CA18/2/3/7510

SOUTH AFRICAN CIVIL AVIATION AUTHORITY

ACCIDENT REPORT – EXECUTIVE SUMMARY

Aircraft Registration	**ZS-OJU**	**Date of Accident**	01/06/2002	**Time of Accident**	0515Z

Type of Aircraft	HAWKER SIDDELEY 748	**Type of Operation**	Scheduled Freight

Pilot-in-command Licence Type	Airline Transport	**Age**	69	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	20963.8 hrs		Hours on Type	1819.3 hrs

Last point of departure	Bloemfontein Aerodrome
Next point of intended landing	George Aerodrome

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

In Vandalenskloof, 7.6 nm from GGV on a bearing 065° Magnetic at a position S33° 54' 42" E022° 28' 33.6"

Meteorological Information	Poor weather conditions with low cloud and rain.

Number of people on board	2 + 1	**No. of people injured**	Nil	**No. of people killed**	2 + 1

Synopsis

The aircraft was on a scheduled freight flight from Bloemfontein to George. Poor weather conditions prevailed over the George area and the pilots had to execute an instrument guided approach for the landing. The ground based Instrument Landing System (ILS) on Runway 29 at George Aerodrome was intermittently unreliable during the approach. The pilots decided to execute a missed approach.

During the missed approach the pilots did not comply with the published missed approach procedure and with a combination of strong winds and possible erroneous heading indications they lost situational awareness. They flew the aircraft into a valley and crashed into the side of the mountains North-East of the George Aerodrome.

Probable Cause

The crew deviated from the prescribed missed approach procedure during an attempted Instrument Landing System landing on Runway 29 at George in Instrument Meteorological Conditions and lost situational awareness aggravated by the presence of strong upper South-Westerly winds. They allowed the aircraft to drift off course resulting in a controlled impact with terrain 6.7 nm North-East of the aerodrome.

Contributing factors to the probable cause were the weather conditions, the intermittent unreliability of the Instrument Landing System, the serviceability of the directional gyro and the uncleared defects.

AIRCRAFT ACCIDENT REPORT

Name of Owner	**:** AirQuarius Contracts (PTY) LTD
Name of Operator	**:** AirQuarius Air Charter (PTY) LTD trading as Airquarius Aviation
Manufacturer	**:** Hawker Siddeley
Model	**:** HS-748 2B
Nationality	**:** South African
Registration Marks	**:** ZS-OJU
Place	**:** In Vandalenskloof, 7.6 nm from GGV on a bearing 065° Magnetic at a position S33° 54' 42" E022° 28' 33.6"
Date	**:** 1 June 2002
Time	**:** 0515Z

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

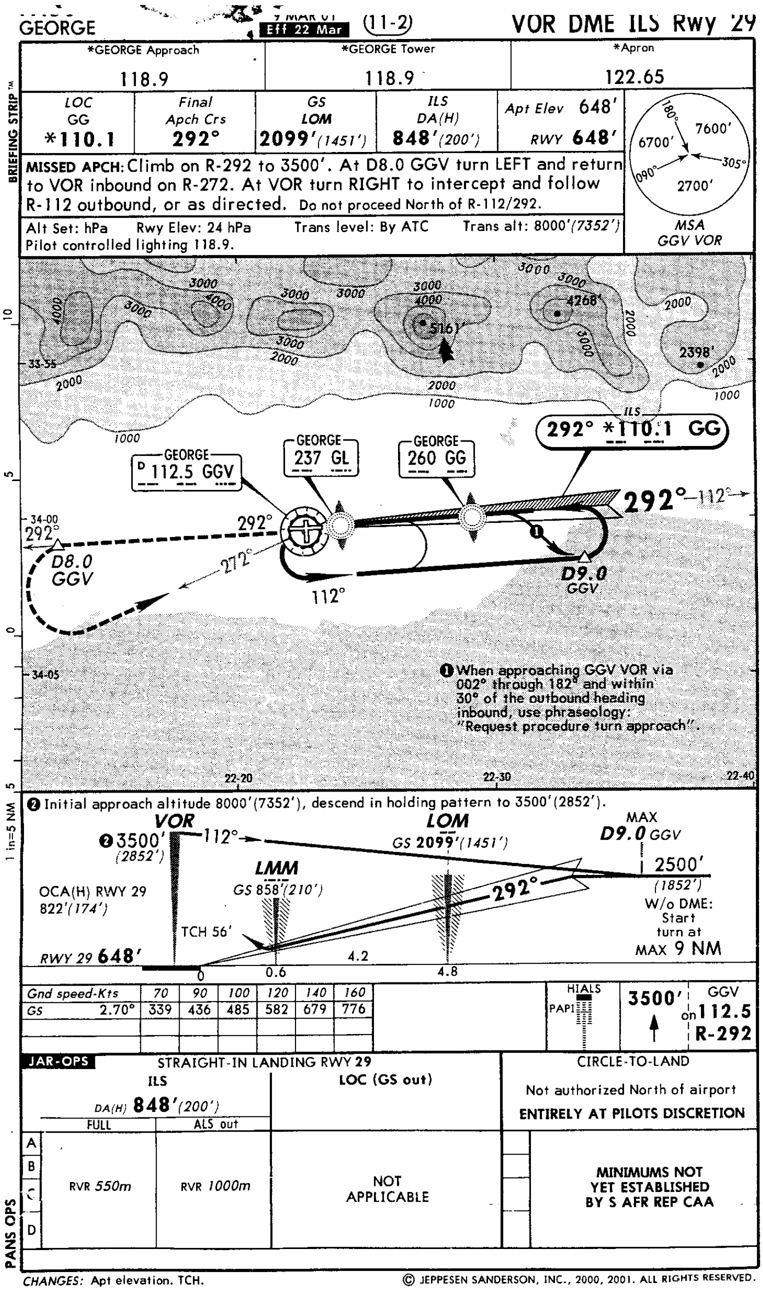
1.1 History of Flight

1.1.1 The aircraft was on a scheduled cargo flight from Bloemfontein to George. These flights were scheduled as night flights to transport overnight cargo between Johannesburg International Aerodrome, Bloemfontein Aerodrome and George Aerodrome. The cargo carried on the fatal flight consisted mainly of post, overnight express packages and motor vehicle spares. The flight originated from George Aerodrome in the evening of the previous day, landed at Bloemfontein Aerodrome and on to Johannesburg International Aerodrome. The pilots for the South bound flight from Johannesburg International Aerodrome to Bloemfontein Aerodrome signed on at 2300Z and start-up was recorded as 0015Z on the captain's flight report form. The flight to Bloemfontein Aerodrome lasted 1 hour 37 minutes and shut down time was recorded as 0152Z.

1.1.2 At Bloemfontein Aerodrome some cargo was loaded off and the aircraft was fuelled up to a total amount of 3520lbs. of fuel. The aircraft was flown further on the schedule to George. The flight time for this flight was according to previous flight folio entries about 2 hours. The aircraft arrived over the George (GGV) Very High Frequency Omni-directional Beacon (VOR) at an altitude of 8000 feet above Mean Sea Level (MSL) at 0456Z. The captain made a radio call to inform George traffic that the aircraft was joining the holding pattern and will be descending in the hold pattern to three thousand five hundred feet above MSL.

1.1.3 There was no Air Traffic Controller (ATC) on duty in the George Tower during the radio calls. The ATC hours of duty was from 08:30 local time (0630Z), thus the unmanned field communication procedures was in force at George Tower during that time of the morning and the pilots complied with these procedures.

1.1.4 According to information gathered from the Cockpit Voice Recorder (CVR), the Flight Data Recorder (FDR) and the documentation found on the accident scene (see figure on right), the pilots intended to fly the VOR, Distance Measuring Equipment (DME), Instrument Landing System (ILS) precision approach procedure for Runway 29 at George (a detailed description of the approach and landing procedure will be included in part 1.8, Aids to Navigation). The aircraft initially passed over the GGV beacon at 8000 feet above MSL as indicated on the approach procedure and flew a racecourse pattern to be able to descend to 3500 feet above MSL as required by the procedure.



1.1.5 After the first pattern was completed and back at the GGV-beacon at about 3900 feet pressure altitude according to the FDR (keep in mind a difference of about 300 feet will appear between the actual altitude and the altitude recorded by the FDR due to the standard air pressure setting of the FDR and the different prevailing atmospheric pressure at the aerodrome), the pilot flying turned the aircraft to the left onto a heading of 112° on the outbound leg. They set a target to descend during the outbound leg to an altitude of 2500 feet above MSL according to the let-down procedure and a DME position of 9 nautical miles (nm) from the GGV-beacon. The FDR recorded that the aircraft was at about 2800 feet above MSL during the turn. During this leg of the approach procedure the pilot flying commented to the captain that they were tracking 101°, but after about two minutes one notice in the FDR data a small amount of correction in the heading to the right. During this outbound leg of the pattern the pilot-in-command switched the navigation aids to the frequency of the ILS for Runway 29 which was 110.1 MHz. He commented that there was no identification signal. This signal indicates that the ILS signal received was the correct ILS and that the ILS is serviceable. On the CVR one could hear the volume for the identification beacon was turned up, but no morse code signal was heard.

1.1.6 At 0506:08Z the aircraft started turning to the left onto a heading of about 290° for the final approach to the aerodrome. Just after the turn the pilot flying commented that he have flags on his Course Deviation Indicator (CDI). The flags the pilot referred to were small indicators in his flying instrumentation which warn that the localiser and glide slope of the ILS is not functional or reliable. However the pilot-in-command did not have the warning indications in his instrumentation and after about 15 to 30 seconds the flags were not indicating anymore in the pilot flying's instrumentation. The pilots proceeded with the approach and the pilot-in-command commented that he saw some ground, but it does not look good. The pilot-in-command also commented several times that they were too high and need to fly down. The windscreen wiper was selected, initially it did not operate, but it seems that it did start to operate a brief while later. The microphone was keyed five times to switch the runway lights on and the meteorological officer stated that he saw the runway light came on at about 0500Z, before he heard the aircraft flew over the aerodrome. A final approach radio call was made and again the pilot-in-command commented to the pilot flying that they were too high on the glide slope.

1.1.7 About 20 seconds after the radio call and about a minute to landing, the pilot flying commented that he had glideslope warning flags and the pilot-in-command agreed that he had the same indication on his instrumentation. The pilot flying saw the "airfield" but also commented that they were "miles too fast". The pilot-in-command evaluated the situation and called for a "go-around" at 0510:54Z. On the CVR one could hear the engines increase in RPM and the landing gear was retracted. The pilot-in-command instructed the pilot flying to climb to 3500 feet above MSL and commented that indications are that the ILS had failed.

1.1.8 About a minute later, at 0511:50Z, after the missed approach procedure was initiated and at an altitude of about 2200 feet above MSL on the FDR, the pilot-in-command told the pilot flying to turn "out" on a heading of 112°. A minute and a half later at 0513:23Z the pilot-in-command commented that they were in a steep turn and were turning through the heading. The pilot flying stabilised the aircraft and at 0514:15Z he indicated that he had warning flags again. At 0514:50Z they switched back to the VOR frequency and intended to fly back to the 9nm position on the outbound leg. At about 0516:20Z they arrived at the 9nm mark on the VOR and started the left-hand turn. According to the FDR the pressure altitude was about 2800 feet above MSL. During the turn the Ground Proximity Warning System (GPWS) issued several "pull up" warning signals. Once they were back on a 290° heading the warnings stopped and the pilots thought they received the warnings because they were past the 9nm mark at 10nm from GGV, close to high ground.

1.1.9 At about 0518Z they received a further set of GPWS warnings, but did not comment on it. The pilot-in-command enquired about the warning flags and the pilot flying commented that he had warning flags again. At 0518:14Z they took power and one can hear the engine increase RPM on the CVR. The pilot-in-command took control of the aircraft at about 0518:35Z and steered a bit to the right according to the FDR data. They received several GPWS and alert signals and the aircraft impacted the side of the mountain at about 0520Z. Both the pilots and the passenger were killed during the accident by the impact forces.

1.1.10 The radar station closest to George Aerodrome was the military station at Soetmuisberg. The radar station is 114.9nm from George Aerodrome on a bearing of 276°M. The radar information related to the flight of the aircraft on the morning of the accident was made available and this information was used to plot a probable flight track of the aircraft. The track obtained from this exercise put the aircraft's track too far to the East and it would suggest that the aircraft had not passed over the George Aerodrome's VOR (GGV) as was established from further information. This plotted flight path was rejected as unreliable.

1.1.11 A further attempt to plot the flight path of the aircraft from where the missed approach was initiated was attempted by using the FDR data. The surface wind was recorded at George Aerodrome as 270°/13knots, but the winds at higher altitudes was not available. The investigator used the comment of the pilot-flying during the one outbound leg, that they were tracking 101° (he probably obtained this information from the Garmin GPS100, Global Positioning System (GPS) fitted to the aircraft), while the FDR recorded a heading of about 111°. The wind factor was calculated using this information and was determined as 224°/38knots. Using this wind factor a probable flight path from the accident site as a known point was plotted. In this plot the probable flight path did not pass over the aerodrome as one would expect when the missed approach was initiated. There were several witnesses that heard or saw the aircraft passing typically over the aerodrome during the missed approach. Several different wind factors were used to plot probable flight paths, but the flight path with an average wind factor of 225°/45knots was the most acceptable. The flight path was plotted from the accident site position and ended at the GL Non-directional Beacon (NDB), which was the most probable point from which a missed approach would be initiated and appeared as follows:

1.1.12 The accident happened in early morning daylight conditions, but in poor weather conditions with rain and low clouds.

1.2 Injuries to Persons

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

1.3 Damage to Aircraft

1.3.1 The aircraft was destroyed by the impact forces during the accident.

1.4 Other Damage

1.4.1 Minor damage was caused to the environment.

1.5 Personnel Information

Pilot-in-Command:

1.5.1 The following information was gathered about the pilot-in-command:

See next page.

Nationality		South African			
Licence No	0270045073	Gender	Male	Age	69
Licence valid		Yes	Type Endorsed	Yes (1P & PI)	
Ratings		Instrument & Instructor Gr2			
Medical Expiry Date		30 September 2002 (ATP Medical Cert.)			
Restrictions		Corrective lenses			
Previous Accidents		No record of previous accidents found in Volume 2, 3 and 4 of Pilot's CAA file.			

Flying Experience:

Total Hours	20963.8
Total Past 90 Days	133.6
Total on Type Past 90 Days	118.7
Total on Type	1819.3
Instrument hours Past 90 Days	3.3
Instruction hours Past 90 Days	31.4

1.5.2 The pilot also logged a total of 3692.9 hours on the HS-748-2A model aircraft. Besides him flying the HS-748 aircraft he logged a total of 4537.8 hours of instruction, with 368.5 hours of the total hours as instruction during night flying conditions.

1.5.3 The pilot's last Instrument Rating Renewal Flight Test was conducted on 10 October 2001 and a proficiency check was carried out with the pilot on 2 March 2002 on a HS-748 aircraft. A Transport Pilot certified this check in the Pilot's Logbook, however the pilot's licence indicated that the instrument test was conducted on 1 October 2001. A line check was carried out with the pilot on a DC3 on 17 March 2002. In the pilot's file at the operator, certificates were found that the pilot had attended a Cockpit Resource Management course and a Dangerous Goods Management course in February 2002.

1.5.4 In the CAA pilot file a Practical Flight Test Report was found of the pilot's instructor's renewal test also carried out on 10 October 2001. The test was carried out in a Hawker Siddeley 748 and was certified with a comment as "very satisfactory".

1.5.5 During an interview with the pilot-in-command's wife and from the flightfolio of the aircraft it was determined that the pilot flew the Johannesburg, Bloemfontein and George route on 29 May 2002 and had two days off till the morning of 1 June 2002. His wife indicated that he was a person that slept well and that he retired for a sleep during the afternoon and evening before the flight on 1 June 2002. According to her he slept about 9 hours before the flight that evening.

Co-Pilot

1.5.6 The following information was gathered about the co-pilot:

See next page

Nationality		British			
Licence No	0270099799	Gender	Male	Age	50
Licence valid		Yes	Type Endorsed	Yes (2P)	
Ratings		Instrument & Instructor Gr3			
Medical Expiry Date		28 February 2002 (Class 1: Commercial pilot)			
Restrictions		Corrective lenses			
Previous Accidents		No record of previous accidents was noted.			

Flying Experience:

Total Hours	1099.75
Total Past 90 Days	63
Total on Type Past 90 Days (HS748-2A)	29.17
Total on Type (HS748-2A)	518.58
Instrument hours Past 90 Days	0.75
Instruction hours Past 90 Days	14.08

1.5.7 The pilot logged all his hours on type on a HS-748-2A model aircraft, which is very similar to the HS-748-2B model aircraft. On his pilot licence he was rated to fly the aircraft as Co-pilot only.

1.5.8 The pilot used to fly the HS-748 aircraft type for a different operator, but the operator stopped operations. This was his first flight for this operator after his last flight with the previous operator on 8 April 2002. There was no evidence of any proficiency checks or route checks on the pilot's operator file, but an entry in his logbook note "route check" on 16 January 2002. This route check was when he was still flying for the previous operator. In the pilot's file at the present operator certificates were found that the pilot had attended a Cockpit Resource Management course on 12 January 2002 and a Dangerous Goods Management course on 6 October 2001.

1.5.9 According to the pilot's logbook, his last flight before the accident flight was on the morning of 30 May 2002. The investigator was unable to trace his where-about since that morning to the evening when he signed on for duty.

1.6 Aircraft Information

1.6.1 The aircraft was imported into South Africa during December 1999. During the month of December several inspections were carried out on the aircraft, it was weighed and a performance test flight was carried out on 17 December 1999. During the flight performance test flight the aircraft climbed at an average rate of 392 feet per minute. When this information was plotted on a DRIFTDOWN data graph recovered on the accident site it suggested that the aircraft performed satisfactory and was also indicated as satisfactory on the Flight Performance Record. The flight manual for the aircraft was approved on 15 December 1999 and a Certificate Relating to Maintenance in respect of the maintenance performed on the aircraft was issued on 21 December 1999 by the Aircraft Maintenance Organisation no. AMO179. Furthermore a Certificate of Maintenance Release for the different categories of the aircraft was also certified on 21 December 1999. This certificate was certified at a total of 12468.9 airframe hours and was due to lapse on 12518.9 airframe hours or 21 January 1999 (no cycles were indicated on the certificate). The last date was obviously an error and should most probably have read 21 January 2000. The aircraft was inspected by a CAA airworthiness inspector on 23 December 1999 and ten outstanding items were noted. The outstanding items were taken care of and the CAA was informed on 6 January 2000. The certificate of airworthiness was issued on 7 January 2000.

1.6.2 The following aircraft related information was gathered from the different sources:

Airframe:

Type	HS-748-2B	
Serial no.	1782	
Manufacturer	Hawker Siddeley	
Date of Manufacture	1982	
Total Airframe Hours (At time of Accident)	14226.7 hrs 19789 cycles	
Last Phase Inspection – Check A & 50hrs (Date & Hours)	23 May 2002	14188.6 hrs 19763 cycles
Hours since Last Phase Inspection	38.1 hrs 26 cycles	
C of A (Issue Date)	7 January 2000	
C of R (Issue Date) (Present owner)	13 December 2001	
Operating Categories	Standard	

Engine:

No. 1 (L/H)

Type	Rolls Royce Dart 536-2
Serial no.	19191
Hours since New	32 938.8 hrs unk. cycles
Hours since Overhaul	4596.8 hrs 2445 cycles

A calculation error was made when the Check A was certified on 15 March 2001. The cycles of the engine suddenly escalated from 1722 to 17730 cycles. The closest estimate of the engine's cycles at the time of the accident could be calculated from 10 September 2000 when the engine was installed on the aircraft. The airframe had accumulated 18986 cycles and the engine 1642 cycles since overhaul. At the time of the accident the airframe had accumulated 19789 cycles and if it is accepted that the engine accumulated cycles at the same rate as the airframe, then the engine was at 2445 cycles since overhaul. The engine cycles since new was unknown at the time of the overhaul.

No. 2 (R/H)

Type	Rolls Royce Dart 536-2
Serial no.	19489
Hours since New	16532.5 hrs 9959 cycles
Hours since Overhaul	3746.1 hrs 2168 cycles

This engine was fitted to ZS-OLE when it was imported during April 1999. On 20 November 2001 the engine was removed from ZS-OLE due to a vibration problem. The combustion section and turbine section of the engine were overhauled by an engine overhaul workshop and the engine was fitted to ZS-OJU at a total of 16353.1 hours since new and 3566.7 hours since major overhaul. The engine accumulated 9835 cycles since new and 2044 cycles since overhaul when it was fitted to ZS-OJU and certified on 15 April 2002.

Propeller:

No. 1 (L/H)

Type	Dowty Rotol LTD
Serial no.	DRG 319/68
Hours since New	16374.8 hours
Hours since Overhaul	1757.8 hours

No. 2 (R/H)

Type	Dowty Rotol LTD
Serial no.	DRG 94/79
Hours since New	11817.3 hours
Hours since Overhaul	1757.8 hours

1.6.3 It was noted that a number of defects were entered in the flight folio of the aircraft, but no “action taken” was entered in the appropriate line of the flight folio. On other occasions defects were entered and the “action taken” was appropriately entered and certified. Several defects related to the autoflight and instrumentation systems of the aircraft were entered in the older flight folio recovered on the accident and were as follows:

Date	Defect	Action taken
26/03/2002	Auto coupled appr – capture LOC but porpoise and oscillate – NAV u/s do not capture	Flight director computer replaced. Pse report back if it persists.
29/03/2002	GPWS/radio alt u/s	No entry
29/03/2002	HSI 10° out actual HG indicated 035° both units	No entry
09/04/2002	Autopilot snake out of limits on finals (APR)	No entry
12/04/2002	Pitch control on autopilot is intermittent	No entry
11/05/2002	NAV flag to 6 miles when flying ILS 03L	VOR/ILS NAV RCVR box replaced P# 51RV-4B S# OFF 491 S# ON 379

1.6.4 The AMO that maintained the avionics of the aircraft was contacted via the owner and they were requested to provide some documents relating to the no entries, but they were unable to provide such documentation.

1.6.5 An interesting observation made in the airframe logbook of the aircraft was that the 'A'-checks carried out on 7, 15 and 25 April 2002 and 8 May 2002 was certified with a signature, but there were no stamps indicating the AMO's licence number. However these checks were stamped in all the engine and propeller logbooks.

1.6.6 In the back of the Aircraft's Airframe Logbook, a list of "lifed items" was found dated 26 Feb. 2001. This list includes many components of the aircraft that have a limited life span related mainly to the hours of operation of the individual components. It was noted that the list contain no components related to the flight instrumentation of the aircraft. When enquiries were made about these components, the investigator-in-charge discovered that all these components were "on-condition items". The CAA approved maintenance schedule of the aircraft recovered on the accident site also contained the "lifed items" list. No definition for what was meant with "on-condition" items was found in the maintenance schedule or any mention was made about reliability programs.

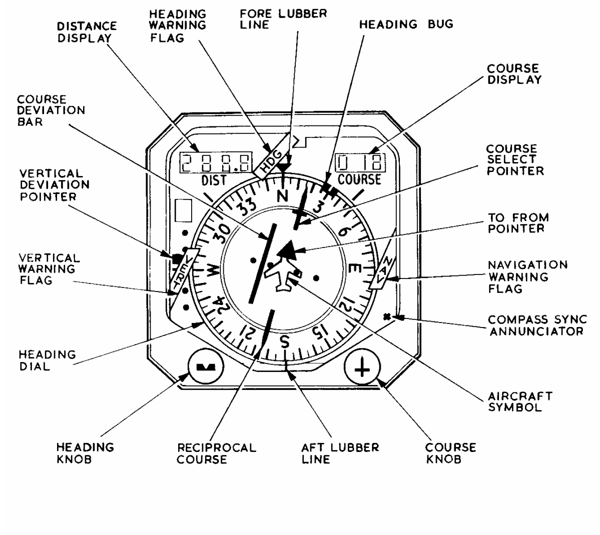
1.6.7 Relating the "on-condition" principle to several maintenance persons in the industry it became clear to the investigator that they perceive an "on-condition item" as an item/component that operate until it become unserviceable and will then be repaired/replaced. They did not know about reliability programs that need to be instituted.

1.6.8 When the manufacturer of the gyroscopic instrumentation was contacted about the service life of gyroscopic instrumentation, the representative confirmed that the components do have a shelf life but do not have a prescribed life limit once fitted to the aircraft. It then becomes an "on-condition" item. When enquiries were made at the maintenance technicians of one of the major airlines that operated Hawker Siddeley 748's in the past, the technicians who maintained the gyros, told the investigator that all these type of components with gyro's spinning at high RPM's were operated on a maintenance schedule with a certain life attached to it relating to the number of hours operated.

1.6.9 The manufacturer's recommendations for the shelf life of gyro products was that all gyro's have a 6-month shelf life which may be extended to 3 years by exercising the gyro every 6 months in accordance with a prescribed procedure. In the event of the shelf life of a gyro exceeding 3 years, the manufacturer recommend that the spin and gimbal bearings should be replaced.

1.6.10 In the airframe logbook of the aircraft, records of the last compass check swing indicated that it was carried out on 23/01/2001, however on the instrument panels of both the pilots the compass deviation stickers was dated 23/10/2001. The previous compass check swing was certified on 23/12/1999, thus it was more possible that the compass check swing was carried out in January 2001 than in October 2001. According to the Civil Aviation Regulations, 1997, Part 43.02.18 referring to the SA Technical Standards 43.02.18 (Aircraft Compass Requirements), a compass check swing should be carried out every 12 months after the initial compass check swing. Thus a compass check swing should have been carried out before or on 23/01/2002, but no records of such a compass check swing was found in the airframe logbook. During this compass check swing, operation of the directional instrumentation should be checked as well, the above suggests that the last time the directional instrumentation was checked under “controlled conditions” were most probably on 23 January 2001.

1.6.11 Due to the implication the horizontal situational awareness have on this accident and the results of the tests on the instrumentation it was deemed necessary to provide a description of the flight direction instrumentation systems of the aircraft. The aircraft was fitted with an Automatic Flight Control System (AFCS). This system was an integration of compass, attitude, autopilot, flight director and navigation instrument sub-systems, together with the equipment necessary to interface these sub-systems with the navigation aids. The flight direction instrumentation of the aircraft consisted of two pairs of flight directors, one system for each pilot. A description of the horizontal situation indicators in the HS748 Crew Manual were as follows:



HORIZONTAL SITUATION INDICATOR (RD 550R)
FIGURE 1

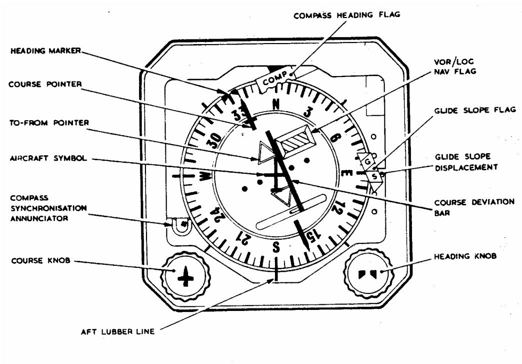
Horizontal Situation Indicators (HSI)

(1) First Pilot Fig. 1.

The HSI on the first pilot’s instrument panel is a combined radio navigation and compass display instrument. The radio navigation display includes glideslope pointer and flag, course deviation bar and flag, a manually set radio course pointer and VOR-TO/FROM pointers. The compass heading reference display includes a magnetic heading card and compass flag, a manually set heading marker and a compass synchronisation annunciator. The two digital type counters are COURSE which is a numeric readout of the course display and DIST which shows the distance measuring equipment (DME) slant distance.

(2) Second Pilot Fig 3

The HSI on the second pilot’s instrument panel is a combined radio navigation and compass display instrument as described in (1) above, but having no digital type counters.



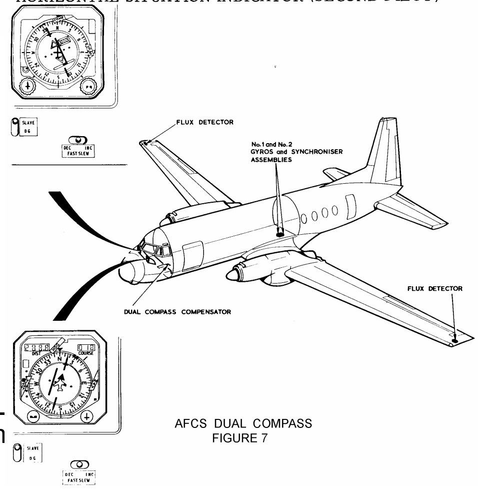
HORIZONTAL SITUATION INDICATOR (SECOND PILOT)

1.6.12 The aircraft’s AFCS also incorporated a Dual Compass. The operation of this sub-system is described as follows:

Each compass sub-system combines the function of a directional gyro and a magnetic compass. Each sub-system operates independently. The components are shown located on the aircraft in figure 7 and signal flow is shown on figure 8 (next page).

Operation

The wing located flux valves sense the earth magnetic field and convert this into electrical reference signals which are fed, via the dual remote compensator, to the gyro and synchroniser assembly. The stabilised heading signals are routed as follows:

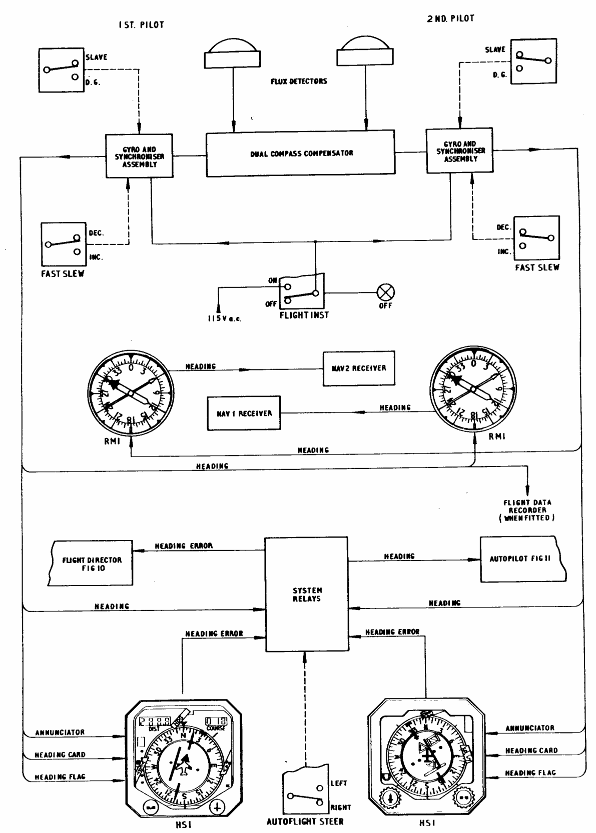


AFCS DUAL COMPASS
FIGURE 7

(1) The first pilot's gyro and synchroniser assembly supplies heading and synchronising signals to the first pilot's HSI and heading to the second pilot's RMI and to the flight data recorder, when fitted. Heading and heading error signals for the flight director and heading signals for the autopilot are routed by the AUTOFLIGHT STEER switch on the centre console being selected to LEFT.

(2) The second pilot's gyro and synchroniser assembly supplies heading and synchronising signals to the second pilot's HSI and heading signals to the first pilot's RMI. Heading and heading error signals for the flight director and heading signals for the autopilot are routed by the AUTOFLIGHT STEER switch on the centre console being selected to RIGHT.

(3) The NAV 1 receiver heading signals are via the second pilot's RMI and the NAV 2 receiver heading signals are via the first pilot's RMI.



AFCS - COMPASS HEADING - FIGURE 8

1.6.13 The reader who would like to be able to understand the internal operation of the Sperry C-14A GYROSYN directional gyro are referred to **Appendix A: (Compass System)** for an explanation of the operation of the system.

1.6.14 During the investigation a Bendix/King KMD 150 MFD, Global Positioning System, Part no. 066-01174-0101, Serial no. 27100415 was recovered. The GPS was fitted to the instrument panel, but no records could be found in the CAA aircraft file, of an application for a modification approval or for a modification approval to fit this instrument in the aircraft. However for the Garmin GPS100AVD and related antenna an APPLICATION FOR APPROVAL OF REPAIR/MODIFICATION OF AN AIRCRAFT was submitted on 1 January 2000. The modification was approved on 9 June 2000, but if one refers to the Airframe Logbook of the aircraft it is noted that the installation of the GPS was certified on 6 January 2000 already.

1.6.15 If one considers the FDR data and the CVR recordings no indications were found that the engines of the aircraft performance were suspect at any time during the flight.

1.6.16 The aircraft was weighed on 15 December 1999. At this occasion the aircraft was in a passenger configuration with 21 seat assemblies, galley units, toilet, etc. The corrected mass of the aircraft was determined as 28710 lbs. at a moment of 1872205.1 lbs-inches. A document called "Weight & Balance adjustments for aircraft – ZS-OJU" was recovered in the aircraft folder on the accident scene. A note on this document indicated – N/B CONFIGURATION FOR JHB-GEORGE AIRWOLD FREIGHT CONTRACTS ONLY. On this mass adjustment document the passenger seats, galleys, toilet, bulkhead, etc was removed and only one seat assembly, the water methanol, cargo net and unuseable fuel was added. A total adjustment was calculated and new values for the Aircraft Prepared for Service (APS) mass were calculated. The mass for the aircraft in the freight configuration was calculated at 27085 lbs at a moment of 1584832.1 lbs-inches and the "zero fuel weight" were stipulated as 36179 lbs. An interesting bit of information on this document was that the aircraft in a 44 seat configuration was indicated as 29200 lbs APS mass. This document was certified on 16 January 2002 by an approved Aircraft Maintenance Engineer at an Aircraft Maintenance Organisation. At the bottom of the document it was written in pencil "Basic Empty Weight for Loadsheet 26521 lbs. and this was the value used by the pilots when they completed the loadsheet for the flight.

1.6.17 A properly completed loadsheet was recovered from the accident scene. On the loadsheet the pilots calculated the Operating mass of the aircraft for the flight as 30641 lbs. They added the masses of the passenger, baggage and freight and calculated the take-off mass of the aircraft as 35646 lbs. The "Allowed Take Off Weight" was indicated on the loadsheet as 46090 lbs. (the investigator was unable to obtain this figure using the TAKEOFF WAT LIMITS in a performance data file recovered on the accident site). The Maximum Takeoff Mass of the aircraft in the performance data file was indicated as 46500 lbs. The calculated take off mass of the aircraft was thus well within the specified mass limits of the aircraft.

1.6.18 An interesting observation relating to the aircraft maximum takeoff mass was that the aircraft was registered in the CAA aircraft file as 19995 kg (44081 lbs). When the operator was audited on 1 August 2000 the maximum takeoff mass of the aircraft was entered as 46500 lbs (20865 kg). The same as the maximum takeoff mass as indicated on the weight schedule in the file recovered from the accident site.

1.6.19 The freight of the aircraft contained several heavy metal automotive components and many boxes and bags with general postage and other overnight freight parcels. Many of these packages were recovered about a week after the accident, but it was not possible to weigh all the packages and many of the heavier damaged components were left on the accident site and only recovered much later with the main wreckage. It was thus impossible to determine an accurate mass of all the freight that was onboard the aircraft, but an estimation of the amount of freight in relation to the indicated 4910 lbs was acceptable to the investigator.

1.6.20 It was noted on the accident scene that some freight were loaded into the rear of the aircraft and it could be accepted that the rest of the freight that was strewn over the area in front of where the aircraft impacted the mountain was placed in the middle of the cabin area. No trim figure was inserted on the loadsheet, but it could be accepted that the aircraft was within its mass and balance limits during take-off and later at the time of the accident.

1.7 Meteorological Information

1.7.1 A South African Weather Service, AERONAUTICAL METEOROLOGICAL DOCUMENTATION package, dated Friday, May 31, 2002 – Time 17:00:00Z, was recovered on the accident site indicating that the pilots obtained a weather report before the flight. This documentation contained Take-off data, Metars (Meteorological Aeronautical Report), Tafs (Terminal Aerodrome Forcasts), Speci (Special Meteorological Aeronautical Report) and Sigmet (Significant Meteorological Forecasts).

1.7.2 The Tafs for Bloemfontein between 1800Z and 0300Z was as follows:

FABL 311500Z 311803 00000KT 9999 BKN025 BKN080 TX05/18ZTNM01/03Z=

The Taf forecasted calm surface wind conditions, more than 10 km visibility with broken cloud at 2500 feet and 8000 feet above ground level.

1.7.3 The aircraft would have landed at George early in the morning at about 0500Z, thus the appropriate Tafs to refer to was between 1800Z and 1800Z and was as follow:

FAGG 311200Z 311818 30010KT CAVOK FM2100 26012KT 9999 SCT020 BKN040 PROB40 TEMPO 0315 4000 SHRA BKN015 FM0600 18010KT 9999 BKN020 TX13/12ZTN10/05Z=

A surface wind of 300°/10knots was forecasted and visibility CAVOK. From 2100Z the surface wind forecast was 260°/12knots, 10km visibility with scattered clouds at 2000 feet and broken cloud at 4000 feet above ground level. There was a 40% probability of change between 0300Z and 1500Z to 4000 m visibility with rain showers and broken cloud at 1500 feet above ground. From 0600Z the surface wind was predicted as 180°/10knots with a 10km visibility and broken cloud at 2000feet above ground level. The forecasted temperatures were generally low and would not have made a significant difference.

1.7.4 The upper winds forecast in the document pack of the pilots forecasted Westerly winds of between 39 and 29 knots at 5000feet and between 31 and 26 knots at 3000feet above mean sea level. The synoptic chart was for 31 May 2002 at 15:00 and it indicated a cold front moving in over Cape Town. The prognostic chart in the document pack for Mean Sea Level (MSL) to Flight Level 100 was issued at 17H00 UTC and was valid from 21H00 UTC on 31 May 2002. The prognostic chart forecasted clear conditions over George, however one have to keep in mind this chart was not valid till the morning of 1 June 2002.

1.7.5 The actual recorded weather conditions at the time of the accident were obtained from the meteorological office at George Aerodrome on 3 June 2002. The following actual recorded surface conditions in the form of a Metar prevailed:

Wind direction	270°	Wind speed	14 knots	Visibility	6000m
Temperature	+10°C	Cloud cover	Scattered & Broken	Cloud base	800 feet & 1400 feet
Dew point	+09°C				

1.7.6 A recording obtained from a Ceilometer recorded cloud ceilings of less than 600feet a short while before 0500Z and just above 600feet at 0500Z.

1.7.7 The observations of the meteorological officer at George Aerodrome at 07:00B (0500Z) concurred with the recorded conditions, which was a total cloud cover of 8 octas consisting of scattered cloud cover (4 octas) with bases at 800feet and broken cloud cover with bases at 1400 feet. He observed a visibility of 6 km minimum and 8 km in the light rain.

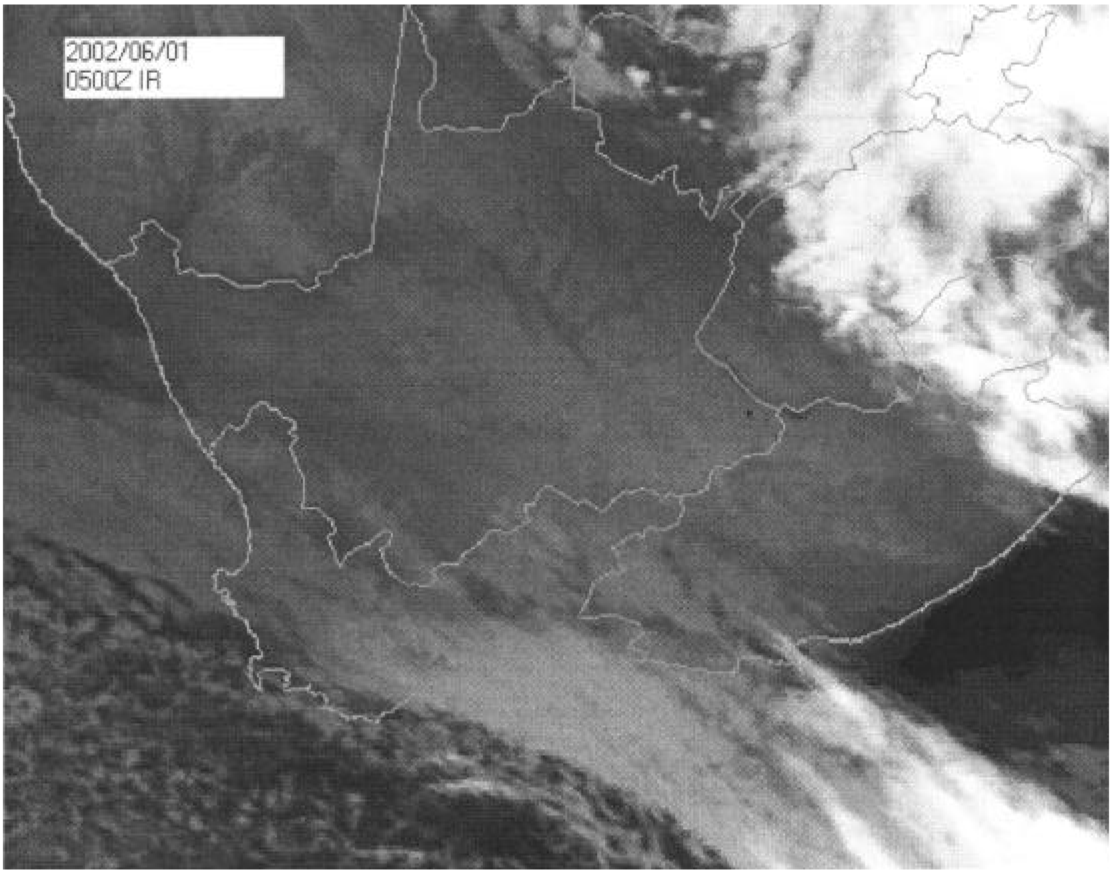
1.7.8 Several of the eyewitnesses (at least 3 were pilots) also observed the meteorological conditions as overcast with low level clouds and rain. The visibility was poor towards the aerodrome and they observed a strong Westerly surface wind. Several eye witnesses saw the aircraft from time to time between the clouds and saw it disappearing in the clouds when it flew over the town of George in a North-Easterly direction. The mountains were covered with clouds and it was raining in the area North of George.

1.7.9 A meteorological report obtained from the South African Weather Bureau confirmed most of the above. The Surface Analysis indicated that a cold front was busy moving into the South-Western parts of the country causing cloudy and rainy conditions along the South coast and adjacent interior.

1.7.10 The Upper Air Analysis indicated an upper-air trough associated with the surface cold front was present over the South-Western part of the country. The Cape Town freezing level was at 7950 feet and the top of the moist level was at about 11000 feet. Wet and dry bulb temperatures were very close and a graph relating these temperatures suggests it was possible that the freezing level could have been very low in the vicinity of the accident. However according to the CVR recordings it did not appear that the pilots had any icing problems

1.7.11 The infrared satellite images for 0430Z and 0500Z showed cloud cover over the Southern and South-Western area of the country. Refer to figure below for the satellite image at 0500Z.

Image on next page



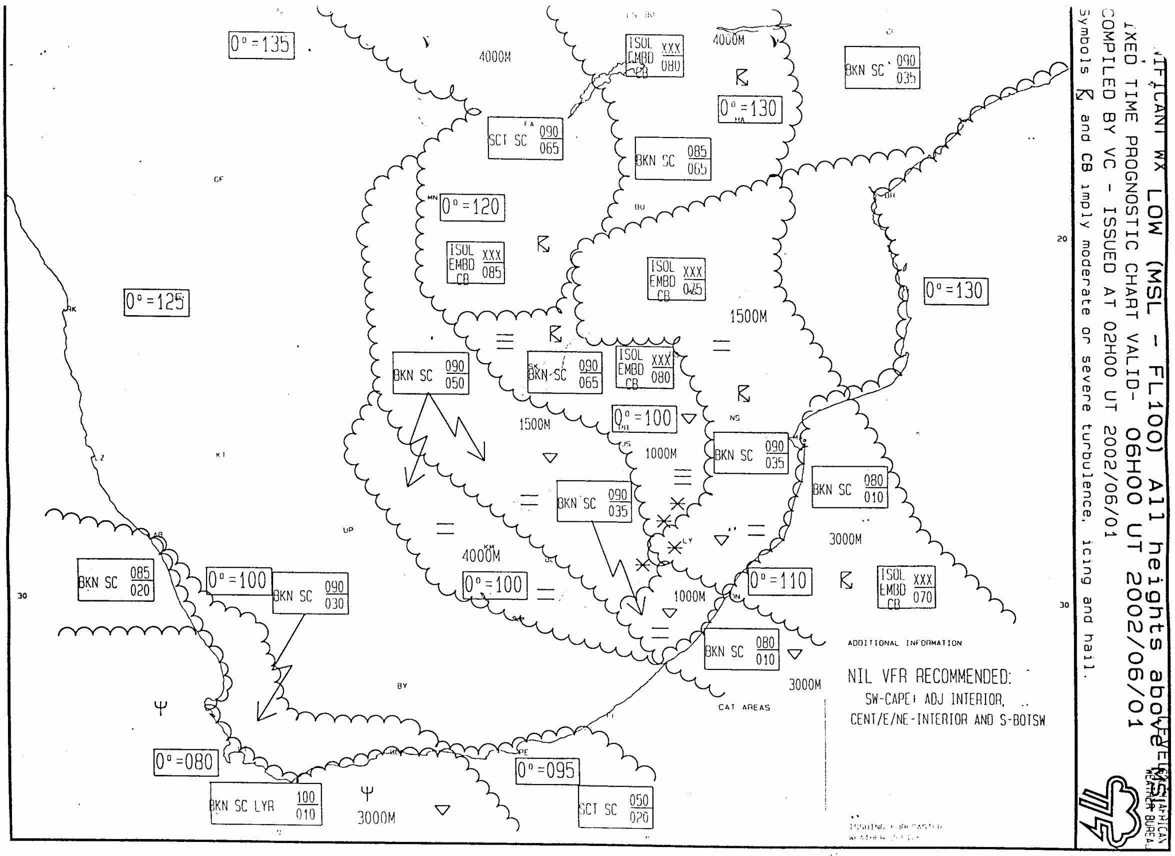
1.7.12 The meteorological report conclude that the most probable conditions at the accident site would have been cloudy conditions with rain and because the freezing level, icing could have occurred on the aircraft. In the cloud visibility would have been zero.

1.7.13 The forecasts for the conditions at George according to the SA Weather Bureau was similar to the above, although it was the more up-to-date forecasts and was thus not in the pilots meteorological documents. The latest Tafs for George was:

FAGG 010000Z 010312 18010Kt 9999 BKN025 PROB40 TEMPO 0312 4000-SHRA BKN015 TX13/12ZTN10/05Z

The Prognostic chart for the time of the accident was issued at 0200Z on 1 June 2002 and was valid 0600Z on 1 June 2002.

on next page



The prognostic chart does indicate broken cloud layers along the coast between 1000feet and flight level 100 with the freezing level at flight level 080.

1.7.14 The upper winds forecast in the Weather Bureau report, forecasted South-Westerly winds of between 28 and 32 knots at 5000feet and between 25 and 33 knots at 3000feet above mean sea level.

1.8 Aids to Navigation

1.8.1 The pilots most probably used a combination of the VOR beacon at Victoria West (VWV), as indicated on their flight plan and the onboard GPS navigation aid to navigate to George. During their approach to George Aerodrome they changed frequency to the VOR beacon at George Aerodrome known as GGV. From the available information, there were no indications that any of these VOR beacons had any malfunctions. The Garmin GPS100 onboard system was still operational after the accident, when it was fitted to a test bench and indicated the position of the accident.

1.8.2 None of the pilots' comments or conversations, recorded on the CVR, gave any indication that they had made use of the Bendix/King KMD 150 GPS during the approach and landing phase of the flight. This was the second GPS receiver that was recovered from the wreckage. The operation of this system was such that it would provide moving map position information to the pilots.

1.8.3 At this point in the discussion it would be advantageous for the reader to understand the operation of an ILS. Many references will be made in the following pages to the operation of such a system. A discussion of the operation of an ILS is attached to this report as **Appendix B: (Instrument Landing System)**Appendix B.

1.8.4 For the approach and landing phase of the flight at George Aerodrome the pilots had to comply with the appropriate published approach procedures. The aerodrome information was available to the pilots either from the Aeronautical Information Publications of the South African Civil Aviation Authority or commercially available publications like the Jeppesen Airway Manual. A Jeppesen Airway Manual was recovered on the accident site and several copies of the appropriate pages from the manual relating to the aerodromes the aircraft had generally flown to namely, Johannesburg International Aerodrome, Bloemfontein Aerodrome, George Aerodrome, Lanseria Aerodrome and Pretoria (Wonderboom) Aerodrome was found on the accident site. Many of the copies were found in a small file, but the George Aerodrome information pages were spread around in the cockpit area of the site. The Jeppesen Airway Manual was updated and appropriately certified on 17 May 2002.

1.8.5 It was determined by the information available from the CVR recordings that the pilots planned and flew the George Aerodrome approach plate procedures for a VOR DME ILS approach on Runway 29. The information on the copies recovered relating to this approach procedures were exactly the same as the information in the recovered Jeppesen Airway Manual. Furthermore the information on the Jeppesen approach plate was similar to and more than the published information on the same approach plate in force at the date of the accident in the CAA Aeronautical Information Publication. It could thus be accepted that what the pilots had available to them was the correct information to carry out the approach and landing safely on Runway 29.

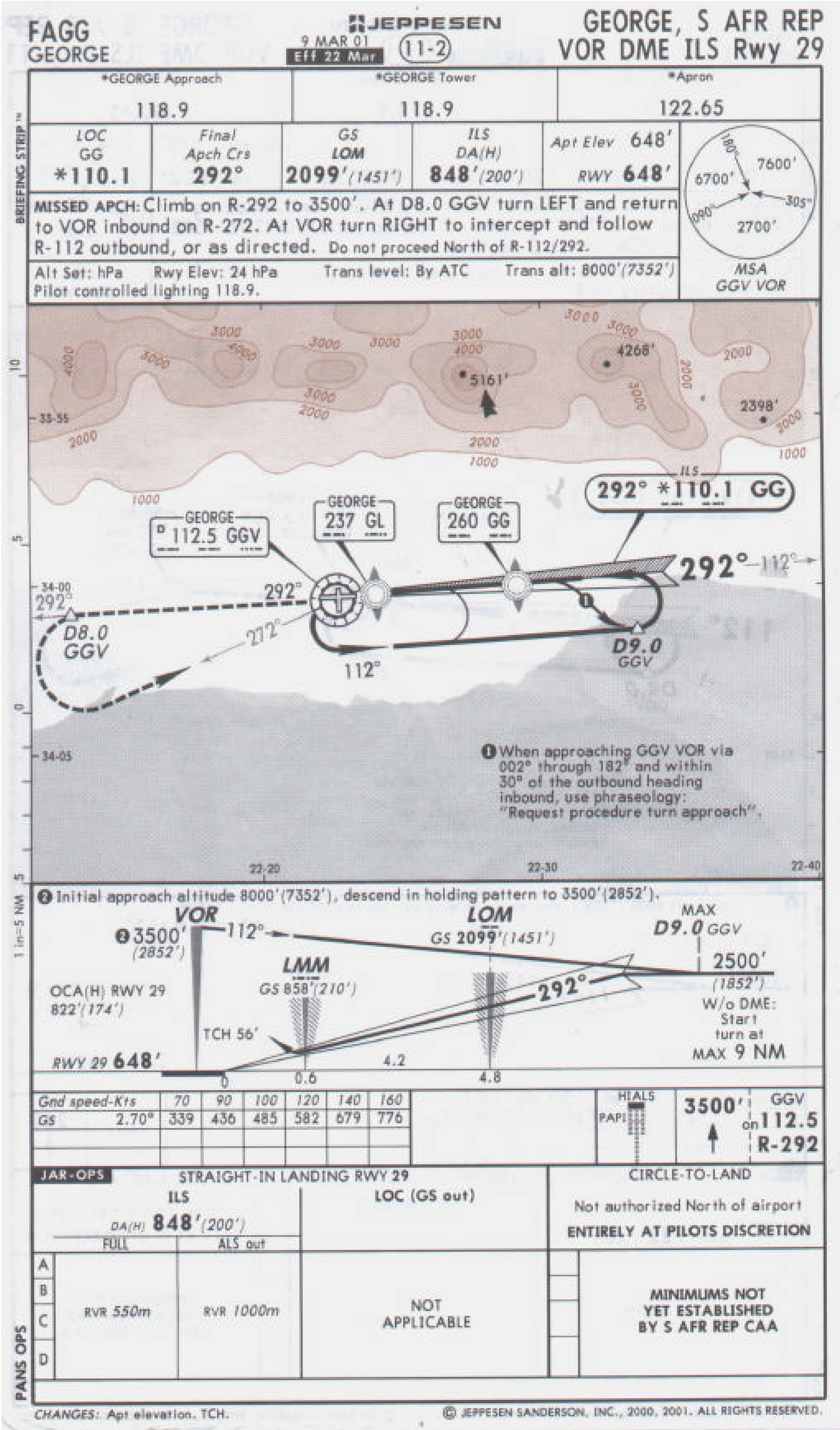
1.8.6 There was Notices to Airman (NOTAM's) in force relating to the ILS of Runway 11 at George. These NOTAM's were available to the pilots in the form of a **PRE-FLIGHT INFORMATION BULLETIN** (dated 31 May 2002 – 15:00 UTC) by the Aeronautical Information Service of the Air Traffic and Navigational Services (ATNS) and was recovered on the accident site. By the CVR recordings one could determine that the pilots were aware of these NOTAM'S relating to the ILS of Runway 11. The NOTAM's that was in force at the time of the accident were as follows:

B0548/2002 **GEORGE** – ILS/LOCALISER RWY 11 FREQ 109,5 MHz UNREL. PILOTS TO EXER CTN. 0204291303 – 0207151000 EST.

B0584/2002 **GEORGE** – ILS LLZ RWY 11 FREQ 109,5 MHz UNREL. PILOTS TO EXER CTN. 0205020958 – 0207151000 EST.

B0655/2002 **GEORGE** – TRANSMISSOMETER (RVR) RWY 29 AND RWY 11 U/S. 0205170735 – 0206171700 EST.

1.8.7 In the light of the NOTAM's in force and the forecast of the wind conditions at George, the pilots made the logical decision to fly the approach procedure for Runway 29. The procedure plate that they used and that was recovered on the



accident site was as illustrated on the next page:

1.8.8 The procedure to fly this let-down pattern was to approach the field on an altitude of 8000 feet above MSL and join overhead the VOR beacon GGV. The aircraft then descend in the holding pattern to an altitude of 3500 feet above MSL when it reaches the point overhead the GGV beacon on a 292 radial. The procedure was to turn to the left at a rate one turn to the heading of 112°M. During this outbound leg of the procedure the aircraft should descend to 2500 feet above MSL and a position of 9nm from the VOR beacon GGV. A warning was included at this point on the pattern that read: "Start turn at MAX 9 NM". The level left-hand turn should be executed at 2500 feet above MSL and maintained until the ILS was intercepted. Usually during the turn or just after the turn the frequency was switched over from the VOR frequency of 112.5 MHz to the ILS frequency of 110.1 MHz. Once the Glide Slope of the ILS was intercepted the aircraft should be flown on this descent path which is usually at an angle of 3° to the horizontal. In the horizontal plane, the path of the aircraft was controlled by the localizer information and in this case the heading of the aircraft on the localizer must be controlled at 292°M. During this leg of the procedures the aircraft pass over the beacons that provide the outer marker and middle marker information and the aircraft may descend to the decision altitude of 848 feet above MSL or 200 feet above ground level. At the decision altitude the pilots need to take the decision to land if they have the runway visual and were able to land.

1.8.9 In the case that the pilots do not have the runway visual or for some other reason it was not safe to land, a missed approach procedure was initiated. This procedure was described at the top of the approach plate as follows:

Climb on R-292 to 3500'. At D8.0 GGV turn LEFT and return to VOR inbound on R-272. At VOR turn RIGHT to intercept and follow R-112 outbound, or as directed. Do not proceed North of R-112/292.

1.8.10 After the radial of 112 was flown past the outer marker (GG NDB-beacon) at an altitude of 3500 feet above MSL, the aircraft need to be flown to intercept the pattern again in a similar way as when the pattern was intercepted with a parallel entry procedure.

1.8.11 To fly this approach procedure there were several approach and landing aids that was used. Initially the VOR beacon GGV was used, which considering the information available was operational during the approach of the aircraft the morning of 1 June 2002. There were three NDB beacons in the area of the George Aerodrome applicable to this approach pattern namely GG, GL and GO. As far as could be determined with the available information, none of these beacons were unserviceable at the time the aircraft flew the approach. The ILS was the last key to the approach pattern. Considering the information gathered from the CVR recordings of the aircraft and by a statement from a maintenance technician of the ILS, it could be deduced that this system was not operational during the time when the aircraft flew the approach.

1.8.12 When the engineering technician on duty for the ground equipment at George Aerodrome left at 1830Z the evening before the accident, the ILS in operation was the one on Runway 29 and at that time it was fully operational. When the technician arrived on duty the morning of the accident at 0555Z for his duty shift that start at 0600Z, he heard the audio alarm in the equipment room. The alarm was caused by the Localizer of the ILS of Runway 29 that had failed. This failure had occurred between the time when the technician had left off duty the previous evening until he arrived on duty the morning. The technician reset the audio alarm as well as the ILS equipment with no further operational problem. According to him the VOR and DME was operating correctly.

1.8.13 According to the recordings of the CVR, when the pilot-in-command tuned the VHF navigation frequency to the ILS frequency of 110.1 MHz he did not receive the GG-morse code (--. --.) as an identification that he had tuned the correct frequency and that the ILS was operational. One can hear the hiss-sound of the audio signal on the CVR-recordings when the pilot turned the volume up in an attempt to hear the identification code. There was however some indications on the pilots' flight directors that the ILS was operational and from time to time the warning flags appeared to warn the pilots that it was not reliable, but they carried on with the approach using the ILS equipment.

1.8.14 In the event that the pilots of an aircraft is not sure of the serviceability and reliability of the ILS on a runway, they need to opt for one of the other approach procedures available at the aerodrome. In this case at George Aerodrome two alternative approach procedures were available to the pilots for an approach on Runway 29. There was a published approach procedure for a VOR DME approach and a NDB approach using the NDB beacons GG, GL and GO.

1.8.15 A control/warning panel (see photo on right) in the control tower provided information to the air traffic controller about the selected ILS and whether the different equipment, eg. localizer, glide path, VOR, DME's were operational. There were green lights indicating that the different equipment was serviceable and a red light if they were off. There was an audio warning devise fitted to the panel to provide an audio warning to the air traffic controller when the equipment becomes unserviceable. This audio warning horn was covered with a metal cup and the cup was taped to the panel with cellulose tape. Glue marks on the surface of the panel face suggested that this metal cup has been stuck to the panel for some time. It was obvious that the serviceability of the navigation equipment could only be monitored by means of this panel if the air traffic controller was on duty.

1.8.16 According to CAA records the ILS for Runway 29 at George was installed during 1973. It was a Thomson 371 system operating on 110.1 MHz. The previous calibration of the system was on 9 May 2002 and the next calibration was due on 21 July 2002. On 9 May 2002 the localiser, glide slope and marker beacons for the ILS of Runway 29 were calibrated. Minor adjustments were made and all the other parameters were found satisfactory. An ILS Flight Inspection Certificate was issued on 13 May 2002.

1.8.17 On 12 June 2002 the ILS and marker beacons for Runway 29 and the VOR was check calibrated. An ILS Flight Inspection Report was certified on 15 June 2002. The localiser was found satisfactory and the following remarks were made about the localiser:

Localiser Stats: TX1, TX2 Operational to Category I
Remarks: Both Localiser transmitters were extensively checked during the flight and the following was found:

1. Before the time of the aircraft crash, the localiser appears to have shut down. If the localiser was not functioning, no localiser signals would have been received by the aircraft's instruments. See ATNS ILS fault report enclosed with report.
2. The Coverage and Off Course Clearance signals of both transmitters were found to be correct. Profiles were flown at the predicted altitude, distance and direction as per the effected aircraft before impact with the mountain. The ILS/DME Instrument Procedure for RWY 29 was flown. Particular attention was focused on the localiser intercept and no discrepancies were found.
3. No obstacles were found within the coverage area, 35 degrees of localiser centreline. Position of crash site is approximately 40 degrees (150 Hz side) from localiser centreline.
4. The identification code was audible within the coverage area.
5. The localiser course structure was found to be within the ICAO recommendation. On both transmitters, the alignment of the localiser centreline was found to be 5µA/150 Hz. This calculates to be 3.5 metres, left-hand side, from the runway centreline at threshold for runway 29. The localiser centreline is within the ICAO recommendation. During the previous Flight Inspection Check performed on the 9th May 2002, the localiser centrelines on both transmitters were found to be 0µA (on runway centrelines) with no adjustment made.
6. All monitors were checked and found to be operating correctly within the ICAO recommendations. This translates to be that if any parameters were to shift outside the ICAO limits, the localiser transmitter would shut down and cease to function until the fault is rectified.

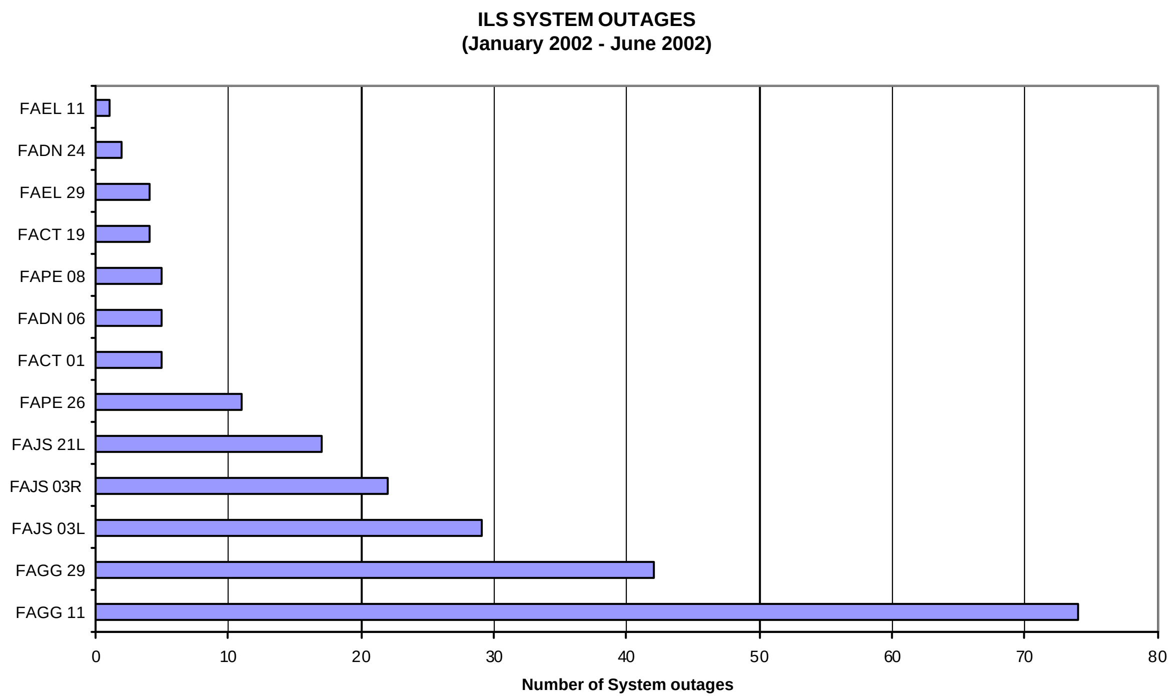
On completion of the After Accident Flight Inspection Check, the Flight Inspection Section recommends the following:

1. The Localiser on FAGG runway 29 remains operational,
2. The CAA should investigate further, what caused the localiser to cease functioning during the night of the 31 May/1 June 2002
3. CAA to investigate the reason as to why the localiser centreline shifted from the previous 9 May 2002 Flight Inspection Check and the subsequent Flight Inspection Check (12 June 2002).

1.8.18 The ATNS ILS fault report referred to in the remarks in 1.8.16 above, refer to two incidents where the localizer for Runway 29 had shutdown in June 2002. The incident was during the night of the accident on 31 May/1June 2002 and another incident on 6 June 2002 in which the localizer for Runway 29 had shutdown overnight.

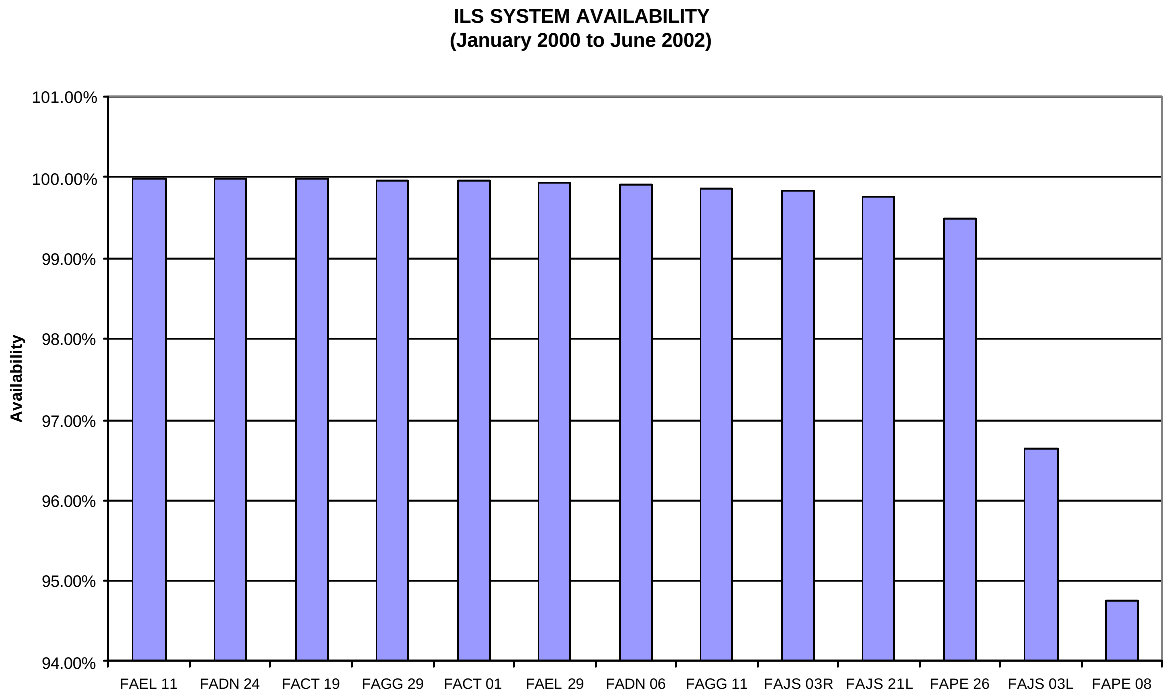
1.8.19 During the check calibration on 12 June 2002 it was found that the Glide Path and Marker Beacons were operational and functioning satisfactory. The VOR GGV was also check calibrated and it was remarked that the approach radial for Runway 29 was flown and no discrepancies were found. The DME was monitored too during the Flight Inspection Check and no defects were identified.

1.8.20 A report was requested from ATNS about the maintenance history of the ILS's at George Aerodrome and it was requested that the performance of these ILS's be related to some of the other similar ILS's in South Africa in the period from January 2002 to June 2002. There were several criteria that may be used to relate the different ILS's to each other. The criteria used in the ATNS report were number of system outages, availability, number of adjustments performed on the ILS's over the last four consecutive flight inspections and the age of the equipment. If the number of outages were considered the following graph illustrates how the different ILS's related to each other:



From this graphic illustration one can see that the two ILS's at George Aerodrome FAGG suffered by far the most outages. The ILS of Runway 29 at George was a Thompson 371 model and the same model ILS was installed at Johannesburg International Aerodrome's Runway 03L also in 1973. This ILS was the third worst performer considering outages. The same model ILS was installed on both runways at East London Aerodrome in 1978 and 1979 respectively. These two ILS's on the other hand performed very well in relation to the other ILS's considered.

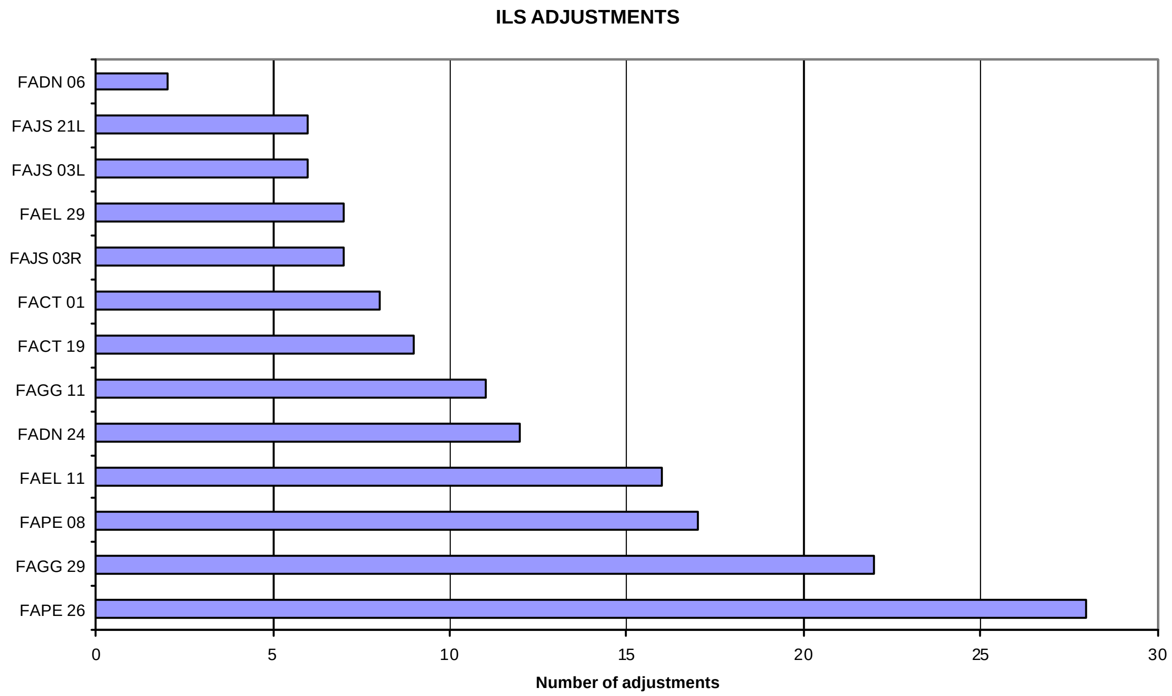
1.8.21 If the availability of the ILS's were considered the following graph was presented:



In this case the ILS's at George Aerodrome performed much better than several of the other ILS's, with the ILS at Port Elizabeth's Runway 08 being the worst performer and thereafter the ILS at Johannesburg International Aerodrome's Runway 03L. In the ICAO Annex 10, Volume 1 – Attachment F (Guidance material concerning reliability and availability of radio communications and navigation aids) it indicates that equipment reliabilities of 1000 hours or more have been consistently achieved. The document suggests that this reliability could be translated to 97.5% reliability in a 24-hour period, thus the likelihood of facility failure of about 2.5% during a 24 hour period. The only ILS that was below these criteria at that time was the ILS at Port Elizabeth's Runway 08.

1.8.22 The next parameter considered to relate the ILS's to each other was the number of adjustments performed to the ILS's over the last four consecutive periodic flight inspections. The graphical presentation of the number of adjustments was as follows:

Graph on next page



Considering the above information it is apparent that the ILS at Port Elizabeth's Runway 26 needed to be adjusted the most times, but the ILS of George's Runway 29 was adjusted the second most times. Interesting enough the ILS of George's Runway 11 did not need as many adjustments as the ILS on Runway 29 although the ILS of Runway 11 had more outings as the ILS of Runway 29.

1.8.23 The ATNS report also considered the age of the ILS's and positioned them accordingly in a table:

ILS SYSTEM PERFORMANCE (Installation Year)		
Position	**ILS**	**Installation Year**
1	FACT 19	2000
2	FACT 01	1999
3	FADN 06	1998
4.5	FAPE 08	1986
4.5	FAPE 26	1986
7	FADN 24	1985
7	FAJS 21L	1985
7	FAJS 03R	1985
9	FAEL 11	1979
10	FAEL 29	1978
11.5	FAJS 03L	1973
11.5	FAGG 29	1973
13	FAGG 11	1991(Second Hand)

The three ILS's that was in the highest positions was the two ILS's from George Aerodrome and the ILS at Johannesburg International Aerodrome Runway 03L.

1.8.24 The final analysis was when the ILS's was ranked against each other in terms of the four basic factors considered above. Once ranked against all ILS's in each parameter the total points apportioned each ILS is then computed as a total penalty against it. Cape Town ILS 19 receives 3,5 points in terms of the number of system outages, 3 in terms of availability, 7 in terms of the number of adjustments and 1 for the year of installation - for a total of 14.5 penalty points - and top spot. The worst performer, George ILS 11, receives 13 points against it in terms of the number of outages, 8 in terms of availability, 8 in terms of the number of adjustments and 13 in terms of installation year for a total penalty of 42 points against it.

ILS SYSTEM PERFORMANCE		
Position	**ILS**	**Total penalty points**
1	FACT 19	14,5
2	FADN 06	17
3	FACT 01	19
4	FADN 24	20
5	FAEL 11	21
6	FAEL 29	24
7	FAJS 21L	28,5
8	FAJS 03R	30,5
9	FAPE 08	34,5
10	FAPE 26	36,5
11	FAJS 03L	37
12	FAGG 29	39,5
13	FAGG 11	42

From this total positioning of the ILS's it is suggested that the worst performers of the ILS's were the two ILS's at George Aerodrome.

1.8.25 The ATNS report concluded and recommended that their findings suggested that the ILS at George Aerodrome Runway 11 should be the first ILS to be replaced followed by the ILS's of George Runway 29, Johannesburg International Runway 03L, Port Elizabeth Runway 26, etc.

1.8.26 A memo was forwarded from the Head of Operations: Aerodrome Infrastructure 3 July 2002 relating to the ILS of Runway 29 at George. In essence it stated the following:

a. The person indicated that the ILS was an old system, but was due for replacement according to the Airports Company of South Africa's (ACSA) phased ILS replacement program. The contract for the renewal of the ILS's was awarded in March 2002.
b. The ILS on Runway 11 was due for replacement before the ILS on Runway 29 due to its performance. Generally the decision process to replace ILS's was made according to criteria like availability, wind direction in particular months and seasonal factors. These decisions were made during joint meetings of representatives of ACSA, ATNS and CAA. International practice is to replace navaids every 10 years, but due to cost and other factors this was not complied with in South Africa.

c. Many changeovers and shutdowns occurred during the months preceding the accident. No NOTAM's were raised for these conditions because none of them exceeded 30 minutes. Outages will not show up during flight calibration because the equipment is switched over to a test mode.
d. In January and April 2002 a faulty changeover card was replaced.
e. In the person's experience, continued repairs on printed circuit boards of Radio Frequency (RF) circuitry causes the RF path to change, introducing inconsistencies, deterioration of the generated signals, resulting in degradation of the signal in space. Although the system will still operate within the legal parameters, side effects are impossible to predict and hard to trace as faults causing instability. Although high grade components are used in the original manufacture, through the years deterioration set in, specially after 25 years service.
f. Logging of all changeovers is recommended, but this will change with the installation of the new systems. Pilots also need to be reminded that outside official hours of ATNS staff the equipment availability is not guaranteed at all times.

1.8.27 The Head of Operations: Aerodrome Infrastructure indicated in his memo that it is international practice to replace navaids every ten years, however when further research was carried out a Federal Aviation Administration Order was found from which could be deduced that they budgeted accepting a life expectancy of aerodrome equipment as twenty years. A German Head of Terrestrial Navigation indicated that they typically accept a life cycle of their navaids as 15 years which goes along with the availability of spare parts and customer service of the manufacturer. Some of their systems have already reached an age of 20 years and more.

1.8.28 After the accident many reports were received by the CAA about the condition of the ILS on Runway 29 at George Aerodrome. It was reported that the glide slope scallop up to one and a half dots at a certain point along the ILS-path. The investigator-in-charge witnessed this scalloping during an approach onto this runway of a scheduled flight. During a meeting at George Aerodrome on 9 April 2003 between ATNS, ACSA and CAA representatives it was decided to move the installation of the ILS on Runway 29 up in the schedule and install it before the one at Port Elizabeth. The ILS was also flight calibrated that day and found to be satisfactory.

1.9 Communications.

1.9.1 The control tower at George Aerodrome was unmanned during the aircraft's approach and attempted landing at the field. The hours of operation on the Saturday of the accident were from 0630Z as published in the Aeronautical Information Publications. The pilots used the unmanned field communication procedures when they approached George Aerodrome. The communications with the tower was recorded in the tower on the 118,9 MHz and the voice recorded on this recording was of the pilot-in-command. This communications were transcribed as follows:

Time	Communication
0438:30	George Traffic, AirQuarius 201, Hawker Siddelley 748. We are five zero miles, one four zero, estimating overhead Golf Golf Victor, zero four five one.
0456:18	George Traffic, Quarius 201 is overhead Golf Golf Victor and joining the hold, descending in the hold to three thousand five hundred feet.
0508:08	Five keystrokes (switch on runway lights)
0509:55	George traffic Quarius 201 is final runway 29.
0510:30	Five keystrokes (switch on runway lights)

1.10 Aerodrome Information

1.10.1 The following information of the George Aerodrome was obtained from the Aeronautical Information Publication:

Aerodrome Location	George FAGG	
Aerodrome Co-ordinates	S34°00'24.1'' E022°22'27.4''	
Aerodrome Elevation	648 feet	
Runway Designations	11/29	02/20
Runway Dimensions	2000m x 45m	1220m x 30m
Runway Used	29	
Runway Surface	Asphalt	
Approach Facilities	ILS, VOR, NDB, PAPI, RWY lights	

1.10.2 During the initial final approach of the aircraft before the missed approach, the pilots clicked the microphone 5 times to switch the runway lights on. The weather officer saw the runway lights illuminating shortly before he heard the aircraft flew over the aerodrome.

1.11 Flight Recorders

1.11.1 The aircraft was fitted with a Fairchild model A100A part no.: 93-A100-80 serial no.: 52884 cockpit voice recorder. The CVR was tested according to the manufacturer's manual and found serviceable on 27 May 2002. The recovery of the CVR from the tail section of the wreck was difficult, but the quality of the recordings was good. The Dukane underwater acoustic beacon Model DK100 fitted to the CVR was functional but the "REPLACE BEACON BY END OF" Aug 2001 date was expired.

1.11.2 The CVR recordings were transcribed and are attached to this report as **Appendix C: (Cockpit Voice Recording Transcript).** It was difficult to align the times of the conversations because the CVR do not have time lines on the recordings. The only time lines that were available were the times on the ATC tapes. These times between the radio transmissions recorded on the CVR were used to determine the approximate times on the CVR. A copy of the CVR recording was played at different speeds until these times corresponded as close as possible to the ATC timelines.

1.11.3 From the CVR recordings one could determine that the co-pilot was flying and the pilot-in-command was monitoring the approach. However the pilot-in-command took control of the aircraft during the last minute and a half of the flight. It was apparent from the CVR recordings that the pilot-in-command coached the pilot-flying all along through the recorded part of the flight. One could hear clearly that the Ground Proximity Warning System (GPWS) was operational and issued warnings.

1.11.4 The flight data recorder fitted to the aircraft was a Plessey model PV1584D, part no.: 650/1/14040/004 serial no.: 3068. The FDR was recovery from below the floor in the tail section of the wreck. The FDR was taken to an approved Aircraft Maintenance Organisation and the data was extracted from the recorder. The quality of the data was good. The FDR was not fitted with an underwater acoustic beacon.

1.11.5 The FDR was transcribed according to the manufacturer's manual and found serviceable on 22 May 2002. A note indicates that the heading data is "Noisy in climb".

1.11.6 The FDR was a very basic recorder which recorded the following parameters:

- Time
- Pressure altitude
- Indicated airspeed
- Heading
- Roll angle
- Vertical acceleration
- Lateral acceleration
- Pitch angle
- Flap setting
- Both engine RPM's
- Ground Proximity warnings.

1.11.7 Using the above data from the FDR, it was attempted to plot the typical flight path of the aircraft on the computer, but the results were not reliable due to too many unknown variables like the wind direction and speed. However the data from the FDR was used with estimated wind-speeds and directions and the flight path plot was produced as presented in 1.1.10 above.

1.12 Wreckage and Impact Information

1.12.1 The investigator-in-charge had very limited time available on the accident site to gather wreckage and impact information due to the inaccessibility of the site (to reach it by foot was a steep climb up the side of the mountain for several hours thus the only alternative was by helicopter). On the day of the accident it was late during the day when the accident site was reached and due to light conditions reducing, the helicopter had to leave. The best part of the second day of the investigation was spent to recover the recorders and when time was available notes were taken. On the third day a helicopter flight was undertaken to recover the CVR and no further time was available. A week later the investigator had a further opportunity to visit the site while the cargo was recovered. The nose of the wreck had moved about a half a meter downward which made it possible to crawl in underneath the nose section and recover the first pilot's instrument panel. The second pilot's instrument panel was recovered by the operator when they pushed the wreck off the cliff it rested on at a later date.

1.12.2 The aircraft impacted the side of the mountain in what appeared to be a small right wing low angle and with a nose up pitch angle of about 15° according to the FDR. The point where the aircraft impacted the mountain was at the top of a small about 70° cliff of about 5 to 7m high. The centre section of the wing and forward fuselage section came to rest on a fairly horizontal area on the top of the cliff, but from this position the mountain side again raised at about 60° for

another about 15 to 20m. At the top of this rise was another horizontal area where the rescue helicopters landed. The estimated magnetic direction of the aircraft at or just before the impact was North-Westerly. The nose of the aircraft rolled in underneath the forward part of the wreck and burst open during the impact with the mountain (refer to the photo). The outsides of the windshields and associated area of the cockpit were found in contact of the surface of the mountain side and the lower areas of the cockpit including the main instrument panels was scattered underneath and to the left of the forward wreckage. The nose landing gear, cockpit centre pedestal and pilot-in-command's body was found in the area to the left of the nose wreckage. The co-pilot's body was stuck in the left-hand inside area of the cockpit wreckage.

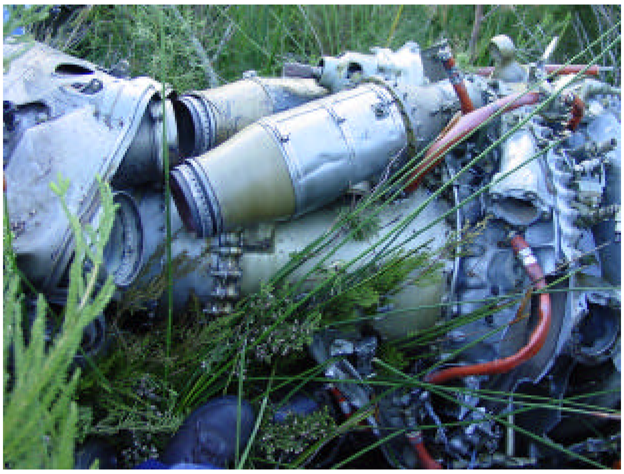
1.12.3 In the aircraft's cargo configuration, a set of passenger seats were mounted in the area behind the cockpit and behind the seats a cargo net was installed. During the impact sequence this area of the aircraft burst open and the cargo net failed partially when the heavy items of the cargo was flung forward. The passenger's body was found in one of these seats. The nose section of the fuselage separated from the rest of the fuselage in front of the wing centre section. Similarly the rear fuselage/empennage separated from the rest of the fuselage in the rear section of the wing centre section. The rear fuselage/empennage of the wreck swung to the right after the impact, but was still attached to the rest of the wreck by the control cables and electrical wire bundles. It was pivoting on a rock that had penetrated the lower rear fuselage area.

1.12.4 Both wings failed from the wing centre section in the inboard area of the engine nacelles. It appeared as if the wings had folded around the curved side of the mountain. The failed left-hand wing fragment separated totally from the wing centre section and impacted the side of the mountain to the left of the main wreckage, resting on the vegetation after the impact sequence. Besides the damage on the leading edge of the wing it was relatively undamaged considering the impact. There was still some fuel in the integral fuel tanks of the wing, but it was impossible to determine the amount of fuel. The right-hand wing impacted the side of the mountain and slid downward/backwards about a meter. This part of the wing suffered a post-impact fire which severely damaged the wing and to a certain extent the engine nacelle. It could be determined from the wing wreckage that the flaps were extended to about half to three-quarter down position (estimated at about 20°).

1.12.5 The flight control mechanisms in the cockpit area were totally destroyed and it was impossible to check the control continuity in this area. As far as possible, the rest of the flight control systems were inspected for continuity and no points of concern were observed. It was accepted that these systems were serviceable at the time of the accident.

1.12.6 The forward sections of the right-hand engine separated from the rest of the engine just behind the combustion chambers. The forward part of the engine carried on a few meters to the foot of the 10 to 15m rise of the mountain. The combustion chambers were spread over this area between the rear and the forward sections of the engine. The right-hand propeller blades had separated from the propeller hub and were also found in the area in front of the main wreckage. All propeller blades found had severe damage to the leading edges of the blades.

1.12.7 The left-hand engine mountings failed during the impact sequence and engine departed from the wing mounting points. The engine failed in different areas along its longitudinal axis with the most severe failures in the area between the reduction gearbox and the first stage centrifugal compressor, the area behind the combustion chambers and in the turbine section case. One of the turbine wheels departed from the engine and was recovered in the area forward of the engine. All the turbine blades were stripped from the turbine wheel.



1.12.8 What appeared to be the left-hand propeller separated from the engine and was found in the area immediately forward of where the left-hand wing was found. The propeller blades were attached to the propeller hub, but the blades were severely bent and damaged by the impact. Especially the leading edges of the blades had severe impact damage as it had impacted the rock surfaces of the mountain. The blades that did not break loose from the pitch change mechanism appeared to be in a flight pitch condition. The propeller shaft failed at the rear of the propeller hub.

1.12.9 During the first and second day of the investigation only the centre instrument panel could be reached where it was stuck underneath the wreckage of the nose section. The information was captured photographically as far as possible. The indications on the engine related instruments suggested that the engines were operational at the time of the accident and that there was fuel in the fuel tanks. However the investigator was able to crawl into the nose wreckage and inspect the three roof panels that sustained minimal damage. These panels contain the selection switches for different aircraft systems and the radio/navigational switch units. None of the positions of the switches were such that it was a point of concern and significant observations on the centre roof panel were:

- Very High Frequency (VHF) communication frequencies selected on COM 1 was 118.1 MHz, which was the tower frequency for either Cape Town or Bloemfontein and COM 2 was selected to 118.9 MHz which was the tower frequency for George Aerodrome.
- VHF navigation frequencies on NAV 1 and NAV 2 were both selected to 110.1 MHz which was the ILS frequency for Runway 29 at George aerodrome.
- Automatic Direction Finder (ADF) frequencies on ADF1 were selected to 570.0 kHz and on ADF2 were selected to 236.5 kHz. The frequency on ADF1 was not one of the NDB beacons in the George Aerodrome area but 236.5 kHz was very close to the frequency of GL which was 237 kHz.
- The transponder code was set at 2706.

1.12.10 The first pilot instrument panel was recovered from underneath the nose section of the wreckage a week after the accident on the day the cargo was recovered. The wreck had moved rearwards and the nose of the wreck had lifted enough for the investigator to crawl in there to gain access to the instrument panel. The significant information obtained from this panel was:

- Airspeed indicator indicating about zero and speed bug indicating about 107 knots.
- The flight attitude director indicator's indication suggests a 15° right-wing low and about 5° nose up condition. The sideslip indicator ball was free to move.
- The horizontal situation indicator indicated a heading of 285° with the course pointer at 260° and the course deviation bar to the right about one dot. The heading, navigation and vertical flags were insight.
- The rate-of-climb indicator indicated a rate of climb of about 150 feet per minute.
- The radio magnetic indicator had separated from the instrument panel and was recovered close to the instrument panel with the heading indicated as 310°. The ADF and VOR needles were free moving and indications of these needles were considered as unreliable. The OFF warning flag was insight.
- The altimeter had separated from the instrument panel too and was recovered close to the instrument panel. The face of the instrument was missing, but the altitude counter indicated an altitude of 2740 feet on a QNH of 1018 milibars. The warning flag was insight.
- The directional gyro slave switch and guard was damaged, but was most probably in the "slave" position and held in the position by the guard.

1.12.11 The second pilot instrument panel was recovered at a later date by the owner\operator and brought to the CAA offices. The significant information obtained from this instrument panel was:

- Airspeed indicator indicated about 30 knots and the speed bugs were at 93 and 95 knots.
- The gyro horizon indicator's pitch and roll sphere had broken loose. The flight director bars were about in the centre and both the glide slope and flight director flags were insight. The glide slope indicator was about a quarter dot below the central position.
- The horizontal situation indicator's bezel and several indicator bars were missing. However the heading dial indicated a heading of 287° and the heading flag was insight. Both the glide slope flag rod and glide slope displacement indicator was bent, thus no reliable information could be derived from these indicators.
- The rate-of-climb indicator indicated a rate of descent of about 200 feet per minute which was considered unreliable.
- The radio magnetic indicator indicated a heading 287°. The ADF/VOR 1 needle was missing and ADF/VOR 2 needle was indicating to the tail of the aircraft and 10° to the left. The warning flag was insight. Both the RMI switches were switched to the ADF position.
- The altimeter's altitude counter indicated an altitude of 4500 feet on a QNH of 1016 milibars. No warning flag was insight.
- The radio altimeter indicated about 80 feet with the altitude bug was set at 200 feet. The warning flag was insight.
- The directional gyro slave switch was in the "slave" position and held in the position by a guard. The fast slew switch was in the decrease position.

1.13 Medical and Pathological Information

1.13.1 Medico-legal post-mortem examinations were carried out on both the pilot-in-command and the co-pilot after the accident. The post-mortem reports as well as the history related to the pilots' previous medical examinations were considered and the medical section of the CAA reported the following of the pilot-in-command:

MEDICAL AND PATHALOGICAL INFORMATION: Pilot-in-command

Survivability

The accident was not survivable. The cause of death was multiple injuries.

Description of post mortem findings

Chief Findings:

- Multiple abrasions and lacerations of the face, upper limbs, chest abdomen and lower limbs.
- Fracture mid-shaft of the left humerus, fracture-dislocation of the right wrist joint, bilateral compound fractures of the tibia and fibula and comminuted fractures of the right distal femur and right knee joint.

- Blunt force injury of the chest with antero-posterior flattening due to numerous rib fractures, laceration of the lungs bilaterally and of the right ventricle of the heart. The coronary arteries had mild atheroma, 10-20% occlusion. Total laceration of the ascending thoracic aorta.

- Bilateral fracture-dislocation of the sacro-iliac joints and fracture of the pubic symphisis.
- Fracture dislocation of T3/T4 with the spinal cord pulled out through this defect from above.

Histology
Histological examination was not performed.

Toxicology screen
The blood alcohol level was 0.00g/100ml. There was enough sodium fluoride in the sample to prevent alcohol formation within. The carboxyhaemoglobin concentration was 7%.

Pre-existing disease
The pilot was 68 years old at the time of his death. He was hypertensive and well controlled on *Zestril* and *Norvasc.* His condition was monitored according to the hypertension protocol. He had no smoking history. The deceased was involved in a motor vehicle accident in 1996 and sustained a laceration to his forehead with no neurological sequelae. His medical certificate carried an operational restriction to fly with corrective lenses.

Discussion
Macroscopic examination of the heart revealed 10-20% occlusion of the coronary arteries. This degree of atherosclerosis is insignificant and can thus not be implicated in the causation of the accident. The carbon monoxide concentration noted in his blood is low and would not have resulted in incapacitation during flight.

Summary
The accident was not survivable. The cause of death was multiple injuries. No alcohol was detected on analysis of tissues sampled. The carbon monoxide detected in the blood sample was insignificant and would not have resulted in incapacitation. Histology was not performed. No medical factors could be sighted as the cause of the accident.

1.13.2 The medical section of the CAA reported the following about the co-pilot:

MEDICAL AND PATHALOGICAL INFORMATION: Co-pilot

Survivability
The accident was not survivable. The cause of death was multiple injuries.

Description of post mortem findings

Chief Findings:

- Multiple abrasions and lacerations of the face, right upper limb, abdomen and lower limbs.
- Fracture floor of the left middle fossa in the skull, fracture mid-shaft of the right humerus, compound fracture of the left tibia and fibula, dislocation of the right knee and bilateral ankle fractures.
- Blunt force injury of the chest with rib fractures, laceration of the heart and contusion of the lungs bilaterally.
- Mild left ventricular hypertrophy with 10-20% narrowing of the left anterior descending coronary artery with atheroma.
- Fractured left superior pubic ramus with right sided retroperitoneal haemorrhage.

Histology

Histological examination was not performed.

Toxicology screen

The blood alcohol level was 0.00g/100ml. There was enough sodium fluoride in the sample to prevent alcohol formation within. The carboxyhaemoglobin concentration was 1 %.

Pre-existing disease

The pilot was 50 years old at the time of his death. His medical certificate carried an operational restriction to fly with corrective lenses. He had at his latest medical examination, been advised to loose weight.

Discussion

Macroscopic examination of the heart revealed less than 10-20% occlusion of the left anterior descending coronary artery as a result of atherosclerosis. This degree of atherosclerosis is insignificant and can thus not be implicated in the causation of the accident. The carbon monoxide concentration noted in his blood is very low and would not have resulted in incapacitation during flight.

Summary

The accident was not survivable. The cause of death was multiple injuries. No alcohol was detected on analysis of tissues sampled. The carbon monoxide detected in the blood sample was insignificant and would not have resulted in any incapacitation. Histology was not performed. No medical factors could be sighted as the cause of the accident.

1.14 Fire

1.14.1 No evidence was found of pre-impact fire, but the post-impact fire was isolated to the right-hand wing. The source of ignition for the post-fire was most probably the fuel that made contact with the hot surface of the failed engine. The fuel for the fire was obviously the aviation fuel that spilled from the damaged integral fuel tanks in the wing of the aircraft. The fire did not consume the wing totally and was probably stopped by the rain at the accident site.

1.15 Survival Aspects

1.15.1 When the ATC came on duty at 0612Z the aircraft has not landed at George Aerodrome yet and an ALERFA was declared. The protection services in the area were contacted for the initial search at the different aerodromes but the aircraft was not spotted at any of these aerodromes. The different search and rescue units were activated and a helicopter was put on standby to start an aerial search when the clouds lifted. At 1016Z the helicopter pilot reported that they have spotted the wreckage soon after they started the flight. The persons onboard were accounted for and were all reported as deceased.

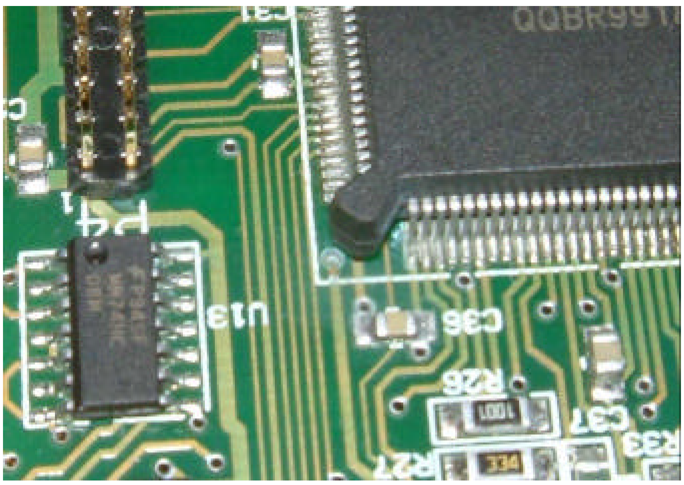
1.15.2 At the moment of impact the aircraft was flying at about 115 knots. With this speed and the nose of the aircraft taking the first impact with the side of the mountain, the impact forces were such that the accident was considered as not survivable to the occupants of the aircraft. From a South African Police Services photograph it was determined that the co-pilot had his safety harness (including shoulder harness) on at the time of the accident. The pilot-in-command was thrown clear of the cockpit area and it was thus impossible to determine whether he had his safety harness on. However in this case these harnesses would not have prevented the fatal injuries in anyway.

1.16 Tests and Research.

1.16.1 The Garmin GPS100AVD GPS-receiver, fitted to the aircraft was taken to an approved maintenance organisation and coupled to a testing bench. The last position recorded on the GPS was S33°54.71' E022°28.56'. The last bearing recorded to FAGG was 064° at a distance of 7.62nm. The last altitude was recorded as 2963feet. This position and other values recorded related closely to the position the aircraft had impacted the mountain. It was thus evident that the pilots used this GPS for reference purposes.

1.16.2 The Bendix/King KMD 150 MFD, Global Positioning System, Part no. 066-01174-0101, Serial no. 27100415 was sent to the manufacturer in the United Kingdom (UK). They were requested to attempt to download the available memory of the unit under the supervision of the Aircraft Accident Investigation Branch of the UK. The back-up battery on the Central Processing Board (CPU) was still intact on the board and had the required potential difference when it was measured. A report of this attempt was as follows:

Unfortunately some corrosion was discovered upon disassembly at the corner of the main processor. The result was that one of the printed circuit board vias has been 'eaten away'. This in itself would not have proved a problem had the circuit trace in question not been the main 5V supply to the memory. As a consequence there was no data retained in the RAM chips to retrieve.



1.16.3 The Pilot's Guide for the KMD150 was consulted and it was determined that in the MAP MODE the pilots would have been able to follow the progress of the approach and landing phase of their flight on a moving map display. By zooming in on the map, one could also obtain more detailed information of the area the aircraft was flying in. According to the CVR recordings none of the comments or conversations of the pilots suggests that they had referred to this GPS. The face of the instrument was severely damaged, thus it was impossible to determine if the unit was switched on.

1.16.4 The flight director instrumentation of the aircraft was removed and shipped to the United States of America for further investigation. One of the directional gyro's was recovered, but the second directional gyro was not recovered from the mountain, thus only one directional gyro was sent to the manufacturer for analysis. The examination was carried out by representatives of the manufacturer of the equipment under the supervision of the Federal Aviation Administration representing the National Transportation Safety Board of America. The components that was examined were as follow:

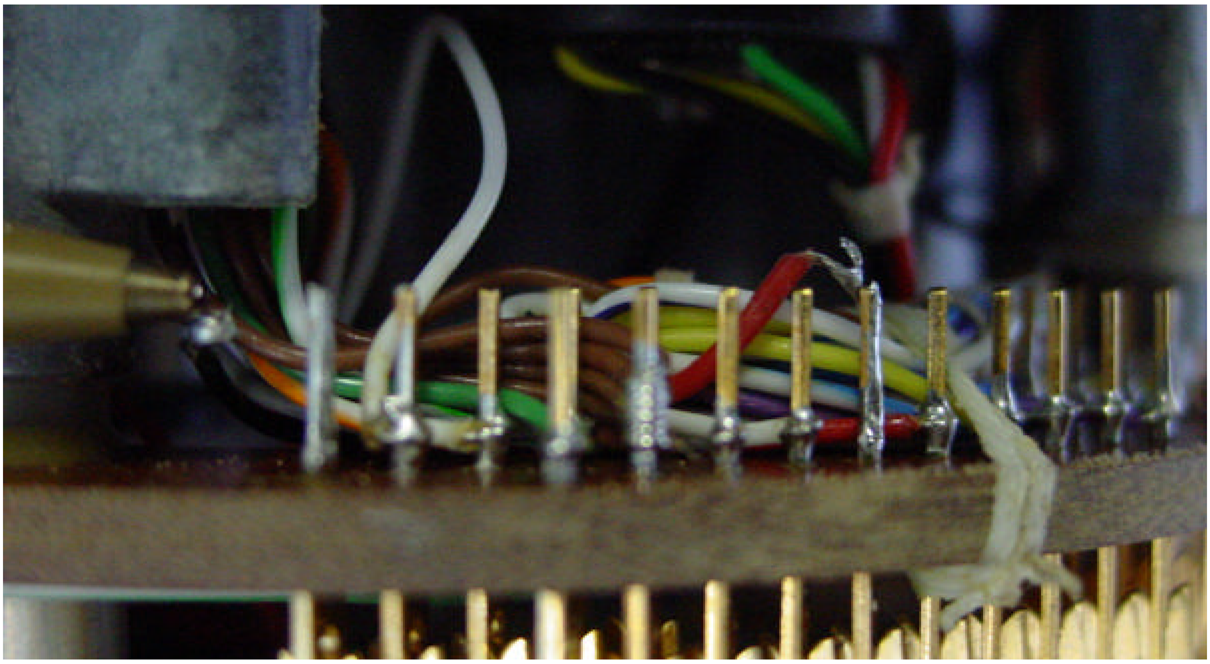
Quantity	Description	Part Number	Serial No.
1	SPERRY Attitude Director Indicator	7001182-904	82080280
1	SPERRY Horizontal Situation Indicator	7001179-916	81110729
1	RD-44 Radio Deviation Indicator	2592920-44	77122395
1	SPERRY Gyro Horizon GH-14	402531-534	79060594
1	Directional Gyro C-14A	2587193-43	84108500
1	Vertical Gyro VG-14A	7000622-901	86055592

1.16.5 A report of the examination of the components was forwarded to the investigator-in-charge and is attached to this report as **Appendix D: (Instrument manufacturer inspection report).** In essence the report has the following findings about the gyros:

Directional Gyroscope:

The gyro appeared in a reasonable condition, thus power was applied to the unit, but it was not operational. Opening the gyro can revealed heavy corrosion of the gyroscopic components. The internal components revealed that:

- The gyro rotor was locked up. A broken gimbal stop implies that the rotor was providing significant inertial momentum.
- The gimbal stop was broken. This suggests that the gyro rotor was rotating to create a high gyroscopic inertia.
- Both heading synchros were operational.
- Examination of internal wiring revealed two wires were not connected (refer to photo below):



- o These two wires were for the field excitation of the levelling motor
- o The wires do not appear to have been disconnected by impact
- o The levelling motor is designed to keep the gyro rotor level relative to the aircraft vertical axis
- o With the levelling motor disconnected the gyroscope will not operate properly
  - ▪ With the aircraft stationary, the C-14A may align and set its output valid
  - ▪ Depending on the friction in the gyroscope, the gyro rotor will precess. Eventually the precession may reach a point where the rotor aligns with the gimbals and the gyroscope “dumps”, ie. The output starts spinning.
  - ▪ Errors between this C-14A and the cross side compass system should be evident in turns
  - ▪ The C-14A with levelling motor disconnected will not pass the Honeywell IT:
    - • drift rate tests will fail
    - • levelling rate tests will fail

Gyroscopic Horizon:

Initial observations were:

- The attitude sphere of the instrument had moved if the position of the sphere was related to photo’s taken at the accident site.
- The gyro flag was in view and flight director flag half in view. These flags were kept out of view when 28V valid signals were received from the flight director and internal gyroscope. The flags were spring loaded into view when the 28V signals were lost. In this case it was not possible to tell whether the flags were in or out of view at the time of impact and loss of power
- The flight director bars were centred in the normal power off position
- The glideslope pointer was out of view

Examination of interior components of gyro horizon:
- The cord the attitude sphere to the gyro assembly was broken hence the free movement of the sphere
- Gyro was out of balance
- Movement of localizer and glideslope meters seemed un-impeded
- Impact mark on attitude sphere suggests 25° pitch up and 67° right bank.

Power was applied to the gyro and it operated. A valid signal was obtained when the gyro successfully erected, but the gyro bearings were extremely noisy and was not able to maintain vertical orientation. During the run-down the gyro drifted off level in roll to the point where the gimbal contacted the roll stop. Total run-down was 18 min. 17 sec.

Vertical Gyroscope:

Initial examination revealed that the gyroscope was in a reasonably good condition. Examination of the internal mechanism revealed that it appeared undamaged with the gimbals free to move and the gyroscope slightly off balance corresponding to a 45° bank with power off. Power was applied and the gyro erected and the valid signal went to valid. A drift in the pitch suggested some friction in the mechanism. A small vibration to the gyroscope let the pitch move back to 359°+ and when the mechanism was moved in the pitch and roll corresponding synchro outputs changed accordingly.

1.16.6 The report from the manufacturer also contains the findings related to the examinations of the indicators. The examination of the indicators was carried out by a different group of representatives and states in essence the following:

Attitude Direction Indicator:

Initial observations were:
- Attitude indicated was not the same as on the photo's on the crash site
- No flags in view
- DH and go-around annunciator lights missing
- Glideslope pointer on left was centred and not flagged
- Flight director command bars were pitched up with a slight right bank. Bars were displaced slightly to left of ADI centre-line
- Fixed aircraft symbol is slightly out of position.

The case of the instrument was cut open and the interior components revealed the following:
- Flight director flag was loose in case
- Attitude sphere was jammed
- Glideslope pointer moved to top of scale (spring loaded position)
- Substandard repairs was carried out on the unit
- Mechanical components were significantly mis-aligned.

No effort was made to operate the unit due to damage.

Horizontal Situation Indicator RD-550 (pilot-flying):

The initial examination revealed the following:

- The indicated heading was 286° with the flags in view.
- Selected course pointer indicate 262° for the head and 84° for the tail
- Glideslope pointer about 1.25 dots above reference
- Course deviation indicator was twisted, indicating .2 dots at tail end and about 1.5 dots at head end
- Compass sync indicator was in the middle
- Loose parts inside

The case was cut open and the interior revealed:

- Three loose screws and a loose board retainer were found
- Heading flag was broken off
- Glideslope motor was free to move, but the pointer was slightly bent upward
- Compass sync motor free to move
- A broken IC and replaced IC were found on CCA A2 board. The quality of the repair appears substandard
- A broken IC was found on CCA A3.

Horizontal Situation Indicator RD-444 (co-pilot):

The initial examination revealed the following:

- The indicated heading was 288° and the compass flag was in view
- The course pointer head was at 304° and tail was at 124°
- The course deviation indicator and the glideslope pointer was missing
- There was no TO/FROM display or selected heading bug
- The course select knob and compass sync indicator was missing
- NAV flag was approximately 10% in view.

The case was removed to examine the internal components and it was observed that there were no loose parts and the glideslope pointer had broken off from the meter movement.

1.16.7 A summary of the manufacturer's examination of the different components indicate that they could not identify whether the flagged instruments were operating at the time of the accident. However no evidence was found to indicate the components were not operable at the time of the accident. The levelling motor in the directional gyroscope was found disconnected; this appears to have been disconnected prior to the accident. The disconnected levelling motor could result in erroneous heading display.

1.16.8 The aircraft was fitted with a flux detector in each wingtip. Only the flux detector (Collins Flux Detector, Part no. 323A-2G and Ser. No. 8170) from the left-hand wingtip was recovered. The right-hand wingtip was severely damaged by the post-impact fire and the flux detector was not recovered. The flux detector was shipped with the rest of the instrumentation to the instrument manufacturer but was returned to the CAA with the other instruments. The manufacturer's comment was that this component was not manufactured by them and should be forwarded to the company which relate to this component. The flux detector was then forwarded to the proper company who agreed to inspect the flux detector under the supervision of the FAA. A test was performed on the unit that was the same as a production test for a similar unit. The test was to check the operation of the similar unit circuitry and can give some insight into the flux detector operation. The test results are attached to this report as **Appendix E: (Flux Detector Inspection Report).** and concludes that:

- The flux detector has a dominant single cycle error with an amplitude of ±15 degrees.
- The flux detector has a large index error of approximately -110 degrees.

1.16.9 The FAA inspector then communicated with the investigator-in-charge as to the results and suggested an attempt to demagnetise the unit and retest it. When the flux detector was returned to the manufacturer company the unit was tilted and the response checked at different positions of rotation. It was determined that the unit was significantly damaged. The test concluded:

The flux detector has internal damage that prevents its correct operation. This could be a broken gimbal. The damage most likely occurred due to airplane impact. Therefore no conclusion can be made about the performance of the flux detector unit prior to the incident.

1.17 Organizational and Management Information

1.17.1 **Operator:**

1.17.1.1 The operator was issued with a Domestic Air Service Licence, number N641D for a Class II Air Service on 6 December 2000. This licence was for types N1 and N2 air service with Category A1, A2 and H2 aircraft. On 15 May 2001 the operator was also issued with a Domestic Air Service Licence, number S670D for a Class I Air Service. This licence was for types S1 and S2 air service with Category A1 and A2 aircraft. The latter air service licence in the type S2 (transport of cargo or mail between two or more specified points) with an A1 category aircraft (any aircraft, excluding a helicopter, with a maximum certificated mass exceeding 20000 kilograms) was applicable to the accident flight. The operator also obtained an International Air Services License (I/N 114) during the August 2000.

1.17.1.2 The last audit carried out at the operator before the accident was on 17 January 2002. Minor findings were noted and the operator was issued with an Air Operating Certificate (AOC) for Part 121 operations on 21 January 2002. The expiry date of the certificate was 31 January 2003 and the aircraft was listed on the certificate. An interesting observation was that both the pilots involved in this accident were not noted on the list of pilot records attached to the audit documentation as they were freelance pilots for the operator.

1.17.1.3 A Flight Operations Manual (FOM) was recovered on the accident site which was approved on 22 May 2001 by the CAA. On the first page of the manual the following statement was printed:

Airquarius undertakes to conduct all operations in accordance with this operations manual.

1.17.1.4 The operator started off in mid 2000 with three aircraft and 15 pilots on their records in the CAA-file. The management structure of the operator, according to the FOM recovered on the accident site, was basically in the hands of five responsible persons. The Chief Executive Officer, a Responsible Person: Aircraft, a Responsible Person: Flight Operations, the Chief Pilot, the Chief Training Captain and an Air Service/Aviation Safety Officer. The Chief Pilot and the Chief Training Captain positions were held by the same person. In the recovered FOM the Responsible Person: Flight Operations and the Air Service/Aviation Safety Officer's names were changed with a pencil. Accept for the CEO and the Responsible Person: Aircraft all the other names that appear on the list of office bearers were active pilots for the operator. It was noted that several changes were made to the office bearers since the first list's date of 1 November 2000 to the present list in the CAA file dated 14 August 2002. When the investigator contacted the operator to confirm the information he was informed that the office bearers had since then changed again.

1.17.1.5 The operator's pilots appeared to be well qualified when one consider the list of pilot records attached to the 17 January 2002 audit checklist. Nine pilots of the group of fifteen were the holders of Airline Transport Pilot Licenses. Although the two pilots that flew the aircraft on the accident flight were not listed on the Pilot Records list, they were also well experienced with the aircraft according to their pilot logbooks. The operator kept files for both the pilots with their general information on the files. The pilot-in-comand's file included a line check report on it, which was not yet on the co-pilot's file, but the co-pilot had only started to fly for the operator.

1.17.1.6 The operator started with three aircraft on its AOC in 2000 and the amount of aircraft steadily grew to a total of five in January 2002 and to eleven in the beginning of 2004. Most of these aircraft could be considered as large aircraft.

1.17.1.7 The documentation recovered from the accident site and those requested and received from the operator gave the investigator the impression that the operator kept its documentation at a good standard and available to the flight crews.

1.17.1.8 The operator forwarded a copy of the passenger's ticket, which was handed to the passenger, to the investigator. This passenger's ticket was a requirement of the Air Services Licensing Act of 1991. It was interesting to note that the CONDITIONS OF CARRIAGE on the passenger's ticket absolved the carrier from liability for injury or damage to the passenger.

1.17.2 Aircraft Maintenance Organisation

1.17.2.1 In the file containing the information of the aircraft, recovered on the accident site, was an Aircraft Maintenance Organisation (AMO) Approval certificate for the AMO (AMO179) that maintained the aircraft. The approval certificate found in the file had an expiry date of 20 October 2001, but the CAA AMO-file indicated that the AMO had a valid approval certificate at the time of the accident, with an expiry date of 20 October 2002.

1.17.2.2 The AMO was audited by a CAA Airworthiness Inspector on 2 October 2001. The conclusion to this audit was as follows:

Findings and observations were made during the audit. During an audit the process of sampling is used. Bearing this in mind the findings/observations identified during the audit could or could not be the only ones existing in the company. The organisation should follow a process of internal audits to identify if any other non-conformances exist and rectify these. Also, the effectiveness of corrective and preventative actions taken should be reviewed during management reviews.

The audit team will make recommendations to the CAA Engineering Review Board, for its consideration.

1.17.2.3 The review board recommended that the AMO's approval should be renewed and surveillance should be carried out. The AMO's Approval was issued on 21 October 2001 with an expiry date of 20 October 2002. The AMO did not renew their approval after it expired and the responsible manager emigrated.

1.17.3 Civil Aviation Authority

1.17.3.1 Regulation of civil aviation in South Africa is conducted by the South African Civil Aviation Authority (CAA), which was established on 1 October 1998, following the enactment of the South African Civil Aviation Authority Act in September 1998. The Act provides for the establishment of a stand-alone authority charged with the promotion, regulation and enforcement of civil aviation safety and security in South Africa.

1.17.3.2 The creation of the CAA was a product of the Government's new priorities of policy development, economic restructuring, addressing social inequalities and the implementation of a "user-pays" system. Additionally, the previous regulator (the National Department of Transport) had been struggling to fulfil its functions and was operating with decreasing funds, increasing workloads and an inability to attract and retain skilled staff.

1.17.3.3 Surveillance at Operator

The CAA flight operations inspection section inspected the operator on 17 January 2002 and only minor findings and observations were made. Notes were made about the following points:

- No simulator available – all training done on the aircraft
- CRM to be completed by end February 2001
- Responsible person aircraft has been changed. DOT has been advised. On their approval, OPS manual will be submitted for approval.
- The safety plan is acceptable and in place. The safety officer is presently not keeping notes/minutes of safety discussions/ meetings with crew members. There is therefore no record of these discussions/meetings.
- Some of the crew members have CRM + DG training outstanding this is already being rectified. Schedule of booked courses is attached.
- We already have copies of these documents which have not changed, with the exception of passenger ticket, a copy of which is attached.

The recommendation was that the AOC should be issued and the Cockpit Resource Management (CRM) and Dangerous Goods (DG) training should be checked on by the end of February 2002.

No record was found on the CAA operator file that the CRM and DG training was checked at the operator in February 2002. However when the pilot-in-command's pilots file was received from the operator there was evidence that the pilot had completed these training in February 2002. The co-pilot's file also had certificates on it indicating that he had completed these training in the last few months.

1.17.3.4 Surveillance at Aerodrome

The last inspection carried out by the CAA airports section at the George Aerodrome before the accident was on 4 November 2001. Several non-compliances were noted and the aerodrome management was notified about these non-compliances by a follow-up Notification on 12 November 2001. The non-compliances were divided into three different areas namely: Runway approach lights, OHSACT in buildings and Civil. The non-compliances that might have an implication on this accident were:

- The angle's of some of the runway approach lights needs to be checked and set correctly.
- On some of the barrettes the approach lights needs to be removed, cleaned and repainted.
- There are runway lights of which earth wires has corroded to such an extent that it is falling off.

- The white circular band around the windcone to be cleared of soil and vegetation to make it always conspicuous from a distance away.
- Several runway and ILS holding position markings wrong or need painting.

The CAA notification required that rectification of the non-compliances be initiated and where practical possible must be completed by 15 January 2002. A letter dated 2 January 2002 from the aerodrome manager indicated that except for some minor delays all non-compliances were attended to.

The AERODROME LICENCE was issued on 23 January 2002 and was valid from 1 February 2002 to 31 January 2003.

The navigational aids at the aerodrome were flight calibrated on a regular basis as required by ICAO Annex 10, volume 1 and Document 8071, volume 2. The last routine flight inspection of the navigation aids including the ILS of Runway 29 at George Aerodrome was carried out on 9 May 2002 and the systems were found satisfactory. The performance of the navigational aids was monitored by the CAA inspector dealing with navigational aids. Thus the ILS was monitored with relation to the percentage availability, amount of outages and the other parameters discussed in point 1.8 (Aids to Navigation) of this report. These ILS parameters fell within the acceptable limits and were thus not a concern to the inspector.

The ILS systems on both the runways at the George Aerodrome were due for replacement due to the age of the equipment and the performance of the equipment relative to other similar systems in South Africa. The CAA airports inspector tasked with navigation aids provided the investigator-in-charge with a copy of a fax from ATNS head office dated 27 October 1998 with a *Proposed replacement schedule for Instrument Landing Systems.* This proposal was a product of meetings with ACSA, ATNS and CAA representatives about the replacement of ILS equipment. In this proposal the ILS's on Cape Town's Runway 19 and Port Elizabeth's Runways 08 and 26 was indicated as HIGH replacement priority. With the ILS's at George Aerodrome's runways and a few other aerodromes' ILS's as medium replacement priority. A note at the bottom of the proposal indicates that at that time already the type of ILS's at George experienced an average of 16 failures each per year, but the type of ILS's at Port Elizabeth experienced an average of 30 failures each per year.

1.17.3.5 Surveillance at Aircraft Maintenance Organisation

The required CAA surveillance was carried out by the CAA airworthiness inspector at the Aircraft Maintenance Organisation (AMO 179) and no anomalies were noted in this surveillance process.

1.17.4 **Airports Company of South Africa**

1.17.4.1 The Airport Company South Africa (ACSA) is the largest airports authority in Africa. ACSA owns and operates South Africa's nine principal airports, including the three major international airports at Johannesburg, Cape Town and Durban. The other six are domestic airports at Bloemfontein, Port Elizabeth, East London, George, Kimberley and Upington.

Before the formation of ACSA, airports countrywide were owned and operated by the state. Nine airports were transferred to ACSA when the company was officially established on 23 July 1993. ACSA's sole shareholder from that time until partial privatisation was the state, through the Minister of Transport. In April 1998, Aeroporti di Roma, an Italian airports management firm, won a competitive bid to become ACSA's strategic equity partner and bought 20% of the company's shares. The other five empowerment shareholders own a total of 4,22% of the shares.

The navigational aids on the ACSA airports are owned by ACSA, but are routinely and correctively maintained under a contract agreement by ATNS. A program was put in place in 1998 during a consultation process between ATNS, ACSA and CAA to replace the different aging navigation equipment on the ACSA aerodromes. This plan included several ILS's on the nine main aerodromes.

1.17.5 **Air Traffic and Navigational Services**

1.17.5.1 The Air Traffic and Navigational Services Company Limited of South Africa was created as a state owned, limited liability company by the enactment of Act No 45, dated 31 March 1993. The legislation established ATNS as a provider of Air Traffic Control and related services on a commercial "user pay" basis.

The introduction of charges for services provided by ATNS took effect with the vesting of the Company in August 1993. The company took personnel from the South African Government Department of Transport involved in these services into employment with effect from 1 April 1994. ATNS has, since the 1995/96 financial year, operated entirely from revenue generated from its customer base.

Operationally, the mission of the company is discharged in South Africa's continental and adjacent oceanic airspace. The latter comprises the vast area within the boundaries of South Africa's coastal borders – due West (into the Atlantic Ocean) to 10°W longitude, due East (into the Indian Ocean) to 75°E longitude, and along these longitudes due South to the South Pole (excluding the Mauritius FIR which extends to 45°S).

Whilst the ATNS Company is a commercially successful business organization which fully meets the demands and requirements of its customer base, the company retains various links with the state for the purposes of amongst others, responding to economic regulation and setting of service and safety standards.

ATNS entered into a contractual agreement with ACSA on 8 May 2000 to routinely and correctively maintain the navigational equipment on ACSA aerodromes to meet the ICAO Standard Recommended Practices. The contract charges are revised annually at the anniversary of the agreement. Furthermore ATNS advise ACSA on a monthly basis about the performance of the navigational equipment on their aerodromes, with detailed performance statistics against the service agreement.

1.18 Additional Information

1.18.1 The Flight Operations Manual (FOM) of the operator for Part 121 operations was recovered from the wreckage on the accident scene. Included in the FOM as Annexure C, was the Standard Operating Procedures (SOP) for Hawker Siddelley 748 aircraft operated by the operator. Certain parts of the FOM and the SOP, applicable to the accident will be quoted in the next points.

1.18.2 The FOM states that the **pilot-in-command** shall amongst others:

- *be responsible for the safe operation of the aeroplane and safety of its occupants and cargo during flight time*
- *ensure that all operational procedures and checklists are complied with Operations Manual*

The FOM also states that the **first officer/co-pilot** shall amongst others:

- *assist in the safe and efficient conduct of the flight*
- *to carry out such duties concerning the flight, in accordance with the company Standard Operating Procedures, including procedures, limitations and performance as are allocated to him by the pilot-in-command*
- *to confirm the safe navigation of the aircraft, maintaining a continuous and independent check upon both the geographical position of the aircraft and its safe terrain clearance*

1.18.3 With relation to **APPROACH & LANDING MINIMA,** the FOM indicate three main criteria that must be complied with namely:

- Decision Height
- Visual reference
- Required Runway Visual Range (RVR)

Relating to Precision Approaches the minimas for Category II ILS Approaches (procedures for an approach to decision height lower than 200 feet but not lower than 100 feet and RVR of not less than 350 meters), the decision height will not be lower than the most restrictive of the following:

Please see next page

- The minimum Decision Height (DH) specified in the Aircraft Flight Manual if any
- The minimum height to which the precision approach aid can be used without the required visual reference
- The Obstacle Clearance Height/Obstacle Clearance Level for the category of aircraft
- The DH to which the flight crew is authorized to operate
- 100 feet.

The pilots may carry on with the landing phase below the decision height, after the approach once they have attained visual reference with the ground and can maintain it. This could include cues like three consecutive lights of either centre line of the approach lights or some of the other related runway lights. The visual reference must also include a lateral element of the ground pattern.

The required RVR was determined with information from a table. The RVR was related to the category aircraft and the decision height. For the accident type of aircraft the RVR was 300 according to the FOM.

1.18.4 The FOM of the operator indicate the following under the heading “NAVIGATION PROCEDURES” with the sub-heading “Standard Navigation Policy”:

(i) *Company aeroplanes may be fitted with a variety of navigational equipment. Irrespective of the particular fit, however, the general principal for all operations should be that all such equipment is checked for serviceable and normal operations before each flight. Once in flight, the equipment not directly required for navigation along the selected route should be tuned to ground stations within range whose indications will enable the accuracy of the primary aids to be verified, or from which the bearing and distance indications will enable ground-speed checks or ETA adjustments to be made. The routine use of all fitted equipment will ensure that errors in performance or faulty operation may be detected, and rectification arranged at an early stage.*

Reliance should not be placed on information derived from ground beacons until the appropriate coded signal has been identified and confirmed by both pilots……. …..In flight, other available navigation equipment should be selected and used to confirm the accuracy of the primary aid, and to be readily available for use if the primary equipment gives indications of inaccuracy or malfunction. Above all, flight crew members must remain alert to the possibility of errors in programming or performance, and be prepared to revert to the use of raw data provided by such standard VOR, ADF and DME equipment as are available.

1.18.5 Relating to the Ground Proximately Warning System (GPWS) the FOM prescribes that in an event of a GPWS warning during the approach (at any stage), immediately initiate the pull-up procedure. Furthermore the FOM states, it is absolutely vital that the proper pull-up procedure is initiated immediately the warning sounds. The pull-up procedure is described as follows:

The pull-up must be automatic and is commanded thus:
"Pulling-up" *by the pilot flying – or commanded thus:*

"Pull-up" *by the pilot non-flying*

Then simultaneously:

Apply maximum thrust ….. call: ***"MAXIMUM THRUST"***
Overboost (firewall) the engines if ground contact is imminent
Disengage autopilot and autothrottle (if applicable to aircraft type)
Level wings
Rotate aircraft towards a minimum of 15 degrees pitch

Adjust pitch altitude to achieve the best climb angle for the configuration. Always respect the stick shaker.

NOTE: The control input required in respect of rotation rate and pitch angle may, depending on circumstances, need to be a maximum "G" maximum energy manoeuvre. Slow rotation or underpitch is not acceptable.

Monitor vertical speed, pressure altimeter and radio altimeter.
Do not reconfigure flap/gear until ground contact is no longer a factor.
Reconfigure only when appropriate to ensure maximum climb performance.
Continue to climb until:
The GPWS warning stops and it is positively determined that the terrain which caused the warning is no longer a hazard.

Notify ATC, re-check navigation and safety altitudes and evaluate the situation.

1.18.6 Relating to **"Aerodrome and Runway facilities communication and navigational aids"** the FOM stipulate:

Destination aerodromes must be equipped with necessary services, such as ATC, sufficient lighting, communications, weather reporting, navaids and emergency services; and at reporting, navaids and emergency services; and at least one letdown aid (ground radar would qualify), should be available for an instrument approach, the airport should meet the performance requirements applicable at the expected landing weight.

1.18.7 The STANDARD OPERATING PROCEDURES (SOP) of the operator for the Hawker Siddelley 748 aircraft was found in the FOM as Annexure C with the effective date as 1 March 2001. The procedures relating to the approach and landing of the aircraft was as follows:

11.5. APPROACH

At the appropriate stage of the descent the PF (pilot flying) shall call for the approach checks. The PNF (pilot non-flying) shall read the checklist. Both pilots shall complete the checks. The PNF will call approach checklist completed.

With each flap selection, the PNF will cross check speed and if correct will action the request, monitor the movement and verbally confirm the selection made i.e. "15° flap selected running light out".

If 22½° flap is scheduled for landing. The approach is to be flown with 15° flap.

*Water Methanol to be switched **on** for all approaches.*

THE INSTRUMENT APPROACH

Monitored Approach

*It is company policy for a monitored approach to be performed when the cloud base is 500 ft or less and/or visibility is less than 2 km. In a monitored approach, the Captain monitors the approach while the F/O flies the aircraft on instruments. At the decision height, the Captain makes the decision regarding landing or executing a missed approach. If a **'MISSED APPROACH'** is called by the Captain, the F/O will execute the missed approach maneuver. If the Captain has visual contact, he shall call out **'I HAVE CONTROL'** and perform the landing.*

For the precision approach, make the interception angle for the localiser no more than 30° if possible. From this point onwards standard call-outs will apply to touch-down.

Start the intercept with 15°. FLAP and speed 140 kts. Maintain this until one dot below the glide slope. Extend the gear and, on glide slope intercept, extend 22½° FLAP. Maintain 120 kts to the outer marker. At the outer marker reduce to the appropriate speed and only if visual extend full flap at 300 ft.

Standard "Call Outs"

11.6. GO AROUND

Once started, a Go Around must be completed, by applying full power, reducing flap 1 notch simultaneously rotating the aircraft smoothly into the initial climb attitude and retracting the gear. Commence a progressive acceleration. As long as speed VAT + 10 or above, select or maintain flaps at appropriate approach flap setting.

When the speed is 110 kt IAS, select (or maintain) 15° flap.
Accelerate to achieve 130 kt IAS. At or above 400 ft. Select flaps up, and reduce to climb power. Climb at 130 kt IAS to 1500 ft. AGL and then continue as for take-off.

12. LANDING

It is recommended that the landing checklist is completed no later than 1000 ft on final approach and is normally initiated when the landing gear is called for, i.e. ***"LANDING GEAR DOWN AND LANDING CHECKS".***

The Captain makes all landing gear selections. Both pilots will monitor gear selection and indication.

When selecting 22½° flap, *the landing lights should be selected at the same time.*

Use 22½° flap *for landing, only when necessitated by landing WAT limits.*

Select 27½° flap *when committed to land. Aim to achieve VAT (+1/3 wind speed if necessary) at the threshold. If the airspeed at this point exceeds the VAT (or adjusted VAT) by more than* ***15 knots*** *a go-around* ***must*** *be carried out on a limiting runway.*

If gusty conditions prevail increase VAT by 1/3 reported surface wind speed plus gust, up to a maximum of 15 knots.

1.18.8 The STANDARD CALL OUT'S HS748 in the SOP's for the **Descent and approach** were as follows:

Descent and approach	At : 1000ft above initial approach altitude or circuit height	"1000ft above initial" or circuit
	Intercepting localiser	"localiser alive"
FINAL	Intercepting glide slope	Glide slope alive One dot
	Final fix inbound (altimeter instruments and flags cross-check)	"Outer Marker", "VOR". Time etc. .... Feet altimeters and instruments cross-checked
	500ft above field elevation (altimeters, and flags cross-checked)	"500 feet in the slot"
APPROACH	After 500 ft above field elevation	Call out significant deviations from programmed air speed, descent and instrument indications
	100ft above minimums (DH or MDA)	"100 feet to minimums"
	Minimums	"minimums" "contact" or "go around"
	Time to missed approach point (MAP) elapsed	"time" "contact" or Go around"

1.18.9 An independent investigator well known for his knowledge on human factor aspects were requested to prepare a short paper on the subject of COCKPIT GRADIENT and extracts from this paper is as follows:

The Cockpit Gradient is a term used to describe the relationship between Captain and the cockpit crew. It has an influence on communications, assertiveness, teamwork, situational awareness and safety. The gradient is referred to as being steep or shallow. A shallower gradient would be a more casual, open, easier to speak up in type of cockpit. The reason for a steep or shallow cockpit gradient seems best found in culture and training.

TEAMS

Cockpit crews are teams, and the captain is the team leader. We must not forget the fact that teams also operate in an organizational context. The aspects that relate to a safe operation, from the pilots side, are often influenced by their teamwork as well as their organizational culture and context. We know aspects such as decision-making, errors, situational awareness, and communications and resource management, to name a few, influence performance and the safe outcome of a flight. One can see how these relate to the cockpit gradient as well. It is also noted that we need mutual situational awareness. That is the captain also needs to be on par as to the actual state and position of the aircraft, and to do this it may mean the FO has to speak up, *or communicate in a way the captain will understand. This is more difficult in a steep cockpit gradient climate. A shallow cockpit gradient should enhance communications, which should help with the sharing of information, establishing interpersonal relationships, establishing predictable behaviour, maintaining attention to the task and monitoring as well as being a good management tool. All these are necessary to manage the risks in aviation, in the cockpit or between management and pilots.*

1.19 Useful or Effective Investigation Techniques

1.19.1 No such techniques were employed.

2. ANALYSIS

2.1 Flight operation:

2.1.1 The decision to schedule the aircraft's arrival at George Aerodrome before the official hours of operation of the ATC was an operational decision by the operator relating to the required service, but the flight crew accepted that they will need to approach and land at an aerodrome where there will be no ATC service in operation. The implication of no ATC on duty in the control tower was not so much the unmanned field procedures for air traffic reporting, but it was that there would be no-one to monitor the serviceability of the ground based approach instrumentation. The warning panel next to the ATC in the control tower warn about any of the beacons or the ILS systems that become unserviceable and then the ATC could warn the pilots about the situation during the communications with the pilots.

2.1.2 If one considers the conversation between the pilots as recorded by the CVR, it suggests that a Monitored Approach procedure was followed by the pilots with the co-pilot flying and the pilot-in-command monitoring the situation. This procedure was followed although the meteorological conditions were technical better than the cloud base and visibility as indicated in the procedure.

2.1.3 The pre-approach briefing was not available on the CVR recordings, but according to the information available on the different recorders and documentation recovered, the pilots planned an approach according to the VOR DME ILS procedure on Runway 29 at George. The pilots initially joined the approach procedure according to the plan and flew the procedure as prescribed. During the last outbound leg before the final approach (on the procedure as a 112° heading), the co-pilot's remark about the aircraft tracking 101°, should have given them some indication of the wind strength. It was possible that the co-pilot noticed the effect of the wind probably by relating the heading steered to the track as indicated by the Garmin GPS100, but did not complete his observation or commented about it any further to the pilot-in-command.

2.1.4 The aircraft must have drifted a fair amount in a Northerly direction during the last outbound leg. The pilots turned left at the 9nm DME position, steered the aircraft towards Runway 29 and eventually managed to pass over aerodrome as observed by several witnesses. The pilot-in-command selected the ILS frequency on both VHF navigation systems and did not obtain the aural identification coded signal. The FOM clearly state that information derived from ground beacons should not be relied upon until the appropriate coded signal has been identified and confirmed by both pilots. In this case the pilot-in-command selected the frequencies and turned the volume up, but heard no indication signal. No recording on the CVR suggest he questioned the serviceability of the ILS at that time and the co-pilot did not question the pilot-in-command's actions or the serviceability of the ILS either.

2.1.5 It was however a point of concern that the ILS was most probably off (as indicated by the lack of the identification signal), at the time the approach was flown, but judging by the comments of the pilots, the localiser and glide slope flags in the aircraft flight instrumentation did not indicate the lack of the signal consistently. There were intermittent indications on the aircraft instrumentation that the ILS was operational. This probably made the pilots to believe that it might have been the coded aural signal that was malfunctioning, although they did not mention it. Only shortly after the go-around call was made, did the pilot-in-command suggest that the ILS had failed. However when they turned left again after the outbound leg of the missed approach procedure, in what they had perceived as a final turn to intercept the ILS again, the frequencies were again changed to the ILS frequencies on both VHF navigational systems that they had perceived to have failed on them a few minutes ago.

2.1.6 The pilots could have kept one of the VHF navigation systems on the VOR (GGV) frequency and cross check their progress by relating the aircraft's heading to the appropriate VOR radial. There were the two marker beacons, namely GG and GL too, that the pilots could have used to reference themselves during the final approach. One of the ADF units was tuned to the frequency of GL, but no indication on the CVR was found that the pilots used this information available on the RMI instrument.

2.1.7 During the short finals phase of the first approach for landing, the pilots had glide slope warning flags displayed on their instrument displays. The co-pilot mentioned that he saw the aerodrome and that they were "miles too fast". The pilot-in-command assessed the situation and called for a missed approach. His decision for the missed approach procedure was obviously based on the warning flags displayed and that he did not have the runway in sight to such an extent that in his opinion a safe landing could be executed. The high and fast condition of the aircraft might have contributed to his decision to execute a missed approach procedure.

2.1.8 The pilots did not comply with the approach procedure when the missed approach was called for. They did not fly the aircraft on a 292 VOR radial to the 8nm DME position and then returned to the GGV beacon. Instead the pilot-in-command instructed the pilot flying to turn the aircraft back to a heading of 112° (out-bound leg). The co-pilot flew the aircraft into a steep turn reaching up to 43° bank angle according to the FDR, past the heading and when the pilot-in-command pointed it out to him he corrected it immediately by steering the aircraft back to a heading of approximately 105° on the outbound leg. One could interpret this left turn as an attempt from the co-pilot to comply with the missed-approach procedure and to return to the GGV beacon, but he put the idea aside when the pilot-in-command commented about the aircraft flying "through" the heading. The co-pilot did not question the pilot-in-command about this deviation from the approach procedure.

2.1.9 The plot of the flight path could at best be considered as an effort to visualise the path that the aircraft had flown in a horizontal plane from the most probable point where the missed approach was initiated, namely the NDB beacon GL to the accident site. The recorded surface wind was 270° at 14 knots, but it was apparent from a comment of the co-pilot that they were tracking about 10° towards the North of their intended track. This suggested that a much stronger wind factor was prevailing at higher altitudes and the final average wind factor used to plot the flight track was 225° at 45 knots. The calculated wind factor gave the impression that it was too high, but when the probable flight path was plotted with these values, the track started and ended at the correct positions which suggests that these average wind values were reasonably accurate. The second point that needs to be kept in mind was that the heading and speed information used as basis to plot the flight track was obtained from the FDR and the FDR obtained the heading information from the captain's HSI system. If the data from this HSI system was inaccurate, maybe due to the condition of the directional gyro, the plot will obviously be relatively inaccurate.

2.1.10 Referring to the plot of the probable flight path (inaccurate as it might be), it suggests that the aircraft had passed over the 112 VOR radial very soon after the turn mentioned in paragraph 2.1.6 above. This was most probably due to the wind factor (keep in mind that according to the FDR the aircraft had already reached about 4000 ft above MSL) and the position of the aircraft nearly flying over the town of George was confirmed by an eyewitness. No information on the CVR suggests that the pilots were aware that they had drifted so severely in a Northerly direction and the pilot-flying steering the aircraft on heading of about 103° on the outbound leg worsen the situation of the Northerly drift towards the mountains significantly. It is however possible that he could have obtained erroneous heading information from the HSI due to the directional gyro's condition and the steep turn executed after the go-around. The recorded FDR heading information was obtained from the pilot-in-command's side of the directional instrumentation and it is a mystery why he did not correct the pilot flying to steer a heading of 112° as they intended to. On the other hand they were already on the wrong side of the 112 VOR radial, which they did not expected and seemed to have not noticed that.

2.1.11 The procedures manual prescribe that immediate action should be taken when a GPWS warning is heard. The pilots had lost their situational awareness at the time the warning was issued and did not react accordingly. They were under the impression that they had exceeded the 9nm DME point before the turn and had just flown too close to the mountains on the Eastern side. The question still stand if they had applied the procedure as described in the FOM when they received the first GPWS warning if they would have been able to avoid the accident? At the first GPWS warning the aircraft was heading in a Northerly direction at an altitude of about 2500 feet above MSL. To climb clear of the mountains from that position on a straight out heading was a debateable point.

2.1.13 No mention was made to the second GPS system and it was possible that this system was either not used by the pilots or not even switched on, although it could have provided them with valuable position information.

2.1.12 From a human factors point of view, one need to remember that there was a highly experienced pilot-in-command and not so experienced co-pilot in the cockpit, which in itself was a good point. The co-pilot however had not been flying this type of aircraft for about two months, after the operator both the pilots flew for, suspended operations. This was his first flight with the present operator as a freelance pilot. One could derive from the CVR recorded conversations that the relationship between the pilots was indicative of an instructor-student relationship more than as two pilots checking and rechecking each other. Although the co-pilot was qualified, experienced and current to fly the aircraft he depended totally on the pilot-in-command's experience. On the other hand the pilot-in-command was the absolute leader in the cockpit and was a fine instructor. The co-pilot accepted his authority without questioning it. This cockpit climate was indicative of a steep gradient type climate and some of the risks of this type of cockpit climate are decision-making errors and situational awareness which was the case during the events that lead to this accident.

2.1.13 The time of the day when the accident happened should also be taken into consideration. According to the pilot-in-command's wife he slept well before the flight, but no information was available about the co-pilot's rest before the flight. The human body is not at its best at that time of day especially after it was working from midnight to the morning. Although the body is not necessary physically tired, the person's concentration is not as it was when he woke up and that is usually the time when the landing needs to be carried out.

2.2 **Aircraft:**

2.2.1 In general the aircraft was maintained according to the approved maintenance schedule for the aircraft however a few small points of concern were identified. The flight folio which is the document that should indicate to the pilots that the previous recorded defects were taken care off was not properly kept in the sense that certain defects were entered, but no entries were made in the "action taken" column. This suggests that although some action might have been taken to rectify the defect, this was not properly documented and communicated to the flight crews. They should thus not accept the aircraft for a flight unless the previous defects were properly certified as some action was taken. With these action taken entries not in the flight folio the aircraft could technically be considered as not airworthy. On the other hand if a recorded defect or a similar defect was recorded soon after the initial defect it would suggest that there was still a problem with the system that gave rise to the initial defect.

2.2.2 Several of the recorded defects (refer to 1.6.3) were related to the heading of the aircraft for example on 29 March 2002 a defect was recorded where the HSI was indicating a 10° difference from the actual heading. No entry was made in the flight folio relating to action taken about this defect. The ground engineers generally take care of these types of defects, but they generally sign it off on their normal maintenance documents and do not sign it off in the flight folio, because the flight folio is kept in the aircraft. It seems that the documentation relating to this was not kept by the avionics AMO. Without the knowledge of what actions were taken about these defects, it was thus impossible to understand what effect these defects might have had on the operation of the directional instrumentation of the aircraft at the time of the accident. However some of these defects could have had indicated a directional gyro problem, unfortunately the second directional gyro was not available for testing. On the other hand if there was a defect on one directional gyro it would cause a difference in reading between the HSI and the RMI and the pilots would have probably noticed it. If this had occurred during the high bank rate turn it was possible that the pilots might have not noticed it under the work load at the time. Cross checking the HSI with the magnetic compass was another method of checking the accuracy of the HSI system. Another method was to relate the heading to the indications on the GPS, which was also problematic because the GPS indicated track direction (remember the comment on the CVR from the co-pilot about them tracking 101°). This was the heading of the aircraft and the wind effect combined.

2.2.3 According to the documentation it seems that the compass swing was not carried out when it was due to be carried out before or on 23 January 2002. From an airworthiness point of view, if the compass swing was not carried out, it could impact negatively on the serviceability of the aircraft. The compass systems of the aircraft could have became out of adjustment over the period of one calendar year and thus the requirement to check the accuracy of the heading indication instrumentation. However it is a debateable point if it was possible that if this compass swing operation was carried out, that the defective directional gyro would have been identified. Furthermore the pilots could have easily checked the difference in heading readings between the HSI and RMI indicators and the standby-compass and GPS fitted.

2.2.4 No documentation was available in the airframe logbook about when the directional gyro was fitted and or if any repairs was carried out on the directional gyro. It would be impossible to determine who removed the two wires to put the levelling torque motor out of operation. The gyro would not have passed the release tests of the manufacturer, thus it could be accepted that the wires were disconnected at a later stage. The gyro's balance was probably just a small bit out which caused it to erect and operate without becoming suspect by the crews.

2.2.5 The HSI's and the RMI's operated across, this means the HSI's heading information of the first pilot was displayed on the second pilot's RMI and in the same way the second pilot's HSI's heading information was displayed on the first pilot's RMI. When the first pilot's instrument panel was recovered the HSI indicated 285° and the RMI indicated 310°. On the second pilot's panel the HSI indicated a heading of 287° while the RMI also indicated a heading of 287°. If the second pilot's HSI also indicated a heading of 310° then it would have suggested that they were related to the defective directional gyro, but only the RMI on the first pilot's panel indicated a totally different heading. It could thus be accepted that the heading indication on the first pilots RMI was unreliable. It is possible that the instrumentation system had accepted the flux detector's information, because it was not slaved to directional gyro. On the other hand the serviceability of the flux detectors could not be determined either.

2.3 Meteorological Conditions:

2.3.1 The aerodrome was to a certain extent covered by scattered clouds and rain. Several witnesses saw the aircraft and even the pilots commented at different times that they saw some ground, but it was not dear. The cloud cover to the North of the town of George was such that the mountains were covered and the witnesses saw the aircraft disappear into the clouds towards the mountains. The pilots had a weather report with them and were aware that they would have to carry out an instrument approach. There was also a possibility of icing, but the possible icing conditions most probably did not have a bearing on the probable cause of the accident.

2.4 Approach facilities of the Aerodrome:

2.4.1 As far as could be determined, except for the ILS of Runway 29 at George the rest of the approach ground based equipment operated satisfactorily. The reason for the failure of the ILS at the time of the accident was not determined. The technician arrived at the facility and heard the audio warning sound, he then reseted the system and it operated satisfactorily. The rain could have had an effect on it, but if one consider the history of both the ILS's at George Aerodrome it should have given pointers to the fact that these ILS's were longer in operation than the internationally accepted service-life of such systems. The systems were periodically flight tested as required and passed the tests every time, but the reliability of the ILS could not be determined during these tests, that information was only available by the history records that was kept by ATNS for each ILS in the country. If one considers that the ILS of Runway 29 at George was about 99.7% available, much more than the referred 97.5% it seems that it was still performing within acceptable limits. It was however very interesting that if the ILS's in the country was considered in all the relevant aspects (outages, availability, adjustments and age), that the two ILS's at George were the worst performers and thus the decision to replace them ahead of the other ILS's.

2.4.2 After considering the above discussion one need to now consider that the pilots approached the runway in good faith that all the approach facilities were operational. When they tuned in on the ILS and did not hear the audio identification code, they should have disregarded the ILS as unserviceable. It did however seemed that there was some indications that the system was operational. According to the CVR information they had unserviceable flags and then it disappeared for a while and it was only during the short final approach that they re-appeared. The correct procedure at the end of the day was to consider the ILS as unserviceable and carry out the approach with the aid of the other beacons. The disappearance and re-appearance of the warning flags could suggest that the ILS was in the process of switching from the one transmitter to the standby transmitter and then when the signal was still outside the monitored parameters it switched it off.

2.4.3 Records of meetings with representatives of ACSA, ATNS and CAA relating to the replacement of the ILS's were dated as far back as 1998. The process however took several years to eventually come in to being and several of the ILS's in South Africa was replaced in the months after the accident.

3. CONCLUSION

3.1 Findings

3.1.1 Both the pilots were the holders of valid pilot licenses and were rated to fly the type of aircraft under instrument meteorological conditions.

3.1.2 A steep authority gradient cockpit climate existed between the two pilots with the extensively experienced pilot-in-command in an instructor role and the less experienced co-pilot following the pilot-in-command without questioning him.

3.1.3 The aircraft was generally maintained according to the approved maintenance schedule of the aircraft.

3.1.4 There were several defects relevant to the serviceability status of the navigation equipment of the aircraft entered in the flight folio which were not cleared. This rendered the aircraft technically unairworthy.

3.1.5 According to the flight data recorder, cockpit voice recorder and evidence on the accident scene, the engines performed satisfactory with no cause of concern.

3.1.6 Only one of the two directional gyroscopes were recovered and it was discovered during an inspection of the component, that this directional gyroscope had several defects of which the two wires that were found disconnected was the worst. This caused the levelling torque motor not to operate.

3.1.7 The vertical gyroscope and related indicators were also inspected and no serious anomalies were found. The flux detector was damaged and could not be tested.

3.1.8 A shelf life was attached to the gyroscopes, but once fitted to the aircraft they become on-condition items. No definition of “on-condition” items could be found in the aircraft’s approved maintenance schedule.

3.1.9 The compass check swing was not carried out before or on 23 January 2002 as required.

3.1.10 The aircraft was most probably loaded correctly and its mass and balance was within limits.

3.1.11 It was impossible to download the data from the second Bendix/King GPS, which was fitted to the aircraft without a modification approval, but was probably not used either.

3.1.12 The pilots were in possession of a weather report applicable to the time of the flight.

3.1.13 The George Aerodrome was covered with scattered and broken clouds during the approach of the aircraft and there was also clouds covering the mountains to the North of the town of George.

3.1.14 Although the recorded surface wind was 270°/14knots, there was a strong wind blowing at a higher altitude. The calculated wind strength was 225°/45knots.

3.1.15 The pilots were in possession of a copy of the appropriate approach procedure chart for the Runway 29 at George Aerodrome. They attempted to fly the aircraft according to this approach procedure until they came to the point where they had to carry out a missed approach and then did not follow the approved procedure for a missed approach.

3.1.16 The warning/switch board in the tower, gave an indication of the serviceability of the ground based approach instrumentation, but this could only be communicated with the pilots if the ATC was on duty.

3.1.17 When the ATNS technician came on duty the morning of the accident he found the ILS of Runway 29 had become unserviceable during the night. He reset it and no cause for the ILS to become unreliable was reported.

3.1.18 The ILS equipment for Runway 29 at George Aerodrome was 29 years old and according to flight calibration and history records it was performing within acceptable limits.

3.1.19 The CVR was downloaded and the recordings clarified the circumstances of the flight substantially.

3.1.20 The FDR was downloaded and although only basic data was recorded, it provided the needed information to be able to plot a probable flight path of the aircraft during the approach and missed approach procedure.

3.1.21 From the plot of the flight path and the CVR recordings it could be determined that the pilots did not comply with the missed approach procedure as described on the approach plate. This resulted in them loosing their situational awareness, furthermore they disregarded the warning flags which indicated that the facility was not reliable.

3.1.22 The aircraft impacted the side of the mountain with a small nose up and a small right-hand wing low attitude. The aircraft was destroyed during this impact.

3.1.23 The pilots and passenger suffered multiple injuries during the impact.

3.1.24 The accident was considered as unsurvivable.

3.1.25 The operator was licensed to carry out the flight and was the holder of a valid Air Operating Certificate.

3.1.26 The Aircraft Maintenance Organisation was the holder of a valid approval certificate.

3.1.27 The CAA's different sections had carried out the required surveillance at the different organisations.

3.1.28 The pilots did not comply with the FOM procedures relating to the identification of navigation aids and the ground proximity warning system.

3.2 Probable Cause/s

3.2.1 The crew deviated from the prescribed missed approach procedure during an attempted Instrument Landing System landing on Runway 29 at George in Instrument Meteorological Conditions and lost situational awareness aggravated by the presence of strong upper South-Westerly winds. They allowed the aircraft to drift off course resulting in a controlled impact with terrain 6.7 nm North-East of the aerodrome.

3.2.2 A significantly contributing factor was the weather conditions that prevailed in the area during the aircraft's approach to land and missed approach.

3.2.3 A further contributing factor to the accident was the intermittent unreliability of the Instrument Landing System of Runway 29 at the time the aircraft commenced its approach to land at George Aerodrome and how the pilots reacted to this situation.

3.2.4 Another contributing factor was the directional gyro that was not serviceable and could have provided the pilots with faulty directional information.

3.2.5 It should also be considered that the uncleared defects could have contributed to the probable cause of the accident.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that the maintenance schedules for the remaining HS748 fleet operating in South Africa should be reviewed to ensure that the flight instrumentation that are maintained under the on-condition provisions be maintained according to the manufacturer's provisions. This could entail that a reliability program be developed for such items.

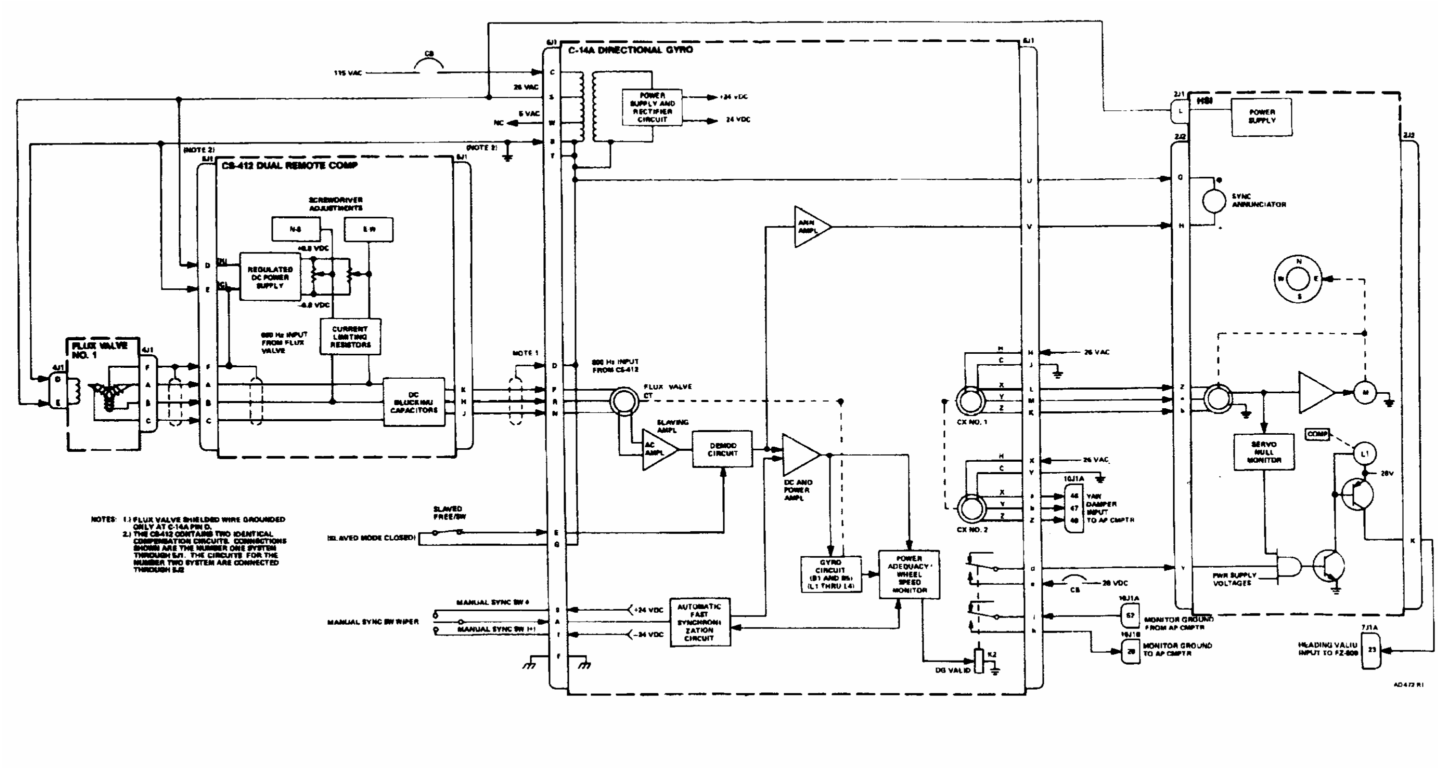
4.2 It is recommended that the Instrument Landing Systems for both the runways at George Aerodrome should be replaced, considering the history, age and reliability of these systems. This has since been attended to.

4.3 It is recommended that the Airports Company of South Africa with the co-operation of the Air Traffic and Navigation Services consider the installation of a radar system to guide aircraft to land safely at the George Aerodrome.

5 APPENDICES

5.1 Appendix A: (Compass System)

1. C-14A Compass System Functional Description (See figure 212.)



Basic power for the system is the 115V 400 Hz input to the C-14A Directional Gyro. This provides internal power for the gyro and a 26 Vac power output for the flux valve and CS-412 Dual Remote Compensator.

The flux valve senses the horizontal component of the earth's magnetic field. Using the 26 Vac reference signal, it provides an output signal that represents aircraft heading in the earth's magnetic field. This signal will provide a command to keep the rotor spin axis of the gyro aligned to magnetic north in the slaved mode.

The CS-412 Dual Remote Compensator compensates the flux valve for single-cycle (hard iron effects) by biasing the flux valve coils with a low level dc voltage. The procedure for adjusting this level of compensation is discussed in the GROUND CHECK procedure. Two independent compass systems can be compensated by the CS-412.

In the slaved mode of operation, the directional gyro is slaved to a position relative to the magnetic heading reference as supplied by the flux valve and the CS-412.

The directional gyro receives an input from the flux valve through the flux valve control transformer (FVCT). The output from the FVCT is tuned to 800 Hz and applied to the slaving amplifier. The slaving amplifier output is then applied to the precession coils in the gyro and to the annunciator.

Slaving of the directional gyro is accomplished by supplying current flow through precession coils affecting the sensitive axis of the gyro. The MANUAL SYNCHR0NIZATION switch is used to engage fast slaving of the directional gyro. When fast slaving is engaged, the slaving rate is increased from approximately 3.5 degrees per minute to approximately 30 degrees per minute. Once engaged, fast slaving continues until the compass card of the HSI indicates within 4 degrees of actual heading, at which time the normal slaving rate is assumed.

In the free mode of operation, magnetic information from the flux valve and CS-412 is disabled in the gyro and no slaving is performed. The directional gyro provides compass information as a product of the position of the aircraft with reference to the position of the unslaved gyro. As no slaving is performed, the displayed heading information is subject to error as the result of free gyro drift.

During operation of the directional gyro, any of the following conditions will cause a loss of the heading valid signal supplied to the HSI and the monitor ground to the Autopilot Computer:

(a) low voltage to the directional gyro power supply

(b) improper wheel speed of the spin motor

(c) fast sync (manual synchronization)

The HSI receives three-wire compass information from the C-14A and uses it to move a compass card to the proper location. The three-wire compass information is connected to the stator of a heading control transformer. As a change in compass information occurs, the stator and rotor of the synchro are no longer positioned for a null and a displacement signal is created in the rotor. This displacement signal is then amplified and used to drive the dc torquer motor. The motor is mechanically connected to the rotor of the heading synchro, so as the compass card reaches its proper position, the rotor is moved to null the displacement signal and the compass card stops.

Synchronization between the flux valve and the actual heading of the aircraft is indicated by the compass synchronization annunciator of the HSI. When the + is in view on the annunciator, the compass card is rotating in the counterclockwise direction (actual heading greater than indicated). When the • is in view, the compass card is rotating in the clockwise direction (actual heading less than indicated). When synchronized, the annunciator slowly oscillates between the + and the •.

The HDG flag in the HSI will be out of view when the servo null monitor is below its threshold (compass card accurately represents aircraft headings), the internal power supply is at its proper level, and the 28 V dc heading valid from the C-14A is present. A 28 V dc heading valid signal is applied to 2J2-X and to the FZ-500, when the HDG flag is out of view.

2. Functional Operation of Sperry C-14A Directional Gyro

The output from the FVCT is tuned to 800 Hz and applied to the slaving amplifier. The slaving amplifier output is then applied to the precession coils in the gyro and to the annunciator.

The precession coils located on the outer gyro gimbal receive the error signal from the slaving amplifier. The current through these coils creates a field which reacts with the permanent magnet located on the inner gyro gimbal. This reaction creates a torquing force which precesses the gyro in the vertical axis.

The directional gyro contains an electrically-driven gyro that is gimbaled with full freedom about the outer (vertical or azimuth) axis, and with ±85 degrees of freedom about the inner (horizontal) axis.

The gyro is maintained in a level position by a leveling torque motor located on the outer gimbal case. This leveling torque motor is operated by controlled voltages routed through a split ring leveling switch located on the inner gimbal. The controlled voltages for the leveling action are obtained from the split-phase gyro motor. The leveling torque motor is geared to the gimbal so that the torque is applied to maintain the gyro wheel level with respect to the gyro case.

The automatic synchronizer causes the directional gyro to automatically align itself to the magnetic heading of the airplane at a fast slave rate during the start-up initialization cycle. This automatic synchronization can be manually initiated by a cockpit-mounted, fast synchronization and manual slew switch.

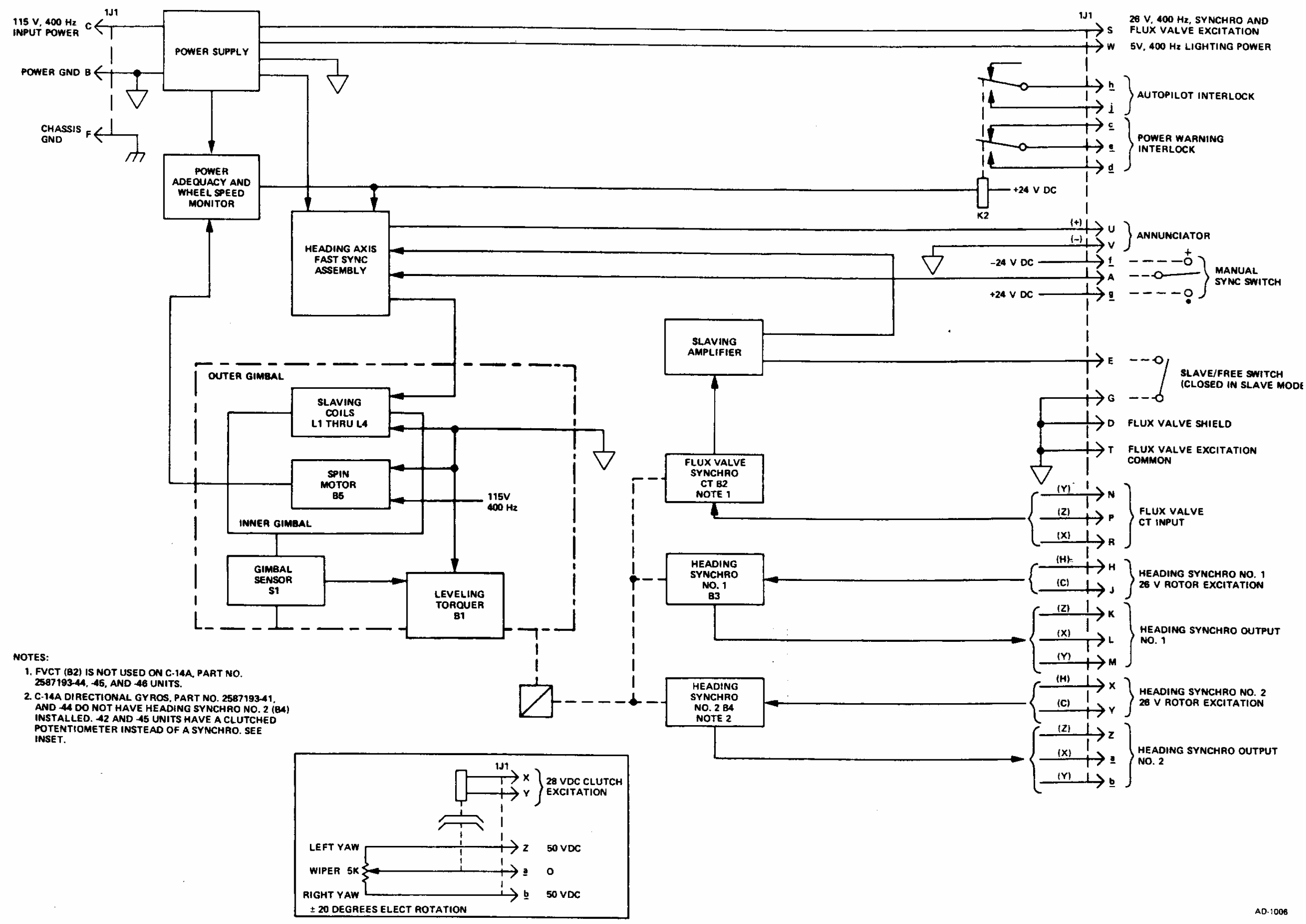
NOTE: The C-14A, Part No. 2587193-47 contains a circuit (M1) that allows the manual fast sync switch wiper to be grounded externally instead of being connected back to the unit connector pin 1P1-A as required in all other C-14, A or D units.

The power adequacy and wheel speed monitor continually monitors the following:

- Gyro motor control field voltage.
- Loss of electrical power to the system.
- Fast synchronization operation.
- Gyro spin motor speed.
- Power supplies.

In addition, the *C-6* indicator servo loop excitation is monitored when operating the system with the C-6 indicator.

The power requirements and bias voltage levels for the systems' operation are obtained from the power supply.



C-14A Directional Gyro
Block Diagram
Figure 1-3

Page 1-9/1-10
Nov 15/80

5.2 Appendix B: (Instrument Landing System)

A. GENERAL DESCRIPTION

Instrument landing system (ILS) facilities are a highly accurate and dependable means of navigating to the runway in IFR conditions. When using the ILS, the pilot determines aircraft position primarily by reference to instruments. The ILS *consists of:*

a. the localizer transmitter;

b. the glide path transmitter;

c. the outer marker (can be replaced by an NDB or other fix);

d. the approach lighting system.

ILS is classified by category in accordance with the capabilities of the ground equipment. *Category* I ILS provides guidance information down to a decision height (DH) of not less than 200 ft. Improved equipment (airborne and ground) provide for *Category* II ILS approaches.

A Decision Height (DH) of not less than 100 ft. on the radar altimeter is authorized for Category II ILS approaches.

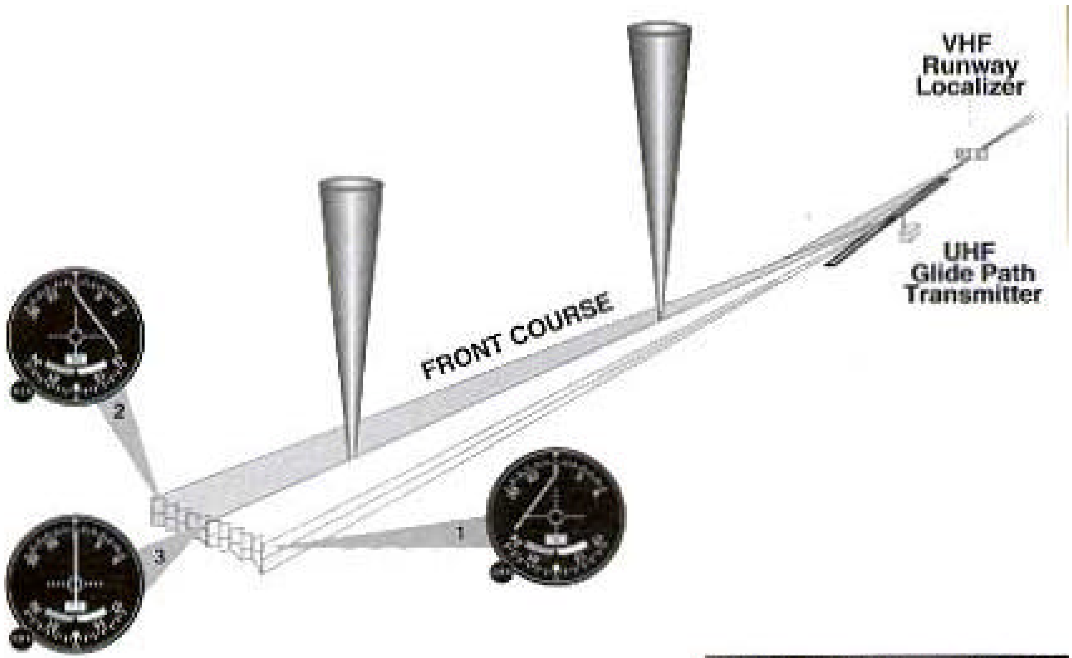
The ILS provides the lateral and vertical guidance necessary to fly a precision approach, where glide slope information is provided. A precision approach is an approved descent procedure using a navigation facility aligned with a runway where glide slope information is given. When all components of the ILS system are available, including the approved approach procedure, the pilot may execute a precision approach.

B. LOCALIZER

1. GROUND EQUIPMENT: The primary component of the ILS is the localizer, which provides lateral guidance. The localizer is a VHF radio transmitter and antenna system using the same general range as VOR transmitters (between 108.10 MHz and 111.95 MHz). Localizer frequencies, however, are only on odd-tenths, with 50 kHz spacing between each frequency. The transmitter and antenna are on the centerline at the opposite end of the runway from the approach threshold.

The localizer *back course* is used on some, but not all ILS systems. Where the back course is approved for landing purposes, it is generally provided with a 75 MHz back marker facility or NDB located 3 to 5 NM from touchdown. The course is checked periodically to ensure that it is positioned within specified tolerances.

2. SIGNAL TRANSMISSION: The signal transmitted by the localizer consists of two vertical fan-shaped patterns that overlap, at the center (see **ILS Localizer Signal Pattern** figure, below). They are aligned with the extended centerline of the runway. The right side of this pattern, as seen by an approaching aircraft, is modulated at 150 Hz and is called the "blue" area. The left side of the pattern is modulated at 90 Hz and is called the "yellow" area. The overlap between the two areas provides the on-track signal.



ILS LOCALIZER SIGNAL PATTERN

The width of the navigational beam may be varied from approximately 3° to 6°, with 5° being normal. It is adjusted to provide a track signal approximately 700 ft wide at the runway threshold. The width of the beam increases so that at 10 NM from the transmitter, the beam is approximately one mile wide.

The *localizer is identified* by an audio signal superimposed on the navigational signal. The audio signal is a two-letter identification preceded by the letter "I", e.g., " I-OW ".

The *reception range* of the localizer is at least 18 NM within 10° degrees of the on-track signal. In the area from l0° to 35° of the on-track signal, the reception range is at least 10 NM. This is because the primary strength of the signal is aligned with the runway centerline.

The localizer system consists of two transmitters with the one transmitter active and the other transmitter on stand-by. The monitor system is an independent system which monitors the localizer radiated course signal and is positioned a predetermined distance from the localizer antenna. The monitor checks the integrity of the localizer signal and if an error in the signal is detected then the system switch over to the stand-by transmitter and a “change-over” is logged. When the integrity of the localizer radiated signal is still not to the monitor’s set standards the localizer system will shut-down and a “shut-down” will be recorded. The system will activate an alarm which usually includes an audio alarm. To put the localizer system back into operation it needs to be reset.

3. LOCALIZER RECEIVER: The localizer signal is received in the aircraft by a localizer receiver. The localizer receiver is combined with the VOR receiver in a single unit. The two receivers share some electronic circuits and also the same frequency selector, volume control, and ON-OFF control.

The localizer signal activates the vertical needle called the *track bar* (TB). Assuming a final approach track aligned north and south (see **ILS Localizer Signal Pattern** figure, above), an aircraft east of the extended centerline of the runway (*position 1*) is in the area modulated at 150 Hz. The TB is deflected to the left. Conversely, if the aircraft is in the area west of the runway centerline, the 90 Hz signal causes the TB to deflect to the right *(position 2*). In the overlap area, both signals apply a force to the needle, causing a partial deflection in the direction of the strongest signal. Thus, if an aircraft is approximately on the approach track bur slightly to the right, the TB is deflected slightly to the left. This indicates that a correction to the left is necessary to place the aircraft in precise alignment.

At the point where the 90 Hz and 150 Hz signals are of equal intensity, the TB is centered, indicating that the aircraft is located precisely on the approach track *(position* 3).

When the TB is used in conjunction with the VOR, full scale needle deflection occurs 10° either side of the track shown on the track selector. When this same needle is used as an ILS localizer indicator, full-scale needle deflection occurs at approximately 2.5° from the center of the localizer beam.

Thus the sensitivity of the TB is approximately *four times greater* when used as a localizer indicator as opposed to VOR navigation.

In the localizer function, the TB does not depend on a correct track selector setting in most cases; however, the pilot should set the track selector for the approach track as a reminder of the final approach.

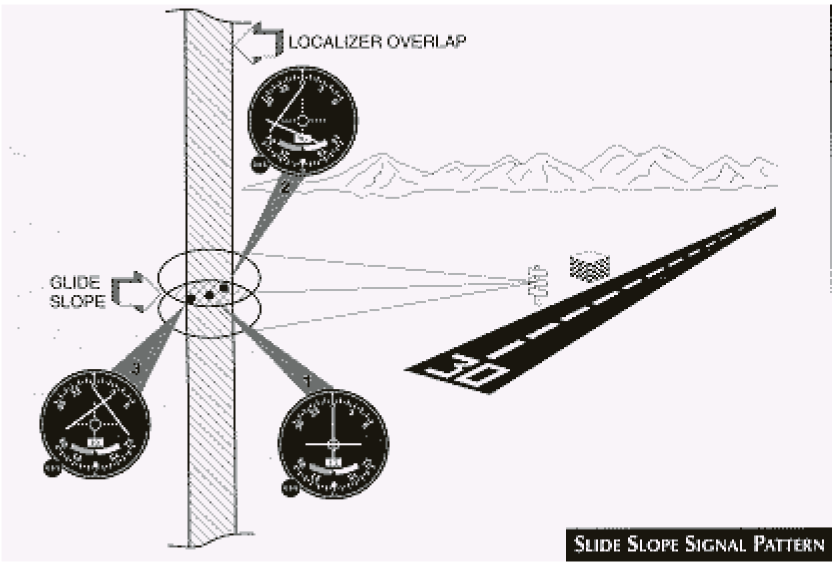
When an OFF flag appears in front of the vertical needle, it indicates that the signal is too weak, and, therefore, the needle indications are unreliable. A momentary OFF flag, or brief TB needle deflections, or both, may occur when obstructions or other aircraft pass between the transmitting antenna and the receiving aircraft.

C. GLIDE SLOPE EQUIPMENT

1. TRANSMITTER: The glide slope provides vertical guidance to the pilot during the approach. The ILS glide slope is produced by a ground-based UHF radio transmitter and antenna system, operating at a range of 329.30 MHz to 335.00 MHz, with a 50 kHz spacing between each channel. The transmitter is located 750 to 1,250 feet (ft) down the runway from the threshold, offset 400 to 600 ft from the runway centerline. Monitored to a tolerance of ± 1/2 degree, the UHF glide path is "paired" with (and usually automatically tuned by selecting) a corresponding VHF localizer frequency.

Like the localizer, the glide slope signal consists of two overlapping beams modulated at 90 Hz and 150 Hz (see **Glide Slope Signal Pattern** figure, below). Unlike the localizer, however, these signals are aligned above each other and are radiated primarily along the approach track. The thickness of the overlap area is 1.4° or .7° above and .7° below the optimum glide slope.

This glide slope signal may be adjusted between 2° and 4.5° above a horizontal plane. A typical adjustment is 2.5° to 3°, depending upon such factors as obstructions along the approach path and the runway slope.



SLIDE SLOPE SIGNAL PATTERN

False signals may be generated along the glide slope in multiples of the glide path angle, the first being approximately 6° degrees above horizontal. This false signal will be a reciprocal signal (i.e. the fly up and fly down commands will be reversed). The false signal at 9° will be oriented in the same manner as the true glide slope. There are no false signals below the actual slope. An aircraft flying according to the published approach procedure on a front course ILS should not encounter these false signals.

The glide slope system also consists of two glide slope transmitters with an active transmitter and a stand-by transmitter. Similar to the localizer system, the glide slope monitor system is an independent system which measures the glide slope radiated signal with relation to either the glidepath angle or the displacement sensitivity. It is positioned a predetermined distance from the glide slope antenna. The monitor checks the integrity of the glide slope signal and if an error in the signal is detected the system switches over to the stand-by transmitter and a "change-over" is logged. When the integrity of the glide slope radiated signal is still not to the monitor's set standards the glide slope system will shut-down and a "shut-down" will be recorded. The system will activate an alarm which usually includes an audio alarm. To put the glide slope system back into operation it needs to be reset.

2. SIGNAL RECEIVER: The glide slope signal is received by a UHF receiver in the aircraft. In modern avionics installations, the controls for this radio are integrated with the VOR controls so that the proper glide slope frequency is tuned automatically when the localizer frequency is selected.

The glide slope signal activates the glide slope needle, located in conjunction with the TB (see **Glide Slope Signal Pattern** figure, above). There is a separate OFF flag in the navigation indicator for the glide slope needle. This flag appears when the glide slope signal is too weak. As happens with the localizer, the glide slope needle shows full deflection until the aircraft reaches the point of signal overlap. At this time, the needle shows a partial deflection in the direction of the strongest signal. When both signals are equal, the needle centers horizontally, indicating that the aircraft is precisely on the glide path.

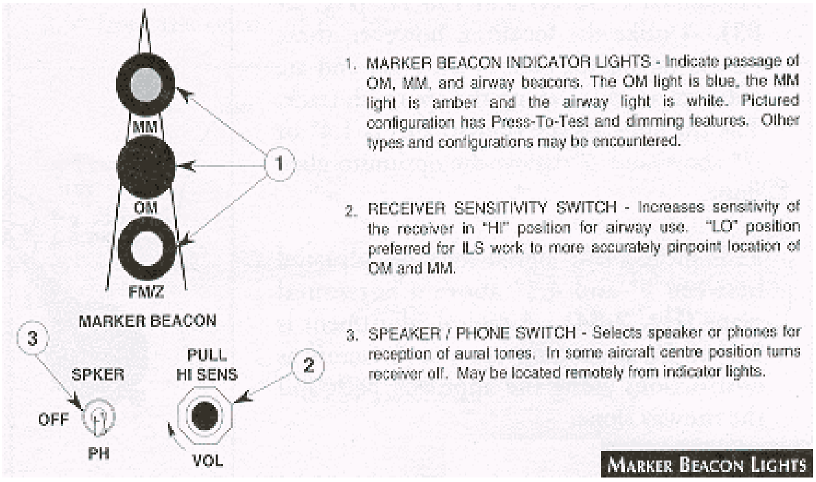
The pilot may determine precise location with respect to the approach path by referring to a single instrument because the navigation indicator provides both vertical and lateral guidance. In the **Glide Slope Signal Pattern** figure, above, *position* 1, shows both needles centered, indicating that the aircraft is located in the center of the approach path. The indication at *position* 2 tells the pilot to fly down and left to correct the approach path. *Position* 3 shows the requirements to fly up and right to reach the proper path. With 1.4° of beam overlap, the area is approximately 1,500 ft thick at 10 nautical miles (NM), 150 ft at l NM, and less than one foot at touchdown.

The apparent sensitivity of the instrument increases as the aircraft nears the runway. The pilot must monitor it carefully to keep the needle centered. As said before, a full deflection of the needle indicates that the aircraft is either high or low but there is no indication of how high or low.

D. ILS MARKER BEACONS

1. GENERAL: Instrument landing system marker beacons provide information on distance from the runway by identifying predetermined points along the approach track. These beacons are low-power transmitters; that operate at a frequency of 75 MHz with 3 W or less rated power output. They radiate an elliptical beam upward from the ground. At an altitude of 1,000 ft, the beam dimensions are 2,400 ft long and 4,200 ft wide. At higher altitudes, the dimensions increase significantly.

2. OUTER MARKER (OM): The outer marker (if installed) is located 3 1/2 to 6 NM from the threshold within 250 ft of the extended runway centerline. It intersects the glide slope vertically at approximately 1,400 ft above runway elevation. It also marks the approximate point at which aircraft normally intercept the glide slope, and designates the beginning of the final approach segment. The signal is modulated at 400 Hz, which is an audible low tone with continuous Morse code dashes at a rate of two dashes per second. The signal is received in the aircraft by a 75 MHz marker beacon receiver. The pilot hears a tone over the speaker or headset and sees a blue light that flashes in synchronization with the aural tone (see the **Marker Beacon Lights** figure, below). Where geographic conditions prevent the positioning of an outer marker, a DME unit may be included as part of the ILS system to provide the pilot with the ability to make a positive position fix on the localizer. In most ILS installations, the OM is replaced by an NDB.



MARKER BEACON LIGHTS

3. MIDDLE MARKER (MM): Middle markers have been removed from all ILS facilities in Canada but are still used in the United States. The middle marker is located. approximately .5 to .8 NM from the threshold on the extended runway centerline. The middle marker crosses the glide slope at approximately 200 to 250 ft above the runway elevation and. is near the missed approach point for the ILS Category l approach.

4. BACK MARKER (BM): The back course marker (BM), if installed, is normally located on the localizer back course approximately four to six miles from the runway threshold. The BM low pitched tone (400 Hz) is beard as a series of dots. It illuminates the aircraft's white marker beacon light. An NDB or DME fix can also be used and in most locations replace the BM.

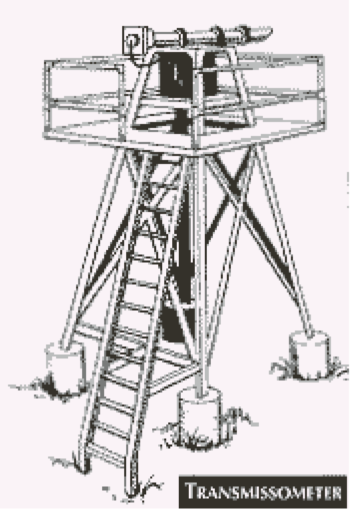
E. LIGHTING SYSTEMS

1. GENERAL: Various runway environment lighting systems serve as integral parts of the ILS system to aid the pilot in landing. Any or all of the following lighting systems may be provided at a given facility: approach light system (ALS), sequenced flashing light (SFL), touchdown zone lights (TDZ) and centerline lights (CLL-required for Category II [Cat II] operations.)

2. RUNAWAY VISIBILITY MEASUREMENT: In order to land, the pilot must be able to see appropriate visual aids not later than the arrival at the decision height (DH) or the missed approach point (MAP).

Until fairly recently, the weather observer simply "peered into the murk", trying to identify landmarks at known distances from the observation point. This method is rather inaccurate; therefore, instrumentation was developed to improve the observer's capability.

The instrument designed to provide visibility information is called a *transmissometer.* It is normally located adjacent to a runway. The light source (see the **Transmissometer** figure, on the right) is separated from the photo-electric cell receiver by 500 to, 700 ft. The receiver, connected to the instrument readout in the airport tower, senses the reduction in the light level between it and the light source caused by increasing amounts of particulate matter in the air. In this way the receiver measures the relative transparency or opacity of the air. The readout is calibrated in feet of visibility and is called runway visual range (RVR).



3. RUNAWAY VISUAL RANGE (RVR): The RVR is the maximum distance in the direction of take-off or landing at which the runway or the specified light or markers delineating it can be seen from a height corresponding to the average eye-level of pilots at touchdown.

Runway visual range readings usually are expressed in hundreds of feet. For example, "RVR 24" means that the visual range along the runway is 2,400 ft. In weather reports, RVR is reported in a code: R36/4000 FT/D; meaning RVR for Runway 36 is 4000 ft and decreasing. Because visibility may differ from one runway to another, the RVR value is always given for the runway where the equipment is located. At times, visibility may even vary at different points along the same runway due to a local condition such as a fog bank, smoke, or a line of precipitation. For this reason, additional equipment may be installed for the departure end and mid-point of a runway.

Runway visual range reports are intended to indicate how far the pilot can see along the runway in the touchdown zone; however*, the actual visibility at other points along the runway may differ* due to the siting of the *transmissometer*. The pilot should take this into, account when making decisions based on reported RVR.

Runway visual range is not reported unless the prevailing visibility is less than two miles or the RVR is 6,000 ft or less. This is so because the equipment cannot measure RVR above 6,000 ft. When it is reported, RVR can be used as an aid to pilots in determining what to expect during the final stages of an instrument approach. Instrument approach charts state the advisory values of visibility and RVR.

Runway visual range information is provided to the ATC arrival control, sector, the PAR position, and the control tower or FSS. It is passed routinely to the pilot when conditions warrant. RVR information may be included in aviation weather reports.

Ground visibility will continue to be reported and used in the application of take-off and landing minima. At runways with a transmissometer and digital readout equipment or other suitable means, RVR is used in lieu of prevailing visibility in determining the visibility minima unless affected by a local weather phenomenon of short duration.

The normal RVR reading is based on a runway light setting of strength 3. If the light settings are increased to strength 4 or 5, it causes a relative increase in the RVR reading. No decrease in the RVR reading is evident for light settings of less than setting 3. Pilots shall be advised when the runway light setting is adjusted to 4 or 5. If the RVR for a runway is measured at two locations, the controller identifies the touchdown location as "ALFA and the mid runway location as "Bravo".

In all cases, the pilot can request a light setting suitable for his or her requirements. When more than one aircraft is conducting an approach, the pilot of the second aircraft may request a change in the light setting after the first aircraft has completed its landing.

Because of the complex equipment requirements, RVR usually is only available at more active airports and not necessarily for all runways. If RVR equipment is not available or temporarily out of service for a given runway, the pilot uses the observer method to provide visibility information. In this case, the visibility is expressed as miles or fractions of a mile. The relationship between RVR values and visibility is shown below.

F. NDBs AT MARKER BEACON SITES

Additional aids may be available to assist the pilot in reaching the final approach fix. One of these aids is the NDB which can be co-located with or replace the outer marker (OM) or back marker (BM). It is a low-frequency non-directional beacon with a transmitting power of less than 25 watts (W) and a frequency range of 200 kilohertz (kHz) to 415 kHz. The reception range of the radio beacon is at least 15 nautical miles (NM). In a number of cases an en route NDB is purposely located at the outer marker so that it may serve as a terminal as well as an en route facility.

5.3 Appendix C: (Cockpit Voice Recording Transcript).

Accident flight on 1 June 2002.

Time	Origin	Phrases
	PIC	120 at a 1000 feet a minute, should give you about 180 knots.
0448:38	PIC	OK, vertical speed is looking good. So hit it there and…..
0449:02	PIC	OK, you can go 1018
	CP	OK, 1018 coming and DME we got 21miles.
	PIC	Daar's hy.
0449:46	PIC	See like my old friend used to say, I don't tell you ???.
	CP	Emmm
0451:17	CP	Ehh, what do you reckon for the trim?
	PIC	OK, the temperature round about tenish, so it will be…about 80%.
	CP	Ja,
0451:31	PIC	O, should be about 95.
	CP	Eight five, about 85%.
	PIC	80 should be fine for this lot.
0452:10	PIC	You could off-course have the choice, stay in the hold and descend to three thousand five hundred, or slow down drastically and just turn outbound and keep descending to two thousand five hundred.
	CP	Ja.
	PIC	So the choice is yours.
	CP	Nine miles, what you reckon are we going to loose that speed that quickly and (pilot-in-command) I don't know if we get down that fast.
0452:40	PIC	Ja, but then we must have, you know, gear down and 22 flaps.
	Alt alert	**Alert signal**
	CP	Thousand to go
	PIC	That is checks…….
	CP	Maybe we should do one hold, hey.
	PIC	OK.
0452:50	CP	Get myself sorted out.
	PIC	Then it is comfortable.
	CP	Ja.
0453:22	CP	OK, the approach checks we have done as well.
	PIC	Ehh, we haven't yet.
	CP	….. that those then.
	PIC	We can do. And the approach checks says. Radio/Nav equipment, except for the ILS its not , set. Altimeters, 1018 checked.
0453:45	CP	8000 feet we got.
	PIC	The water/methanol we're going too…agg, I think we will

		go to stand-by.
	CP	OK.
0453:56	PIC	And open.
	CP	Right
	PIC	En fuel heaters is auto and hold and flaps to come and I'll just heat up that one a little bit.
0454:10	CP	OK, eeeh, the speed is good we can take some flap if we want to, but you think that would be a good idea in this case.
	PIC	Eeh, jaa, I would take at least 7 and a half.
0454:30	PIC	There 7 and a half is set.
	CP	Thank you.
	PIC	Put the light out.
0454:45	CP	We stay at 8000 till we over the beacon and then …..
	PIC	Ja
	CP	Descending turn, hey? What do we want to set this to after that? Down to?
	PIC	3500
	CP	OK.
0454:57	Alt alert	**Alert signal**
	CP	Do that now.
	PIC	Eh, I mean, I know that on this heading the mountains are way behind us so…
	CP	OK
0455:10	PIC	I'll give you 15 flap.
	CP	OK, thanks
	PIC	And then we can go down
	CP	OK
	PIC	This little bit of …..
	CP	Alright we can altitude select, eh.
	PIC	That's him.
0455:23	CP	And alt off.
	PIC	Daar's hy.
	CP	Down to 35.
	PIC	And remember we must get the nose down to go down.
	CP	O, ja, it's a….
	PIC	Its not going to happen.
0455:45	CP	OK, nearly at the beacon.
0455:53	CP	There goes the flag, so …. And we nail it at that rate of descent, do we?
	PIC	A 1000 should be fine.
	CP	Ja, should go for that.
0456:09	CP	Then we should hit the beacon in 15 to 20 seconds, eh and turn left 112.
	PIC	That's him.
0456:17	CP	There goes the beacon.
	PIC	Daar hy.
0456:20	PIC R/T transmis	George Traffic Aquarius 201 is overhead Golf Golf Victor and joining the hold descending in the hold to 3 thousand

	sion	500 feet.

	CP during the R/T	Start the watch.
0456:40	CP	That's 15 seconds, 20 seconds turning left 112.
	PIC	OK.
	CP	Just bring her around.
0457:41	CP	OK, going level on that, ehh, 1 minute from now, hey?
	PIC	Ehh, checks
0458:32	PIC	5 seconds to…
	CP	Ja, checks and round we go, left some more.
	PIC	And the turn out.
0459:21	CP	One dot
	PIC	Sorry, (co-pilot)?
	CP	OK, radio was alive. One dot closing on thing.
	PIC	Oh, ja,
	CP	Says fly left a bit.
0459:39	PIC	And 1000 foot to go.
	CP	Ja.
	PIC	So, more or less.
0459:45	Alt alert	**Alert signal**
0500:43	CP	A bit more intercept hey.
	PIC	Ja.
	CP	That's better.
0500:58	PIC	OK, now it is coming in nicely.
	PIC	OK, ….
0501:18	CP	OK, hold 35.
	PIC	Hold is … on. Not that it matters much, because.
	CP	Very close to the beacon now, will leave that in.
	PIC	Go down shortly in any case.
	CP	OK.
0501:34	Alt alert	**Alert signal**
	PIC	500 coming in, 2500 is set.
0501:40	CP	OK, overhead the beacon again.
	PIC	Altitude select on.
	CP	Turning left, turning left again 112
	PIC	Its set.
	PIC	And now we can descend at about 500 feet a minute and …...
	PIC	OK
0502:02	Alt alert	**Alert signal**
	Alt alert	**Alert signal**
0502:47	CP	And we go out to…… After here we go out to 9 miles.
	PIC	Affirm
	CP	Right
0503:25	Alt alert	**Alert signal**
0503:35	PIC	OK, I will give you ILS

	CP	Thank you
	PIC	One Zero One
	CP	One One Zero One, ja, OK.
0503:53	CP	OK, 2500 feet. Four miles, Five miles to go.
	PIC	And there is no identification.
	Radio	Volume was turned up. Background noise with no signal.
	CP	Now we tracking 101.
	PIC	OK.
0504:27	CP	I gonna go right a bit.
	PIC	Just give us D, oh ???. DME in hold, but ja, OK.
	CP	Zak down. Which is the hold on here?
0504:45	PIC	You just turn that little knob.
	CP	This one?
	PIC	Ja.
	CP	This is as far right as it will go.
	PIC	Just come left and take it back to the right, but I think it is alright.
0505:23	PIC	And just flick that knob again please? Daar's hy.
	CP	OK, we got it, eight and a half.
	PIC	OK
0505:39	PIC	At nine miles…..
	CP	At nine miles we turn left.
	PIC	That's him.
	CP	To intercept the ILS.
	PIC	We descend to… ehh
	CP	Ehh….. 845, ehh 850
0505:59	PIC	850, ja, which is 200 on here.
	CP	200 on the rad alt.
	PIC	That's it.
0506:11	PIC	Now I am starting to see a bit of ground here, but it's not….
	CP	Oh, OK.
	PIC	But it is not wonderful, but …ehh.
	CP	What can we go down to?
	PIC	To ….
0506:23	CP	Is it best to take the auto-pilot out or let it go down on it?
	PIC	No, let it go down on auto-pilot.
	CP	Ok, set this down to……850 feet.
	PIC	850, ja.
	Alt alert	**Alert signal**
	CP	Oops.
	CP	Oh, would do 800, but it will do 900, won't do 850
	PIC	OK, that's fine.
	CP	I will select to go down, ehh.
0506:31	CP	Ehh, where do we take the gear, at the outer marker?
	PIC	OK, ehh, just get down, just get down.
	CP	That's it.
	PIC	We will take the gear…..
0507:04	CP	Outer marker, ehh

	PIC	Ohh, aag, at about one dot which is…..
	CP	OK
	PIC	Which is good to take it now, I think.
	CP	OK, it says fly up at the moment but, ehh
	PIC	Ja, correct, because……
0507:24	PIC	And we are OK there
0507:35	CP	I flags on, I've got flags on my side. Oh wrong ehh, ohh got them both ja.
	PIC	Ja.
	CP	I've got a flag on my, CDI. How is yours?
0507:45	PIC	OK, mine is fine.
	CP	OK, its indicating OK. It seems to be working OK, but … ehh.
0508:02	CP	Got to go down some more, hey.
0508:08	Key strk	*5 key strokes could be heard.*
0508:35	PIC	OK, we're on the slope, I give you…..
	CP	22 and a half
	PIC	Give you 22 and a half,
	CP	Landing checks please
	PIC	Trim up.
	CP	OK, I've got some ground visual.
	PIC	25 percent, OK and I suggest put your wiper on.
	CP	OK, which is here.
0508:56	PIC	And we getting above the slope, we are not going down, so lets get down.
	CP	OK, down.
	PIC	We are about a dot high.
0509:10	PIC	The windscreen wiper, (co-pilot).
	CP	Ehh, it did not seem to wanna work.
	PIC	OK, just switch it on and leave it for a while.
	CP	***Oh, ja.***
0509:18	Alt alert	**Alert signal**
	CP	OK, the autopilot going out, that's ehh…..
	PIC	OK
	Alert	**Alert signal**
0509:30	CP	Whoops, watch the speed (softly)
	PIC	Don't dive it down like that, my goodness gracious me.
	PIC	Keep going down, keep going down, we not going down. Go down, down we're a dot high.
0509:53	PIC (Radio transmission)	George traffic Aquarius 201 is final runway 29.
	PIC	Remain a dot high, get down. Otherwise we are not…..going …. We are two dots high.
0510:11	CP	I've got glideslope flags on mine.
	PIC	Ja, so is mine….. OK. Oh ???? what have we got.
0510:23	Alert signal	Two signals

	CP	There is the airfield there.
0510:33	Key strk	*5 key strokes could be heard.*
	CP	We miles too fast.
0510:54	PIC	Bloody well see what is up. OK, lets go around.
	Engines sound	Hear the noise of the engines increase.
	CP	Gear up, OK.
	PIC	Let's climb up to three thousand five hundred feet.
	CP	OK
0511:26	PIC	I would imagine that the ILS had failed.
	CP	Emm.
0511:46	Alert	**Alert signal**
	PIC	Nou, ja, let's turn out again on heading of 112.
0511:59	CP	OK, turning left on one, one, ehh one zero two now. One, one two.
	PIC	One, one, two, ja.
	CP	Turning left.
	PIC	OK, clear left.
	CP	I'll keep climbing, ehh.
0512:12	Alert	**Alert signal**
	PIC	And I have put the autopilot in for you.
	CP	OK.
	PIC	So get your heading bug.
	CP	Jaaaaa.
0512:44	PIC	Is the heading bug on the left turn.
	CP	One, one, two, ja.
	PIC	OK, keep climbing, keep climbing and get that speed to a reasonable one.
0513:12	Alt alert	**Alert signal**
0513:23	PIC	We are doing a 60 deg…. 45 degree angle of bank turn right through the heading. Heading for the mountains and let's get the nose down so that we…..
	CP	Get some attitude properly, that's better.
0513:45	PIC	And descend down to 2500 feet again.
	CP	OK, one one two…..
	PIC	OK, autopilot is in for you again.
	CP	OK
0514:07	CP	Down to two five.
	PIC	Affirm.
	PIC	And now how is your flag there, back again.
0514:15	CP	Flagged again.
	CP	But it was the other end that they were talked about the ILS being intermittent.
	PIC	Ja.
0514:31	Alt alert	**Alert signal**
0514:44	PIC	OK, we back to 15 flap.
	CP	Done.
0514:50	PIC	Oh my, this is ridiculous, anyway let's see. I'm giving you the VOR again.

	CP	OK
	PIC	OK, we back to VOR.
0515:31	PIC	And we are maar, go back to 9 miles again
	CP	OK
0516:15	Alt alert	**Alert signal**
	PIC	OK
	CP	OK
	CP	9 miles coming, speed OK, turning left.
	PIC	Affirm
0516:33	CP	Speed a bit high for the flap.
0516:56	GPWS	Pull up
	GPWS	Pull up
	GPWS	Pull up
	CP	Pull up my chum.
	GPWS	Pull up
	GPWS	Pull up
	CP	What's that there?
0517:18	CP	10 miles still.
	PIC	OK, that's bearable.
	CP	OK
0517:25	CP	That's why they say max. 9 miles. Get that pull up.
	PIC	Ja, O, my liewe ???? man.
	CP	?????.
0517:40	GPWS	Pull up
	GPWS	Pull up
	GPWS	Pull up
0517:55	PIC	OK, how is your flags now?
	CP	They OK at the moment.
	CP	OK, two and a half thousand.
	PIC	OK.
0518:06	CP	That, the glide slope is out now it's all out again.
	PIC	And we must go down.
0518:14	PIC	Let's just take a bit more power there. (engines spool up)
0518:35	Alert	**Alert signal**
	PIC	Let me take it.
	CP	You got it.
	PIC	????? man.
0519:05	Alert	**Alert signal**
0519:29	GPWS	Pull up
	GPWS	Pull up
	GPWS	Pull up
	Alert	**Alert signal**
0519:50	GPWS	Pull up
	Alert	**Alert signal**
	GPWS	Pull up

5.4 Appendix D: (Instrument manufacturer inspection report).

Examination of Honeywell Components recovered from HS-748 ZS-OJU

Introduction

On June 1, 2002, an HS-748 aircraft, operated by Airquarius Aviators as a cargo aircraft, crashed near George, South Africa. The crew of two and one passenger were killed. This aircraft was equipped with Honeywell avionics, including gyroscopes and flight instruments. Some of the Honeywell equipment was recovered and sent to Honeywell in Glendale, Arizona for examination. Equipment sent to Honeywell was:

AD-550	P/N 7001182-904	S/N 82080280	Attitude Direction Indicator
RD-550	P/N 7001179-916	S/N 81110729	Horizontal Situation Indicator
RD-444	P/N 2592920-44	S/N 77122395	Horizontal Situation Indicator
GH-14	P/N 4020531-534	S/N 79060594	Gyro Horizon Indicator
C-14A	P/N 2587193-43	S/N 84108500	Directional Gyroscope
VG-14A	P/N 7000622-901	S/N 86055592	Vertical Gyroscope

This equipment was examined on Wednesday, November 20, 2002.

Gyroscopes

The gyroscopic components were examined at the Honeywell Deer Valley facility in the morning of the 20th of November. Attending this examination were:

John Eller	FAA	Scottsdale FSDO
Steve O'Hanian	Honeywell	Regulatory Interface
Ray Runkle	Honeywell	Gyroscope Product Engineer
Steve Balmer	Honeywell	Gyroscope Technician
Joe Lazaro	Honeywell	Customer Support Engineer
Jim Sneed	Honeywell	Accident Investigation

Components examined were: C-14A, GH-14, and VG-14A.

C-14A Directional Gyroscope Examination

The C-14A, P/N 2587193-43, S/N 84108500, is shown as received in Figure 1.

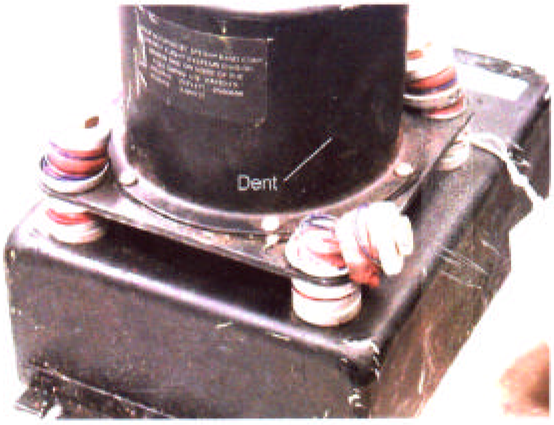


Figure 1: C14A Directional Gyroscope

Page-1 Rev A

Initial visual examination revealed:

- The unit was in reasonably good condition
- There was a shallow dent about one-half way between the top of the gyro can and the mounting flange on one side
- The four vibration isolaters showed signs of deformation due to torsion between the gyro can the mounting base
- There were no Honeywell or Sperry repair stickers
- There was an unidentified third party sticker ("AIRCRAFT INSTRUMENTS" date illegible)
- Unit was C-14A Compass, P/N 2587193-43, S/N 84108500, MOD A
- Gyro Synchronizer Assembly was P/N 4019190-3, S/N 84108500, MOD A

Since the unit appeared in reasonably good condition, power was applied to determine whether the unit was operable before tearing it down. The unit did not operate.

Opening the gyro can revealed heavy corrosion of the gyroscopic components (Figure 2).

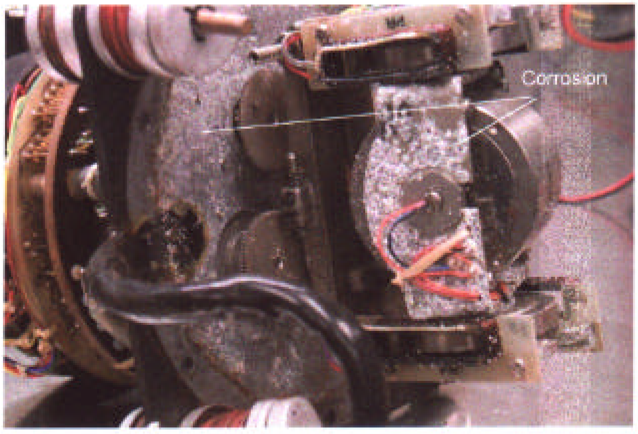


Figure 2: Internal Components of C-14A Directional Gyroscope

Findings from the examination of the internal components are:

- The gyro rotor was locked up. It was not possible to determine whether this was pre- or post-impact; however, ~~the torsional deformation of the vibration isolaters, and~~ the broken gimbal stop (below) ~~imply~~ implies the rotor was providing significant inertial ~~resistance~~ momentum. ~~to turning of the gyro case.~~
- The gimbal stop was broken. This stop prevents out of range excursions of the rotor mounting gimbals. Since all the components in the gyro assembly underwent the same accelerations, this stop must have been broken due to ~~differential rotations of the components~~precession of the rotor assembly,. This ~~differential rotation~~precession implies the rotor was rotating to create a high gyroscopic inertia.
- There are two heading output synchros, both synchros were operational.
- Examination of the internal wiring revealed two wires not connected (Figure 3).
  - These two wires are for the field excitation of the leveling motor
  - The wires do not appear to have been disconnected by impact
  - The leveling motor is designed to keep the gyro rotor level relative to the aircraft -vertical axis
  - With the leveling motor disconnected the gyroscope will not operate properly
    - With the aircraft stationary, the C-14A may align and set its output valid
    - Depending on the friction in the gyroscope, the gyro rotor will precess. Eventually the precession may reach a point where the rotor aligns with the ~~gumbles~~ gimbals and the gyroscope "dumps", i.e. the output starts spinning.

Page-2 Rev A

- Errors between this C-14A and the cross side compass system should be evident in turns
- The C-14A with leveling motor disconnected will not pass the Honeywell IT
    - ~~Scoresby~~ Drift rate tests will fail
    - Leveling rate tests will fail

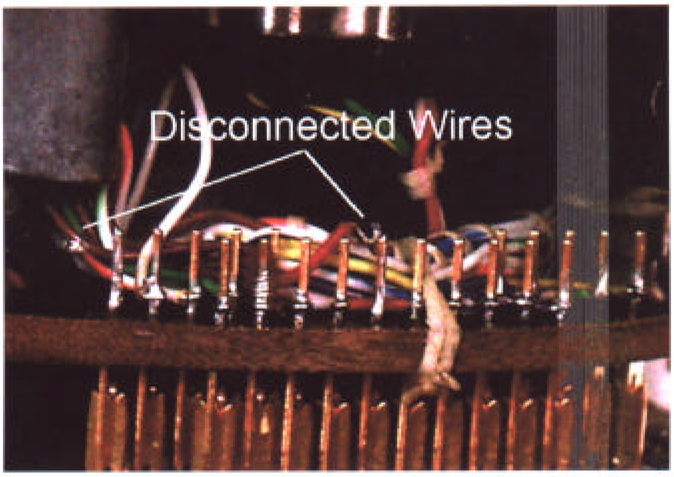


Figure 3: C-14A Directional Gyroscope showing disconnected wires

GH-14 Gyroscopic Horizon Examination

The GH-14, P/N 4020531-534, S/N 79060594, is shown as received in Figure 4 and Figure 5.

Figure 4: GH-14 Front

Figure 5: GH-14 Top

Initial examination revealed:

- Bezel was attached to the unit case with duct tape, indicating partial disassembly to remove the unit from the aircraft panel. Consequently, it could not be determined if the Honeywell seals were intact at the time of the accident.
- Attitude Sphere is level in pitch, rotated 135° counterclockwise in roll. (This differs from pictures taken at the crash site showing the attitude sphere with a extreme nose high pitch attitude and about 20° clockwise in roll (left bank).
- Front faceplate glass is missing
- The gyro flag is in view and the flight director flag is half in view. These flags are held out of view when a 28V valid is received from the flight director or from the internal gyroscope. They are spring loaded to return to view when the 28V signal is lost. It is not possible to tell ~~when these flags are free to move (as they are in this instrument)~~ whether the flags were in or out of view at the time of the impact and loss of power.
- Flight director bars are centered (normal power off position)
- Glideslope pointer is out of view.
- The GH-14 is P/N 4020531-534, S/N 73060594, MOD A,B,C,E, G,H,J,L.
- There is a Honeywell repair sticker indicating unit was repaired in a Honeywell shop in Apr 1995.

The GH-14 with case removed is shown in Figure 6.

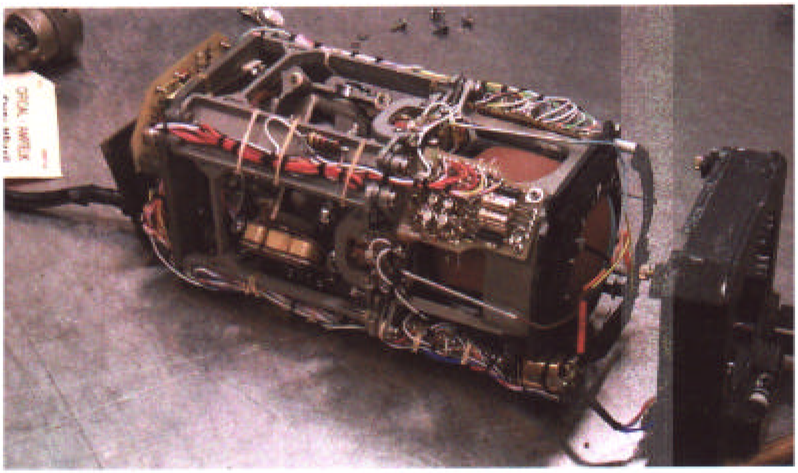


Figure 6: GH-14 with case opened

Page-4 Rev A

Examination of the interior components of the GH-14 revealed:

- The cord tying the attitude sphere to the gyro assembly was broken loose, allowing the sphere to rotate in pitch.
- The attitude sphere displayed pitch was approximately 80° off from the pitch attitude of the gyro assembly
- The gyro was out of balance despite the presence of a large number of balance weights
- The "Valid Interlock" relay had broken loose
- The movement of the localizer ~~motor~~ meter movement seemed un-impeded
- The movement of the glideslope ~~motor~~ meter movement seemed un-impeded.
- There is an impact mark on the attitude sphere and corresponding blue paint on the indicator frame (Figure 7).
- Aligning these marks gives an attitude of 25° pitch up and 67° right bank .

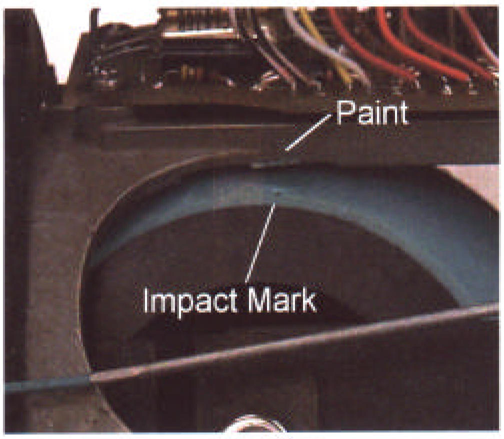


Figure 7: Impact Mark and Paint

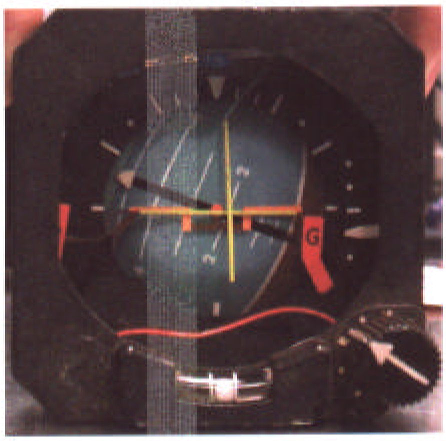


Figure 8: Attitude at Impact

Because the GH-14 mechanism appeared relatively undamaged, power was applied to see if the gyro would operate. The gyro operated, but the bearings were extremely noisy. The attitude valid signal went valid, indicating the gyro had successfully erected. The gyro was not able to maintain vertical orientation. Upon removal of power it required approximately 6 minutes for the gyro to rundown and drift off level in roll to the point where the gimbal contacted the roll stop.~~to brake stop.~~ Time for the gyro to totally run down was 18 minutes 17 seconds.

VG-14A Vertical Gyroscope Examination

The GH-14, P/N 7000622-901, S/N 86055592, is shown as received in Figure 9.

Page-5 Rev A

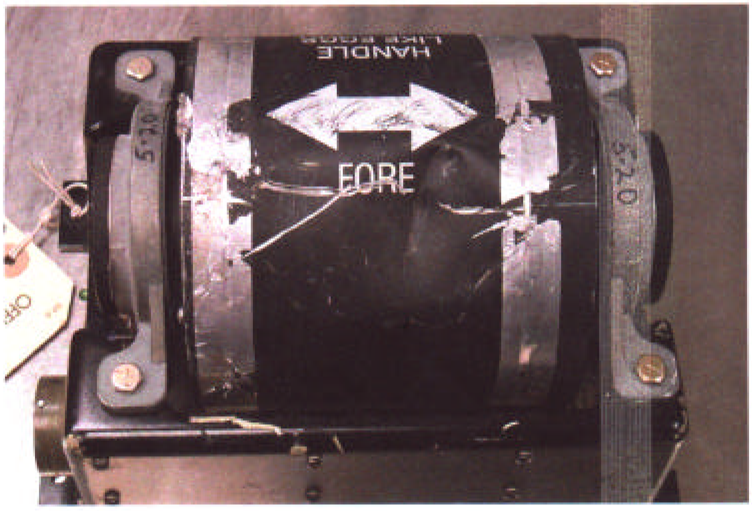


Figure 9: VG-14A

Initial examination revealed:

- Unit was a VG-14A vertical gyroscope, P/N 7000622-901, S/N 86055592, MOD A.B.C.D.E.F.
- Unit had a Honeywell repair sticker indicating repair and modification at a Honeywell shop on May 22, 1992.
- Unit had a sticker from "Field Aviation Accessories Limited" dated May 29, 1992.
- Unit had a dent in ;the gyro can approximately ¼inch deep under the "FORE" label (see Figure 9).
- The Honeywell seal on the gyroscope can was intact.

The gyroscope case was opened and the internal mechanism examined (Figure 10).

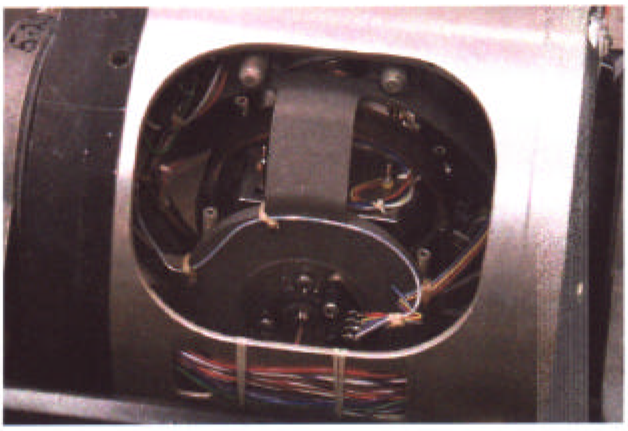


Figure 10: VG-14A Internal Components

This examination revealed:

- No apparent internal damage
- Gimbals were free to move
- Gyroscope slightly off balance – corresponding to a 45° bank with power off

Since the mechanism appeared undamaged, power was applied.

- The VG-14A erected to a pitch of 359° 5' and roll of 000° 12'.
- The 28V valid output went valid, as well as the green LED valid indicator on the Gyro mounting base.
- The pitch slowly drifted down from 359°, indicating some friction in the mechanism.
- When a small vibration was applied to the gyroscope, the pitch moved back to 359°+.
- When the assembly was move in pitch and roll the corresponding synchro outputs changed accordingly.

Page-7 Rev A

Indicators

The indicators were examined at the Honeywell Bell Road facility in the afternoon of the 20th of November. Attending this examination were:

John Eller	FAA	Scottsdale FSDO
Phil Hubacek	Honeywell	Regulatory Interface
Mark Romero	Honeywell	Indicator Product Engineer
Ron DeCoste	Honeywell	Indicator Technician
Joe Lazaro	Honeywell	Customer Support Engineer
Jim Sneed	Honeywell	Accident Investigation
Carlos Ovando	Honeywell	Quality

Components examined were: AD-550, RD-550, and RD-444.

.

AD-550 Attitude Direction Indicator Examination

The AD-550, P/N 7001182-904, S/N 82080280, is shown as received in Figure 11 and Figure 12.

Figure 11: AD-550 Front View

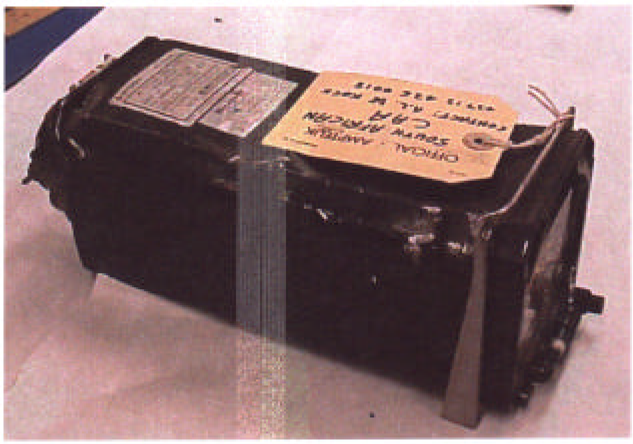


Figure 12: AD-550 Side View

Initial visual observations of the AD-550 were:

- The unit was P/N 7001182-904, S/N 82080280, MOD A and C.
- Unit had a Honeywell shop repair sticker showing repair on April 7, 1995.
- Honeywell shop seals are broken.
- No Flags in view
- Attitude is approximately 90°+ nose up, slight right bank (this differs from pictures taken at the crash site which show approximately 5° nose up with a slight right bank.)
- DH and Go-Around annunciator lights (in top corners of ADI case) are missing
- Glideslope pointer on the left is centered and not flagged
- Flight Director command bars are pitched up with a slight right bank. Bars are displaced slightly to left of ADI center-line.
- Fixed aircraft symbol is slightly out of position
- Inclinometer is not damaged and operating properly.
- Glass faceplate is cracked.
- DH set control, digit dim control, and ATT test controls are jammed.

In order to examine the AD-550 further, the case had to be cut open to reveal the interior components (Figure 13). Examination of the interior components revealed:

- The Flight Director flag was found loose in the case.
- The attitude sphere was jammed
- The Glideslope pointer had moved to the top of the scale (spring loaded to bias out of view)
- The CCA A4 showed substandard repair
- The mechanical components were significantly mis-aligned.

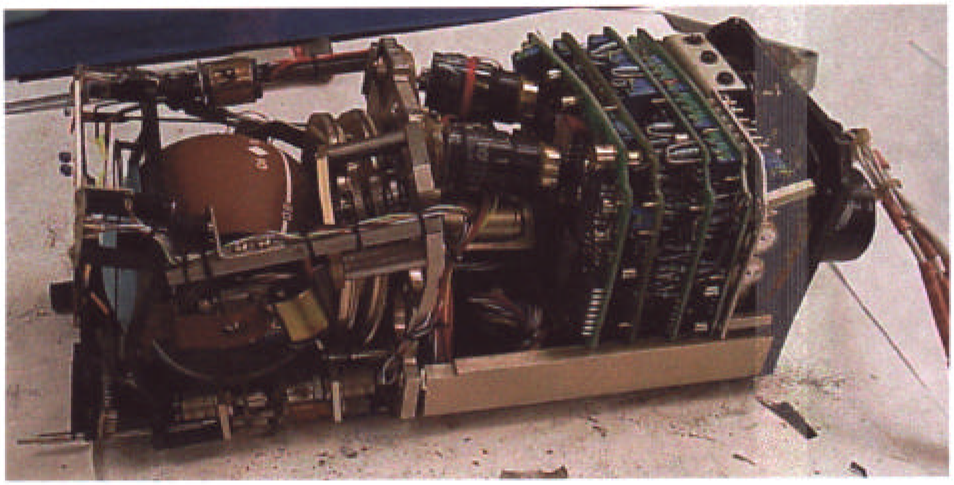


Figure 13: Interior of AD-550

Due to the substantial damage to the mechanical components, no effort was made to operate this instrument.

RD-550 Horizontal Situation Indicator Examination

The RD-550, P/N 7001179-916, S/N 81110729, is shown as received in Figure 14.

Figure 14: RD-550 Front View

Initial visual examination revealed:

- Unit is P/N 7001179-916, S/N 81110729, MOD A,B,C, and D.
- Unit has a Sperry shop repair sticker showing repair on October 24, 1985.
- Sperry (Honeywell) shop seals are missing.
- Flags are in view.
- Heading is approximately 286°.
- Selected course pointer is 262° for the head and 84° for the tail.
- Glideslope pointer is about 1.25 dots above reference.
- Course Deviation Indicator is twisted, indicating about .2 dots at tail end (connection to meter movement) and about 1.5 dots at head end.,
- Compass sync indicator is in the middle.
- Front glass is undamaged.
- Parts are loose inside case.

In order to investigate the interior components, the case was cut open (**Figure 15**).

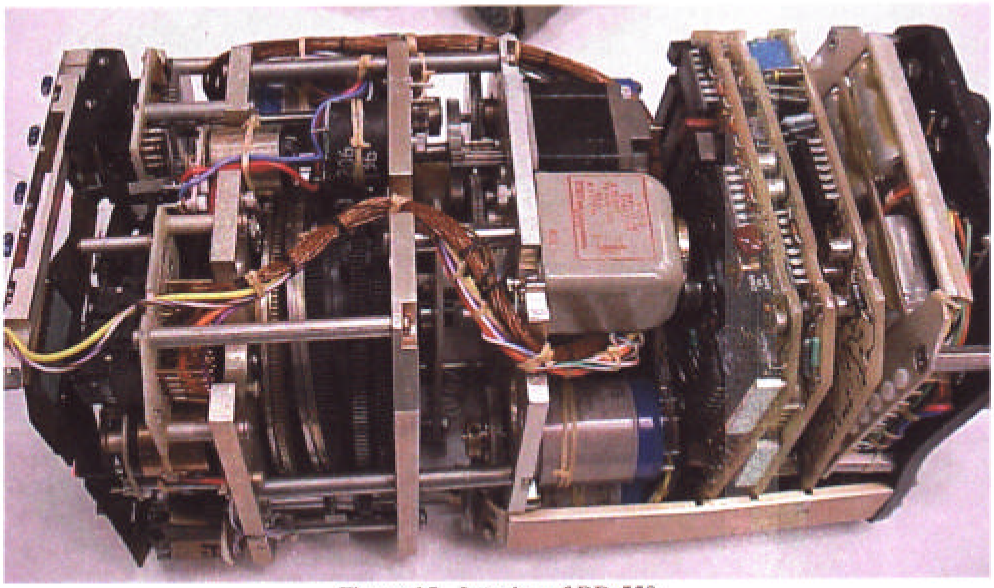


Figure 15: Interior of RD-550

Examination of the interior revealed:

- Three loose screws and a loose board retainer were found.
- The heading flag was broken off from the heading flag motor.
- The glideslope motor was free to move, but the pointer was slightly bent upward.
- The compass sync (X-O) motor was free to move.
- A broken IC and a replaced IC, which doesn't appear to be a Honeywell part, were found on CCA A2 (Figure 16). The quality of repair on A2 appears substandard.
- A broken IC was found on CCA A3.

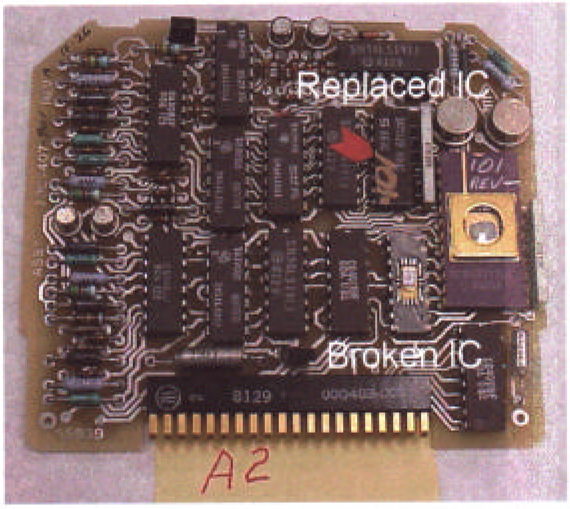


Figure 16: RD-550 CCA A2

RD-444 Horizontal Situation Indicator Examination

The RD-444, P/N 2592920-444, S/N 77122395, is shown as received in Figure 17 , Figure 18 and Figure 19.

Figure 17: RD-444 Front View

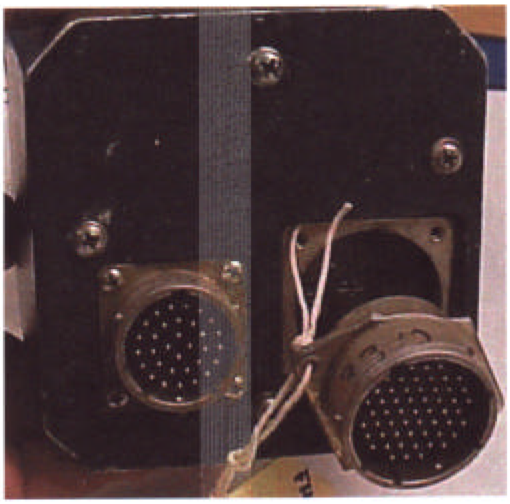


Figure 18: RD-444 Rear View

Figure 19: RD-444 Top View

Initial visual examination revealed:

- Unit is P/N 2592920-444, S/N 77122395, MOD A, B, C, D,E,F,G,J,K, and L.
- Unit has a partial "Aerospatiale SECA" repair sticker, broken at the intersecion of the bezel and case.
- Compass flag is in view.
- Front glass and bezel are missing.
- Heading is 288°.
- Course pointer head is 304°, tail is 124°.
- The Course Deviation Indicator is missing.
- The Glideslope pointer is missing.
- There is no To./From display.
- There is no Selected Heading Bug.
- Course select knob is missing.
- One rear connector is loose (Figure 18).
- Compass sync indicator is missing.
- NAV flag is approximately 10% in view.

The RD-444 case was removed for further examination of the internal components (Figure 20).

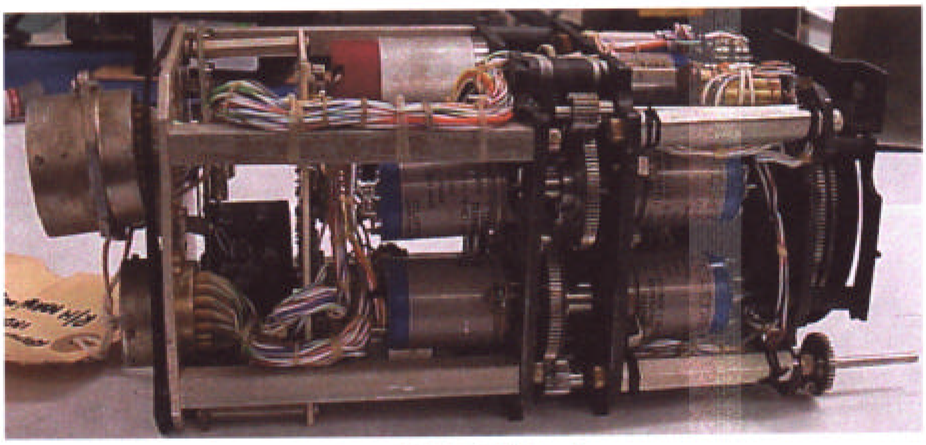


Figure 20: RD-444 Interior

Examination of the internal components of the RD-444 revealed:

- No loose parts.
- Glideslope pointer broken off from meter movement.

Summary

Examination of the components from ZS-OJU could not identify whether the flagged instruments were operating at the time of the accident. No evidence was found to indicate the components were not operable at the time of the accident. The leveling motor in the C-14A directional gyroscope was found disconnected; this appears to have been disconnected prior to the accident. The disconnected leveling motor could result in erroneous heading display.

1-14-03

Jim Sneed
Honeywell

5.5 Appendix E: (Flux Detector Inspection Report).

Rockwell Collins
323A-2G Flux Detector
Test Report
Prepared for FAA

NOTICE: The contents of this document are proprietary to Rockwell Collins, Inc. and shall not be disclosed, disseminated, copied, or used except for purposes expressly authorized in writing by Rockwell Collins, Inc.

NOTICE: This document contains technical data which may be Restricted for export under the International Traffic in Arms Regulations (ITAR) or the Export Administration Regulations (EAR). Violations of these export laws may be subject to fines and penalties under the Arms Export Control Act (22 U.S.C. 2778).

Rockwell Collins, Inc.
400 Collins Rd. NE
Cedar Rapids, Iowa 52498

CAGEC 4V792

Notices and Signatures

Notices

- This document is a paper representation of the master copy which is maintained in the Product Development Management (PDM) system.
- The following software was used to produce this document:
- Desktop Publisher: Microsoft Word 2002
- Graphics Software: Microsoft Word 2002

Approval Signatures

	Name	Signature
Prepared By:	P. Leigh Ellery	
Approved By:	K.L. "Dude" Kerley	

Revision History

Ver/Rev	Date	Originator	Reason for Change
-	10/16/2003	P.L. Ellery	Original Release
A	11/4/2003	P.L. Ellery	Added addendum on broken gimbal hypothesis

Scope

This document presents the results of Rockwell Collins testing of 323A-2G flux detector S/N 8170 requested by the FAA.

Introduction

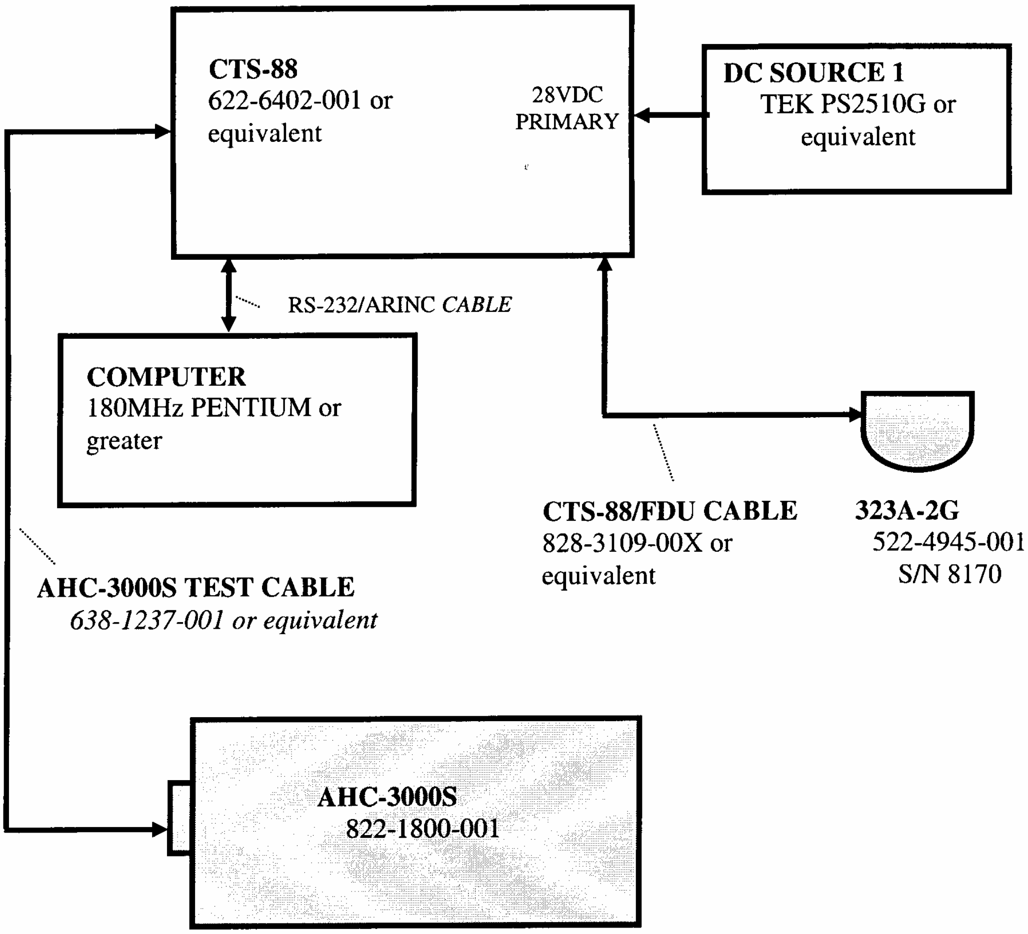
The FAA requested help in determining the operational status of 323A-2G flux detector serial number 8170.

The 323A-2G flux detectors were originally manufactured for Collins by Barfield of Miami Florida. Collins does not possess any test equipment used to directly test the flux detector. Collins does however manufacture Attitude and Heading computers (AHC-3000S) that interface to the flux detector. An AHC-3000S unit was used to determine the status of 323A-2G serial number 8170.

Test Equipment

AHC-3000S	822-1800-001	S/N 12BYK
LeCroy oscilloscope LC534AM	469-0066-532	cal due 8/31/2004
Index stand (surveying tripod)		

Test Setup



CTS-88
622-6402-001 or equivalent
28VDC PRIMARY
DC SOURCE 1
TEK PS2510G or equivalent
RS-232/ARINC CABLE
COMPUTER
180MHz PENTIUM or greater
CTS-88/FDU CABLE
828-3109-00X or equivalent
323A-2G
522-4945-001
S/N 8170
AHC-3000S TEST CABLE
638-1237-001 or equivalent
AHC-3000S
822-1800-001

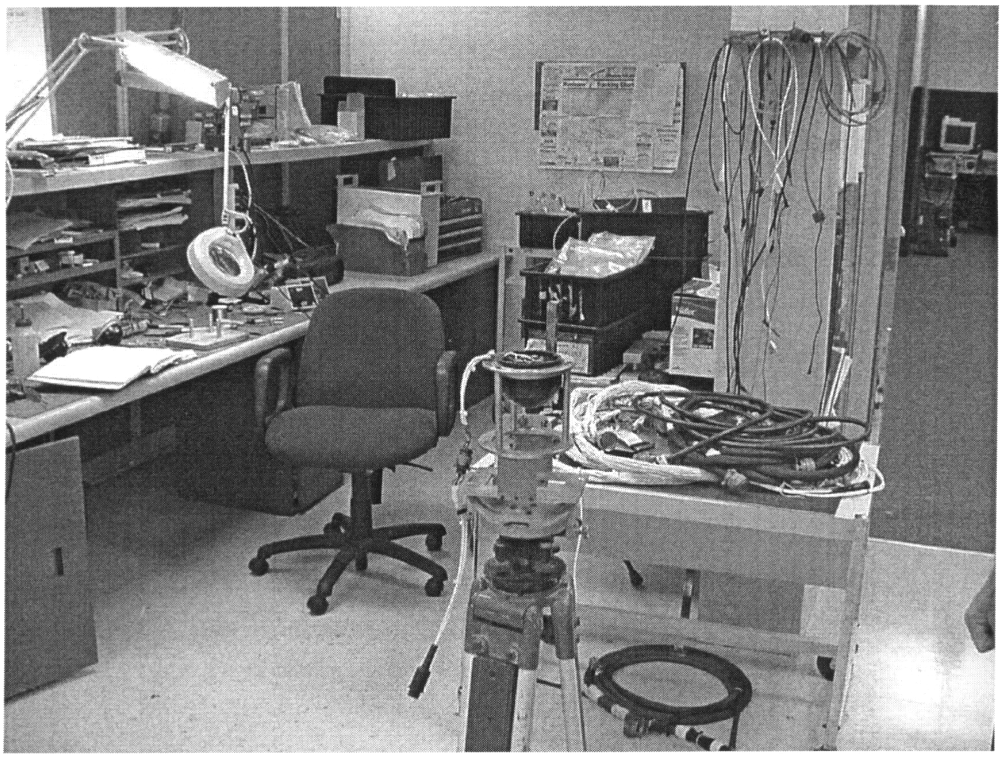


Figure 1 - Flux Detector Mounted to Index Stand

Test Preparation

The 323A-2G unit was removed from the airplane by cutting the interconnecting cable. To facilitate testing, the unit cover plate was opened to access the mounting terminals. The original wiring was inspected and looked to be in good condition. Some solder flux residue was observed in and around the solder joints on the lugs. The cut cable was then removed and replaced with a Collins made interconnecting cable and connector.

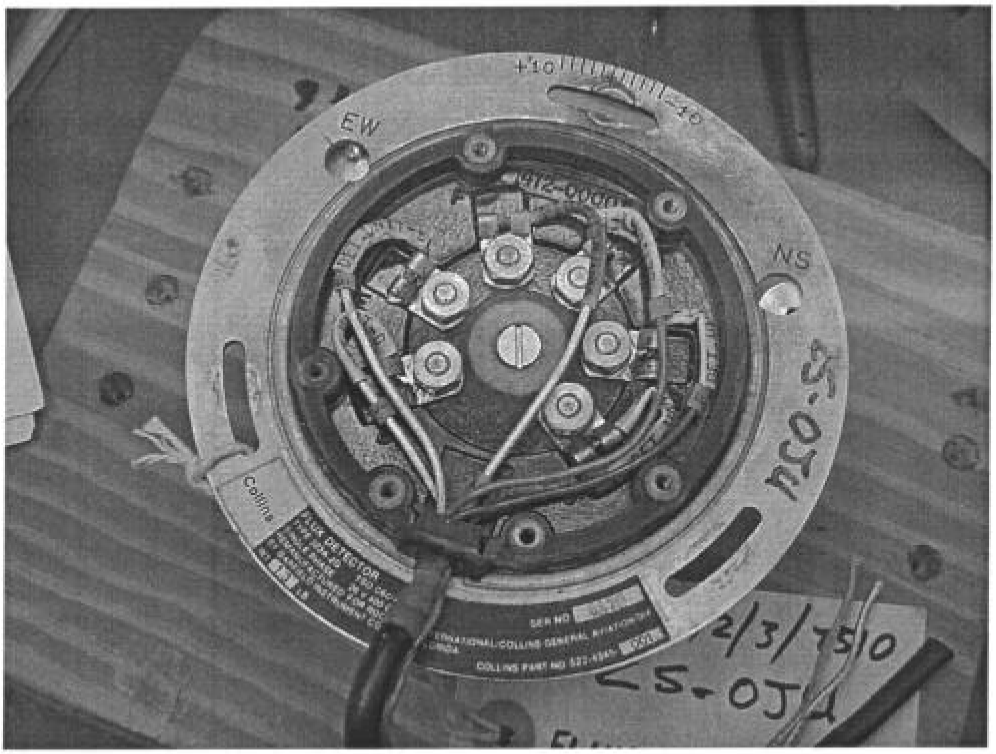


Figure 2 - Flux Detector with cover plate removed showing original aircraft wiring

The original wiring connection was as follows:

Terminal	Wire	Function
A	Green	Pickup A
B	Red	Pickup B
C	Blue	Pickup C
D	Blue stripe	Excitation D
E	Red stripe	Excitation E
F	Clear (no stripe)	Shield

No top level Barfield serial number could be found on the aluminum mounting ring.

A Barfield serial number 32222 was scratched on the black bakelite near the exit notch for the wiring (under the grommet shown in the photo).

Test Results

Test 1: AHC-3000S Production Test Requirements

AHC-3000S production test requirements (Collins Part Number 827-22866-005) step 4.3 (shown below) was performed. This test is really checking the operation of the AHC-3000S circuitry, but can give some insight into flux detector operation.

TEST NO.	PROCEDURE	SETUP INSTRUCTIONS	DESIRED RESULTS
4.3.1	INSERT SYNCHRO FDU AND FDU SELECT BOX INTO FDU INPUTS.	IMU MODE SELECT 323A-2G FUNCTION ON THE SELECT BOX ROTARY SWITCH S1 AND NORMAL ON SWITCH S3.	
4.3.2	WITH FDU CONNECTED, MEASURE FREQUENCY AND PEAK-PEAK VOLTAGE OF EXCITATION A SIGNAL AND EXCITATION B SIGNAL		FREQUENCY: 430+/-5 HZ VOLTAGE: EXC A NLT 36V PK-PK VOLTAGE: EXC B NLT 18V PK-PK
4.3.3	AVERAGE FDU ADC A, B AND C COIL VALUES FOR AT LEAST 1 SECOND. RECORD THESE AVERAGE VALUES.	READ A, B AND C COIL VALUES FROM FDU ADC AS 16-BIT SIGNED INTEGERS.	A, B AND C COIL AVERAGES
4.3.4	CALCULATE HEADING Y COMPONENT: Y=-(B-C)/SQRT(3). DEFINE HEADING X COMPONENT: X=A.		INITIAL HEADING X AND Y COMPONENTS
4.3.5	PERFORM FOUR QUADRANT ARC-TANGENT OF Y COMPONENT DIVIDED BY X COMPONENT.		INITIAL HEADING IN DEGREES
4.3.6	TRANSLATE HEADING.	SELECT TEST ON FDU SELECTION BOX SWITCH S3.	
4.3.7	AVERAGE FDU ADC A, B AND C COIL VALUES FOR AT LEAST 1 SECOND. RECORD THESE AVERAGE VALUES.	READ A, B AND C COIL VALUES FROM FDU ADC AS 16-BIT SIGNED INTEGERS.	A, B AND C COIL AVERAGES
4.3.8	CALCULATE HEADING Y COMPONENT: Y=-(B-C)/SQRT(3). DEFINE HEADING X COMPONENT: X=A.		FINAL HEADING X AND Y COMPONENTS
4.3.9	PERFORM FOUR QUADRANT ARC-TANGENT OF Y COMPONENT DIVIDED BY X COMPONENT.		FINAL HEADING IN DEGREES

SIZE	CAGEC	DWG NO.		REV
A	4V792	827-2866-005		-
SCALE: NONE		MSWD XP	SHEET 29	

TEST NO.	PROCEDURE	SETUP INSTRUCTIONS	DESIRED RESULTS
4.3.10	CALCULATE EXPECTED FINAL HEADING FROM INITIAL HEADING: EXPECTED = (240 + INITIAL) MODULO 360.		VERIFY FINAL HEADING IS WITHIN +/- 5 DEGREES OF EXPECTED FINAL HEADING.

Step 4.3.2:

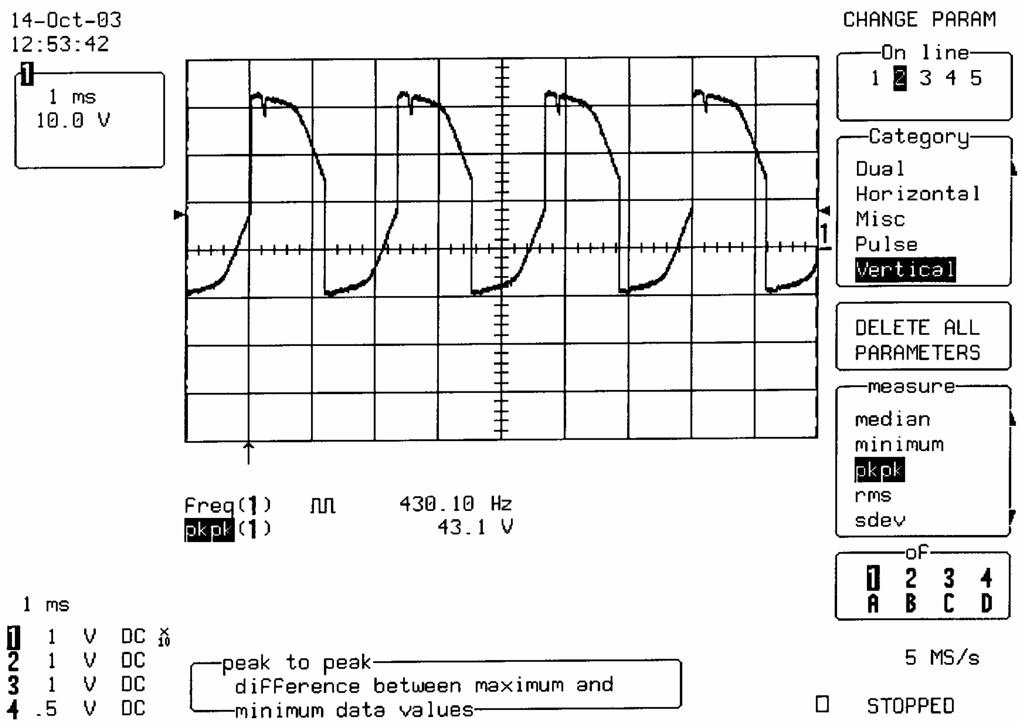


Figure 3 - Excitation Terminal D Waveform

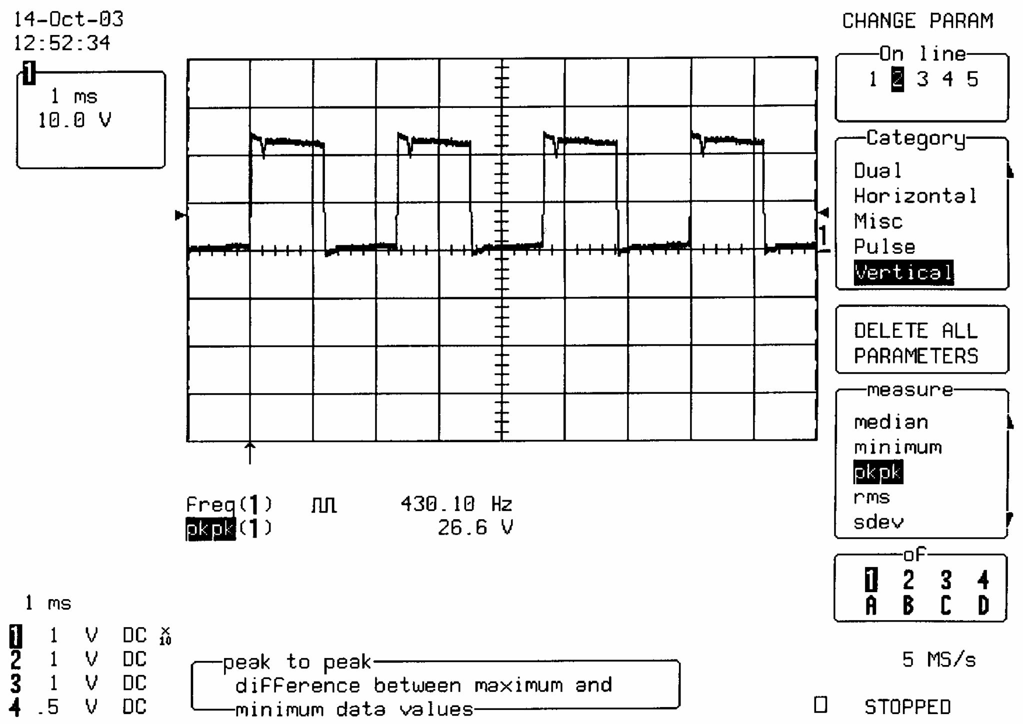


Figure 4 - Excitation Terminal E Waveform

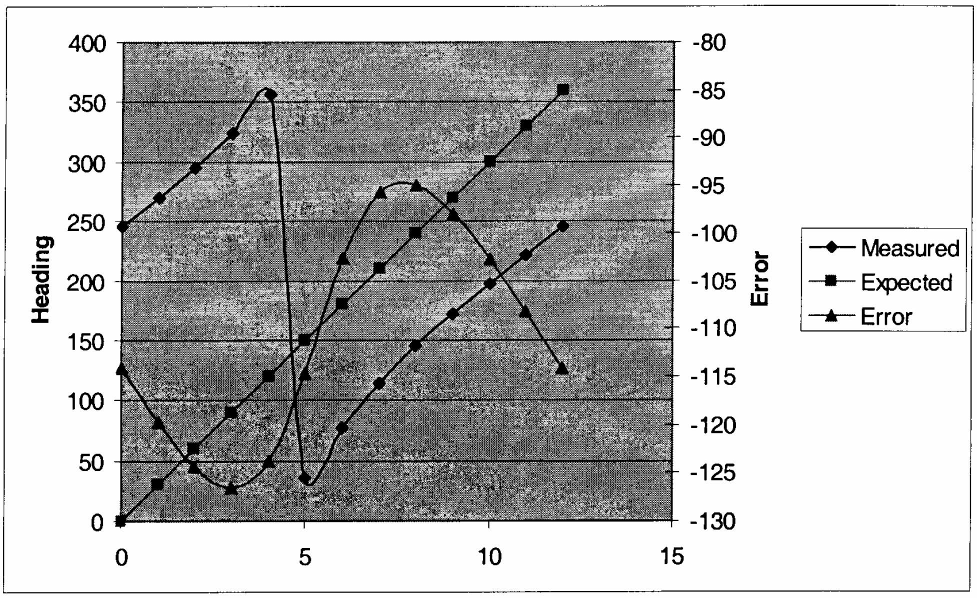
Excitation D 430.1Hz, 43.1Vpp => pass
Excitation E 430.1Hz, 26.6Vpp => pass

Step 4.3.5: Initial heading = 245.1
Step 4.3.9: Final heading = 124.25
Step 4.3.10: Expected final heading = 125.1 => pass

Test 2: Compass Check Swing

A 12-point check swing was performed on the index stand. The starting point of the swing was approximately north, but the flux detector read 245.9 degrees.

Step	Measured	Expected	Error
0	245.9	0	-114.1
1	270.18	30	-119.82
2	295.57	60	-124.43
3	323.39	90	-126.61
4	356.23	120	-123.77
5	35.31	150	-114.69
6	77.44	180	-102.56
7	114.36	210	-95.64
8	145.08	240	-94.92
9	172.04	270	-97.96
10	197.18	300	-102.82
11	221.7	330	-108.3
12	245.9	360	-114.1



Conclusion

The flux detector has a dominant single cycle error with an amplitude of +/-15 degrees.

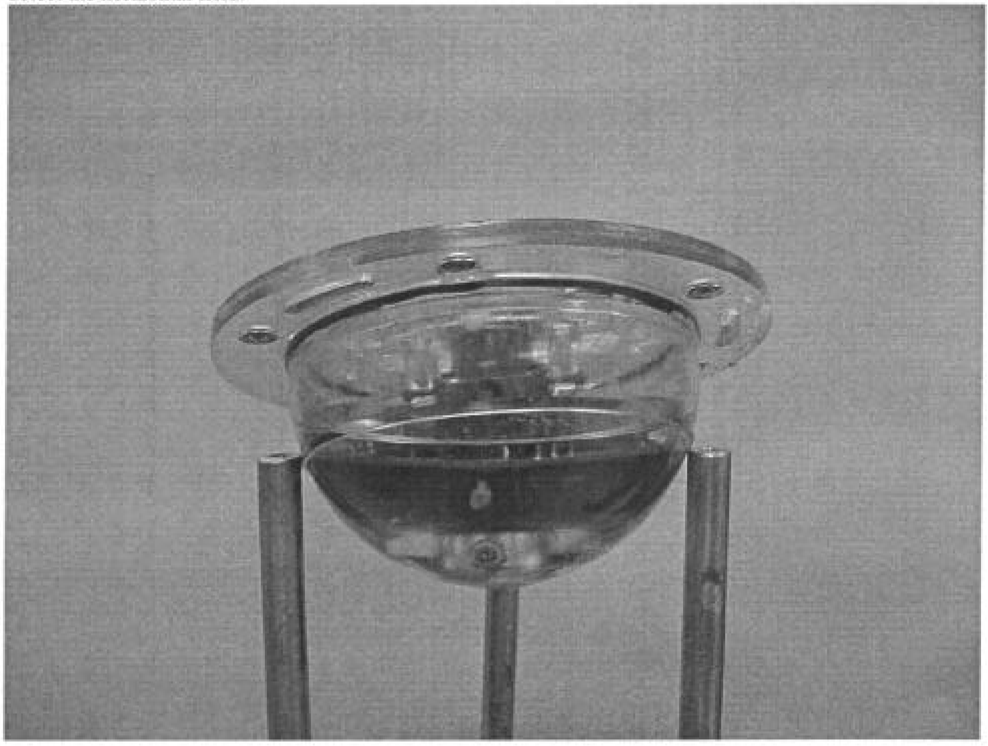
The flux detector has a large index error of approximately -110 degrees.

Addendum

The flux detector was brought back to Collins on October 31st 2003 for further analysis.

The FDU was tilted from side to side and it was noticed that the internal gimballing system did not respond as expected. The FDU was then tilted to 90 degrees and rotated. At different points the internal mechanism would "thump" indicating that there was significant damage. A good FDU smoothly follows this motion. Without a working gimbal the FDU will pick up earth's vertical magnetic field and provide erroneous heading data.

The following picture shows a clear case flux detector (not a 323A-2G model, but one that contains a gimballing mechanism nonetheless). It can be seen how the gimbal keeps the FDU level so it will only detect the horizontal field.



To determine the actual failure the FDU would need to be opened up and examined.

Final Conclusion

The flux detector has internal damage that prevents its correct operation. This could be a broken gimbal. The damage most likely occurred due to airplane impact. Therefore no conclusion can be made about the performance of the FDU prior to the incident.

Compiled by:

Dr. A.L. de Kock for Commissioner for Civil Aviation		Date : 5 May 2004
Investigator-in-charge	: ………………………………	Date : ……………..
Co-Investigator	: ………………………………	Date : ……………