AIRCRAFT INCIDENT REPORT AND EXECUTIVE SUMMARY

Reference	CA18/3/2/0707

Aircraft Registration	**ZS-PYM**	**Date of Incident**	19 March 2009	**Time of Incident**	1210Z
Type of Aircraft	BAe 146-200		**Type of Operation**	Commercial	

Pilot-in-command Licence Type	Airline Transport	**Age**	37	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	9 850,0		Hours on Type	633,0

Last point of departure	George Aerodrome (FAGG)
Next point of intended landing	Cape Town International Aerodrome (FACT)

Location of the incident site with reference to easily defined geographical points **(GPS readings if possible)**

On runway 19 at Cape Town International Aerodrome (FACT)

Meteorological Information	Wind direction 350°, wind speed 6 kts, temperature 14°C, cloud base 3 500 ft, cloud cover SCT, dew point 13°C, visibility good

Number of people on board	2 + 2 + 19	**No. of people injured**	0	**No. of people killed**	0

Synopsis

The aircraft was flown on a scheduled flight from Cape Town International Aerodrome (FACT) to George Aerodrome (FAGG). After landing on runway 29, the flight crew experienced a no. 1 engine flame out and the no. 3 engine spooled down into a hung state. Line maintenance was carried out on the aircraft to bring it back to service. The aircraft was then flown on another scheduled flight from FAGG to FACT.

After landing on runway 19 at FACT, the flight crew experienced a four-engine flame out. The initial information indicated that the thrust modulation system (TMS) was malfunctioning. Further investigation found that during base maintenance, the TMS was deactivated. In accordance with the manufacturer's maintenance manual, the aircraft maintenance organisation (AMO) was required to depower the system by pulling three primary circuit breakers to deactivate the TMS. However, it was found that the AMO had pulled a total of seven (three primary and four actuator centering) circuit breakers. It is clear that the maintenance carried out by the AMO in this regard was not according to the manufacturer's maintenance manual. The manufacturer's maintenance manual warns that the four actuator centering circuit breakers should not be pulled. There was a verification done in respect of the impact and influence in the event that the four actuator centering circuit breakers are pulled. The result thereof was that the actuators would not centre. Subsequently, during approach and landing sequence of the flight, when the flight crew moved the throttles in the ground idle position, the actuators retracted and the power levers on the engine fuel controls moved below the ground idle position, causing the engines to spool down to sub-idle and flame out.

Probable Cause

All four engines spooled down and flamed out uncommanded.

<u>Contributory remarks:</u>
The thrust modulation system (TMS) was malfunctioning.
The AMO did not comply with the minimum equipment list (MEL 76-10-01) procedures, when deactivating/reactivating the TMS. The AMO did not comply with manufacturer's maintenance manual and other instructions for safe operation and continued airworthiness when carrying out maintenance on the TMS.
The information of the four centering actuator circuit breakers being pulled was not written up in any of the AMO maintenance documentation. The line stations were not aware of the centering circuit breakers being pulled.

IARC Date		Release Date	

AIRCRAFT INCIDENT REPORT

Name of Owner/operator	**:** South African Airlink (Pty) Ltd
Manufacturer	**:** British Aerospace
Model	**:** BAe 146-200
Nationality	**:** South African
Registration Marks	**:** ZS-PYM
Place	**:** Cape Town
Date	**:** 19 March 2009
Time	**:** 1210Z

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 two hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997), this report was compiled in the interests 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.

ABBREVIATIONS IN THE REPORT:

AOC	: Air Operating Certificate
APU	: Auxiliary Power Unit
ATC	: Air Traffic Controller
ATS	: Air Traffic Services
ATNS	: Air Traffic and Navigation Services
SACAA	: South African Civil Aviation Authority
CAR	: Civil Aviation Regulations
ATPL	: Airline Transport Pilot Licence
F/O	: First Officer
CVR	: Cockpit Voice Recorder
DFDR	: Digital Flight Data Recorder
IFR	: Instrument Flight Rules
AMO	: Aircraft Maintenance Organisation
AME	: Aircraft Maintenance Engineer (employed by AMO)
AMM	: Aircraft Maintenance Manual
ILS	: Instrument Landing System
DME	: Distance Measuring Equipment
MEL	: Minimum Equipment List
SOP	: Standard Operating Procedures
ACSA	: Aerodromes Company of South Africa
FACT	: Cape Town International Aerodrome
FAJS	: OR Tambo International Aerodrome
FAGG	: George Aerodrome
FAKN	: Kruger Mpumalanga International Aerodrome

FAPH	: Gateway Aerodrome – Phalaborwa
ft	: Feet
kts	: Knots
METAR	: Meteorological Aeronautical Report
MHz	: Megahertz
TOD	: Top of Descent
PALT	: Pressure Altitude
VHF	: Very High Frequency
AG	: Attention Getter
MWS	: Master Warning System
CDU	: Control Display Unit
TMS	: Thrust Modulation System
MTOP	: Maximum Take-Off Power
GA	: Go Around
VDC	: Volt Direct Current
ESS BUS	: Essential Bus
MCT	: Maximum Continuous Thrust
DESC	: Descent
SYNC	: Synchronise
KIAS	: Knots Indicated Air Speed
N1	: Turbofan Speed (Low Compressor)
N2	: Engine Spool Speed (High Compressor)
N1E1	: N1 Engine 1
N1E2	: N1 Engine 2
N1E3	: N1 Engine 3
N1E4	: N1 Engine 4
TGT	: Turbine Gas Temperature
MCT	: Maximum Continuous Thrust

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On Thursday 19 March 2009 at 0507Z, a BAe 146-200 aircraft took off from Cape Town International Aerodrome (FACT) to George Aerodrome (FAGG). The flight crew flew the aircraft on a scheduled domestic flight under instrument flight rules (IFR) by day. There were 4 aircrew and 57 passengers onboard the aircraft. En route to FAGG, at 0534Z, the flight crew requested landing clearance from FAGG ATC. The first officer (F/O) was at the controls flying the aircraft. After being cleared by ATC, the F/O landed the aircraft on runway 29 at 0550Z. When the aircraft touched down on the runway, the captain observed an amber attention getter (AG) annunciator light illuminated. The captain then looked towards the master warning system (MWS) and saw that the amber Elect▲ was on and that the number one generator was inoperative. Shortly thereafter, a red AG annunciator light illuminated, due to the no. 1 engine flaming out. When the captain saw what was happening, he immediately took over control of the aircraft and completed the landing. The aircraft airspeed was ±80 KIAS at the time. After taking over control, the captain observed that the red and amber AG annunciator lights were still illuminating. At this time, the no. 3 engine also started to spool down into a hung state, though it did not flame out. The captain observed the following readings for no. 3 engine on the instruments: the N2 gauge indicated ±20% (it is normally at 50% ground idle); the N1 was just under 20% (it is normally 20%); the TGT was slightly lower than the other engines; the red Oil Press caption illuminated and the oil pressure gauge indicated a low oil pressure.

1.1.2 When the aircraft was vacating the runway, the F/O took the Abnormal and Emergency Checklists and started to action the low oil pressure emergency procedure checklist on the no. 3 engine and the flame out emergency procedure checklist on the no. 1 engine. On the apron, the flight crew executed a normal engine shutdown on the no. 2 and no. 4 engines. When the cabin doors were opened, the passengers disembarked normally from the aircraft without incident. The flight crew remained seated inside the aircraft, assessing and attempting to determine the cause of the engine flame out. Both pilots' attention was drawn to the thrust modulation system (TMS) and they observed blue arrow annunciator lights illuminating for the no. 1 and no. 3 engines. The flight crew found the fact that the blue arrow annunciator lights were illuminating strange, because normally all the lights on the TMS are off when the system is not energised and switched off.

1.1.3 The flight crew reported the defect to the operator line station at FAGG, who consulted with main base at FAJS for input into the rectification action. Following the consultations, line maintenance work was done on the aircraft. After the maintenance was completed, the flight crew performed engine ground runs to satisfy themselves of the serviceability status. All four engines started normally and the engine runs were done up to maximum take-off power (MTOP) without experiencing any further abnormalities. The captain ran the engines up to MTOP and to idle with the TMS switched on and off. All systems seemed to be fine and operating as required. The captain also simulated an approach and landing scenario, by running the engines up to MTOP and selecting the TMS to synchronise but at the same time also retarding the thrust levers. The TMS was assessed as operating normally. The captain duplicated the procedure with all four engines and then with the no. 1 and |no. 3 engines separately. Everything appeared to be acceptable. On completion of the line maintenance work, the aircraft was certified serviceable and released to service.

1.1.4 For the return flight to FACT, 19 passengers were taken on board the aircraft. At 0727Z, the aircraft departed from FAGG to FACT on a scheduled domestic IFR flight by day. The captain was at the controls and flying the aircraft. En route to FACT, the captain observed that the TMS for the no. 2 engine was not functioning correctly. When the aircraft was flying in the downwind sector of the landing approach to Cape Town, the throttles were set to flight idle. The captain observed that the no. 2 engine speed was at ±50% (which is approximately the ground idle for the engines) and that the other three engines were operating normally at ±60%. A visual approach was executed to land on runway 19. During the landing, the captain observed the red and amber AG annunciator lights illuminating again. Shortly after touchdown, with the throttles set at ground idle, the aircraft experienced an all-four-engine spool down and flame out. The captain gave instructions to the F/O to notify FACT ATC of the engine flame out situation. The aircraft had enough momentum to roll forward on the runway and vacate onto taxiway Charlie. The auxiliary power unit (APU) was still operating and gave electrical power to the hydraulic system, which enabled the captain to apply necessary brakes to steer the aircraft from the runway safely.

1.1.5 When the aircraft was stationary on the taxiway, the captain contacted the maintenance personnel at the FACT line station and was advised to restart the engines and to taxi the aircraft to the apron. The captain restarted the engines and saw them spooling up to 17% only. According to the captain, it appeared as though there was no fuel flow to the engines. The aircraft was then towed from the taxiway to the apron area. After the cabin doors were opened, the passengers disembarked normally from the aircraft without incident. The flight crew remained seated in the cockpit during the disembarkation of the passengers and observed that the two blue arrow annunciator lights were illuminating on the TMS again.

The aircraft did not sustain any damage and there was no injury to the occupants.

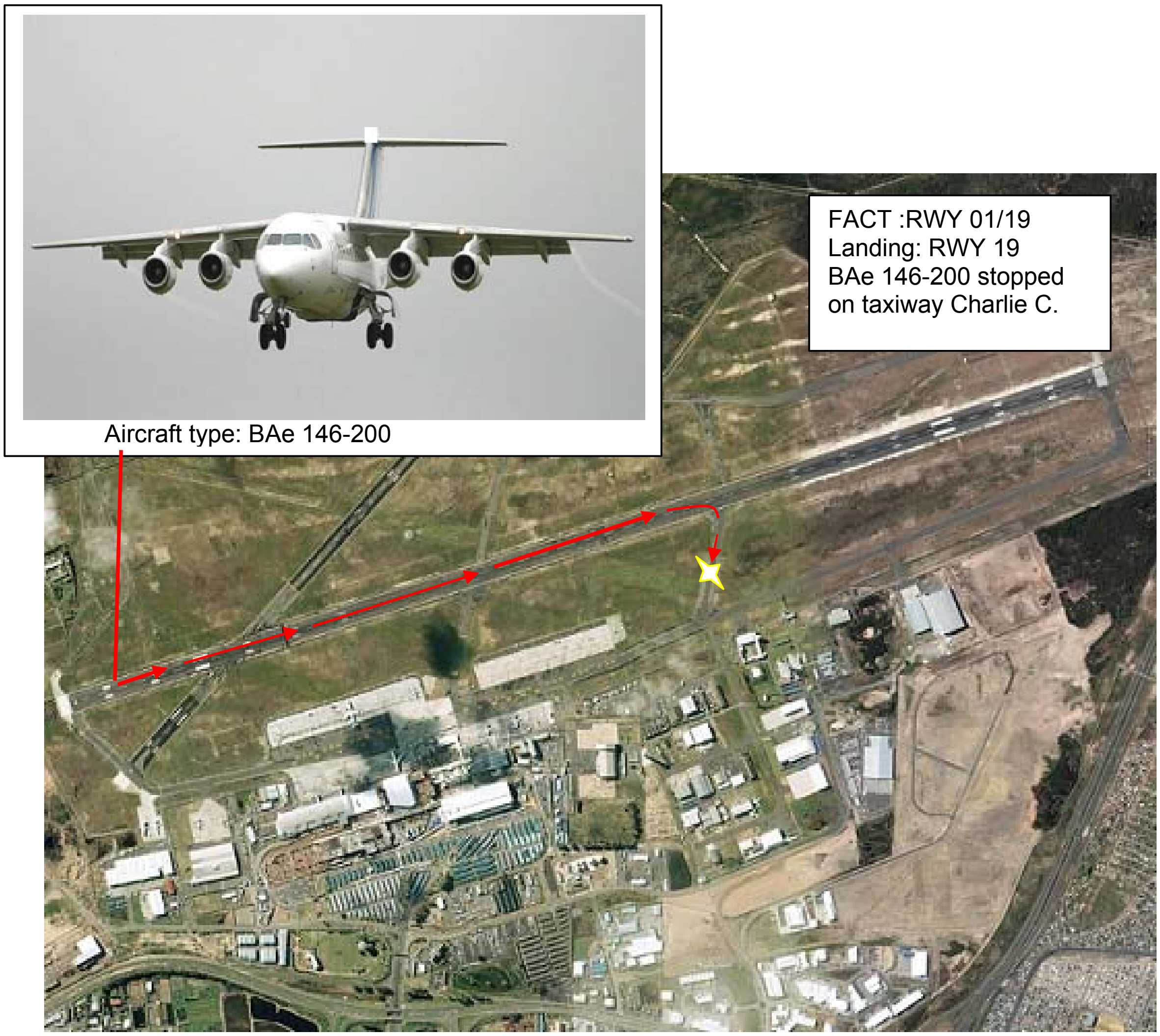

Figure 1: Cape Town Int. Aerodrome (FACT), runway 19 landing direction and taxiway C

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	2	2	19	-

1.3 Damage to Aircraft

1.3.1 The aircraft did not sustain any damage in the incident.

1.4 Other Damage

1.4.1 There was no other damage.

1.5 Personnel Information

1.5.1 Captain:

Nationality	South African	Gender	Male	Age	37
Licence Number	xxxxxxxxxxxxx	Licence Type	Airline Transport		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument; Night				
Medical Expiry Date	31 January 2010				
Restrictions	None				
Previous Accidents	None				

1.5.2 Flying experience:

Total Hours	9 850.0
Total Past 90 Days	110.0
Total on Type Past 90 Days	92.0
Total on Type	633.0

1.5.3 The captain completed training on the aircraft type on 31 May 2008. He submitted an application for issuance of a type rating to the SACAA on 2 June 2008. Complying with regulatory training requirements, the pilot also submitted proof of training information that indicated that he flew a total of 33.3 hours on the type. The SACAA reviewed his application and issued the type rating on 03 June 2008.

1.5.4 According to the operator, the captain's flight and on-duty times for the previous 48 hours were as follows:

1.5.4.1 The captain reported for duty on 18 March 2009 at 1100Z and was on duty until 2053Z. According to the information given on the Crew Roster Report, the captain accumulated 06:59 flight time and 09:53 duty time. The following day, 19 March 2009, he accumulated another 1:58 hours flight time and 04:34 hours duty time.

1.5.5 According to the captain, the F/O flew the aircraft to FAGG. The captain took over control of the aircraft during landing when they experienced the engine flame-out incident. On the flight back to FACT, the captain flew the aircraft.

1.5.6 First officer:

Nationality	South African	Gender	Male	Age	27
Licence Number	xxxxxxxxxxxxx	Licence Type	Commercial		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instructor Grade 2, Flight Tests, Instrument; Night				
Medical Expiry Date	30 June 2009				

Restrictions	None
Previous Accidents	None

1.5.7 Flying experience:

Total Hours	3 033.8
Total Past 90 Days	157.1
Total on Type Past 90 Days	150.3
Total on Type	1 123.6

1.5.8 The F/O completed training on the aircraft type on 16 May 2007. He submitted an application for issuance of the type rating to the SACAA on 18 May 2007. Complying with regulatory training requirements, he submitted proof of training information that indicated a total of 37.6 hours on the type. The SACAA reviewed the application and issued the type rating on 18 May 2007.

1.5.9 According to the operator, the F/O's flight and on-duty times for the previous 48 hours were as follows:

1.5.9.1 The F/O was on duty on 18 March 2009 from 1106Z to 2053Z. According to the information given on the Crew Roster Report, the F?O accumulated 06:59 hours flight time and 09:46 hours duty time. The next day, 19 March 2009, he accumulated another 1:58 hours flight time and 13:05 hours duty time. There was no anomaly identified with the flight on duty time of the flight crew.

1.5.10 Cabin Crew Members:

1.5.10.1 In-command flight attendant (ICFA):

Nationality	South African	Gender	Male	Age	30
Licence Number	xxxxxxxxxxxxx	Licence Type	Cabin Crew		
Licence Valid	Yes	Type Endorsed	Yes		

1.5.10.2 Flight attendant:

Nationality	South African	Gender	Female	Age	22
Licence Number	xxxxxxxxxxxxx	Licence Type	Cabin Crew		
Licence Valid	Yes	Type Endorsed	Yes		

1.5.11 Both flight attendants were found to be appropriately qualified, experienced and rated on the aircraft type. The performances of the flight attendants were professional and there was no proof of any anomaly identified with their cabin duties on the day.

1.5.12 According to the operator, the flight and on-duty times of the flight attendants for the previous 48 hours were as follows:

1.5.12.1 The flight attendants started work on 18 March 2009 at 0909Z and worked to 1853Z. According to the information given on the Crew Roster Report, the flight attendants accumulated 06:59 hours flight time and 09:46 hours duty time. The next day, on 19 March 2009, they accumulated another 1:58 hours flight time and 07:05 hours duty time. There was no anomaly identified with the flight on-duty times of the flight attendants.

1.6 Aircraft Information

1.6.1 Airframe:

Type	BAe 146-200	
Serial No.	E-2058	
Manufacturer	British Aerospace	
Date of Manufacture	1986	
Total Airframe Hours & Cycles (At Time of Incident)	33 335.73 hours	33 672 cycles
Last Phase Inspection (Date, Hours & Cycles)	13 February 2009	33 227 hours 33 566 cycles
Hours & Cycles Since Last Phase Inspection	108.73 hours 106 cycles	
C of A (Issue Date)	29 November 2007	
C of R (Issue Date) (Present Owner)	03 April 2008 South African Airlink (Pty) Ltd.	
Operating Categories	Standard	

1.6.2 Engine no. 1

Type	Honeywell ALF 502 R-5	
Serial No.	LF 05145 AC	
Hours & Cycles Since New (HSN & CSN)	27 606.72 hours	28 383 cycles
Cycles Since Hot Section Inspection (CSHSI)	3 097 cycles	

1.6.3 Engine no. 2

Type	Honeywell ALF 502 R-5	
Serial No.	LF 05604 AC	
Hours & Cycles Since New (HSN & CSN)	26 623.24 hours	24 626 cycles
Cycles Since Hot Section Inspection (CSHSI)	3 987 cycles	

1.6.4 Engine no. 3

Type	Honeywell ALF 502 R-5	
Serial No.	LF 05185 AC	
Hours & Cycles Since New (HSN & CSN)	28 493.25 hours	28 105 cycles
Cycles Since Hot Section Inspection (CSHSI)	3 773 cycles	

1.6.5 Engine no. 4

Type	Honeywell ALF 502 R-5	
Serial No.	LF 05231AC	
Hours & Cycles Since New (HSN & CSN)	28 135.15 hours	28 872 cycles
Cycles Since Hot Section Inspection (CSHSI)	690 cycles	

1.6.6 Fuel:

The aircraft was refuelled at Cape Town with Jet A-1 on 19 March 2009. The fuel uplifted was total of 4 790 *l* (1 265.384 US gal). After refuelling the aircraft, the total fuel capacity was 7 500 *l* (1 981.29 US gal). According to the captain, at the time when they experienced the incident at FAGG there was a total of 5 700 *l* (1 505.78 US gal) fuel in the aircraft. At Cape Town when they experienced the second incident, the total fuel carried onboard was 3 300 *l* (871.76 US gal). There was no anomaly identified with fuel status.

1.6.7 Mass and balance:

1.6.7.1 The masses relevant to the take-off and landing were as follows:

Zero Fuel Weight	26 300 kg
Take-off Fuel Weight	5 000 kg
Actual Take-off Weight	31 100 kg
Trip Fuel (Burn-off)	-1 800 kg
Taxi Fuel	-200 kg
Corrections	-100 kg
Actual Landing Weight	29 200 kg
Maximum Allowable Take-off Weight (MTOW)	42 184 kg
Maximum Allowable Landing Weight	36 740 kg

1.6.7.2 The calculated actual take-off weight was 31 100 kg, indicating that the aircraft was 11 084 kg below the maximum take-off weight of 42 184 kg. The aircraft burned off 1 800 kg of fuel after take-off and landed with an actual landing weight of 29 200 kg, which was 7 540 kg below the maximum landing weight for the aircraft.

1.6.7.3 The mass and balance of the aircraft was found to be within limits and did not contribute to the cause of the incident.

1.6.8 Maintenance:

1.6.8.1 According to the flight crew, the two incidents of the engine flame-outs were associated with the TMS malfunctioning, and that this malfunctioning could be related to a component or systems defect/malfunctioning. To verify if there was any evidence of this defect re-occurring, the maintenance records of the aircraft were reviewed with specific emphasis on determining if there were any entries made of deferred defects of the TMS.

1.6.8.2 Maintenance records indicated that the TMS was reported to be faulty on 17 March 2009, prior to a scheduled flight to Kruger Mpumalanga International

Aerodrome (FAKN). The flight crew reported the defect of the TMS to the AMO. According to the AMO, the TMS defect was investigated, and they took a decision to defer the defect and then deactivate the TMS. The aircraft was released to service under MEL ATA 76-10-1 conditions.

1.6.8.3 According to the MEL, the TMS may be inoperative provided that:

(i) All four actuators are centered,

(ii) The system is depowered by pulling and collaring the primary circuit breakers, and

(iii) The actuating centering circuit breakers must **NOT** be pulled.

1.6.8.4 When the method of compliance with the MEL requirements was investigated, it was found that the AMO had not complied with the identified MEL conditions in that:

(i) The AMO did not follow the correct maintenance procedure in ensuring that all four actuators were centered, prior to deactivating the system.

(ii) Instead of pulling and collaring only the primary circuit breakers, the AMO also pulled the actuator centering circuit breakers.

(iii) The collaring of the circuit breakers was done with black tie raps.

1.6.9 The aircraft was then flown for two flights (FAJS to FAKN, FACT to FAGG and FACT) with the TMS deactivated on the 17 March 2009. After the last flight to FACT, the line station installed two components (a TMC and a control display unit [CDU]) on the incident aircraft, which had been removed from another aircraft. After the components were installed, the system was reactivated and aircraft certified serviceable. The deferred defect was then cleared and MEL 76-10-1 exceptions were no longer applicable.

1.6.10 It was found that during the reactivation of the system, the AMO only reset the primary circuit breakers. The other four actuator centering circuit breakers were not reset. The aircraft was released to service with this potentially unsafe condition.

1.6.11 On 18 March 2009, the aircraft flew six scheduled flights (FACT to FAGG, FAGG to FACT, FACT to FAKN, FAKN to FACT, FACT to FAGG and FAGG to FACT). There were no further TMS defects reported on the day.

1.6.12 On 19 March 2009, the aircraft was flown again from FACT to FAGG and back. According to the information in the aircraft technical log, after landing at FAGG, the flight crew reported an incident of where the no. 1 engine had flamed out and the no. 3 engine spooled down to a hung state. This was associated with the blue arrow warning lights illuminating on the CDU as observed by the flight crew. The AMO Line Station carried out an engine flame-out troubleshooting inspection as described above. On completion of the inspections and maintenance, the defect was closed with an entry in the technical log recording the rectification action as follows:

Note: All systems were shut down and powered up again. Engine runs carried out with and without TMS operative. All parameters were normal. Fuel and Oil filters bypass valves were checked and found normal.

1.6.13 When the above maintenance was carried out, the maintenance personnel involved were not aware of the actuator circuit breakers having being pulled. According to the personnel, they conducted a visual check of the circuit breakers panel for circuit breakers that tripped. All circuit breakers that they looked at were in normal pushed-in position. On completion of the maintenance, all relevant information of the activities followed was forwarded to the AMO.

1.6.14 The aircraft was certified serviceable and flown from FAGG to FACT with the TMS reactivated. When the aircraft landed at FACT, all four engines flamed out. According to the record of information in the aircraft technical log, the no. 2 engine TMS blue arrow down ▼ warning light was illuminating and flashed continuously. This condition happened even in synchronise (SYNC) mode, irrespective of which engine was the master and position of the thrust lever. The blue arrow warning lights were flashing with down - ▼ and up - ▲ indications.

1.6.15 After the incident happened at FACT, troubleshooting inspection was carried out on the aircraft. It was established that the TMS was not functioning correctly and as a result caused all four engines to flame out. The AMO proceeded with maintenance procedures to determine which of the TMS components were at fault. The TMC was identified as being one of the components that was malfunctioning. In their process of elimination, the AMO removed and installed between aircraft the two components namely the TMC, part no. 2117578-9, serial no. 85-263; and the CDU, part no. 2117576-3, serial no. 18-281.

1.6.16 After maintenance was carried out on the aircraft at Cape Town, the TMS was temporarily deactivated. The aircraft was then operated under MEL conditions. Only when referring to the four actuator centering circuit breakers did the AMO discover the anomaly of the four actuator circuit breakers being pulled.

1.7 Meteorological Information

Wind Direction	350°	Wind Speed	6 kts	Visibility	Good
Temperature	14°C	Cloud Cover	SCT	Cloud Base	3 500 ft
Dew Point	13°C				

1.7.1 The above weather information was submitted by the captain in a Pilot Accident/Incident Questionnaire.

1.8 Aids to Navigation

1.8.1 The aircraft was flown under IFR by day. The flight crew landed at FACT on runway 19. The following radio navigation and landing aids were available at FACT:

(i) non-directional radio beacon (NDB), CB: frequency 462.5 kHz
(ii) very high frequency omnidirectional radio range (VOR), CTV: frequency 115.7 MHz
(iii) distance measuring equipment (DME), CTV/CTI/KSI: frequencies 1191 MHz, 110.3 MHz and 109.1 MHz

(iv) instrument landing system (ILS), LOC: frequency 109.1 MHz
(v) instrument landing system (ILS), GP CATII: frequency 331.4 MHz
(vi) runway centrelines and identification markings

1.8.2 All the above identified navigation and landing aids were serviceable and under 24-hours operation.

1.8.3 The navigational equipment found installed in the aircraft was as per approved MEL. There was no report of the flight crew experiencing any anomalies with the aircraft navigation equipment.

1.9 Communications

1.9.1 George Aerodrome (FAGG):

1.9.1.1 The Air Traffic Services (ATS) communication facilities available at FAGG are Tower/Approach (118.9 MHz) and Apron (122.65 MHz). There was no proof of any anomaly experienced with the ATS communication facilities at the Aerodrome.

1.9.1.2 According to FAGG ATC, the aircraft was cleared for ILS approach on runway 26. The ATC did not receive any transmissions on 118.9 MHz or 121.5 MHz to report any abnormality. The flight crew contacted the tower from the apron approximately 20 to 30 minutes after the landing, requesting clearance to do engine run-ups. The ATC gave instructions to taxi to the threshold of runway 20 for engine run-ups.

1.9.2 After the passengers boarded the aircraft at FAGG, it was cleared for take-off for the flight back to FACT.

1.9.3 Cape Town Int. Aerodrome:

1.9.3.1 The ATS communication facilities available at FACT are Control (125,1 MHz), Information (126,5 MHz), Approach (119,7 MHz), Tower (118,1 MHz) and Ground (121,9 MHz). The communication facilities are available 24 hours a day. There was no record of any anomaly experienced with the ATS communication facilities.

1.9.3.2 According to the ATC, the incident was reported to the tower immediately after it had happened. After the flight crew confirmed the status of the aircraft, the flight crew were given instructions to exit the runway into taxiway C (Charlie). The ATC then also activated the crash alarm for the fire and rescue services to dispatch to the incident site. The aircraft was safely recovered to the apron.

1.9.4 The aircraft had VHF transmitter radio equipment installed (2 x Collins 618M-5). In addition to the VHF radio equipment, the flight crew could communicate with the ATC by means of microphone, to cabin crew by means of passenger assist (PA) and the passengers by means of an aircraft intercom system. There was no record of any anomaly experienced with the aircraft communication equipment on the day.

1.9.5 Flight crew communication:

1.9.5.1 According to the captain, at the time when they experienced the incident at FAGG, he did not deem it necessary to inform ATC of the engine flame-out incident, as they were occupied with a relatively high workload in the cockpit, and didn't require any assistance from ATC or the emergency services. The captain did not think that it would be a problem, as ATC was not in any way involved in the incident.

1.9.5.2 The communication at FACT was explained as follows: The captain instructed the F/O to notify the ATC of the incident. Once the F/O was finished talking to ATC, he was then instructed to contact another operator's control office to ask them to contact their engineers to bring out a tug to tow the aircraft to the apron.

1.9.5.3 When the aircraft was stationary on taxiway C, the captain phoned their operator duty engineer to follow up on their earlier request for a tug to tow the aircraft. In the conversation, the captain was given instructions by the engineer to start up the engines and to taxi the aircraft to the apron. The captain hesitated at first out of fear that he might cause damage to the engines. The engineer initially agreed but a few minutes later confirmed that the instructions were supported by the main base at FAJS. The captain was unsuccessful with the start-up and only then did the engineer volunteer to bring the tug to tow the aircraft from the taxiway to the apron.

1.9.6 Flight attendants communication: During the flight to FAGG and FACT, everything went as normal until the landing. The flight attendants were informed by the captain of the incident and requested to keep the passengers calm, seated and that the aircraft would be towed to the apron. In both incidents, the passengers disembarked from the aircraft normally without sustaining any injury.

1.10 Aerodrome Information

1.10.1 Departure aerodrome:

Aerodrome Location	George Aerodrome (FAGG)	
Aerodrome Co-ordinates	S34º00'.24.1" E022º22'.27.4"	
Aerodrome Elevation	648 ft	
Runway Designations	11/29	02/20
Runway Dimensions	2 000 x 45	1 160 x 30
Runway Used	29	
Runway Surface	ASPH	
Approach Facilities	NDB, ILS, DME	

1.10.2 Arrival aerodrome:

Aerodrome Location	Cape Town International Aerodrome (FACT)	
Aerodrome Co-ordinates	S33º58'05.3" E018º36'16.7"	
Aerodrome Elevation	151 ft	
Runway Designations	01/19	16/34
Runway Dimensions	3 201 x 61	1 701 x 46
Runway Used	19	
Runway Surface	ASPH	
Approach Facilities	NDB, ILS, DME, VOR	

1.11 Flight Recorders

1.11.1 The Flight Recorders installed on the aircraft were the following:

(i) The flight data recorder (FDR) that was installed in the aircraft was a Plessey type, part no. 650/1/14040/209, serial no. 10027, and the cockpit voice recorder (CVR) was a Fairchild A 100 type, serial no. 6015.

(ii) The FDR and CVR recorders were removed in a serviceable condition from the aircraft on 23 March 2009, after a request by the SACAA.

1.11.2 The CVR had a magnetic tape as a reading medium and could only retain the last 30 minutes of the crew voice communications and noise within the cockpit environment. Regretfully, the CVR was not deactivated and the aircraft was flown on a ferry flight in excess of two hours from FACT to FAJS on the 19 March 2009. Consequently the data could not be extracted from the CVR in the investigation.

1.11.3 The FDR was taken to a local service provider for downloading of information on 27 March 2009. The FDR was in a good condition and completely serviceable. The recording medium within the unit is a magnetic tape, with a recording duration of 25 hours. This particular FDR records in ARINC 573 mode. The number of parameters recorded is dependent on the aircraft configuration and flight data acquisition unit (FDAU) fitted. For this aircraft, the number of parameters recorded is 46. Included below is an extract of a read-out report of FDR data downloaded and found to be pertinent to the incident.

1.11.4 The summary of the FDR read-out information on the graph below was for the initial engine incident at FAGG (no. 1 engine flame-out and no. 3 engine spooled down into hung state).

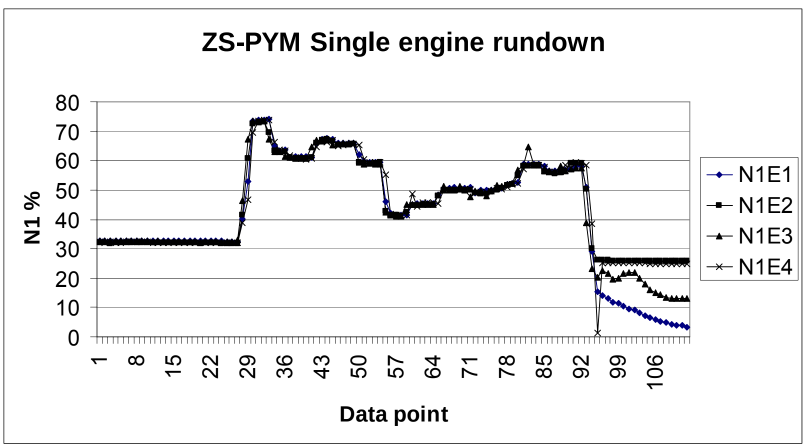

Figure 2: Graph of single-engine rundown

1.11.4.1 The FDR data on the graph can be summarized as follows: During the approach for landing to FAGG, the aircraft engines (N1E1, N1E2, N1E3 and N1E4) were all operating at approx. 33% as indicated on the graph, data points 1 to 27. The engine throttles were advanced to increase the power to approx. 75%. The engines' power was gradually reduced to approx. 60% and then 40%. There was an increase again of engine speed to 60% when on touchdown engine N1E1 flamed out and N1E3 spooled down into a hung state. The other two engines N1E2 and N1E4 was operating and producing power below 30%, at an estimated level of approx. 25%.

1.11.5 The summery of the FDR read-out at FACT for the four engines flaming out was plotted on a graph. According to the FDR read-out information, the recording of the incident was from 00:07:47 to 00:19:39, which is approx. 12 minutes into flight until the aircraft touched down at FACT.

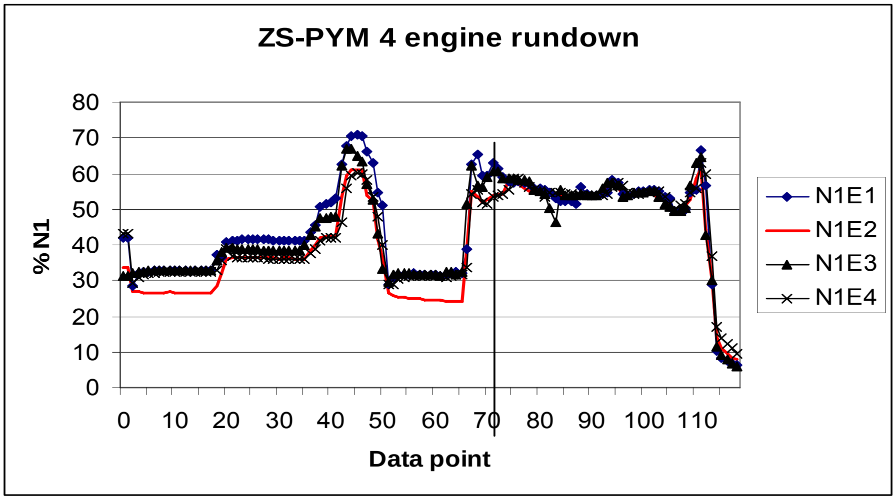

Figure 3: Graph of all-four-engine rundown

1.11.5.1.11.11.5.1 The FDR data on the graph can be summarized as follows: During the approach for landing at FACT, the engines' performance was measured at approximately (N1E1 = 42.1%, N1E2 = 33.8%, N1E3 = 31.1% and N1E4 = 43.3%). Four seconds into flight, three of the engines (N1E1, N1E3 and N1E4) ran down to approx. 30% and N1E2 to 26.5%. The graph further shows that from data points 15 to 35, 60 seconds later the throttles were advanced to performance levels (N1E1 = 37.3%, N1E2 = 28.4, N1E3 = 35.8% and N1E4 = 35.5%). The engines operated at these performance levels for 64 seconds. The throttles were then advanced to performance levels (N1E1 = 70.5%, N1E2 = 60.8%, N1E3 = 63.4% and N1E4 = 58.4%).

1.11.5.2 The no. 2 engine performance had improved from the initially indicated low levels. For some reason, all four engines then started to spool down to slightly above of 30% as indicated by data points 50 to 65 on the graph.

1.11.5.3 After approx. 68 seconds, the throttles were advanced again to N1E1 = 62.8%, N1E2 = 53.9%, N1E3 = 60.5% and N1E4 = 53.9%). The engines operated normally above 50% for a duration of 148 seconds, as indicated by data points 70 to 115. There was a slight increase in engine power to above 60% which lasted approx. 8 seconds, where after all four engines spooled down to below 10% and flamed out.

1.12 Wreckage and Impact Information

1.12.1 The aircraft sustained no damage in the incident.

1.13 Medical and Pathological Information

1.13.1 There were no injuries sustained by the crew and passengers in the incident.

1.14 Fire

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

1.15 Survival Aspects

1.15.1 The incident was considered to be survivable. The aircraft was intact and had not sustained any damage. There was also no injury sustained by the crew or passengers.

1.15.2 The fire and rescue services activities at both aerodromes (FAGG and FACT) were reviewed and no anomalies could be identified. The crash alarm was activated by FACT ATC and the fire and rescue services dispatched to the incident site and handled the situation professionally. The flight deck crew did not report the incident to FAGG ATC, thus there was no requirement for fire and rescue services.

1.15.3 Due to the nature of the two incidents, where the aircraft was still intact and no injury was sustained and/or damage caused, there was no need to conduct an emergency evacuation from the aircraft. All the occupants disembarked the aircraft normally.

1.16 Tests and Research

1.16.1 According to the available information of incident and accident history, which is held on file at the regulator, it appears that this was the first time that an incident of this nature was reported. The State of Design and Manufacture also had no evidence of a notification received of a similar incident happening with the TMS.

1.16.2 Following what was observed by the AMO at FACT, the TMS was temporarily deactivated and aircraft flown on a ferry flight to the AMO main base at FAJS on 19 March 2009. When the aircraft arrived at FAJS, the AMO conducted further investigation into the engine flame out situation. The AMO was also requested to send the components to the manufacturer for testing. For this purpose, the AMO requested the assistance of the Aircraft Manufacturer.

1.16.3 Upon receiving notification of the engine flame out, the manufacturer responded to the AMO some advice. The AMO was informed that the TMS problem could have been as a result of the actuators not centering. This may have been caused by a wiring fault between the control display unit (CDU) through wires to the relays KS5 and KS10. The AMO was then directed to consult the aircraft maintenance manual (AMM) for guidance of rectification procedures.

1.16.4 According to the AMO, prior to the aircraft being flown on the ferry flight to FAJS, there was a self-test and system operational check performed on the TMS. No proof could be found of a system fault and there were also no faulty codes evident at the time of the testing. Procedures received from the manufacturer related to the troubleshooting were performed and the aircraft was released to service with the condition of it operating under an MEL 70-10-1 exemption.

1.16.5 In order to have a clear understanding of the TMS operation, with specific reference to it malfunctioning, the following relevant technical information was extracted from BAe 146 Series/AVRO 146-RJ Series AMM.

(i) According to the AMM, the TMS is designed to manage engine thrust by trimming, with limited authority, the thrust control lever settings selected by the pilot. Performance of the system is based on parameters of engine fan speed (N1), high-pressure turbine speed (N2), turbine gas temperature (TGT), altitude, total air temperature and engine bleed configurations.

(ii) The system operates in a variety of modes, selection being made by the pilot through the CDU, which interfaces by means of a twin ARINC 429 Data Bus with a microprocessor-based TMC. The computer drives four actuators – one on each engine – to provide limited trim authority on thrust control lever settings.

(iii) Power is supplied to the TMC from the 28 VDC BUS no. 1 and 2 when the Avionics B master switch is closed. The 28 VDC BUS no. 1 powers a power supply within the TMC that supplies +8 VDC to power the CDU. The 28 VDC BUS no. 2 supplies actuation power via the CDU to the open and closed drivers in the TMC, which in turn extend or retract the actuators. The 28 VDC ESS BUS is used to centre the actuators.

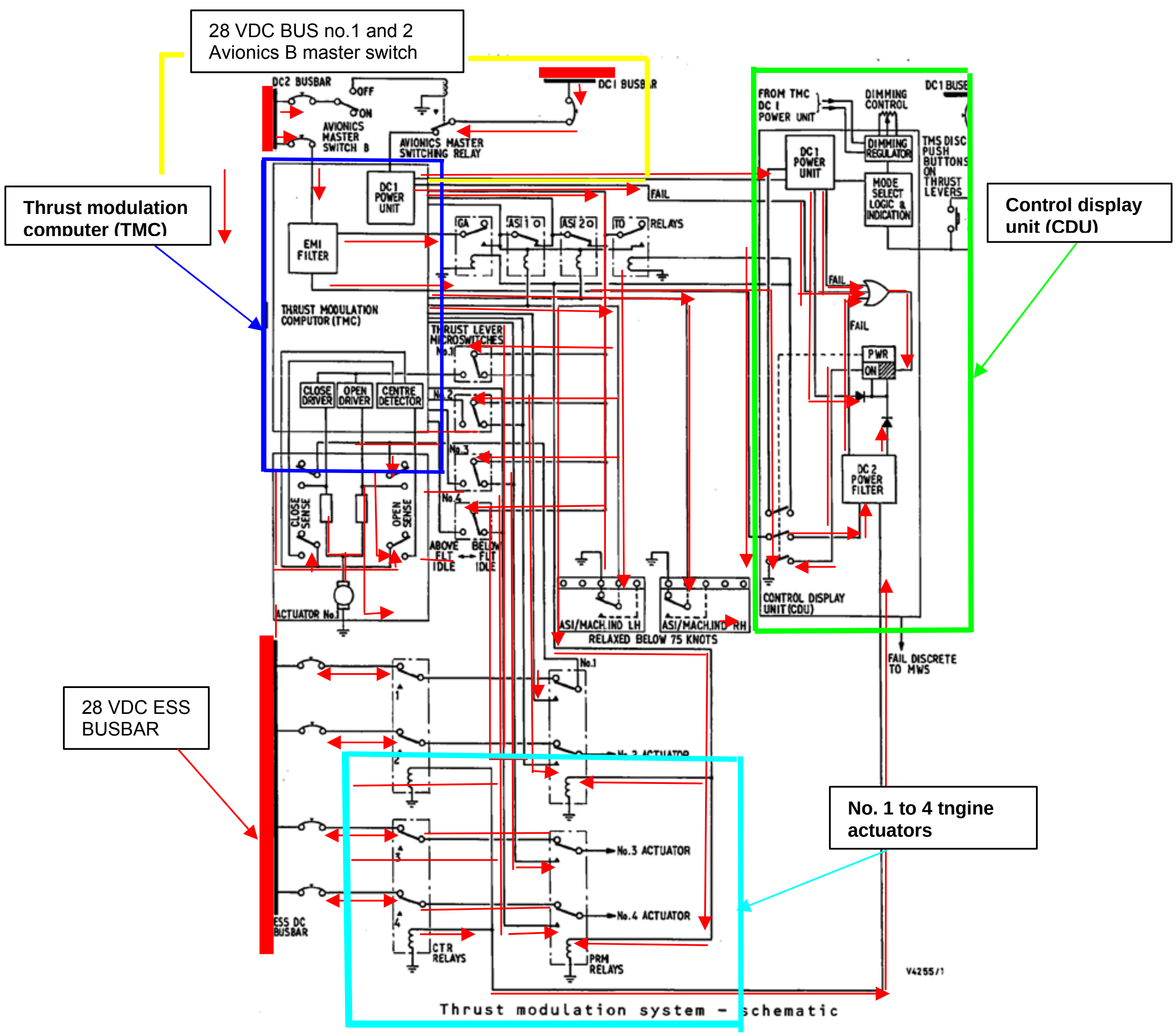

Figure 4: Wiring diagram of the TMS

1.16.6 The CDU consists of a chassis assembly containing a front panel display assembly, plug-in printed circuit assemblies, a regulator supply, and an EMI filter assembly. The CDU supply means of selecting a temperature reference for either full take-off power or flexible take-off power and TMC calculate target fan speed (N1). This value will be displayed on the CDU.

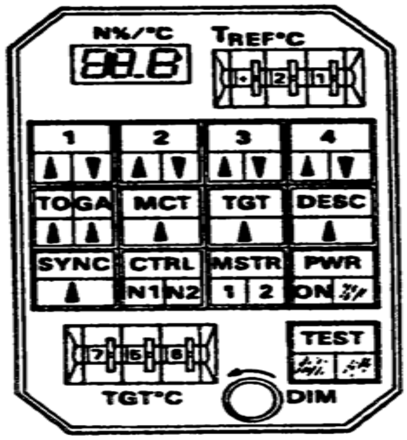

Figure 5: Control Display Unit (CDU)

1.16.7 When the TMS is energised power on, a white 'on' annunciator light and legends of mode switches will illuminate. If there is a power failure, the white 'on' light will extinguish and a yellow annunciator will illuminate. When power is first applied to the system, or restored following a power failure, a series of self-tests are automatically performed to ensure system integrity. A failure of any of these tests will illuminate the amber quadrant of the test switch/indicator on the CDU and the TMS fail capsule on the MWS, and display a fault code in the N%/°C window. An unsuccessful self-test will inhibit selection of any TMS operating modes, leaving the system in standby. A successful initialisation self-test will not be annunciated. The result being that the test switch PASS/FAIL annunciator will also be left dark. A successful test completion will permit mode selection.

1.16.8 The illumination and dimming controls are selected on the Avionics Master B switch and supplies lighting power to the CDU legends. The power push button energises the TMS, which supplies power to engine actuators through the CDU.

1.16.9 The TMS computes and displays target fan speed (N1) on the N%/°C display. Engines are driven to the computed target N1 value by the actuators trimming their throttles. All actuators are restricted to trim between the limits of centre and full advance. The N%/°C indicator displays target engine speed/TGT for the selected mode. The target engine speed is displayed in terms of percentage of maximum spool speed. The target speed displayed is N1 for take-off (TO) mode and N2 for descend (DESC) mode. The GA annunciator light, which illuminates white when on, only comes on if power is selected (pilot input) and/or when TMS Disconnect (TMS DISC) mode is selected. This mode is selected by depressing either of the two TMS DISC switches on the outer thrust control levers.

1.16.10 The actuator is driven by a bi-directional 28VDC split-field motor. The actuator has an irreversible screw jack with positive non-jamming radial type retract and extension stops. Centering of the shaft is achieved through an electrical contact shut-off cam and two switches mounted on individual threaded shafts. Adjustment on the relative position of the centering switches is provided. Adjustable rod ends are self-aligning bearing types.

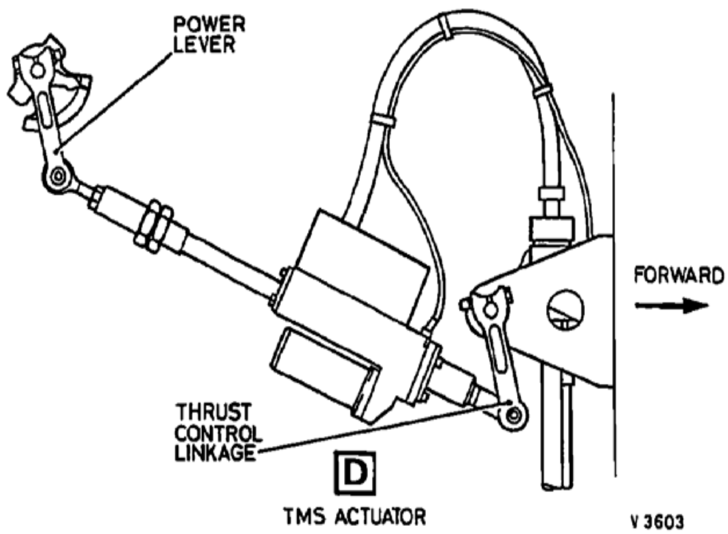

Figure 6: Throttle modulation system actuator

1.16.10 Engine actuators indicators identifiers 1 to 4 indicate which actuators have been commanded beyond their limits of control or have failed to respond to a system centering command. If the actuators were commanded beyond their limits of control, one of the arrows in the associated engine identifier comes on to indicate that the actuator has been commanded to move beyond its control limits. The sense of the arrow advises the direction of thrust control lever movement required to allow the actuator to re-enter its authority limits. The blue arrow (up▲) or white arrow (down▼) advises the necessity for thrust control lever advance or retardation respectively.

The sequence is as follows:

(i) Verify aircraft power is ON, and then energise the TMS.
(ii) Momentarily depress one or both TMS disconnect (GA) push buttons located on the outer throttle levers.
(iii) Verify that the GA indicator lamp (white) on the CDU lights up and any other mode annunciator arrow indicators are extinguished.
(iv) Verify that the GA indicator arrow lamp (green) lights up on the CDU. If a GA indicator arrow lamp fails to light, non-centered actuators are indicated by the engine actuator (1, 2, 3 and 4) on the CDU. The arrows flash until the TMS disconnect (GA) button is depressed again; then the arrows remain on steady until the actuators are centered.

1.16.11 The TMS performs the function of temperature/speed trim and synchronisation of the four engines. The system uses a microprocessor to control the trim actuators between the thrust control levers and the engine power lever in the mode selected. The actuators trim the fuel control lever position to maintain control based on the mode of operation selected. The principal modes of operation associated with the TMS functions are as follows:

(i) Take-off (TO)
(ii) TMS disconnect
(iii) Maximum continuous thrust (MCT)

(iv) Turbine gas temperature (TGT)
(v) Flight descent (DESC)

1.16.12 The synchronisation in N1 (turbofan speeds) or N2 (engine spool speed) with either engine 1 or 2 as master may be selected in TGT mode. It may also be selected as an alternate to TO, TMS Disconnect, MCT, or DESC.

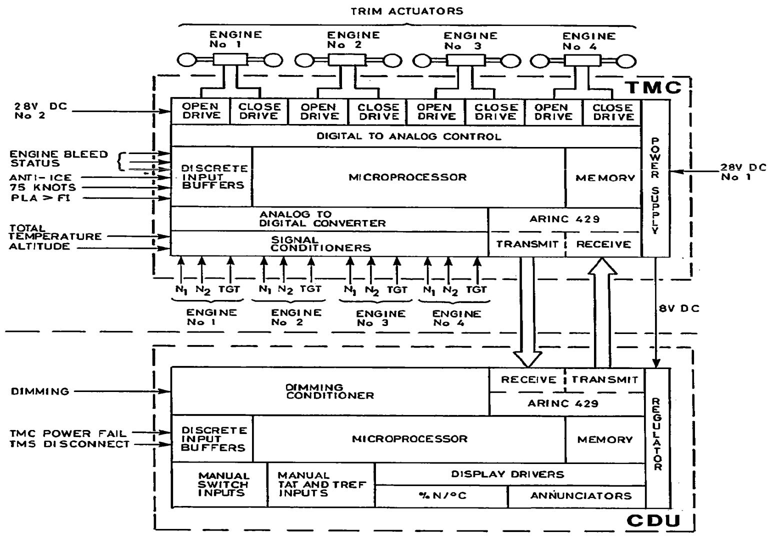

Figure 7: Block diagram of TMS

1.16.13 In take-off, as thrust control levers are advanced beyond the position of their micro switches (just below flight idle), all engines are controlled independently to target N1 during the complete acceleration period. Actuator authority is restricted to the limits of zero trim (centre) and full extend. All actuators trim up fully initially. As the engines accelerate to target N1, the actuators commence with trimming down against advancing thrust control levers to trim engine speeds to target. While the engines are accelerating to target, the blue arrows in the engine identifiers come on. As each engine attains target speed, its associated blue arrow goes off. Should a thrust control lever be advanced so far that its actuator has reached the limit of its trim-down authority (centre) when seeking to trim the target, a white arrow in the associated engine identifier comes on advising the pilot to retard that thrust control lever.

Note: At 75 kts indicated airspeed (IAS), all the actuators freeze at the trim position they have attained and remain so until an alternative mode is selected or thrust control levers are retarded below flight idle, when actuators centre.

1.16.14 The pilot will select MCT mode by pressing the MCT push button. The MCT arrow comes on green; all other mode arrows go off.

1.16.15 Pilot inputs by selecting DESC mode on the CDU and retarding the throttle to flight idle bulk. Target values (N2) are indicated on the CDU N%/deg.C display. The N2 limits values are 60% without engine anti-ice and 67% with engine anti-ice. The N1 limit, TGT and N2 targets are compared, the value of which is used for system control (lowest wins).

1.16.16 The TMS is set with authority limits. A total system hardware failure cannot cause a cumulative power loss greater than associated with a single engine shutdown under critical flight conditions. The ground idle stop is between 10 to 15°, and engine off is between 0 to 3°. The authority of the trim actuator is limited in such a way that the thrust control lever retraction from the maximum to flight idle bulk, with the trim actuator at the maximum close authority does not cause the engine power lever to enter the engine shutdown region.

1.16.17 The TMS is configured with authority limits that allow safe operation with 0.5 in (12.7 mm) trim authority. The authority limits are affected by both mechanical and electrical methods:

(i) Mechanical stops in the actuator limit maximum travel to 0.5 in (12.7 mm).

(ii) Electrical interlocks cause actuators to centre whenever the thrust control lever is retracted below the flight idle baulk.

1.16.18 If the thrust control levers are below the flight idle baulk, it is sensed by a micro switch. The micro switch activates between ground idle and flight idle baulk. The position of the micro switch is set at 56% to 57% N2. The TMS, with engine anti-ice selected on, attempts to maintain 67% N2 below 200 ft in opposition to the thrust control lever, retarding to the 60% N2 flight idle baulk position. To eliminate this conflict, the TMS is automatically disconnected at 200 ft during a landing approach. The 200 ft relay (KE10) is energised through a RAD ALT switch at 200 ft. In any mode except take-off (TO), 28 VDC is applied to the input of the pulse generator (KS28), whose output is 28 VDC for 2 seconds providing a disconnect (DISC) discrete to the TMC, and the TMS is automatically disconnected.

1.16.19 The total usable fuel capacity of the aircraft is 11 728 *l* (3 099 US gal), which is contained in three integral tanks, one in each wing and one in the centre section. The wing tanks each carry a total of 4 614 *l* (1 219 US gal), and the centre section tank carries 2 500 *l* (661 US gal). Each wing tank contains two feed compartments at the outboard end, and in each is be mounted an engine fuel supply pump. The centre section tank contents are automatically transferred to the the wing tanks as space becomes available during use. The fuel is supplied to the engines by four AC motor-driven flooded pumps. Each pump provides an independent feed to its associated engine via a low-pressure valve. A common feed interconnection and valve fitted between the pair of pumps in each wing tank and a cross-feed interconnection and valve is provided between the pump systems in the two wing tanks. The fuel for the auxiliary power unit (APU) will be supplied from the main engine cross-feed line via a low-pressure valve.

1.16.20 Under normal flight conditions, no management will be required other than to switch on all pumps immediately after engine start and to select the centre tank switch to Auto if this tank contains fuel.

1.16.21 The thrust of each engine are controlled by a thrust control lever mounted in the control console in the flight compartment. The engine power lever and high-pressure fuel valve control are combined in one spindle on the engine. The first movement of the control from ‘off’ position opens the high-pressure valve and the remaining movement controls the engine thrust. When the thrust levers are positioned to approximately the correct location for mode selected, the actuators trim each engine power lever to achieve the required setting. If the thrust levers are outside captured range of ths TMS, an indication will be given on the CDU to advance or retard the power lever of the appropriate engine.

1.16.22 Aircraft Manufacturer’s Report:

(i) According to the manufacturer, with all actuators centered, arrows would not be displayed on the CDU, but the continuous test facility in the TMS will display ‘actuators not centered’ as blue or white arrows, even when the CDU power is selected ‘off’. The actuators are normally commanded to the centre position during the approach, landing and when the system is selected ‘off’.

(ii) On the approach, the TMS automatically disconnects at 200 ft, causing power to be supplied via the TMS actuator control circuit breakers and external relays to the centering pin on the actuators. Actuators that do not centre cause the engine identifier arrow to flash. If the system does not receive the disconnect signal (actuators are not centered), throttle micro switches direct centering power from the TMC via the alternate pins in the external relays to the actuators when the throttles are moved below flight idle on landing.

(iii) When the TMS is selected off, centering power is supplied to each of the actuators via the same circuit used in the automatic disconnect function. It was concluded that the rundown of engines no. 1 and no. 3 was due to the TMS actuators not being centre. With blue arrows on the TMS when the throttles are at the ground idle, the power levers on the engine fuel controls are below the ground idle position, causing the engines to run down. Possible causes of non-centered actuators are:

- o the TMS actuator control circuit breakers were open
- o actuators got stuck or seized
- o incorrectly rigged or faulty throttle micro switch
- o damaged wiring or faulty relays.

The fact that the actuators did not centre when the TMS was selected off would suggest that the TMS actuator control circuit breakers were open.

(iv) The FDR data confirms the issue with the no. 2 engine TMS. As the throttles are retarded to flight idle (TMS DESC mode assumed), it is evident that there is a problem with the no. 2 engine actuator, which appears to be in a retracted position causing the lower N1. The other engines display representative flight idle N1 as these actuators are not retracted (the TMS DESC mode limits the actuator authority to the area between centered and fully extended).

(iiv) The FDR also shows that the throttle advance at approximately data point 76 TMS SYNC was selected. At lower thrusts, one would expect the engine N1 spools to be synchronized. If engine no. 2 (TMS actuator retracted) was selected as the master engine, the other engine actuators would be expected to be in the retracted area for a common throttle setting. If again the actuators do not centre when the TMS disconnects at 200 ft, all actuators will be in the retracted condition when the throttles are moved to ground idle. With the throttles in the ground idle position and the actuators retracted, the power levers on the engine fuel controls would be below the ground idle position, causing the engines to run down to sub-idle and flame out. Although this scenario could be caused by a wiring fault or the failure of relays, the fact that all four actuators did not centre when the TMS was disconnected at 200 ft or when the throttles were moved below flight idle would suggest that the TMS actuator control circuit breakers were open.

1.16.23 A review was conducted on the possibility of a similar four-engine rundown (caused by thrust lever position changes/TMS system) in flight. The engine condition is dictated by the thrust lever position in the flight deck, modified by the input from the TMS. The worst-case engine failure scenario would be failure of the master engine on an approach in landing configuration with the power levers back at the flight idle baulk. The TMS addresses this scenario by observing the minimum N2 for flight idle, not permitting the other engines to follow the master engine should it fall below the minimum N2. This behavior is evident in the FDR download. In flight with weight off the wheels, the flight idle baulk is extended, providing a minimum thrust lever control setting of 60% N2 (67% N2 if any engine has anti-icing selected on). The flight idle baulk is extended by the squat switch systems removing the power supply from the solenoids, which allows the baulk actuators to extend under spring pressure. Shutdown of the four engines in flight via the thrust levers is extremely remote requiring failures in both squat relay systems to initiate an uncommanded retraction of the flight idle baulk and crew action to retard throttles below the flight idle position.

1.16.24 When TMS power is removed, power is supplied to the centering pin of the actuators via the centering circuit breakers. If the centering circuit breakers are pulled, the actuators will not centre if they move from the centre position for any reason. *Wiring Manual* Chapter 73-20-04 Fig. 105 page 102 illustrates the centering circuit breakers (1KS 3, 2KSD 3, 3KS 3 and 4KS 3) and the circuitry between these and the centre drive pin no. 7 on the actuators. With TMS disconnected or powered 'off', power from these circuit breakers is directed via relays to the centre drive pin no. 7 on the actuators. When these centering circuit breakers are tripped, there is no facility available to centre the actuators.

1.17 Organisational and Management Information

1.17.1 The AMO that was responsible for maintenance of the aircraft had a valid Part 145 AMO Approval Certificate, issued on 03 October 2008 with an expiry date of 30 September 2009. The certificate had all the appropriate category ratings included on it, which allowed the AMO authorisation to conduct maintenance on the aircraft.

1.17.2 The operator had a valid Air Service licence and a Part 121 Air Operating Certificate (AOC), issued on 05 August 2008 with an expiry date of 30 April 2009. The registration, ZS-PYM was authorised for utilisation.

1.17.3 The management of FAGG and FACT is currently administered by ACSA. Both FAGG and FACT had valid Aerodrome Licences, issued on 30 January 2009 and 30 September 2008 respectively, with expiry dates 31 January 2010 and 30 September 2009 respectively.

1.17.4 The control towers at FAGG and FACT are both administered by Air Traffic and Navigation Services (ATNS). Both control towers had valid Air Traffic Services Unit Approvals, which expire on 30 November 2009 and 31 October 2009 respectively.

1.17.5 The operator notified the aircraft manufacturer immediately of the incident and continued to consult them throughout their internal investigation process, sharing information about the probable cause of the engine flame-out. The manufacturer assisted the operator in a very professional way by giving clear guidance on how to resolve the problem. The lines of communication between the operator and aircraft manufacturer were found to be transparent with the aim of returning the aircraft back to service in a serviceable condition.

1.17.6 The operator was under the impression that no investigation would be conducted into the incident and started with the maintenance troubleshooting on the aircraft. The result has been that the flight data recorders (FDR and CVR) were not removed from the aircraft for downloading.

1.18 Additional Information

1.18.1 Release to service:

1.18.1.1 Due to the current circumstances of the maintenance irregularity in respect of the of the four actuator centering circuit breakers, it was important to verify the validity of the Technical Log, Task Cards and Certificate of Release to Service of the aircraft. The verification was done to establish compliance by the AMO with the certification requirement that reads as follows:

Note: I hereby certify that I am satisfied that the above-mentioned aircraft, and all its equipment is in every way serviceable for flight, and that all maintenance has been carried out in accordance with the Civil Aviation Regulations, 1997.

1.18.1.2 According to the AMO Manual of Procedure (MOP), defects arising during maintenance input may fall into one of two categories:

(i) Those that require immediate rectification and;
(ii) Those that may be deferred to a more suitable time for rectification.

1.18.1.3 All defects, regardless of their status, will be recorded in the relevant maintenance records and as well as the corrective actions implemented to rectify (or defer) such defects. The release to service thus encompasses the manner (and associated documentation) with which an aircraft, engine or component is released after having undergone maintenance.

1.18.1.4 The Civil Aviation Regulations (CAR), 1997, Part 43.02.2, require that any person who carries out maintenance shall use methods, techniques and practices that are prescribed in the current manufacturer's maintenance manual or any instructions for the safe operation and continued airworthiness of the aircraft. On completion of the maintenance, such person shall ensure that the condition of the aircraft or aircraft component is satisfactory for release to service.

1.18.2 Referring to the above information, according to the instructions in the manufacturer's maintenance manual (Chapter 76-12-14), for deactivation/reactivation maintenance practices of the TMS, the following is required and is the procedure to be used in accordance with the requirements of MEL 76-10-1, namely that whenever any part of the main or associated systems is dismantled, adjusted, repaired or renewed, that part of the system that has been disturbed shall be subjected to a duplicate inspection for security of locking devices, full and free movement, and direction and tension checks.

1.18.3 According to CAR, Part 43.03.6, no person shall certify an aircraft component for release to service after the initial assembly, subsequent disturbance or adjustment of any part of an aircraft or component control system unless a duplicate safety inspection of the control system has been carried out, and the duplicate safety inspection is recorded and certified in the appropriate logbook or other maintenance record.

1.18.4 Records indicate that the AMO did not comply in full with the regulations. Almost all the relevant maintenance procedures in the MOP were not complied with. The maintenance practices used to deactivate or reactivate the TMS was not in compliance with the manufacturer's maintenance manuals. On completion of the maintenance, the required documents (Technical Log and Task Cards) were certified and the aircraft was returned to service.

1.18.5 After the TMS was deactivated at FAJS, the AMO deferred the defect in the Technical Log. No entries were made in the Technical Log or Task Cards to indicate that the four actuator centering circuit breakers had been pulled. Obviously, due to the information being excluded or not made available, the AMO personnel at the FACT and FAGG line stations were not aware of the deactivated status of the circuit breakers.

1.18.6 According to the MEL, the operator was required to comply with M (maintenance) and O (Operations) conditions. The identified procedures dictate the procedures to be followed from both maintenance and operations, in event of the TMS being deactivated. During the investigation, it was found that the identified M and O procedures were not inserted into the MEL as required by the manufacturer. The proof found was of the M procedure that was contained in the Airline Operations Manual. The O procedure could not be found in the Operations Manual.

1.19 Useful or Effective Investigation Techniques

1.19.1 None

2. ANALYSIS

2.1 The South African operator held a valid AOC and utilised the aircraft for airline transportation operations. On the day of the incident, the aircraft was operated on a scheduled domestic IFR flight by day between FACT and FAGG. After touchdown at FAGG the flight crew experienced the first incident, namely an engine flame-out (no. 1 engine). The engine flame-out was associated with the TMS malfunctioning. Line maintenance was carried out on the aircraft to rectify the defect. After the line maintenance, engine ground runs were performed by the flight crew to confirm the serviceability status of the aircraft, the aircraft was certified serviceable and flown to FACT. En route to FACT, the TMS for the no. 2 engine was not functioning correctly. The engine speed (N2) was lower than the other three engines. When the aircraft arrived at FACT, it landed and after touchdown all four engines spooled down and flamed out uncommanded.

2.2 The technical information that was obtained from the FDR download was used in the investigation. The technical data read-out from the FDR confirmed that the no. 2 engine functioned incorrectly. This was determined to be influenced by the actuator being in a retracted position, causing a lower N1 setting. The other three engine actuators were not retracted and their power settings were not affected.

2.3 Initial information made available from the operator was that the TMS of the aircraft was the cause of the engines flaming out. The AMO identified this during the troubleshooting maintenance inspections that were carried out on the aircraft. Indications were that the two components, the TMC and CDU, were faulty and caused the malfunction. In order to verify the correctness of the finding, the AMO proceeded to remove the suspect components from the aircraft. The AMO installed serviceable components (TMC and CDU) from another aircraft into the incident aircraft. The TMS was tested again and engine runs were carried out to verify the serviceability status of the aircraft.

2.4 The faulty components (TMC and CDU) were sent to the manufacturer for further investigation. In the interim, while awaiting the results, the operator had taken a decision to deactivate the system temporarily and operate the aircraft under MEL conditions, and the aircraft was released for service with the TMS deactivated. The results of the component investigation indicated that no faults were identified with the components.

2.5 After discussion was held with the AMO, a review of the maintenance practices undertaken when the AMO deactivated the TMS on 17 March 2009 was conducted. In order to comply with the MEL requirements, it appeared that the AMO pulled a total of seven circuit breakers (C/Bs), i.e. the primary and actuator centering C/Bs. The circuit breakers were then collared with black tie-raps. After the last flight on that day, the AMO reactivated the TMS, but only three (primary) circuit breakers were reset and the other four actuator centering circuit breakers were left pulled and collared.

2.6 According to the MEL, the AMO was not allowed to pull the actuator centering circuit breakers. Also, after the actuator centering circuit breakers were pulled, the relevant information was not brought to the attention of other maintenance personnel who reactivated the TMS. Hence, these affected circuit breakers were not expected to be to have been pulled. However, it is possible that the circuit breakers may trip in cases of electrical power overload. Should that have been the case, the white area of the circuit breakers would then be exposed and could have been easily observed.

2.7 The influence of the four pulled actuator centering circuit breakers was investigated to determine if the circuit breaker problem was a contributing factor in the incident, in consultation with the State of Design and Manufacture. It was determined that when the TMS power is removed, power is supplied to the centering pin of the actuators via the centering circuit breakers. If the centering circuit breakers were pulled as reported by the AMO, the actuators would not centre if they moved from the centre position for any reason. At what time this occurred during the two incidents (actuators moving from the centre position) could not be determined.

2.8 These actuators are normally commanded to the centre position during the approach, landing and when the system is selected ‘off’. On the approach the TMS automatically disconnects at 200 ft, causing power to be supplied via the TMS actuator control circuit breakers and external relays to the centering pin on the actuators. If the actuators do not centre, it causes that particular engine identifier arrow to flash. If the system does not receive the disconnect signal (actuators not centered), the throttle micro switches direct centering power from the TMS via the alternate pins in the external relays to the actuators when the throttles are moved below flight idle on landing. When the TMS is selected ‘off’, centering power is supplied to each of the actuators via the same circuit used in the automatic disconnect function. Again, if the actuators do not centre when the TMS disconnects at 200 ft, all actuators will be in the retracted condition when the throttles are moved to ground idle. With the throttles in the ground idle position and the actuators retracted, the power levers on the engine fuel controls will be below the ground idle position, causing the engines to run down to sub-idle and flame out.

2.9 The AMO has maintenance procedures documented in their MOP to prevent this type of thing happening. It is evident that the procedures were not followed in this regard.

There were comments made ~~to~~ explaining that when the TMS was reactivated, it was probably at night after the last flight, hence the maintenance personnel involved would have found it difficult to notice that the four actuator circuit breakers were pulled. Another disadvantage could have been that the circuit breakers were collared with black tie raps, thus making it virtually impossible for anyone to spot that the circuit breakers were pulled. The comments above may be true, but only if the maintenance was done in the open outside of proper hangar facilities or away from adequate lighting, or the lights located in the aircraft inspection bay, where the circuit breakers panel is, were not switched on or were inoperative. The maintenance personnel were following the instructions of the MEL, and after identifying three primary circuit breakers, removed the black tie raps and reset the three primary circuit breakers only. When referring to the information in the above paragraph, it is clear that the incident was caused by an aircraft mechanical malfunction caused by maintenance procedure deviation.

2.10 It is also necessary to review the actions of the flight crew. The flight crew completed simulator training to have the rating of the BAe 146 type endorsed on their licences. The aircraft technical training received was reviewed with special focus on the exposure given to the operations functions of the TMS and appeared to be adequate. Prior to all of the above happening, the following indications would have been visible to the flight crew in the cockpit. With all actuators centered, the arrows would not be displayed on the CDU but the continuous test facility in the TMS would display 'actuators not centered' as blue or white arrows even when the CDU power is selected 'off'. Actuators that do not centre cause the engine identifier arrow to flash. If the actuators were commanded beyond their limits of control, one of the arrows in the associated engine identifier would come on to indicate that the actuator has been commanded to move beyond its control limits. The sense of the arrow advises the direction of thrust control lever movement required to allow the actuator to re-enter its authority limits. The blue arrow (up▲) or white arrow (down▼) advises the necessity for thrust control lever advance or retardation respectively. Should a thrust control lever be advanced so far that its actuator has reached the limit of its trim down authority (centre) when seeking to trim, the target the associated engine identifier would come on advising the pilot to retard that thrust control lever.

3. CONCLUSION

3.1 Findings

3.1.1 The captain had a valid Airline Transport Pilot Licence (ATPL) and the aircraft type rating was endorsed on it.

3.1.2 The F/O had a valid Commercial Pilot Licence (CPL) and the aircraft type rating was endorsed on it.

3.1.3 Both flight crew members had valid Class 1 medical certificates with no medical restrictions.

3.1.4 The flight attendants or cabin attendants held valid Cabin Crew Licences and the aircraft type rating was endorsed on it. The flight attendants also had valid medical certificates without any restrictions.

3.1.5 The operator had a valid Air Service Licence and Air Operating Certificate (AOC).

3.1.6 The aircraft operated in air transportation operations, which was in accordance with the CARs, Part 121.

3.1.7 The aircraft had a valid Certificate of Airworthiness (C of A) and Certificate of Release to Service (CRS).

3.1.8 The aircraft was operating in between two sectors on scheduled domestic flights, i.e. Cape Town International Aerodrome (FACT) and George Aerodrome (FAGG).

3.1.9 None of the occupants on board the aircraft sustained injuries in the incident.

3.1.10 The aircraft did not sustain any structural damage.

3.1.11 After touchdown at FAGG, the flight crew experienced an engine problem associated with thrust modulation system (TMS), which caused the to no. 1 engine flame-out and the no. 3 engine to spool down to a hung state. The incident of the engine flame-out was not communicated or reported to FAGG ATC.

3.1.12 After touchdown at FACT, the flight crew experienced an engine problem associated with the TMS, which caused all four engines to flame out.

3.1.13 The AMO that was responsible for maintenance of the aircraft had valid AMO Approval Certificates at the Main Base (FAJS) and Line Stations (FAGG and FACT). The AMO was appropriately authorised to do maintenance on the incident aircraft.

3.1.14 The aerodromes and ATSUs used by the operator on the day of the incident both had valid licences.

3.1.15 According to the Technical Log, the TMS had a fault on 17 March 2009. The TMS was temporarily deactivated and the defect was deferred.

3.1.16 When the TMS was deactivated, the aircraft was operated within the MEL, 76-10-01 condition.

3.1.17 It was found that the AMO did not comply with the exceptions of the MEL. The AMO pulled a total of seven (primary and actuator centering) circuit breakers to depower the TMS. The AMO did not fully comply with the Civil Aviation Regulations or manufacturer's maintenance manual and instructions for safe operation and continued airworthiness when carrying out maintenance on the TMS. When no.1 engine flamed out and no.3 engine spooled down to a hung state at FAGG, it was because of the TMS actuators were not centered. With the throttles at ground idle, the power levers on the engine fuel controls would be below the ground idle position causing the engines to spool down.

3.1.18 The TMS actuators are normally commanded to centre during approach, landing and when the system is selected 'off'. The TMS was selected off during maintenance at FAGG and FACT. It could not be established that the actuators were centered. The pilot observed blue arrow lights illuminating on the CDU, even when the TMS was switched off.

3.1.19 The flight crew reported that the no. 2 engine was not functioning correctly en route to FACT. This is an indication that no. 2 engine actuator was in a retracted position causing the lower N1 readings. The reason for the other engines operating normally was because their actuators were not retracted the same as the actuator of the no. 2 engine.

3.1.20 The TMS synchronise (SYNC) mode was also selected but did not correct the situation of the no. 2 engine in flight, because at lower thrusts it is expected that the engine N1 spools would be synchronised. If the no. 2 engine was selected as the master engine, the other engine actuators would be retracted in the same area for common throttle setting.

3.1.21 Due to the actuators not centering, the TMS disconnected at 200 ft during the approach for landing at FACT. This was as a result of all engine actuators being in retracted condition when the throttles were moved to ground idle. With the throttles in the ground idle position and the actuators retracted, the power levers on the respective engine fuel controls would be below the ground idle position causing the engines to run down to sub-idle and flame out.

3.1.22 It is considered that the training provided by the AMO had not adequately addressed the maintenance procedures to be followed with regard to the need for duplicate inspections to be conducted. This is specifically relevant to maintenance performed on engine control systems.

3.2 Probable Cause/s

3.1 All four engines spooled down and flamed out uncommanded.

3.2 **Contributing factors:**

3.2.1 The TMS was malfunctioning.

3.2.2 The AMO did not comply with the MEL, 76-10-01 procedures when de-activating/re-activating the TMS.

3.2.3 The AMO did not comply with manufacturer's maintenance manual for safe operation and continued airworthiness when carrying out maintenance on the TMS.

3.2.4 The information of the four centering actuator circuit breakers being pulled was not written up in any of the AMO maintenance documentation. The Line Stations were not aware of the centering circuit breakers having been pulled.

4. SAFETY RECOMMENDATIONS

It is recommended that the Commissioner for Civil Aviation instructs the SACAA Flight Operations and Airworthiness Departments:

4.1 To ensure that the M&O MEL procedures do not refer to a document that is not carried on board. The MEL and Ops manual should be amended to clearly reflect the operating procedures in the event of TMS or other system malfunctions.

4.2 To ensure that the operator requires that all flight crew and AMO personnel receive additional training in dealing with TMS and other system malfunctions.

4.3 Enhance their oversight mandate with regards to the operations of the AMO, so as to verify that all procedures and regulatory requirements are adhered to.

5. APPENDICES

5.1 None.

Report reviewed and amended by the Advisory Safety Panel, 30 October 2009.

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