct oversight over classified Non-Type Certified Aircraft (NTCA) which operates commercially in accordance with Civil Aviation Regulations (CAR) Part 96 requirements and replace with a division or section which ever seen to be suitable whom will be charged with the responsibility to conduct effective and efficient oversight activities.

4.4 It is recommended that the Director of Civil Aviation (DCA) should consult with the State of Design and Manufacture (United Kingdom) with the view to source assistance from the aircraft manufacturer – British Aerospace Systems into a process of reviewing the continued airworthiness status of the Lightning ex-military aircraft currently on the Civil Aircraft Register. The aim of the recommendation is for the DCA to request that BAE Systems to inspect the aircraft and provide detailed technical report which covers both operations and airworthiness factors relevant to the Lightning aircraft in so far as aviation safety.

4.5 It is recommended that the Minister of Transport through the office of the Director of Civil Aviation participating with different affected Government Departments institute a board of enquiry into the Lightning ex-military aircraft and all other ex-military aircraft operations which are on the Civil Aircraft Register and currently owned by ordinary civilians. These ex-military aircraft has the potential to pose a threat to the State Security and Aviation Safety.

4.6 It is recommended that the Director of Civil Aviation (DCA) through the relevant departments (Airworthiness and Flight Operations) in CAA should develop requirements for appointed of appropriate person/s to act in the role of Accountable Manager (Operator and Aircraft Maintenance Organisation). This will ensure that proper leadership is shown in the approved organisation in accordance with the stipulated requirements in the approved Manual of Procedures (MoP). There was evidence found indicating that Quality Control Systems in both identified entities were not appropriately implemented as required by the MoP which is in contravention of the applicable regulations.

4.7 It is recommended that the Commissioner for Civil Aviation should through the

relevant department (Airworthiness) ensure that Operators and Owners which are operating ex-military Fighter Jet aircraft should have installed serviceable ejection seats.

5. APPENDICES

5.1 Appendices A: Copy of Aircraft Manufacturers Technical Report.

Compiled by :

.....
for Commissioner for Civil Aviation

Date:

Investigator-in-charge:

Date:

Co-Investigator:

Date:

Appendices:

**Letter from UK CAA to Classic Jet Aircraft Company presented
to SACAA about issuance of the Permit to Fly
(Page one)**

SAFETY REGULATION GROUP

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For the attention of ^{NAME REMOVED}XXXXXXXXXX
Classic Jet Aircraft Company
36 Vapron Road
Mannamead
Plymouth
Devon
PL3 5NN

Our ref 9/97/10MG/03/01/2

10 February 1997

Dear Sir

LETTER TO THE CAA CHAIRMAN REF: LIGHTNING AND BUCCANEER AIRCRAFT

I have been asked to reply to your letter addressed to ^{NAME REMOVED}XXXXXXXXXX the Chairman of the CAA, regarding the Lightning and Buccaneer Aircraft.

All of the items to which you refer have previously been addressed by the Authority. It is noted that you consider the two Regulation 6 appeals have not led to a conclusion, this is incorrect, the Authority did clearly reach a conclusion, all the issues raised at the hearings were promulgated by letters dated 2 July 1992 and 25 June 1991 signed by ^{NAME REMOVED}XXXXXXXXXX and ^{NAME REMOVED}XXXXXXXXXX respectively.

In respect to the summary items of your letter dated 3 February 1997, the CAA comments are as follows:

1. The original submission from the South African Authority inferred that the aircraft would take off and land from Boscombe Down, being under the control of Boscombe Radar throughout the test.

It was subsequently apparent that the aircraft flew to Exeter and completed the sorties from Exeter not Boscombe. It was also understood that the first aircraft was under operational control of the MOD prior to transfer to the South African register whereas the second aircraft had been out of service for a prolonged period. The circumstances were not therefore identical or comparable.

BCAR A3-7 does not allow acceptance of an aircraft for a Permit to Fly to be considered as series - other than for a type approved aircraft. By definition each aircraft must be assessed on its own merits.

2. It is not the duty of the Authority to gain a direct in-depth knowledge of military aircraft. In cases where an application for a Permit to Fly is received for such an aircraft, the Authority has to seek necessary guidance and advice from the persons familiar with that or similar types. In many cases the original type design organisation will be the only organisation approved for such information.
3. The complexity categorisation under BCAR A8-20 by the Authority is based on the guidance and advice provided in the response received for item 2 above.
4. A 'competent organisation' in the context of maintaining, operating and the continuing airworthiness support for ex-military aircraft, is one that the Authority can be satisfied will provide standards at least equivalent to those for which the in-service safety record has been achieved.

(Page two)

2

10 February 1997 NAME REMOVED
For the attention of X X X X X

This raises two issues:

Firstly, the in-service accident data for the Lightning which has so far been made accessible to the Authority, demonstrates a safety record considerably worse than other similar ex-military aircraft which have been granted Permits to Fly by the Authority.


(Note: A satisfactory safety record is a requirement of BCAR Chapter A3-7 para 3.1(d) and Appendix I para 2.1 for any ex-military aircraft, independent of the "complexity category".

Secondly, in the same way that the Authority may need to seek advice on the aircraft itself (See 2 above), it will also need to seek similar advice and in some cases (complex aircraft) direct support for the control and operation in order to be satisfied that the "competent organisation" criteria has been met.

5. The Authority has and will contrive to demonstrate a consistent policy on the issuance of Permits to Fly to ex-military aircraft by the application of BCARs A3-7/B3-7 and A8-20.

I must re-iterate that there is nothing new in the above. All the items have been discussed many times and little will be achieved until the applicant, be it the South African Authorities or the Lightning Group address the requirement of the Authority.

Yours faithfully



NAME REMOVED
X X X X X

Head of Applications and Certification Section

Appendix:

Letter from Directorate of Civil Aviation (DCA) to Minister of Transport
(Page one)



DEPARTMENT OF TRANSPORT

MEMORANDUM

TO: MINISTER

Reference: J2/42

Enquiries: ^{NAME REMOVED} XXX XXXX Ext 2593


SUBJECT: ACCEPTANCE OF AN EX-MILITARY ENGLISH ELECTRIC LIGHTNING T MK5 XS 452 AIRCRAFT AND A BLACKBURN BUCCANEER S2B XW987 AIRCRAFT, FROM THE UNITED KINGDOM ON TO THE REGISTER OF THE REPUBLIC OF SOUTH AFRICA

1. The purpose of this submission is to obtain approval that:

- (i) Principal Engineer (aeronautical), ^{NAME REMOVED} XXX XXX XX and Principal Airworthiness Inspector, ^{NAME REMOVED} XXX XXX XX, be allowed to visit the Civil Aviation Authority (CAA) of the United Kingdom (UK) in Gatwick, Cranfield, where the Lightning aircraft is being prepared, as well as to visit Boscombe Down for the Buccaneer aircraft, to consult with the UK CAA on their acceptance of the two aircraft to operate in the UK airspace for the purpose of flight testing and positioning for shipping the (Lightning) and ferrying (Buccaneer) and for the acceptance of the two aircraft onto the register of the Republic of South Africa (RSA), during the period 21 to 29 October 1996;
- (ii) the offer of Classic Jets (Pty) Ltd for all travel, accommodation and subsistence expenses be accepted; and
- (iii) for the subsistence and incidental expenses.

2. Classic Jets (Pty) Ltd, Cape Town, has been established to purchase, maintain and operate vintage ex-military jet aircraft. The company has already purchased and registered two Hawker Hunters, a Blackburn Buccaneer and an English Electric Canberra (which has subsequently crashed). The company has now an option to purchase a further Buccaneer aircraft and an English Electric Lightning aircraft. The Lightning aircraft is being prepared for flight at Cranfield, Bedfordshire and the Buccaneer aircraft is being prepared at Boscombe Down, UK.

(Page two)

3. The English Electric Lightning WS 452 aircraft has been undergoing major maintenance at Cranfield, Bedfordshire, in preparation for being shipped out to the RSA and has been registered with the UK CAA, but has not been able to obtain a permit to fly, due to a UK requirement that an aircraft classified as "Complex" must have the manufacturers support. This is not possible to obtain and a stalemate exists. Discussions with the UK CAA are required to clarify the major issues and to see if concessions for the operation in RSA are possible. The company have also purchased a second Blackburn Buccaneer S2B XW 987 at Boscombe Down. The aircraft are being prepared by a company named The Classic Jet Aircraft Company, Plymouth, Devon, UK. It is proposed that a visit be made by officials from this department, ~~XXXXX~~ ^{NAME REMOVED} Principal Engineer Aeronautical and ~~XXXXXX~~ ^{NAME REMOVED} ~~XXXXX~~ ^{REMOVED} Principal Airworthiness Inspector. ~~XXXXXX~~ ^{NAME REMOVED} ~~XXXXXX~~ is the area inspector where these aircraft are to be operated in the RSA, where Classic Jets, Cape Town, is preparing these aircraft to ensure that all documentation is in place before registration marks are issued and a ferry C of A being provided. Registration marks and an Authority to Fly are being requested for these aircraft such that the UK CAA will allow flight testing and positioning flights in the UK. This issue needs to be discussed with the UK CAA to ensure that there will be no misunderstandings and that the procedures followed by this Department will be acceptable to the UK CAA.
4. Classic Jets (Pty) Ltd. have indicated in their letter (see Appendix A) that they are willing to provide air travel, accommodation and subsistence for the period required to undertake the above tasks.
5. Provision will however, have to be made for subsistence and incidental expenses: -
- | | | |
|-----|---------------------------------------|------------------|
| (a) | Subsistence allowance: | |
| | UK £8 per day for x 2 days per person | R 916.00 |
| (b) | Incidental expenses: | R 500,00 |
| | TOTAL: | R1 416.00 |
6. Funds to cover the above expenses are included in the 1996/1997 budget under responsibility 1466 402211 3066. 
7. As Director-General, I wish to confirm that I have no objection to the Department's officials accepting the offer from Classic Jets (Pty) Ltd.

(Page three)

8. IT IS RECOMMENDED FOR YOUR CONSIDERATION THAT:

- (A) ^{REMOVED}XXXXXXXXXX AND ^{NAME REMOVED}XXXXXXXXXX UNDERTAKE THE VISIT TO THE UNITED KINGDOM TO ENABLE ACCEPTANCE OF THE LIGHTNING T MK 5 AIRCRAFT AND BUCCANEER S2B AIRCRAFT ONTO THE SOUTH AFRICAN REGISTER; and
- (B) THE OFFER OF CLASSIC JETS (PTY) LTD FOR TRAVEL AND RELATED EXPENSES FOR THE ABOVE VISIT BE ACCEPTED; and
- (C) THAT THE SUBSISTENCE AND INCIDENTAL ALLOWANCES BE APPROVED.

9. For your consideration please.

^{NAME REMOVED}
XXXXXXXXXX
 DIRECTOR-GENERAL: TRANSPORT
 DATE:^{96.10.18.}.....

DIRECTOR-GENERAL: TRANSPORT

Recommendation in paragraph 8 that:

- (A) Messrs ^{NAME REMOVED}XXXXXXXXXX and ^{NAME REMOVED}XXXXXXXXXX undertake a trip to the United Kingdom from 21 to 29 October 1996 is approved/ not approved/ or
- (B) The offer of Classic Jets (Pty) Ltd to provide air travel and related expenses for the trip to the UK is approved / not approved / or
- (C) Subsistence and incidental allowances are approved / not approved / or

^{REMOVED}
XXXXXXXXXX
 MINISTER OF TRANSPORT
 DATE:^{21/10/96}.....

Appendices

Thunder City AMO Corporate Commitment



THUNDER CITY AIRCRAFT COMPANY (PTY.) LTD.
ISSUE 2 REV 5. Revision Date: 30/06/2009

Page 12 of 100
AMO 288

PART 1

MANAGEMENT

1. Corporate commitment

1.1

- 1.1.1 The Members and Accountable Manager and the Organisation have committed themselves to comply with the airworthiness requirements as set out in this document and approved by the Commissioner for Civil Aviation.
- 1.1.2 All maintenance carried out by this Organisation shall be strictly in accordance with the Civil Aviation Regulations, 1997, as amended and in compliance with this approved Company Manual of Procedure as well as all amended to date aircraft, component and equipment Manufacturer's Manuals and Instructions.
- 1.1.3 Only aircraft, components and equipment for which this Organisation is rated shall be maintained and only when the facilities, specialized equipment, tooling, amended to date airworthiness data and certifying personnel to maintain these aircraft, components and equipment are available.
- 1.1.4 It is understood that any new or amended Regulations, published in the South African Civil Aviation Regulations, and/or any other Instructions issued by the CAA, and/or any instructions issued by the aircraft, component and/or equipment manufacturer's from time to time, which may be in conflict with these procedures, that the provisions of the latter shall prevail.
- 1.1.5 It is further understood that the CAA reserves the right to suspend, withdraw and/or amend the approvals of the Aircraft Maintenance Organization (AMO).
- 1.1.6 These procedures are accepted and approved by the undersigned and must be adhered to at all times.

A handwritten signature in black ink, appearing to read 'M.A. Beachy Head'.

SIGNATURE ON BEHALF OF
THUNDER CITY AIRCRAFT MAINTENANCE
COMPANY (PTY.) LTD.

NAME: M.A. Beachy Head


Accountable Manager
POSITION

Appendices:

Commercial Authority to Fly


AW 01206 CAR24L

**SOUTH AFRICAN CIVIL AVIATION AUTHORITY
REPUBLIC OF SOUTH AFRICA**



CERTIFICATE NO : J15/ ZU-BEX

AUTHORITY TO FLY		
1. Nationality and registration marks	2. Manufacturer and type/variant designation of aircraft	3. Aircraft serial number
ZU-BEX	ENGLISH ELECTRIC LIGHTNING T5	95011
4. Categories <input type="checkbox"/> COMMERCIAL <input type="checkbox"/>		
5. This aircraft does not meet the comprehensive requirements of the International Civil Aviation, dated 7 December 1944. The authority to fly is issued in terms of the Aviation Act, 1962 (Act 74 of 1962), as amended, and the Civil Aviation Regulations, 1997 as amended, in respect of the above-mentioned aircraft which is considered to be airworthy when maintained and operated in accordance with the foregoing and the pertinent operating limitations, and airworthiness code as provided by Part 24 and Part 96 of the Civil Aviation Regulations, 1997 as amended.		
6. Special conditions : SEE REVERSE SIDE		
7. Expiry Date : 12 October 2010		
Date of issue : 26 October 2009		


 FOR COMMISSIONER
 CIVIL AVIATION
 COMMISSIONER FOR CIVIL AVIATION

Reverse side of Authority to Fly

SPECIAL CONDITIONS OF AUTHORITY TO FLY

1. This aircraft is restricted to the Air Service Licensing Act of 1990 and the Air Operators Certificate issued for commercial operations.
2. No person may operate the aircraft described :
 - (i) except in accordance with the applicable Regulations and in accordance with the conditions and limitations which may be prescribed by the Commissioner as part of the Certificate;
 - (ii) over any foreign country without the special permission of the authority of that country;
 - (iii) except in terms of the Part 96 Operations Manual;
 - (iv) except in terms of Part 94 when not engage in commercial activity;
 - (v) if the ownership is changed;
 - (vi) if the aircraft was involved in an accident or incident.

Appendices –

Certificate of Release to Service – Calendar time and operating hours expired.

THUNDER CITY AIRCRAFT MAINTENANCE COMPANY (PTY.) LTD. SITE 10, CAPE TOWN INTERNATIONAL AIRPORT TEL: (021) 532-2330, FAX: (021) 531-3735/567-0886		AMO 288 NO.:
CERTIFICATE OF RELEASE TO SERVICE		
AIRCRAFT REGISTRATION: <u>ZU-BEX</u> AIRCRAFT MODEL: <u>F4U</u> AIRCRAFT SERIAL NO.:	Time: <u>13:00</u> Date: <u>31/12/02</u>	Signature: <u>[Signature]</u>
CATEGORY "W" ELECTRICAL I hereby certify that I am satisfied that all the electrical equipment and related systems are in every way serviceable for flight and that all maintenance has been carried out in accordance with the Civil Aviation Regulation, 1997, as amended, and its Approved Maintenance Schedule.	Time: <u>13:00</u> Date: <u>31/12/02</u>	Signature: <u>[Signature]</u>
CATEGORY "W" INSTRUMENTS I hereby certify that I am satisfied that all the instrument equipment and related systems are in every way serviceable for flight and that all maintenance has been carried out in accordance with the Civil Aviation Regulation, 1997, as amended, and its Approved Maintenance Schedule.	Time: <u>11:40</u> Date: <u>24-12-02</u>	Signature: <u>[Signature]</u>
CATEGORY "W" RADIO I hereby certify that I am satisfied that all the radio equipment and related systems are in every way serviceable for flight and that all maintenance has been carried out in accordance with the Civil Aviation Regulation, 1997, as amended, and its Approved Maintenance Schedule.	Time: <u>12:00</u> Date: <u>27/12/02</u>	Signature: <u>[Signature]</u>
CATEGORY "C" ENGINES I hereby certify that I am satisfied that all the engines and related equipment are in every way serviceable for flight and that all maintenance has been carried out in accordance with the Civil Aviation Regulation, 1997, as amended, and its Approved Maintenance Schedule.	Time: <u>13:00</u> Date: <u>31/12/02</u>	Signature: <u>[Signature]</u>
CATEGORY "A" AIRCRAFT I hereby certify that I am satisfied that all the airframe and related equipment are in every way serviceable for flight and that all maintenance has been carried out in accordance with the Civil Aviation Regulation, 1997, as amended, and its Approved Maintenance Schedule.	Time: <u>13:00</u> Date: <u>31/12/02</u>	Signature: <u>[Signature]</u>
NOTE: THIS LAST ITEM MUST NOT BE SIGNED AS FINALLY RELEASING AIRCRAFT UNTIL THE ABOVE ITEMS HAVE BEEN SIGNED.		
This certificate lapses at a total of <u>1672</u> <u>HRS</u> hours of flight time when check <u>1</u>		
Will be due on <u>1672</u> <u>HRS</u> (date), whichever occurs first, unless the aircraft is involved in an accident or becomes		
unserviceable in which case the certificate is invalid for the duration of the period.		
EXTENSION This Certificate will now lapse at a total of _____ hours of flight time when check _____ will be done.	Time: _____ Date: _____	Signature: _____ Word Number: _____

Appendices:

Flight Servicing Certificate – Extension of Ejection Seat Servicing

LIGHTNING FLIGHT SERVICING CERTIFICATE

A/C Type : <u>Lightning</u>	A/C Ser. No. <u>ZU BEX</u>	Total A/F Hrs: <u>1739.00</u>	Cert No: <u>200</u>	TCY/LIT/1
CAPTAIN'S AFTER FLIGHT CERTIFICATE Chute: <input checked="" type="checkbox"/> Streamed; <input type="checkbox"/> Not Streamed: I certify that each unserviceability has been raised and details of the flight have been entered in the flying log.		FUEL LOADS I Mk 5 Internal = 5656 lbs Ventral = 7630 lbs F Mk 5 Internal = 5656 lbs Ventral = 10396 lbs Overwings = 14662 lbs		
AFTER FLIGHT SERVICING I certify that the above Servicing has been completed.		REPLENISHMENT CERTIFICATE Fuel load required LBS Litres - Lbs x 1.77 Lbs - Litres - 1.77 Fuel in tanks after Fuel in tanks after REFUEL/DEFUEL/CHECK REFUEL/DEFUEL/CHECK Fuel remaining (LBS) Fuel put in/out TOTAL IN A/C <u>7630</u> Fuel Type <u>327 A1</u> AVPIN Name: <u>CERTIFYING INSPECTOR ONE</u> Signature: <u>[Signature]</u> Time/Date: <u>16.11.02</u>		
BEFORE FLIGHT/TURNDOWN SERVICING I certify that the above Servicing has been completed.		HYD ACC: @ 15 C Wheel Brakes = 1700 psi F Services = 1500 psi R Services = 1500 psi T/P 1 = 1500 psi Fuel = 115 psi TYP 2 = 1500 psi All 1 = 1500 psi All 2 = 1500 psi OXYGEN: 5/8 Min TYRE PRESS MAIN: TMk5 = 300 psi +/-0 FMk6 = 330 psi +/-0 NOSE: TMk5 = 245 psi +/-0 FMk 6 = 250 psi +/-0 ENGINE OIL MIN LEVEL Engines = 2 pints down ATGB above min		
FLIGHT REQUIREMENTS LOG <u>SEATS 50 DAYS EXTENTION</u> <u>POST AIR SHOW 145 DAYS</u>		OXYGEN STATE: <u>Full</u> Signature: <u>[Signature]</u> BRAKE CHUTE STATE: Ser No: <u>[Signature]</u> Filled/Checked Signature: <u>[Signature]</u>		
FLIGHT RELEASE CERTIFICATE I hereby certify that this aircraft has been inspected I.A.W Approved Maintenance Schedule and is fit for its intended flight.		CAPTAIN'S ACCEPTANCE CERTIFICATE I accept this a/c as fit to fly and I am aware of the entries in the limitations log and the Flight Requirements Log.		
Name: <u>Certifying Inspector One</u> Time: <u>16.11.02</u> Signature: <u>[Signature]</u> Date: <u>16.11.02</u>		Name: <u>THE PILOT</u> Signature: <u>[Signature]</u> Licence No: <u>TA 202 2020</u> Date: <u>14/</u> Time: <u>11:15</u>		

EJECTION SEAT AND COMPONENT LOG CARDS

EJECTION SEAT TYPE	MARK	SERIAL No. (PORT)	AIRCRAFT SERIAL No.		
(45) TYPE 4 BSB MK 2	2	45	ZU-BEX.		
LOG CARDS FOR THE FOLLOWING COMPONENTS * ARE CONTAINED IN THIS PACK					
COMPONENT	24/7/2007	10/09/2008	Serial Numbers		
	On Receipt	1st Change	3rd Change	4th Change	No. of Sheets Enclosed
SEAT STRUCTURE	45	45			
EJECTION GUN TYPE 4M MK1	10184	10184			
DROGUE GUN TYPE 9 MK 2	6264	6264			
BAROMETRIC TIME RELEASE UNIT TYPE 6 MK 1	14335	14335			
BREECH TIME DELAY FIRING UNIT	5795	5795			
CANOPY INITIATORS					
EMERGENCY OXYGEN BOTTLE					
OXYGEN REGULATOR/HYDRAULIC VALVE					
DROGUE WITHDRAWAL LINE No Serial No. MBEU 26698					
MAIN DROGUE (5ft)	DL 5014	DL 5014			
AIR BOTTLE					
ROCKETPACK	N/A.	N/A.			
PARACHUTE PACK (A49)	A524886	A524912			
PERSONAL SURVIVAL PACK (A49)	2380				
* Delete Components not applicable					

(FORM A.701b AFIXED OVER LEAF)

NOTE - THIS CARD IS TO BE COMPLETED IN PENCIL

Appendices:

Change of Serviceability Log – Defects Deferred to next service (Check 2)

Change of Serviceability Log

Aircraft Type LIGHTNING Mk T5 Serial No Zu-BEX

Aircraft Placed Unserviceable						
Time and Date	Airframe Hours	How Found or Aircrew Code	By Whom (Name)	Serial Number of Work (SNOW)	Reason for Placing Unserviceable	Job Number
(a)	(b)	(c)	(d)	(e)	(f)	(g)
20/7/9	1736.05	FLT	The pilot	0369	Pump S on continually.	1
20/7/9	1736.05	FLT	The pilot	0370	Please bleed main branches	2
14/10/9	1737.20	Routine	The certifying inspector ONE	0371	ANNUAL INSPECTION TO BE CARRIED OUT.	3
30/10/09	1738.30	FLT	The pilot	372	#1 ENGINE NOZZLES TO BE INSPECTED UNCORRELATED FLUCTUATIONS IN #1 ABATE/FW PUMP	4
30/10/09	1738.30	FLT	The pilot	373	FUEL WARNING ODCOMBOARD DURING TAXI	5
30/10/09	1738.30	FLT	The pilot	374	GEN CUTS OUT AT LOW RPM WITH ASSOCIATED LOW BATT VOLTAGE	6
30/10/09	1738.30	FLT	The pilot	375	LOUD BACKGROUND NOISE ASSOCIATED WITH GENERATOR OR ALT OR INVERTER	7
30/10/9	1738.30	FLT	The pilot	376	FUEL LEAKING INTO PITOT/STATIC SYSTEM (LEAKING OUT OF PITOT PROBE)	8
						9
						10

Note For Army Use, print name under signature

Change of Serviceability Log

Aircraft Type LIGHTNING Mk T5 Serial No Zu-BEX

Aircraft Placed Unserviceable						
Time and Date	Airframe Hours	How Found or Aircrew Code	By Whom (Name)	Serial Number of Work (SNOW)	Reason for Placing Unserviceable	Job Number
(a)	(b)	(c)	(d)	(e)	(f)	(g)
20/7/9	1736.05	FLT	The pilot	0369	Pump S on continually.	1
20/7/9	1736.05	FLT	The pilot	0370	Please bleed main branches	2
14/10/9	1737.20	Routine	The certifying inspector ONE	0371	ANNUAL INSPECTION TO BE CARRIED OUT.	3
30/10/09	1738.30	FLT	The pilot	372	#1 ENGINE NOZZLES TO BE INSPECTED UNCORRELATED FLUCTUATIONS IN #1 ABATE/FW PUMP	4
30/10/09	1738.30	FLT	The pilot	373	FUEL WARNING ODCOMBOARD DURING TAXI	5
30/10/09	1738.30	FLT	The pilot	374	GEN CUTS OUT AT LOW RPM WITH ASSOCIATED LOW BATT VOLTAGE	6
30/10/09	1738.30	FLT	The pilot	375	LOUD BACKGROUND NOISE ASSOCIATED WITH GENERATOR OR ALT OR INVERTER	7
30/10/9	1738.30	FLT	The pilot	376	FUEL LEAKING INTO PITOT/STATIC SYSTEM (LEAKING OUT OF PITOT PROBE)	8
						9
						10





Note For Army Use, print name under signature

Change of Serviceability Log

Previous _____ /2 Page Completed Certificate	Signature
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Zu - BEX.

Page No 38 / 1

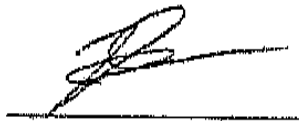
Record of Work Carried Out, Replacements Etc							Author: Signature
Repairs, Storage Instructions, Modifications, Special Technical Instructions Servicing Instructions or other Work including Component Replacements. Note 1. State Serial Numbers of Replacement Items, where applicable. 2. RN Only. Quote Workshop Reference ORN.	Signature of Operative(s)	Time and Date Completed	Trade	Man Hours	Signature of Supervisor	Certified Defect Cleared or Transferred to MOD Form 703/70	
(h)	(j)	(k)	(l)	(m)	(n)	(p)	
1 STD PRES. SWITCH REMOVED AND SCRAPABLE SWITCH FITTED. TESTED AND SERVICED. SN. FITTED. 317.	CERTIFYING INSPECTOR A	12.00 21/2/09			<i>[Signature]</i>		
2 PORT & STBA BRAKES BLEAD.	CERTIFYING INSPECTOR A	14.20 27/2/09			<i>[Signature]</i>		
3 ANNUAL INSPECTION CARRIED OUT.	<i>[Signature]</i>				<i>[Signature]</i>		
4 DEFERRED TO NEXT SERVICING (CHECK 2)	CERTIFYING INSPECTOR C				<i>[Signature]</i>		
5 DEFERRED TO NEXT SERVICING (CHECK 2)	CERTIFYING INSPECTOR C				<i>[Signature]</i>		
6 DEFERRED TO NEXT SERVICING (CHECK 2)	CERTIFYING INSPECTOR C				<i>[Signature]</i>		
7 DEFERRED TO NEXT SERVICING (CHECK 2)	CERTIFYING INSPECTOR C				<i>[Signature]</i>		
8 P. TOT / STABIC SYSTEM DRAWN	CERTIFYING INSPECTOR C	16.00 02/02/09			<i>[Signature]</i>		
9							
10							

Note: For Army Use print name under signature

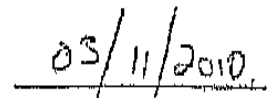
STATEMENT

I, Riaan Hermanus Combrinck ID #: 8310015024081 hereby give a statement regarding the logbook entries made in the logbook of ZU-BEX pertaining to the deferred snags referred to by Mr. Jeremiah the CAA crash investigator assigned to the crash of ZU-BEX.

The snags mentioned to me in a telephone conversation with Jeremiah and then shown to me in an interview with Mr. Amanullah Mohamed of the CAA Cape Town offices have been written in the logbook by me on the written dates as in the logbook. Due to my lack of experience with these aircraft I discussed these snags with my superiors. It was decided by my superiors after the discussion that these problems would be attended to during the check 2 servicing that was due on ZU-BEX. I was then told to defer the snags in the logbook of ZU-BEX.



R.H Combrinck



Date

Appendices

Accident Preliminary Report

SOUTH AFRICAN



**CIVIL AVIATION
AUTHORITY**

INTERIM REPORT NO. 1 IN RESPECT OF THE INVESTIGATION INTO THE CAUSE(S) OF AN ACCIDENT INVOLVING AN ENGLISH ELECTRIC LIGHTNING MK T5 AIRCRAFT, ZU-BEX, DURING AN AIR DISPLAY ON 14 NOVEMBER 2009.

The objective of a serious incident investigation is to establish the cause (s) of the incident and to take steps to prevent a further occurrence. As such the objective is not to apportion blame or liability.

The purpose of this investigation is therefore to ensure that the investigation is conducted in the most effective and comprehensive way to establish the cause(s). The investigation team is committed to adhering to the International Provisions defined in Annex 13 to the Convention on International Civil Aviation, of which South Africa is a signatory.

It is trusted that the investigation will lead to the introduction of corrective actions, should any deficiencies be identified, to ensure the continued safety of passengers transported in South African airspace and on South African aircraft.

Issued by the AIID

SACAA

22 December 2009

Contents

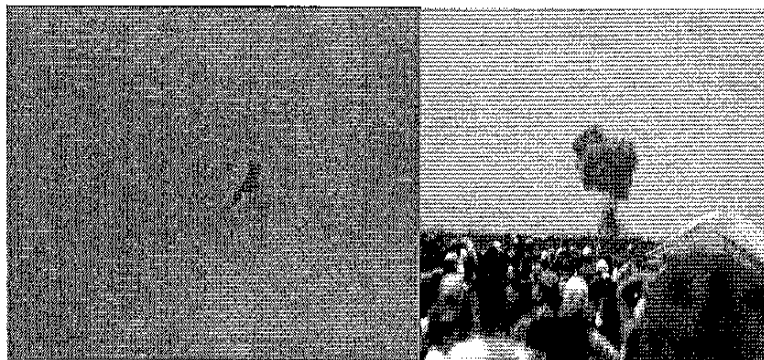
	Page
1.0 Background	3
2.0 The Investigation	4
3.0 Actions taken to date	4
4.0 Summarized information obtained to date	5
5.0 The Aircraft's Ejection Seats	7
6.0 Organizational and Management Information	9
7.0 Interim Safety Recommendations	9
8.0 Activities to follow	10

1.0 Background

The pilot accompanied by a passenger flew the aircraft from Cape Town International Airport (FACT) to Overberg – Test flying and Development Aerodrome (FAOB) on the 13 of November. On arrival at FAOB, the pilot did not land the aircraft, but immediately proceeded with his validation flight for the air show. After he completed the display sequence in front of the air show operation officer, the pilot landed the aircraft and taxied to Apron B (hard stand) where he parked the aircraft for the afternoon.

Later that afternoon, the pilot accompanied by different passenger flew the aircraft again, but in the area of Overberg. After landing on the runway, the pilot stopped and requested clearance from the tower to light up the afterburners of the aircraft. The event of the afterburners was quite a spectacle for the people that witnessed it. After he completing this short show, the pilot taxied the aircraft back into the direction of Apron B. He was still on the runway when the engines of the aircraft suddenly flamed out. The pilot attempted to restart the engines but was not successful. The aircraft was then towed back to Apron B where it remained parked overnight. Back on the apron the Air Force Fire Fighters noticed an excessive fuel leak and to stop possible damage to the apron, the fire fighters put drip trays under the aircraft.

On the day of the Air Show, when it was time for the aircraft to fly, the pilot started up the engines of the aircraft and taxied to the threshold of the active Runway 28. The aircraft took off in a westerly direction and was positioned in the circuit and commenced with his routine. Approximately halfway through the routine, the pilot made an emergency call: "PAN...PAN" and reported to the control tower that he was experiencing a hydraulic problem. He further requested that the runway safety nets be raised and emergency services be put on alert. Shortly thereafter he reported that one of the landing gear main wheels did not extend and requested to fly away from the display area where he would attempt to address the problem. This was followed by a report that he was now experiencing a double hydraulic problem and losing control of the aircraft. He then stated that he was going to eject from the aircraft. However he experienced an ejection seat failure and the aircraft impacted the ground in a dive. The pilot was fatally injured and the aircraft was destroyed by the impact and the post impact fire.



2.0 The Investigation

- 2.1 The process followed to date is in compliance with internationally accepted practices.
- 2.2 On arrival at the accident scene, the team of accident investigators, commenced with an onsite investigation.
- 2.3 The aircraft disintegrated on impact and no major structures of the airframe or engines remained intact.

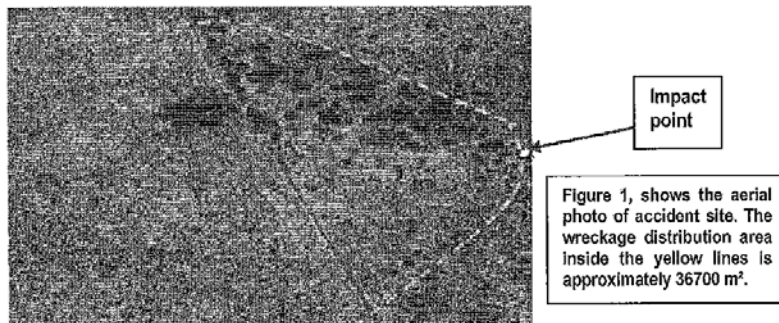


Location of impact point at GPS co-ordinates
S34 31.232 E020 22.618

- 2.4 The aircraft was not equipped with a Cockpit Voice Recorder (CVR) or a Digital Flight Data Recorder (DFDR).

3.0 Actions taken to date include:

- The accident site was examined and aircraft wreckage examined in detail for possible defects and to exclude factors that are not relevant to the cause of the accident;

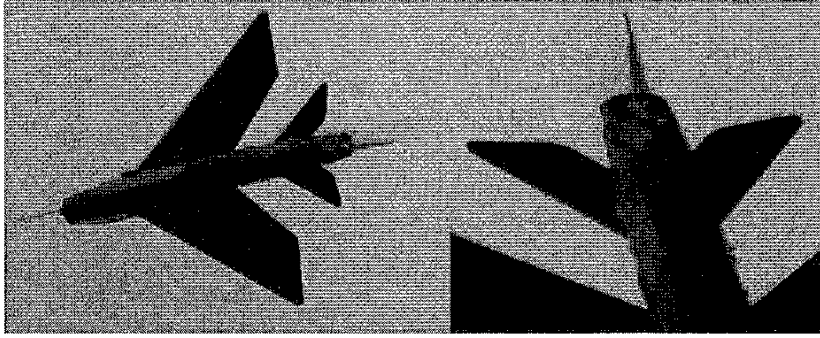


- The transcription and analysis of Air Traffic Control recordings;
- Obtaining video and photographic material from various witnesses;

- Compilation and review of relevant records in respect of the aircraft maintenance, operational and crew records is ongoing.

4.0 Summarized Information obtained to date:

- The English Electric Lightning is a supersonic jet fighter aircraft of the Cold War era, remembered for its great speed and unpainted natural metal exterior finish. It is the only all-British Mach 2 fighter aircraft. The aircraft was renowned for its capabilities as an interceptor; RAF pilots described it as "being saddled to a skyrocket". The Lightning was used throughout much of its service life by the Royal Air Force and the Royal Saudi Air Force. The aircraft was a regular performer at air shows and was the first aircraft capable of super cruise. The Lightning was also one of the highest performance aircraft ever used in formation aerobatics.
- During its service with the RAF a number of aircraft were lost in accidents with some causes identified as hydraulic related issues.
- On being phased out of service, some of the aircraft were sold to private owners and the Lightning aircraft is now largely retired to museums, but three examples were maintained in a flyable condition at "Thunder City" in Cape Town, South Africa.
- One of them ZU-BEX was in a dual side by side seating configuration and was exported to Republic of South Africa (RSA) in 1997.
- The aircraft was first issued with an Experimental Certificate of Airworthiness (CoA) on 31 August 2000. The aircraft operated in experimental operating category until 30 June 2003. The status of the CoA was later changed on 14 February 2005 and a Commercial Authority to Fly was issued. The aircraft was operated with the Commercial Authority to Fly until the day that the aircraft was involved in the accident.
- The above-mentioned aircraft is thus considered to be airworthy when maintained and operated in accordance with the pertinent operating limitations, and airworthiness code as provided by Part 24 and 96 of the Civil Aviation Regulations.
- The accident and incident history of the aircraft revealed two incidents as reported to the SACAA. In one of the incidents, the pilot (accident pilot) reported a hydraulic failure which he experienced with the aircraft in flight on 16 May 2003. The incident was investigated by the operator and concluded that the HYD 1 Hydraulic Pump failed internally. The hydraulic pump was replaced and system checked.
- Fuel venting was evident during the taxi and take-off of the aircraft.
- Overberg is an unlicensed Military Aerodrome. According to the Aeronautical Information Publication (AIP), prior to flying or landing at Overberg, permission must be obtained from the Officer Commanding of the aerodrome.
- The Air Force was hosting the air show which was planned to start on 14 November 2009. As it is customary a lot of spectators visited the aerodrome. To ensure that the spectators are safe, there was a special demarcated crowd control area which was allocated by the organisers of the event. The spectators was accommodated on the Secondary Taxi Way (Bravo) having a view to the active Runway 28. All other areas of the aerodrome remained restricted and used by the Air Force personnel only.



- It is possible that this fire resulted in the final failure of the hydraulic system;
- The pilot was the sole occupant of the aircraft.
- The pilot attempted to eject from the aircraft, but this was unsuccessful the pilot reported that he was experiencing an ejection seat failure.
- Rescue and fire-fighting services responded appropriately;

5.0 The Aircraft's Ejection Seats

- 5.1 This ex-military aircraft was equipped with two Martin Baker 4BSB NK 2 type ejection seats.
- 5.2 According to the ejection seat and component log card, the port side ejection seat undergone an annual servicing on 08 September 2008 and starboard ejection seat on 10 September 2008. During the servicing, work was carried out on the Seat Structure, Actuator, Barometric Time Release, Drogue Gun, Drogue Withdrawal Line, 22" Drogue, Main Drogue 5FT, and Ejection Gun. The Main Parachute (x 2) and Life Rafts (x 2) were also removed from the ejection seats for a Bay Service Inspection. After the visual inspection was carried out the identified safety equipment were packed and fitted on the seats.
- 5.3 The canopy of the aircraft was also inspected on 09 September 2008. The work carried out was to strip, clean, to inspect, lubricate and assemble all the identified units. According to the servicing record of the canopy, the canopy jettison jacks on the port and on the starboard side together with the canopy jettison bypass valve were serviced.
- 5.4 According to the aircraft explosives record log card, all the ejection seat and canopy explosive cartridges were last inspected on 10 September 2008. An inspection cycle of a 12 month interval is applicable for the cartridges, which implied that the next due date for inspection was to be in September 2009. However, no maintenance records could be found to show that the explosive cartridges were inspected within the applicable interval. Aircraft Servicing Form (MOD Form 700) dated 29 October 2009, indicated that the servicing of the ejection seat and canopy safety equipment was extended by 30 days and again by 45 days. It would appear as if the intention of the operator was to service the ejection seat after the air show.

5.5 The pilot was flying the aircraft from the port side seat and he was properly restrained with the safety belts and harnesses. The seat on the starboard side of the aircraft was not occupied and the safety belts and harnesses were fastened to stop them from swinging loose inside the cockpit. On boarding the aircraft for his display flight, the pilot was assisted by one of the maintenance personnel i.e. safety equipment engineer of the AMO. This was necessary as it was not possible for the pilot to ensure that the safety pins of the ejection seat are pulled and canopy properly closed.

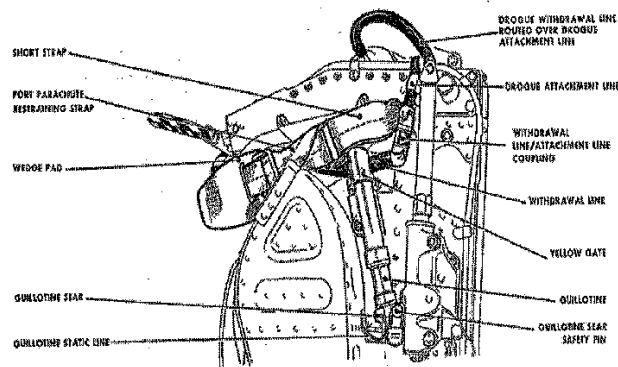
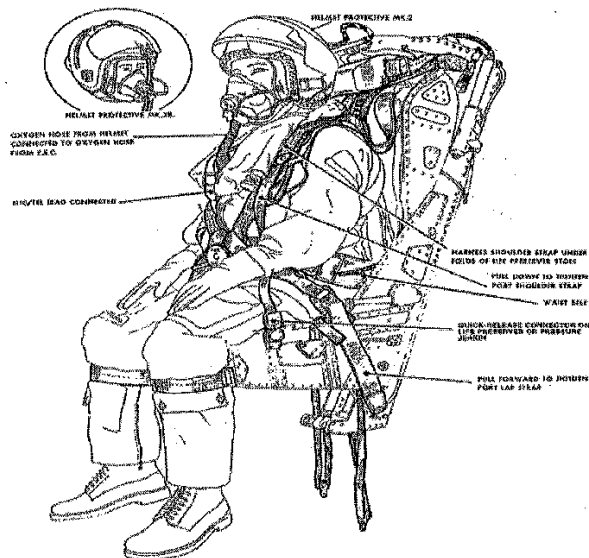


FIG. 10003-1



6.0 Organizational and Management Information

- 6.1 The operator of the aircraft had a valid Domestic Air Services License which was issued on 20 April 2005.
- 6.2 The operator also had a valid Air Operating Certificate (AOC) which was issued on 21 October 2009. The AOC authorized the operator to operate the aircraft in accordance with operations specifications of CAR, Part 96. The registration of the accident aircraft ZU-BEX, was also included on the AOC as one of the approved aircraft to be used by the operator.
- 6.3 A number of ex-military aircraft are being used for commercial operations mostly in various air show events and also to carry passengers. In most cases such passengers have not being exposed to supersonic flight and their medical status not verified before flying.
- 6.4 The operator was subjected to an AOC renewal audit on 6 April 2009. During the audit a finding was raised identifying that the operator did not have a quality or safety system or policy. The finding was noted as being minor. After an ad hoc inspection it was determined that the non-compliance was not addressed by the operator.
- 6.5 The Aircraft Maintenance Organization (AMO) responsible for maintenance of the aircraft had a valid approval certificate which was issued in accordance with CAR, Part 145. The approval certificate authorized the AMO to carry out maintenance on the aircraft type, which was in compliance with their operations specification (Ops Specs). The AMO received a renewal audit annually (12 month interval), which was an evaluation to re-issue the approval certificate.

7.0 Interim Safety Recommendations

- 7.1 Due to the complexity and specialized operational envelopes of the use of ex-military aircraft, it is recommended that the Commissioner for Civil Aviation (CCA) should:

Without delay implement, through the relevant SACAA departments, a process of evaluating the risk factors involved with the continued operation of ex-military aircraft currently on the South African Civil Register.

- 7.2 With regard to the serviceability of the ejection seats, the attention of the CCA is directed to other ex-military aircraft (example ZU-AHV) where the ejection seats were found to have been unserviceable. In this accident an ejection failure resulted in a fatality as the ejection seat did not activate when the pilot attempted to eject from the aircraft. It is therefore recommended that the CCA should:

Without delay implement, through the relevant SACAA departments, a mandatory service instruction to all the operators of ex-military fighter jet aircraft currently on the South African Civil Register, to immediately conduct inspections on their ejection seats and notify the Commissioner in writing within a time prescribed of the serviceability of the ejection seats.

9

8.0 Activities to follow:

8.1 Further action now includes:

- Further research into the various types of accidents involving this type of aircraft;
- Further research into known causes of hydraulic system failures on this kind of aircraft, the maintenance of this aircraft and with specific emphasis on the hydraulic and fuel systems;
- Further research into the known causes of this kind of ejection seat failures, as well as the serviceability of the ejection cartridges;
- The capacity of the operator to service and maintain these complex type of aircraft;
- The operational procedures of the operator in terms of emergencies during the flying of its fleet of aircraft;
- The safety management system the operator has in place and in particular as to its incident and hazard reporting system, for example the engine flame-out and leaking of fuel on the apron.

8.2 The investigation will be ongoing in participation with the accredited parties such as the AAIB of the United Kingdom, supported by advisors from the manufacturers.

Acknowledgement:



The Aircraft Accident and Incident Investigation Division (AIID) of the South African Civil Aviation Authority (SACAA) wishes to acknowledge and thank the above participants and the South African Air Force personnel for their assistance and services rendered to date.

It is trusted that the investigation will lead to the introduction of corrective action, where any deficiencies are identified, to ensure the continued safety of passengers transported in South African airspace.



-END-

Appendices:

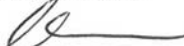
Canopy Jettison Release Mechanism Report

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COMPILED FOR: Civil Aviation Authority	INVESTIGATION REPORT: ENGLISH ELECTRIC LIGHTNING T.5, AIRCRAFT NUMBER ZU-BEX	DOCUMENT NUMBER MET-002-05-10
		DATE 2010-05-01
		ISSUE 1
<p>TEM: CANOPY RELEASE MECHANISM, ENGLISH ELECTRIC LIGHTNING T Mk5, AIRCRAFT NUMBER ZU-BEX</p> <p>1. INTRODUCTION</p> <p>1.1. Selected components from the canopy release mechanism of a crashed English Electric Lightning T Mk5, aircraft number ZU-BEX (Photo 1), were submitted to determine the possible reason/s for failure during operation.</p> <div style="text-align: center;">  </div> <p>Photo 1: ZU-BEX in flight at Air Display (courtesy SACAA)</p> <p>1.2. ZU-BEX crashed during participation of a South African Air Force hosted Air Display at Air Force Base Overberg. The impact proved to be at a high angle and speed resulting in the total destruction of the aircraft (Photo 2). During the final moments of flight the pilot reported an emergency, followed by intent to eject but reported failure to complete the ejection sequence shortly after. The approximate time lapse from declaration of emergency to impact is reported to be 30 - 40 seconds.</p> <div style="text-align: center;">  </div> <p>Photo 2: Point of impact (digital)</p> <p>1.3. Spectator photographs indicated signs of an in-flight fire during the air display sequence (Photo 1, red arrow). This proved to be the primary causational factor for this accident but do not form part of this investigation.</p>		

English Electric Lightning ZU-BEX

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		DATE 2010-05-01
<p>1.4. Cockpit voice and tower communication recordings retrieved by the SACAA indicates markedly higher levels of cockpit wind-noise during the pilot's last report of ejection failure.</p> <p>1.5. Although some components for this investigation were retrieved by the SACAA from the crash site, other relevant parts and components had to be retrieved from a third party (Photo 3) in order to complete this investigation. This evidence proved to be severely contaminated with extensive secondary damages inflicted during the storage and transportation thereof.</p>		
		
<p>Photo 3: Relevant components retrieved from a third party (digital)</p>		
<p>1.6. Ejection Sequence. The English Electric Lightning (EEL) aircraft's ejection sequence is as follows (See Diagram 1, EEL Canopy Jettison Manual):</p> <p>Step 1 : On demand for ejection, the pilot's firing handle will activate, via a connecting rod and connecting link cable system, the primary cartridge inside the breech.</p> <p>Step 2: Gas exerted from the primary cartridge flow via the connecting lines towards the port- and starboard by-pass valves.</p> <p>Step 3: The gas pressure force the piston upward, the piston crown impacts with the canopy hook release mechanism and force the corresponding side's primary and secondary locks into the unlock positions.</p> <p>Step 4: Gas pressure then follows the pipeline towards the high velocity canopy jettison jack's secondary cartridge firing pin units.</p> <p>Step 5: The secondary cartridge fires and the exerted gas pressure forces the high velocity canopy jacks upward to push the canopy into the air stream for separation.</p> <p>Step 6: The canopy, when released from the main fuselage, then activates the two Martin Baker ejection seat main cartridges by means of a cable connection.</p>		

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		DATE 2010-05-01	ISSUE 1																				
1.6. This report is divided into the following sections:																							
<table><tr><td>(a) INTRODUCTION</td><td>Par. 1</td></tr><tr><td>(b) APPLICABLE DOCUMENTS</td><td>Par. 2</td></tr><tr><td>(c) DEFINITIONS</td><td>Par. 3</td></tr><tr><td>(d) INVESTIGATOR</td><td>Par. 4</td></tr><tr><td>(e) APPARATUS AND METHODOLOGY</td><td>Par. 5</td></tr><tr><td>(f) BACKGROUND INFORMATION</td><td>Par. 6</td></tr><tr><td>(g) INVESTIGATION</td><td>Par. 7</td></tr><tr><td>(h) DISCUSSION AND CONCLUSIONS</td><td>Par. 8</td></tr><tr><td>(i) RECOMMENDATIONS</td><td>Par. 9</td></tr><tr><td>(j) DECLARATION</td><td>Par. 10</td></tr></table>				(a) INTRODUCTION	Par. 1	(b) APPLICABLE DOCUMENTS	Par. 2	(c) DEFINITIONS	Par. 3	(d) INVESTIGATOR	Par. 4	(e) APPARATUS AND METHODOLOGY	Par. 5	(f) BACKGROUND INFORMATION	Par. 6	(g) INVESTIGATION	Par. 7	(h) DISCUSSION AND CONCLUSIONS	Par. 8	(i) RECOMMENDATIONS	Par. 9	(j) DECLARATION	Par. 10
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4. PERSONNEL																							
(a) The investigative member and compiler of this report is Mr C.J.C. Snyman, ID number 6406105057080. Mr Snyman is a qualified Physical Metallurgist (H.N.Dip Metallurgical Engineering, Tech. PTA), Radiation Protection Officer (RPO) registered with the National Nuclear Regulator (NNR) and Aircraft Accident Investigator (SCSI).																							
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6. INVESTIGATION RESULTS																							
<p>The on-site investigation proved that the aircraft canopy did not release from the main fuselage before impact. This investigation will therefore concentrate primarily on the canopy jettison system (Diagram 1) from the English Electric Lightning.</p> <p>A section from the gas feed pipeline (Photo 4) revealed the fractured breach (Photo 5) that contained the primary cartridge. The primary cartridge could not be located. The gas feeding line from the breach to the T-piece as well as the starboard side pipeline up to the inlet side of</p>																							

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the starboard by-pass valve was still found in position. The opposing port side of the feeding line could not be located.

On removal, the T-piece revealed that the port side ferrell was still in position (Photo 6, red arrow) but with no feeding line attached. The opposite starboard side pipeline end revealed the ferrell still in position (Photo 6, blue arrow). Extensive corrosion damages was detected inside the t-piece (Photo 7).

After removal of the port side ferrell from the T-piece (Photo 8, red arrow), metallic deposits were noted on the inside around the circumference of the closed side of the ferrell (Photo 9, red arrow). At higher magnification, the metallic deposit showed a geometry (Photo's 10 and 11, red arrows) corresponding with metal skimmed from the port side gas feed pipeline. An EDS analysis proved that the metallic deposit from the ferrell (EDS Result 2) compares favorable with that of the starboard gas feed pipeline base material (EDS Result 1). No clear indications of attempted 'skimming' of the same nature could be detected on the opposite starboard side ferrell/pipeline contact area (Photo 12, blue arrow).

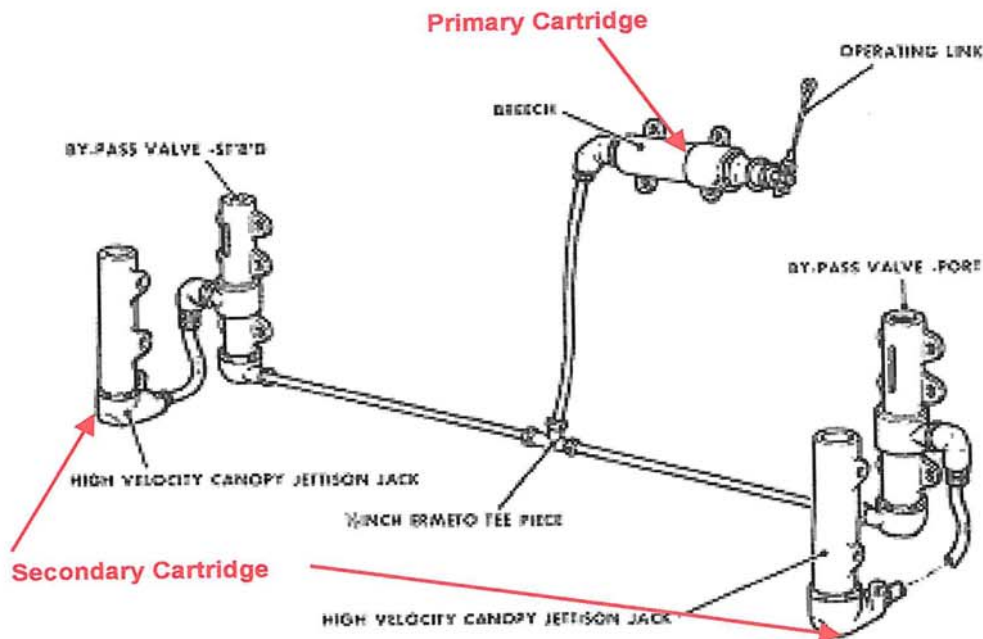
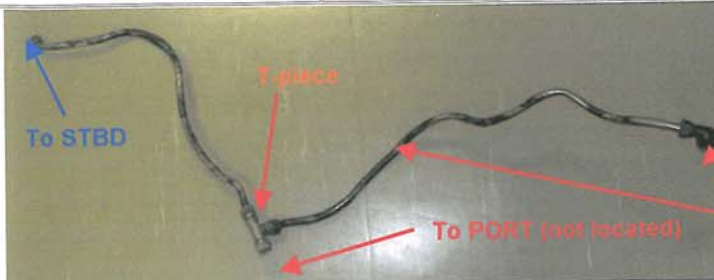


Diagram 1: Layout of the canopy jettison system

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Original Primary Cartridge position inside breech

Gas flow pipeline

Photo 4: Remainder of gas flow pipeline assembly (digital)



Photo 5: Primary cartridge end of pipeline showing fractured breech (digital)

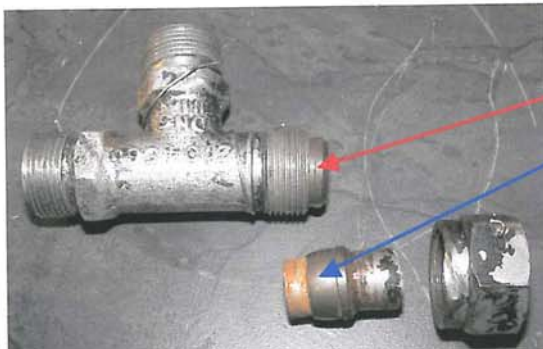


Photo 6: T-piece, removed, with (sectioned) starboard pipeline end showing fitted Ferrell - blue arrow while port side ferrell still in position - red arrow (digital)

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Photo 7: Inner area of t-piece showing corrosion products (digital)



Photo 8: Port side pipeline ferrell removed from position, as found (digital)



Photo 9: Port side ferrell showing metal deposits - red arrow (digital)

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Photo 10: Port side ferrell, showing pipeline deposit (x45, SEM)

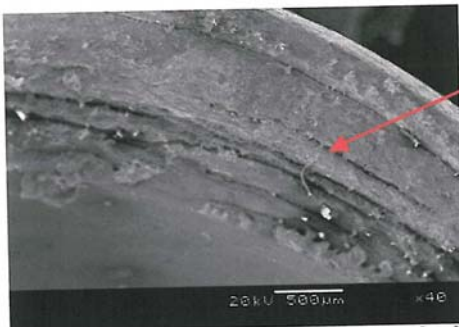


Photo 11: Port side ferrell, showing pipeline deposit (x40, SEM)

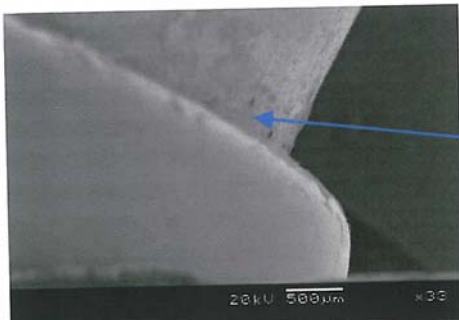


Photo 12: Starboard side pipeline ferrell showing no clear indentations (x33, SEM)

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PIPE BASE 1

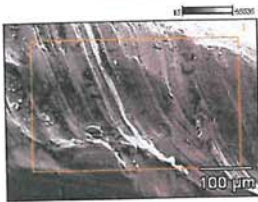


Image Name: PIPE BASE 1

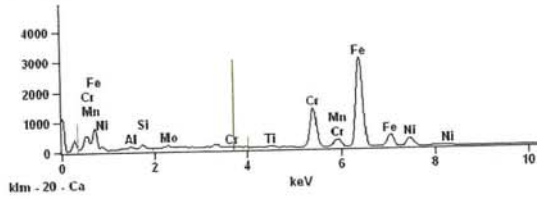
Accelerating Voltage: 20.0 kV

Magnification: 270

Detector: NanoTrace

Full scale counts: 2989

PIPE BASE 1_pt1



	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K	Mo-L
PIPE BASE 1_pt1	0.49	0.71	0.47	17.89	1.78	68.17	9.60	0.90

	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K	Mo-L
PIPE BASE 1_pt1	+/-0.05	+/-0.04	+/-0.05	+/-0.24	+/-0.29	+/-0.54	+/-0.41	+/-0.11

	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K	Mo-L
PIPE BASE 1_pt1	1.00	1.38	0.54	18.87	1.78	66.95	8.96	0.51

	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K	Mo-L
PIPE BASE 1_pt1	+/-0.10	+/-0.08	+/-0.06	+/-0.25	+/-0.29	+/-0.53	+/-0.38	+/-0.06

EDS Result 1: Gas Pipeline Base material

T-PIECE FERREL 1 DEPOSIT 1

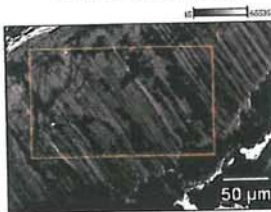


Image Name: T-PIECE FERREL 1 DEPOSIT 1

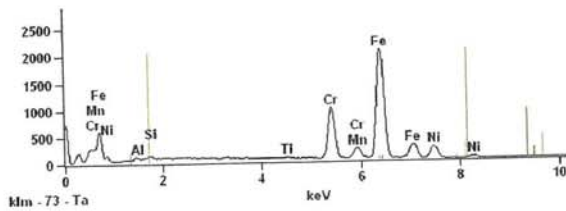
Accelerating Voltage: 20.0 kV

Magnification: 450

Detector: NanoTrace

Full scale counts: 2050

T-PIECE FERREL 1 DEPOSIT 1_pt1



English Electric Lightning ZU-BEX

Weight %							
	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K
T-PIECE FERREL 1 DEPOSIT 1_pt1	0.38	0.69	0.42	18.70	2.48	66.84	10.49

Weight % Error (+/- 1 Sigma)							
	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K
T-PIECE FERREL 1 DEPOSIT 1_pt1	+/-0.06	+/-0.08	+/-0.06	+/-0.28	+/-0.19	+/-0.63	+/-0.50

Atom %							
	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K
T-PIECE FERREL 1 DEPOSIT 1_pt1	0.77	1.34	0.48	19.68	2.47	65.49	9.78

Atom % Error (+/- 1 Sigma)							
	Al-K	Si-K	Ti-K	Cr-K	Mn-K	Fe-K	Ni-K
T-PIECE FERREL 1 DEPOSIT 1_pt1	+/-0.11	+/-0.16	+/-0.07	+/-0.29	+/-0.18	+/-0.67	+/-0.46

EDS Result 2: Metal deposit on inner port side ferrell

Both port and starboard side by-pass valve were located (Photo 13) showing extensive impact damages. Closer inspection revealed no clear impact marks on the portside by-pass valve piston crown (Photo 14, red arrow) while the opposing starboard side by-pass valve piston crown revealed clear impact marks (Photo 15, blue arrow). These impact marks can possibly be attributed to the crown impacting with the starboard canopy un-locking mechanism (see par. 1.6.).

Both the retrieved port and starboard side primary canopy hooks (Photo's 16 and 17) showed extensive impact damages. Notably, the port side canopy hook was found in an angled position (Photo16, red dashed line) relating to the fully 'locked' position while the opposite starboard side canopy hook was found angled in the 'unlocked' position (Photo 18, blue dashed line). Comparing the port side canopy hook with the corresponding position on the canopy frame (Photo 17), it can be derived that the port side canopy hook were forcefully removed from the 'locked' position, most probably on impact.

Impact and scraping marks on the port side high velocity jack sleeve (Photo 19), point towards the forceful expulsion of the jack in a downward and aft direction, most probably on impact (yellow arrow). The opposing starboard side high velocity canopy jack was found in a partially upward position with impact bending damages (Photo 20) to the jack. The sleeve revealed signs of explosion damages (Photo 21), most probably induced by the firing of the secondary cartridge. No canopy frame 'scratch plates' could be located to confirm impact marks from the two high velocity jacks.

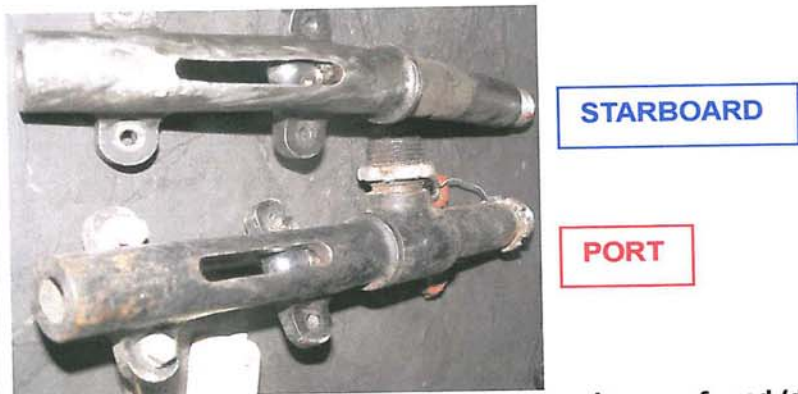


Photo 13: Port and starboard side by-pass valves, as found (digital)

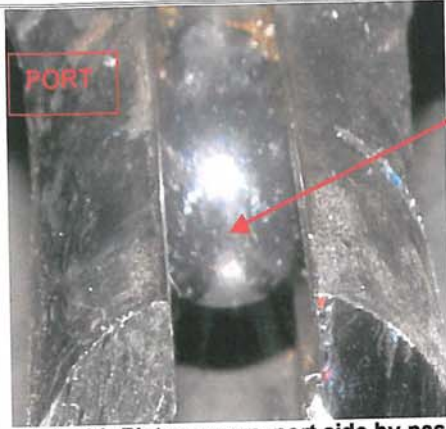


Photo 14: Piston crown, port side by-pass valve piston (digital)



Photo 15: Piston crown, starboard side by-pass valve piston, showing indentation marks (digital)

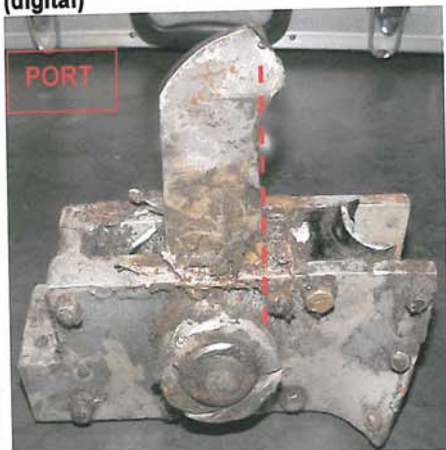


Photo 16: Port side, main canopy hook, as found in locked position (digital)

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Photo 17: Port side, main canopy hook in canopy frame position, showing extensive damages (digital)

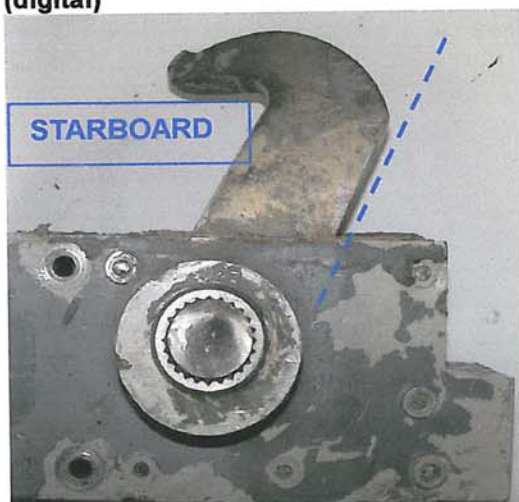


Photo 18: Starboard side, main canopy hook, as found in the unlocked position (digital)

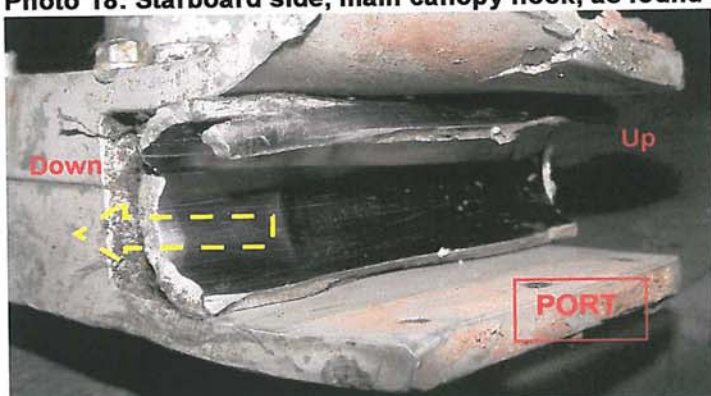


Photo 19: Port side canopy jack sleeve (digital)

English Electric Lightning ZU-BEX

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Photo 20: Starboard high velocity canopy jack showing bending damages (digital)



Photo 21: Starboard canopy jack sleeve showing explosion damages (digital)

Smear samples were taken from various positions in the gas feeding line. The sampling method attempted to retrieve comparable amounts of deposits from each location. During the EDS analysis, which should be considered qualitative, only particulates analogous to explosive residue were considered.

Gunpowder, also called black powder, is a mixture of sulphur, charcoal, and potassium nitrate. It burns rapidly, producing a volume of hot gas and a solid residue. **Potassium nitrate** is a chemical compound with the chemical formula KNO_3 . A naturally occurring mineral source of nitrogen, KNO_3 constitutes a critical oxidizing component of black powder/gunpowder.

A smear sample was taken from the secondary cartridge holder (both secondary cartridges fired as confirmed by the original manufacturer, PMP) to use as reference. The EDS result showed particulates with an average Potassium (K) content of 61% (EDS Result 4).

The EDS result from the breech outlet elbow (primary cartridge holder) revealed a K content of 61% to 63% (EDS Results 5 and 6). This is indicative of a cartridge that fired in the upstream position.

The EDS results from the skimmed pipeline material from the port side t-piece ferrell (EDS Result 3) revealed deposits containing 17% K. This is an indication that the ferrell and pipeline was still in position at the moment of firing of the upstream primary cartridge.

EDS results from the T-piece inner areas revealed a K content of approximately 26% (EDS Result 7). This is indicative of the primary cartridge firing upstream of the gas flow direction.

The sample from the starboard by-pass valve inlet elbow revealed a K content of 15% (EDS Result 8) while the opposing port side position only showed a K content of 5% (EDS Result 9).

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FERREL NO 2 PIPE REMAIN DEP 1

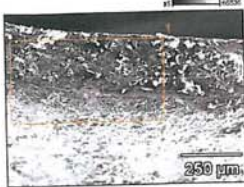
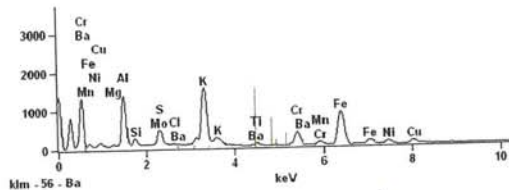


Image Name: FERREL NO 2 PIPE REMAIN DEP 1
Accelerating Voltage: 20.0 kV
Magnification: 130
Detector: NanoTrace

Full scale counts: 1515 FERREL NO 2 PIPE REMAIN DEP 1_pt1



	Al	Si	S	Cl	K	Ti	Fe	Ni	Cu	M	Ba			
FERREL NO 2 PIPE RE MAIN DEP 1_pt1	0.6	15	1.9	2.8	0.3	17	0.2	9.4	1.1	35	3.9	5.7	3.5	1.5

EDS Result 3: Deposits from port side t-piece ferrell

SECONDARY 2

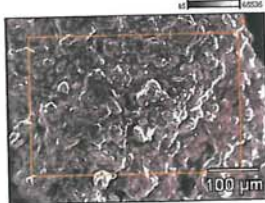
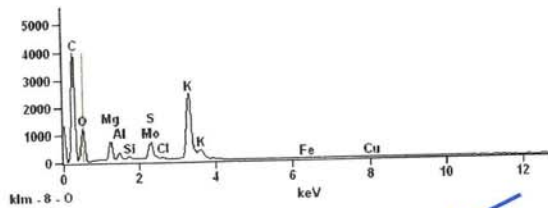


Image Name: SECONDARY 2
Accelerating Voltage: 20.0 kV
Magnification: 250
Detector: NanoTrace

Full scale counts: 3971 SECONDARY 2_pt1



	Mg/K	Al/K	Si/K	S/K	Cl/K	K/K	Cu/K	Mo/L
SECONDARY 2_pt1	12.43	4.18	1.76	6.08	1.26	61.39	2.89	10.02

EDS Result 4: Sample from secondary cartridge holder

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PRIMARY 3

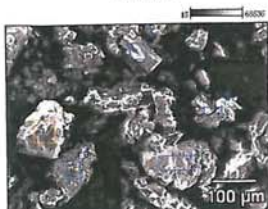
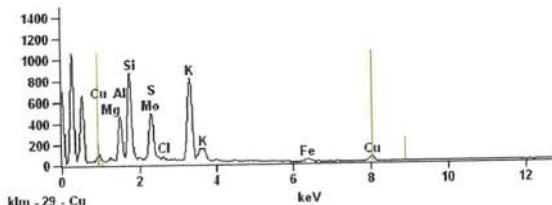


Image Name: PRIMARY 3
Accelerating Voltage: 20.0 kV
Magnification: 220
Detector: NanoTrace

Full scale counts: 1058 PRIMARY 3_pt5



	Mg-K	Al-K	Si-K	S-K	Cl-K	K-K	Ca-K	Fe-K	Cu-K	Mo-L
PRIMARY 3_pt 1	1.40		74.15	3.51		8.39		5.75	1.98	4.81
PRIMARY 3_pt 2	1.52	1.47			17.25	57.57			7.34	14.86
PRIMARY 3_pt 3	1.02	1.08	1.44			22.95			71.16	2.35
PRIMARY 3_pt 4	0.96	1.01	1.98		14.57	2.73	61.66		5.30	11.79

EDS Result 5: Outlet elbow, breach, primary cartridge

PRIMARY 2

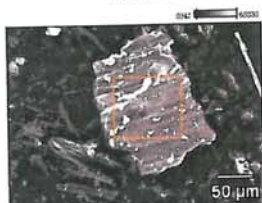
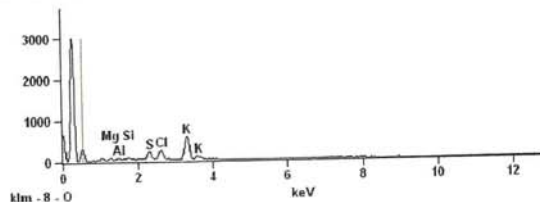


Image Name: PRIMARY 2
Accelerating Voltage: 20.0 kV
Magnification: 370
Detector: NanoTrace

Full scale counts: 2983 PRIMARY 2_pt1



	Mg-K	Al-K	Si-K	S-K	Cl-K	K-K
PRIMARY 2_pt1	2.33	1.22	1.59	11.87	19.59	63.40

EDS Result 6: Same position as EDS 5, outlet elbow, breach

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T-PIECE STBD BLOWBY 4

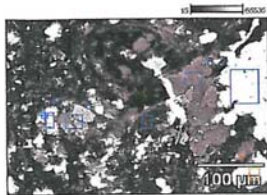
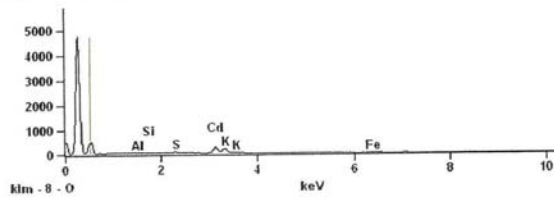
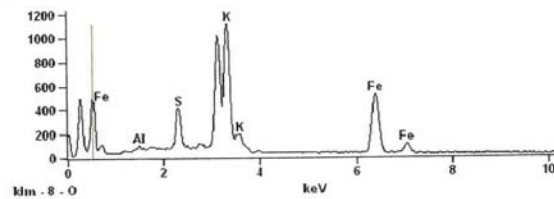


Image Name: T-PIECE STBD BLOWBY 4
Accelerating Voltage: 20.0 kV
Magnification: 330
Detector: NanoTrace

Full scale counts: 4741 T-PIECE STBD BLOWBY 4_pt5



Full scale counts: 1112 T-PIECE STBD BLOWBY 4_pt6



	Mg	Al	Si	S	K	Ca	Ti	Fe	Cu	Cd
	K	K	K	K	K	K	K	K	K	L
T-PIECE STBD BLOWBY 4_pt1- No Data.										
T-PIECE STBD BLOWBY 4_pt2	0.35	2.6	3.6	3.75	9.80	0.9	1.2	13.0	2.3	62.1
		6	5		7	7	9	4	1	7
T-PIECE STBD BLOWBY 4_pt3	0.4	0.4	0.49	0.80	0.0			43.6		54.1
	3	5		4				9		0
T-PIECE STBD BLOWBY 4_pt4	0.2			0.11				0.68	94.9	4.02
	8							1		
T-PIECE STBD BLOWBY 4_pt5	2.4	2.7	5.26	9.20				9.98		70.3
	1	8								7
T-PIECE STBD BLOWBY 4_pt6	0.8		11.6	25.7				61.7		
	8		8	4				0		
T-PIECE STBD BLOWBY 4_pt7	3.3	0.5	2.46	8.95				10.6		74.1
	3	1						0		6

EDS Result 7: Sample from T-piece inner area

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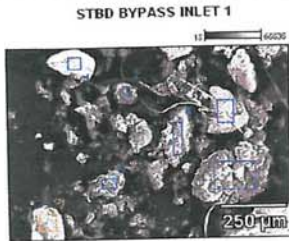
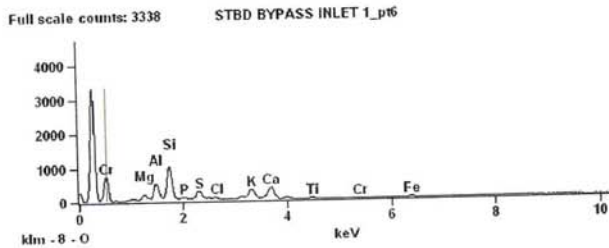
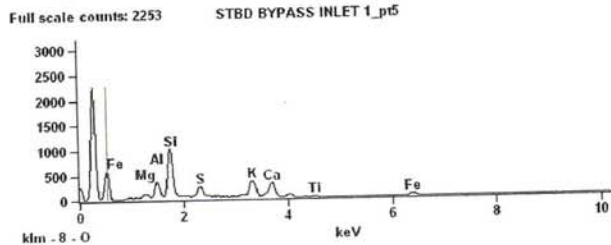


Image Name:
STBD BYPASS INLET 1
Accelerating Voltage: 20.0 kV
Magnification: 120
Detector: NanoTrace



	Weight %											
	Na- K	Mg- K	Al/K	Si-K	P- K	S/K	Cl- K	K/K	Ca- K	Ti/K	Cr- K	Fe- K
STBD BYPASS INLE T_1_pt1		1.58		0.69					97.7 3			
STBD BYPASS INLE T_1_pt2		2.57	5.42	7.21	0.13	1.67		1.64	1.97	76.2	0.49	2.65
STBD BYPASS INLE T_1_pt3		1.29	0.69	2.12	2.27		1.29		1.79	90.5		5
STBD BYPASS INLE T_1_pt4		1.79	15.9 6	21.5 0		9.12		3.35	0.94	47.3		4
STBD BYPASS INLE T_1_pt5		2.86	10.2 2	33.5 0		10.5	6	14.6 7	19.2 2	1.40		7.57
STBD BYPASS INLE T_1_pt6		3.72	13.1 3	28.4 9	2.04	10.5	0.90	10.5 6	19.1 2	3.22	2.18	6.15
STBD BYPASS INLE T_1_pt7		1.26	0.70	3.29	4.36		0.77	1.90	86.0 6			1.66

EDS Result 8: Sample from starboard by-pass valve inlet elbow

(Page seventeen)

PORT BYPASS INLET 1

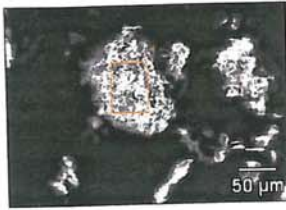
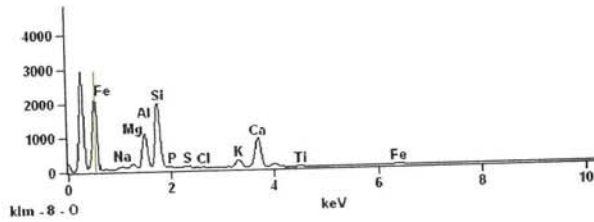


Image Name:
PORT BYPASS INLET 1
Accelerating Voltage: 20.0 kV
Magnification: 350
Detector: NanoTrace

Full scale counts: 2934 PORT BYPASS INLET 1_pt1



	Weight %										
	Na-K	Mg-K	Al-K	Si-K	P-K	S-K	Cl-K	K-K	Ca-K	Ti-K	Fe-K
PORT BYPASS INLET 1_pt1	2.06	2.06	16.30	35.86	0.69	1.73	0.54	5.34	28.80	1.07	5.55

EDS Result 9: Sample from port side by-pass valve inlet elbow

8. DISCUSSION AND CONCLUSIONS

Note: All conclusions are based on the investigation results obtained from the supplied parts only. Some sections of the relevant assembly could not be located at the crash site or from the third party.

Taking into account the dynamics as well as the immense energy released during a high velocity, high angle impact, it should be understood that more than one possible scenario may be applicable. Derived from the investigation results, the following are considered to be the *most probable* cause contributing to the failure of the ejection system:

- 8.1. Smear sample evidence points toward the firing of all three cartridges, most probably following the activation of the ejection seat firing handle by the pilot in flight. On firing of the primary cartridge, the exerted gas pressurized the pipeline en route to the port and starboard by-pass valves via the connected T-piece. Following the starboard line, the impact evidence on the by-pass valve piston crown indicates that the starboard side canopy unlocking system was activated. The primary starboard canopy hook found in the 'fully open' position confirmed this. The activation of the starboard by-pass valve allowed the gas pressure to fire the secondary cartridge in order to activate the starboard high velocity canopy jack. Evidence proved that the jack had limited upward travel resulting in the exploding of the jack sleeve due to the emitted gas pressure from the secondary cartridge. The canopy frame that was still partially in position most probably restricted the upward movement of the starboard jack.

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		DATE 2010-05-01

Following the portside line, the smear sample results revealed notably lower evidence of explosive residue (compared to the same starboard side positions) up to the secondary cartridge. Closer inspection of the port side exit line from the T-piece revealed that the feed line was 'pulled' from the relevant ferrell. Taking into account that none of the other retrieved pipeline/ferrell combinations showed similar signs (in most cases the pipeline/ferrell combination proved to be strong enough to fracture the attachments rather than being separated), this combination raised concerns. The evidence points toward the pipeline being 'pulled' from the ferrell leaving behind the 'skimmed' off pipe material. The exact cause for this failure could not be determined conclusively and may be a due to incorrect fitment causing it to fail under the gas pressure, incorrect pipeline type/material (this line could not be located), pre-accident damages to the line or other. The disconnecting of this line would have deprived the remainder of the port side system of full gas pressure. The absence of indentation marks on the port side by-pass valve piston crown combined with the port side canopy hook found in the 'locked' position seems to confirm this. Although the evidence prove that the port side secondary cartridge did in fact fire, the orientation of the firing pin mechanism towards the impact angle may have caused the firing thereof on impact.

The failure of the port side canopy release mechanism would have left the canopy in a partially open position. This fact could be corroborated by the notably higher wind flow noise detected in the latter part of the cockpit voice recording. Ultimately, the failure of the canopy release system would have left the Martin Baker ejection seats inoperative. Furthermore, the 'jamming' of the canopy release system would have rendered the pilot operated mechanical release system almost impossible to operate in flight.

9. RECOMMENDATIONS

- 9.1. It is recommended that all relevant aircraft to be inspected for correct fitment of all parts from the canopy release system as per OEM specifications.
- 9.2. It is advisable that the operators of relevant aircraft to check for and inhibit corrosion in areas around the T-piece.

10. DECLARATION

- 9.1. All digital images has been acquired by the author and displayed in an un-tampered manner.

English Electric Lightning ZU-BEX

Appendices:

Ejection Seat Cartridges Report

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	<p>PRETORIA METAL PRESSINGS A DIVISION OF DENEL (PTY) LTD</p>	
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INVESTIGATION REPORT ON THE
SEAT EJECTION CARTRIDGES OF THE
ELECTRIC LIGHTNING AIRCRAFT THAT CRASHED
NEAR BREDASDORP



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APPROVAL PAGE

COMPILED BY:



J J BECKER
QUALITY

23 March 2010
DATE

APPROVED BY:



C I VAN DER MERWE
MANAGER: QUALITY CONTROL & ASSURANCE

24/03/2010
DATE



P VAN STADEN
MANAGER: POWER CARTRIDGES

2010/03/24
DATE

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INDEX

1. INTRODUCTION
2. RESULTS OF THE INVESTIGATION
3. CONCLUSION

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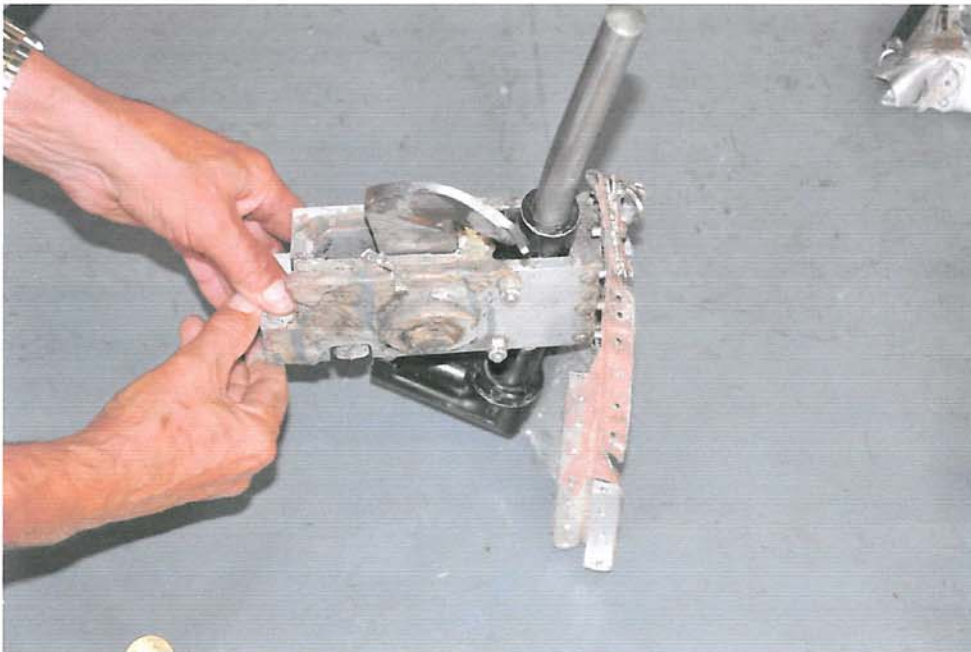
1. **INTRODUCTION**

The Seat Ejection Cartridges which were installed in the Electric Lightning Aircraft of Thunder City that crashed near Bredasdorp were sent to PMP as part of the investigation by Civil Aviation.

2. **RESULTS OF THE INVESTIGATION**

The Seat Ejection Cartridges installed in the Electric Lightning Aircraft were manufactured by PMP in 2000 and 2001.

The gas chamber of the units in which the Secondary Canopy Ejection Cartridges were installed burst open and the shafts were bent. These shafts are used to push the canopy away. Photo's below.



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These units were dismantled and evidence was found that the two cartridges did function when the pilot selected ejection mode.



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The Canopy Jettison Cartridge that ignited the two Secondary Canopy Cartridges was not recovered from the crash area. This Canopy Jettison cartridge did however function and generated enough pressure to initiate both the Secondary Canopy Jettison Cartridges.

The rest of the system could not function due to the Safety Locking Device which was not activated. The Safety Locking Device can only be activated if the canopy is ejected. Photo's below.



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Appendices B:

1.0 Photographs

It is our opinion that the photographs supplied by the South African CAA support the conclusion that there was a large, sustained fire in the rear fuselage prior to the aircraft crashing.

The areas highlighted in red in Figure 1 depict:

- 1) Flames emanating from the starboard rear fuselage around the tailplane.
- 2) Two bright spots of fire (line astern) just aft of the ventral tank.
- 3) Flames emanating from the lower fuselage forward of the lower reheat jet pipe exit.

We believe that the 'glow' highlighted by the yellow circle is the starboard formation light.



Figure 1 – Photo from CAA

Figure 2 shows evidence of flames emanating from the port side of the fuselage around the tailplane. The fire around the jet pipes appears to be more pronounced and 'fierce' than in Figure 1 but the two bright spots of fire are not visible.



Figure 2 – Photo from CAA

We do not know the sequence in which the photos were taken but the advanced properties show that Figure 1 was taken with a Nikon D90 on 14/11/09 at 12:16. Figure 2 was taken with a Canon EOS 450D on 14/11/09 at 12:09. Assuming that the camera times were set correctly (we have no evidence either way) then it would follow that Figure 2 was taken before Figure 1, possibly explaining why the two bright spots are not yet visible. Given the extent of the fire around the jet pipes in Figure 2, however, it would seem more likely that this photo was taken after Figure 1. Without additional evidence this cannot be stated categorically.

Figures 1 and 2 depict atomised fluid or smoke emanating from the rear fuselage and this is also apparent in photos on the internet, which claim to show the aircraft during take-off. It is our opinion that the photos probably depict atomised fuel and there are two separate trails, Figure 3. One of the trails appears to emanate from the fuselage slightly aft of the ventral tank with the other (possibly) emanating from the interface between fuselage and the lower reheat jet pipe exit.



Figure 3 – Two vapour trails during the take-off run

2.0 Aircraft Systems in the Rear Fuselage

Extracts from the RAF Lightning T5 Topic 1 are attached and these provide an overview of the aircraft fuel system, hydraulic system and flying controls; Figures 4, 5 and 6 are from the RAF manual.

2.1 Hydraulics

There are many significant (and critical) items of equipment in the rear fuselage and it is our opinion that the integrity of a number of items would be compromised by a fire of the intensity shown in Figures 1 and 2. Figure 4 shows the location of significant hydraulic components.

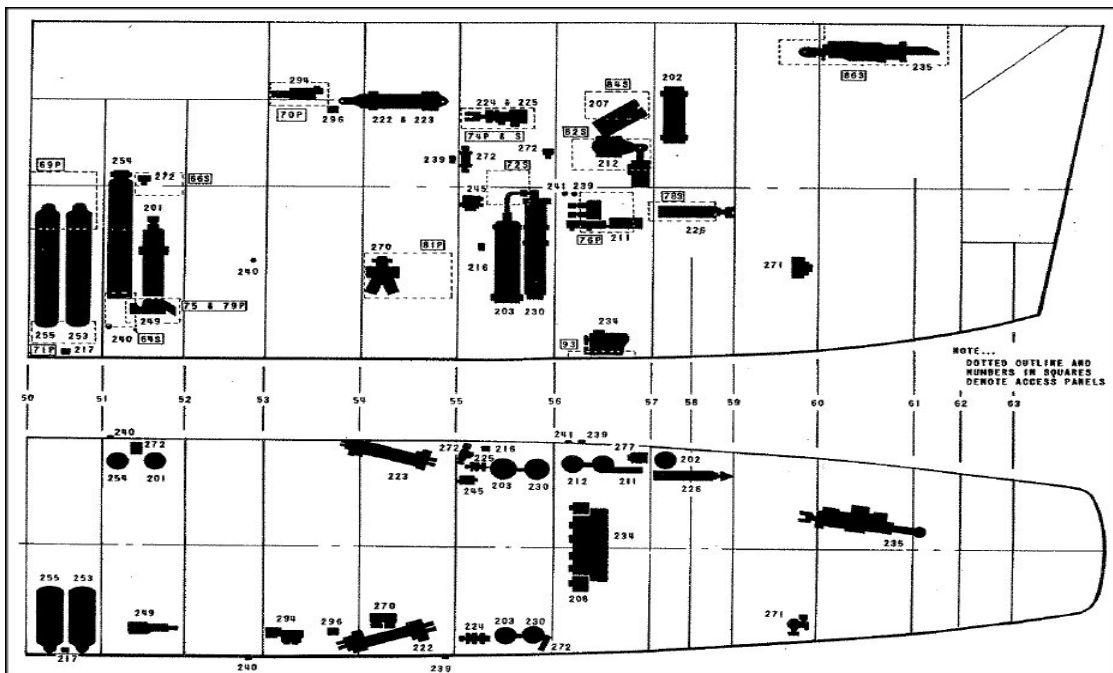


Figure 4 – Location of Major Hydraulic Components

Working rearwards, Items 255 and 253 are the hydraulic reservoirs; they are located between Frames 50 and 51, which is just aft of the centre of the ventral tank and potentially away from the immediate region of fire. Item 203 is the tailplane accumulator and Item 230 is the nitrogen tank for the accumulator; the items are located between Frames 55 and 56, which is at the rear of the ventral tank and therefore most likely in the vicinity of the fire. Item 234 is the tailplane PFCU and it is located between Frames 56 and 57; it is reasonable to assume that its integrity would have been affected by the fire.

2.2 Tailplane Controls

Figure 5 shows a very simplified view of the primary flying controls in the rear fuselage. The controls run along the bottom of the fuselage and it is possible that their integrity would have been affected by the fire; a review of Royal Air Force (RAF) accident reports has shown that several aircraft were lost when the flying control runs were destroyed by rear fuselage fires (while the RAF T5 aircrew manual states that the control rods are resistant to fire, they cannot be expected to last forever).

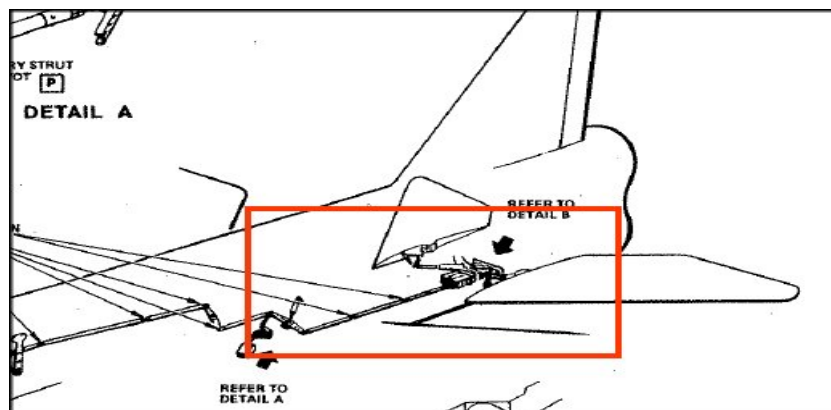


Figure 5 – Simplified view of Primary Flying Control Runs

2.3 Engines and Fuel System

2.3.1 General Layout

The engines in the Lightning, whilst mounted on top of each other, are staggered in longitudinal position with intermediate jet pipes leading to reheat jet pipes at the rear of the aircraft, Figure 6.

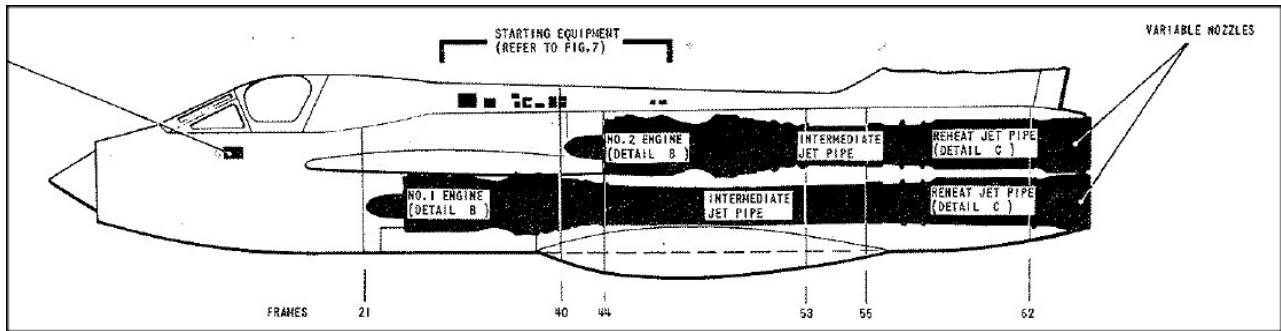


Figure 6 – Positioning of engines and jet pipe arrangement

2.3.2 Reheat System

The location of the reheat jet pipe relative to the engine and the fact that reheat ignition relies on a 'hot streak' method requires fuel pipes throughout the central and rear fuselage, Figures 7 and 8. There are numerous couplings in the pipe runs in close proximity to hot surfaces that could readily act as ignition points in the event of a leak (this was a well known and respected fact when the aircraft were in RAF service).

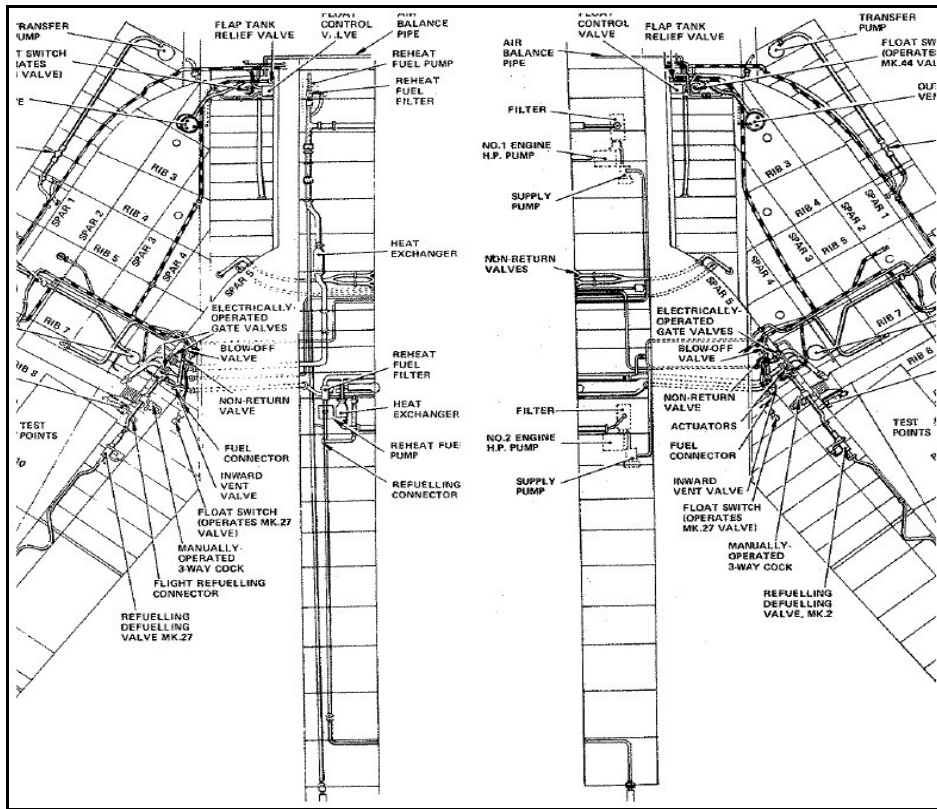


Figure 7 – Overview of the Lightning T5 fuel system

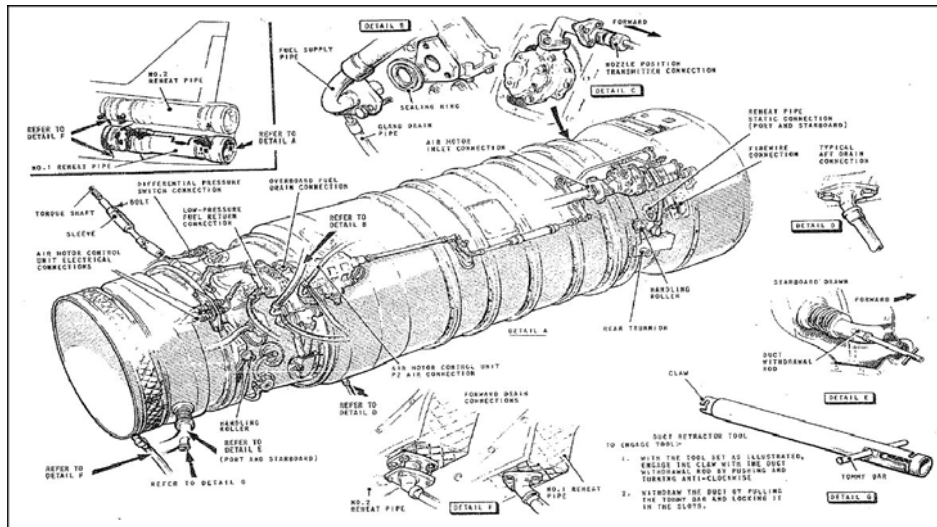


Figure 8 – Basic schematic of the reheat jet pipe and connections

2.3.3 Ventral Tank

The photographs supplied by the CAA show that ZU-BEX was equipped with a ventral fuel tank for the accident flight; the tank feeds into the wing tank system by air pressure when sufficient fuel has been used to operate the wing tank float switches (after 120 to 160lb of wing fuel has been used).

The tank is a stressed skin construction with its upper surface contoured to match the aircraft lower fuselage; there is a rubber seal at the interface between the two.

Fuel transfer is achieved through a single self-sealing fuel coupling and the tank is pressurised using air derived from the engine compressors. Figure 9 depicts a general view of the tank.

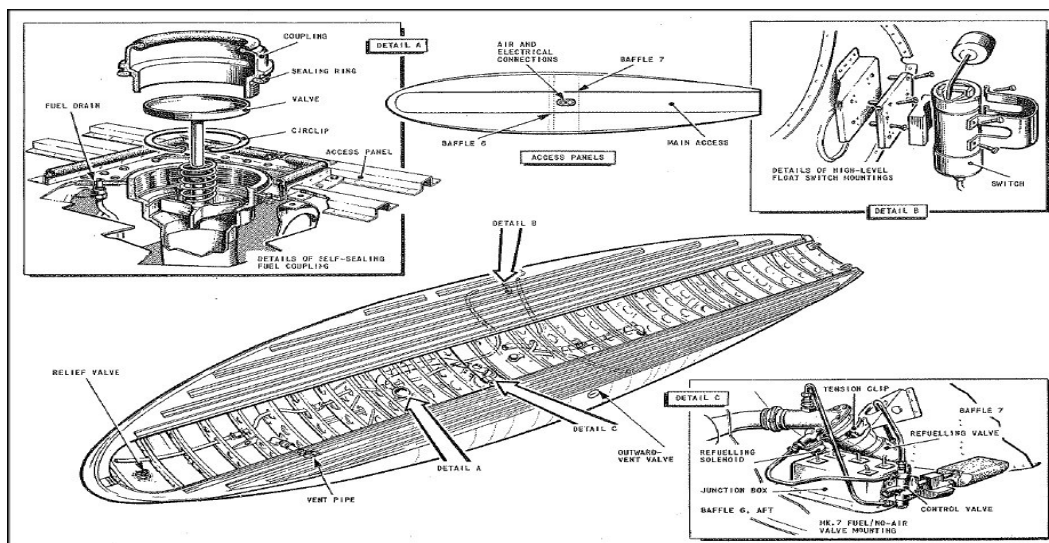


Figure 9 – Schematic of the ventral tank and the fuel coupling arrangement

Whether or not the tank on ZU-BEX contained fuel is unknown but a leak from the tank or coupling could, potentially, result in a fire.

3.0 Fire Detection System

In RAF service the aircraft was equipped with a fire detection and protection system with each engine bay divided into two fire zones separated by a fire-wall. The area between the engine compressor and the fire-wall was Zone 1, the area between the fire-wall and the turbine exhaust was Zone 2. The space surrounding the jet pipes was Zone 3. Zones 1 and 2 were protected by fire extinguishers but Zone 3 was unprotected, Figure 9.

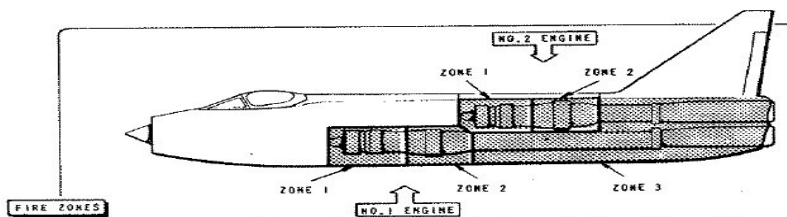


Figure 9 - Fire Zones

A fire in Zone 1 or 2 of the number 1 engine resulted in the illumination of the FIRE 1 warning in the cockpit; in the case of the number 2 engine FIRE 2 would illuminate. A fire in Zone 3 would result in either RHT 1 or RHT 2 illuminating. On the basis of the photographic evidence at Figures 1 and 2 it is probable that either RHT 1, RHT 2 or both would have illuminated if the detection system on ZU-BEX was still installed and operational, although this is merely our opinion.

4.0 Aircrew Manual

The RAF Lightning T5 Aircrew Manual states that in the event of a RHT warning “the aircraft

is to be flown at or above the minimum safe height for as long as possible (minimum five minutes) *whether or not the warning goes out*. The same procedure applies to a persistent FIRE 1 or FIRE 2 warning. During the waiting period, a visual inspection is to be obtained if possible and the performance of the flying controls monitored carefully.” The manual states that if the warning persists after taking the initial actions for a fire, or if the fire warning recurs, it must be assumed that the fire still exists and a safe altitude must be maintained until it can be ascertained whether or not the warning is spurious. The following symptoms (relevant to a T5) are listed as indicating a persistent fire:

- Tailplane control damage.
- Fuel system warnings.
- Total electrical failure.
- Hydraulic malfunctions.
- Loss of rudder control.

The manual states that “the tailplane control rods are resistant to fire” but that “distortion of the airframe or carbonisation of the control bearing lubricant may result in:

- a. Loss of tailplane effectiveness about the neutral position.
- b. Loss of feel.
- c. Increased friction or stiffening of the tailplane control.

Complete loss of tailplane effectiveness is unlikely before other malfunctions necessitate ejection. However, a persistent fire is highly likely to produce some indications of tailplane malfunction within five minutes of the fire starting...”

5.0 Previous Accidents in RAF Service

A summary of RAF Lightnings known to have been lost due to fires is presented at Table 1.

Aircraft Registration	Mark	Date	Brief Summary
XR760	F6	15/07/86	RHT 1 & RHT 2 warnings. Airborne inspection noted white smoke from lower (Number 1) jet pipe and rear fuselage appeared to be melting. Pilot ejected. Investigation concluded a fuel leak in Zone 3 had ignited causing catastrophic damage.
XR761	F6	08/11/84	RHT 1 & RHT 2 warnings. Airborne inspected noted white smoke from the lower jet pipe and flames from the starboard fuselage. Pilot ejected with reports of FIRE 1, RHT 1, RHT 2, GEN, AC, TURB, OIL 2, FUEL 2, PUMPS S, TTC 2 and HYD warnings. Wreckage not recovered.
XR765	F6	23/07/81	RHT 1 & RHT 2 warnings. Controls became ineffective before airborne inspection could be performed and pilot ejected. Pilot of a Lightning that was en route to provide airborne inspection reported a white fluorescent plume from the rear of the abandoned aircraft. Wreckage partially recovered and investigation established evidence of a major rear fuselage fire.
XR768	F6	29/10/74	RHT 1 & RHT 2 warnings. Rear fuselage fire and pilot ejected. No additional information.
XR715	F3	13/02/74	RHT 1 & RHT 2 warnings. Rear fuselage fire and pilot ejected. No additional information.
XS934	F6	03/04/73	Number 1 engine fire. Pilot ejected. No additional information.
XM974	T4	14/12/72	FIRE 1 & FIRE 2 warnings followed by an explosion. Crew ejected. No additional information.
XP700	F3	07/08/72	Flames and stiffening controls. Pilot ejected. No additional information.

XR764	F6	30/09/71	RHT 1 warning and stiffening controls. Pilot ejected. No additional information.
XP705	F3	08/07/71	RHT 1 & RHT 2 warnings accompanied by smoke. Pilot ejected. No additional information.
XS902	F6	26/05/71	Fire and loss of control. Pilot ejected. No additional information.
XP744	F3	10/05/71	RHT 1, RHT 2 and FIRE 1 warnings. Controls stiffened and pilot ejected. No additional information.
XS938	F6	28/04/71	Fire warning. Pilot ejected. No additional information.
XP756	F3	25/01/71	Fire warning. Pilot ejected. No additional information.

Table 1: Summary of RAF Lightnings known to have been lost due to fire

6.0 Summary

The fact that ZU-BEX was on fire during the accident flight cannot be disputed. Photographic evidence is consistent with a sustained fire in the rear fuselage (at least), which, in our opinion and based on previous history within the RAF would have generated either a RHT 1, RHT 2 or both warnings. There is photographic evidence of two atomised trails of vapour / fluid emerging from the rear fuselage during the take-off run and flight. One trail appears to emerge from slightly aft of the ventral tank with the other (possibly) coming from the lower jet pipe area. It is impossible to provide a definitive explanation based on the photographic evidence alone but it is our opinion that the fire most likely occurred as a consequence of a fuel leak. The leak may have emanated from the ventral tank but based on in-service experience with the RAF the more likely scenario is a fuel coupling failure.

Appendices B

ACCIDENT INCIDENT INVESTIGATION DIVISION

ATC INVESTIGATION GROUP FACTUAL REPORT OF INVESTIGATION ZU-BEX ACCIDENT

WARNING: The reader of this report is cautioned that the transcription of an ATC recorder audio recording is not a precise science but is the best product possible from the investigation group's investigative effort. The transcript or parts thereof, if taken out of context, could be misleading. The transcript should be viewed as an accident investigation tool to be used in conjunction with other evidence gathered during the investigation. Conclusions or interpretations should not be made using the transcript as the sole source of information.

Note: Times are expressed in UTC daylight time (UTC).

Location: South Africa, Air Force Base Overberg (FAOB)
Date: 14 November 2009
Aircraft: English Electric Lightning MKT5

* - Unintelligible word

TWR – Tower controller

Lightning – the aircraft involved in the accident

Italic – Afrikaans language

Laksman- Fire department personnel

Voice 1 – Male voice addressed as Dave (pilot)

Voice 2 – Male voice addressed as Paul (ATC)

The following transmissions happened on the 13 November 2009

Time	Source	Content
17:48:17	Voice 1	* Thanks guys I will see you in the morning
17:48:20	Voice 2	Dave just standing * the spark in your right undercarriage, do you want to do something?
17:48:24	Voice 1	Negative it's probably just hot.
17:48:26	Voice 2	Ok
17:48:30	Voice 1	But I will taxi back * can look at it
	Voice 2	Ok
17:50:10	Voice 1	Paul if you could just advise if you see any problem with the undercarriage
17:50:13	Voice 2	I've got the busses on standby they gonna meet you at the corner of * alpha.
17:50:19	Voice 1	Ok thanks I don't think there's a problem
17:50:21	Voice 2	It doesn't look like a * I cant see anything
17:50:24	Voice 1	Ya
17:50:26	Voice 2	*looks fine thanks Dave
17:50:30	Voice 1	It feels fine too we don't use *
17:50:31	Voice 2	*
17:50:43	Voice 1	Confirm the is no one behind me at the moment Paul
17:50:44	Voice 2	Say again
17:50:45	Voice 1	Its apparently clear of flight rules at the moment.
17:50:51	Voice 2	Ya its clear.
17:50:52	Voice 1	Thank you.
17:51:26		*[0:15 sec]
17:51:48	Voice 2	Dave there's a bit of flame at the back of the aircraft now
17:51:53	Voice 1	That's right
17:51:54	Voice 2	ok
17:51:56		*[0:11 sec]
17:52:25	Voice 1	We gona shut it down and then you can * back from here
17:52:	Voice 2	Ok do you have *on
17:52	Voice 1	Say again
17:52	Voice 2	Do we have * on the bags for you
17:52	Voice 1	I am not sure Paul but we * and it just didn't work so we shut it down.
17:52	Voice 2	Alright
17:53:38	Voice 1	We have been standing here for a while Paul must we start it up and taxi back.
	Voice 2	Start and taxi back
	Voice 1	Ya will have to get * relight didn't work in either the last*
	Voice 2	Ah *
	Voice 1	They are on the way with *
17:55:38	Voice 1	Which one is that
17:	Voice 2	Ya just done organized *
	Voice 1	Ok
	Voice 1	Ok will, there might be enough start up fluid will try and start one engine otherwise will have to*
17:56:17	Voice 1	They have to stay until we *
	Voice 2	Ok
17:6:49	Voice 1	If we can get some DC power apparently it will start
	Voice 2	Ya we will get you somebody that knows what we are talking about, now we got ops clerks and * running around looking for somebody that technical *

The following transition was made on the 14 November 2009

Time	Source	Content
10:17:18	Lightning	Lighting pan pan pan
10:17:20	Twr	Copied pan pan pan report, final approach Runway28 we are leading up the net Runway28.
10:17:24	Lightning	Affirm lead up I have a hydraulic failure, two hydraulic failure.
10:17:30	Twr	Copied that sir call on finals, activating the net and services.
10:17:36	Lightning	ok
10:18:17	Lightning	At this stage I can only get only the main not down, I haven't got the port main gear I am gonna attempt to blow it down.
10:18:25	Twr	Copied standing-by sir
10:19:54	Lightning	Tower, lightning, I m looking like I am loosing control of the aircraft I may have to eject.
10:20:01	Twr	Ok, just advise if you do so and aim to the east of the field if you can.
10:20:06	Lightning	Roger I know the is a sea
10:20:36	Lightning	I am trying to * on that thing * to control the aircraft at this stage I have no option.
10:20:46	Twr	I understand I have you visual sir
10:21:20	Twr	<i>lak man tooring</i>
10:21:21	Fire fighters	<i>Gaan voort</i>
10:21:23	Twr	<i>Gooi lig en ruguit by die AGT toe vlieg, hy gaan uit skiet in die wind is in die west*</i>
10:21:29	Fire fighter	<i>Roger ek het die wind by die regiut en gaan nou ry be * toe.</i>
10:22:04	Lightning	<i>Ejection seat failure, ejection seat failure, tell her I love her very much</i>
10:22:17		<i>Loks man Heties</i>
		<i>Stoel het nie gewerk hy is op die grond , ry * vir my uit soen toe regiut</i>

Commentary

Remove preliminary report

Probable cause

Control surface problem

Landing gear problem

Seat ejection problem

Fuel problem –did it cause the fire then the hydraulic problem?

Which probable cause comes first?

What caused the aircraft to crash? Did they hydraulic cause landing gear problems? Was the landing gear down?

The flight was uncontrolled, what caused that? Is it the hydraulic failure?

Landing gear was connected to the hydraulic. Why didn't the pilot bail out as per the procedures? What could have happened if the pilot bailed out?

Probable cause are we looking into the crash or the failure to bail out.

What caused the crash? Uncontrolled flight...

Double hydraulic failure is the primary probable cause that created the sequence of events that caused the crash... gear could not extend, loss of control

Contributory: in-flight fire. Fuel leak, pitostatic - system failure

Uncontrolled flight due to double hydraulic failure – primary probable cause

Primary Contributory

Fuel leakage which resulted into the in-flight fire

Substandard maintenance and inadequate safety oversight.

Check the appendixes and manufacturers report