Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Vickers Vanguard 952, G-AXOP Report on the accident at Hochwald/Solothurn, Switzerland on 10 April 1973

Translation of the report published by the Swiss Federal Department of Transport and Power

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Swiss Federal Department
of Transport and Power

No 1973/12
800

FINAL REPORT OF THE SWISS FEDERAL COMMISSION OF INQUIRY INTO AIRCRAFT ACCIDENTS

on the accident

To Vickers Vanguard 952, G–AXOP

of Invicta International Airlines

Commander:	Capt Anthony Dorman,	deceased
Copilot:	Capt Ivor Terry	"

on 10 April 1973
at Hochwald/Solothurn

Translation of the Report:

Accidents Investigation Branch
Department of Trade
Shell Mex House
Strand, London WC2R 0DP

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0 General

0.1 Brief account

On 10 April 1973 INVICTA International Airlines operated charter flight IM 435 from Bristol to Basel with a Vickers Vanguard 952, G–AXOP. Following two unsuccessful instrument approaches (ILS) to runway 16 the aircraft brushed against a wooded range of hills 16 km south of Basel-Mulhouse airport and crashed in the vicinity of the hamlet Herrenmatt, in the parish of Hochwald/SO, at 09.13 hrs.*

One hundred and four passengers and four crew members were killed in the accident, thirty-five passengers and one hostess were injured. One hostess was unhurt. The aircraft was destroyed.

The accident happened in daylight in heavy snow with low cloud and poor visibility.

Probable cause of the accident:

The Federal Commission of Inquiry into Aircraft Accidents came to the following conclusion:

The accident is attributable to:

– loss of orientation during two ILS approaches carried out under instrument flight conditions.

The following factors contributed to the occurrence of the accident:

– inadequate navigation, above all imprecise initiation of final approach as regards height and approach centre-line.

– confusion of navigational aids and

– insufficient checking and comparison of navigational aids and instrument readings (cross and double checks).

The poor reception of the medium wave beacons and technical defects in LOC receiver No 1 and glideslope receiver No 2 made the crew's navigational work more difficult.

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* *All times in this report are in GMT*

1 Facts Established

1.1 History of the flight (See Annexes 2b, 3a and 5a)

On Tuesday, 10 April 1973, the aircraft G–AXOP, a Vickers Vanguard 952 belonging to the British company Invicta International Airlines (Invicta), was used on charter flight IM 435 from Luton via Bristol to Basel. 139 passengers were taken on board in Bristol. It took off for Basel at 0719 hrs with Captain A Dorman in the left-hand and Captain I Terry in the right-hand pilot's seat.

According to the London and Paris ATC units' recordings of the R/T conversations the flight was routine as far as the Basel-Mulhouse terminal control area, with Captain Terry in charge of the aircraft's radio communications.

At 0849 hrs IM 435 reported to Basel approach control on frequency 121.25 MHz that it had passed the Hericourt beacon heading for Basel (main approach beacon BN). Approach control checked this position report using the surveillance radar equipment and the R/T direction finder and, after ascertaining the correct position, acknowledged the report by transmitting the meteorological conditions and instructing the crew to call Basel aerodrome control on frequency 118.3 MHz (wind 360°/9 kts, runway visual range (RVR) at point A 700 m, at point B 1300 m, snow, cloud base 8/8 120 m, pressure QFE 967.5 mb, QNH 998.5 mb, temperature 0°C, runway in use 34, switch to 118.3).

Flight IM 435 acknowledged and called Basel control tower which instructed it to maintain flight level 70 and to report when it passed BN and, in reply to an enquiry from the crew, allocated runway 16 for the approach. The aircraft was later given permission to descend first to FL 50 and soon afterwards to FL 40.

At 0855.48 the pilot reported passing the BN beacon (also the outer marker of the ILS approach system) and was cleared to descend to 2500 ft, the initial altitude for the instrument approach, with the instruction to report when he passed the MN beacon which forms the northern boundary of the procedure turn.

At 0856.58 hrs the aircraft reported that it had reached 2500 ft and at 0857.42 hrs it reported that it had passed MN, whereupon permission was given for the final approach with the instruction to report when it passed BN again.

At 0900.13 hrs the co-pilot reported passing BN and stated that the aircraft was turning away towards MN again.

Contrary to this statement it did not report passing MN, but at 0903.38 hrs position BN was reported, whereupon clearance to land on runway 16 and the surface wind of 320°/8 kts was transmitted.

At 0905.12 hrs the crew (Captain Dorman) reported that G–AXOP was overshooting and was attempting another approach which was cleared: 'OK, report BN outbound at 2500 ft', which the pilot-in-command (PiC) acknowledged correctly.

At 0907.27 hrs the crew said that they had passed BN outbound, whereupon they were instructed to report MN.

At 0908.10 hrs Basel Control Tower received a telephone call from a meteorologist and former aircraft commander stating that barely two minutes before a 4-engined turbo-prop aircraft with red vertical tail surfaces had flown over the Binningen Observatory (approximately 8 km SE of the airport) at around 50 m above the ground and heading south; he urged several times that the crew be instructed to climb. In the course of the accident inquiry, this observation was confirmed by several witnesses in the Binningen and Basel area. Some surviving passengers also maintained that they briefly saw several houses once during the approach.

At 0908.51 while the meteorologist was still on the telephone the crew reported position MN and were instructed to report BN on final approach.

At 0911.10 hrs Zurich Area Control Centre asked Basel whether they had an aircraft which was flying outbound towards Hochwald, as they had observed an unidentified echo on their radar scope approximately 3-5 nm SW of Basel. The Basel air traffic controller denied this, but then checked his own radar scope and also observed a clean echo on the extended runway centre-line approximately 6 nm S of the airport and moving south.

At 0911.25 hrs, ie during the telephone call from Zurich, the aircraft reported that it was over BN and was once again given permission to land ('435 you may land, report when you sight the lights, the wind is blowing from 320°/8 kts').

At 0912.10 hrs, after finishing the telephone conversation with Zurich, the controller asked the crew 'Are you sure you are over BN?', whereupon Captain Dorman replied 'I think we have got a spurious indication, we are now on the LOC (short pause), on the ILS', which the controller noted with 'Ahh'.

At 0912.33 hrs the pilot confirmed: 'BN is established on glide path and localizer; the ADF's (are) all over the place in this weather', whereupon the controller pointed out to them that he could not see the aircraft on his radar scope.

At 0913.03 hrs the controller requested IM 435's present height, whereupon both pilots simultaneously reported 1400 ft.

The controller then informed the crew: 'I think you are not on the (short pause), you are on the south of the field', which was not acknowledged by the aircraft. All further calls to the aircraft likewise remained unanswered.

At 0913.27 hrs, ie shortly before the controller's last call regarding its position to the south of the field, the aircraft brushed against the wooded ridge of a range of hills in the Jura during the overshoot and climb procedure initiated shortly before, approximately 16 km south of Basel airport, almost exactly along the extended centre line of runway 16. It crashed in the vicinity of the hamlet Herrenmatt, in the parish of Hochwald/SO, somersaulted and parts of it caught fire.

The accident happended in daylight. During the approach manoeuvres the aircraft was almost continually in cloud, the cloud base was low, visibility greatly reduced by driving snow and the wind was blowing with light turbulence from the north.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	104	–
Non-fatal	1	35	–
None	1	–	

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

There was considerable damage to woodland and crops.

1.5 Crew

1.5.1 *General*

The crew consisted of 2 Flight Captains (Captain A Dorman and Captain I Terry) and 4 hostesses who were all licensed to carry out their duties.

On the first route segment Luton – Bristol, Captain Dorman, who was not originally assigned to this flight and had stepped in as a replacement for a co-pilot who was not available, sat in the right-hand pilot's seat and acted as co-pilot. After landing in Bristol the pilots changed duties, in accordance with the company's usual practice in cases where two pilots were qualified as pilots-in-command (PiC), and Captain Dorman moved to the left-hand pilot's seat to assume the duties of PiC.

1.5.2 *Pilot-in-Command Captain Anthony Noel Dorman*

Captain A N Dorman, born 1938, Canadian citizen, held a valid British airline transport pilot's licence No 91778 with PiC rating for Vickers Vanguard and BN 2 A Islander (Britten Norman) and co-pilot rating on DC-3 and DC-4.

Date of last aero-medical examination: 23 January 1973, assessment: fit. Captain Dorman obtained his first PiC licence on 19 January 1971 on BN 2 A Islander. He obtained the PiC endorsement for Vickers Vanguard on 20 August 1971. Last flight check: 28 February 1973, passed.

Captain Dorman had begun his flight training in 1963 with the Royal Canadian Air Force, but it was soon discontinued owing to insufficient aptitude for flying. Following his discharge from the Air Force in 1966 he first obtained a Canadian private pilot's licence, later a commercial pilot's licence and finally a senior commercial pilot's licence. In 1969 Captain Dorman obtained a Nigerian pilot's licence, issued on the basis of the

Canadian licence and an allegedly successful instrument rating test flight which is not entered in his flying log book.

In 1970 and 1971 he made a total of 9 attempts in the United Kingdom to obtain the instrument rating on three different twin-engined light aircraft, which he succeeded in doing on 21 January 1971. He had failed the tests because of inadequate flying and/or theoretical knowledge. He also passed his type tests on DC-3, DC-4 and Vickers Vanguard only after making more than one attempt in each case.

On 25 January 1971 Captain Dorman obtained a British airline transport pilot's licence. After his engagement by Invicta in January 1971, ie just after passing the instrument rating test, he was first employed as co-pilot on DC-4, later on Vickers Vanguard. On 19 October 1972 Captain Dorman was promoted to captain.

Captain Dorman's total flying experience could not be established exactly, as the British Accident Investigation Authorities found numerous discrepancies when examining his flying log book, which cast some considerable doubt on the reliability of the flights recorded. His flying experience with Invicta was 1205 hrs, approximately 1088 hrs were flown on the accident type, including 185 hrs as PiC.

Up to the day of the accident he had made 33 landings in Basel, including 9 instrument approaches. Captain Dorman had flown 17 times with Captain Terry, including twice to Basel.

Captain Dorman's rest periods before commencing the flight from Luton amounted to 27 hrs, his duty period up to the accident was approximately 4 hrs 45 mins. He had flown 23 hrs 25 mins in the last 7 days.

1.5.3 *Co-pilot Captain Ivor William Francis Terry*

Captain I W F Terry, born 1926, British subject, held a valid British airline transport pilot's licence No 78229 with PiC rating for Vickers Vanguard, DHC 1 and DC-4.

He began his flight training with the Royal Air Force on 9 October 1944. Military pilot from 18 November 1947. Flight duty on single- and multi-engined piston aircraft including Neptune, Shackleton, Varsity Valetta and Lancaster.

Date of last aero-medical examination: 26 January 1973: fit.

Captain Terry was first promoted to PiC (on DC-4) on 25 October 1968. He obtained his PiC licence on Vickers Vanguard on 15 March 1971. Last flight check: 28 February 1973, passed. Captain Terry's total flying experience was 9172 hrs, including 3144 hrs 45 mins in civil air transport. He had flown 1256 hrs 10 mins on Vickers Vanguard.

Up to the day of the accident he had made 61 landings in Basel, including 38 on the accident type and a total of 14 instrument approaches.

The pilot had had a rest period of 13 hrs 20 mins before commencing flight IM 435 in Luton, his duty period up to the accident was approximately 4 hrs 45 mins. He had flown 17 hrs 25 mins in the last 7 days.

1.5.4 *Cabin crew*

Gillian R Manning, born 1942 (Killed)
Date of last aero-medical examination: April 1972
Date of last emergency check: 6 March 1973

Joy Sadler, born 1953 (Killed)
Date of last aero-medical examination: March 1973
Date of last emergency check: 29 March 1973

Elisabeth D Low, born 1947 (Uninjured)
Date of last aero-medical examination: March 1973
Date of last emergency check: 29 March 1973

Daphne H Axten, born 1953 (Injured)
Date of last aero-medical examination: April 1972
Date of last emergency check: 6 March 1973

1.6 **Aircraft G–AXOP**

1.6.1 *General*

Owner and operator:	Invicta International Airlines Ltd Ramsgate, Kent, UK
Type:	Vanguard 952
Constructor:	Vickers Armstrong Ltd, Weybridge, Surrey, UK
Serial No and year of construction:	745/1962
Characteristics:	Four-engined mid-wing airliner of all-metal construction; pressurised cabin and retractable tricycle landing gear. Minimum cockpit crew: 2 pilots. The cabin has 3 passenger compartments and is arranged for 139 tourist class passengers and 4 cabin crew.
Engines:	4 Rolls Royce Tyne 512 turbo-prop engines each of 5050 SHP and 1285 lb residual thrust; 4 De Havilland PD 223/466/3 4-blade constant speed propellers.
Valid certificate of airworthiness:	last renewed in May 1972
Valid certificate of maintenance:	issued on 24 March 1973.

1.6.2 *Flying times*

Airframe: 16367 hrs

Engines:	Pos 1	13669 hrs	Since last overhaul	1706 hrs
	2	14010 hrs	" " "	1924 hrs
	3	13262 hrs	" " "	890 hrs
	4	14476 hrs	" " "	1728 hrs

Since the last certificate of maintenance was issued the aircraft had been in operation for approximately 50 hrs.

1.6.3 *Weight and centre of gravity*

Weight:	Maximum take-off weight	66451 kg
	Maximum landing weight	59194 kg
	Take-off weight in Bristol	59027 kg
	Estimated landing weight in Basel	50165 kg

The weight was therefore within the permissible limits.

Centre of gravity: Examination of the position of the centre of gravity showed that this was within the prescribed range.

1.6.4 *Equipment: radio and navigational equipment*

COM:	2 VHF transmitters	Collins 17 L-7
	2 VHF receivers	Collins 51 X-2
NAV:	2 VHF receivers	Collins 51 X-2
	2 VOR instrumentation units	Collins 344 B-1A
	1 glideslope receiver	Collins 51 V-3
	1 glideslope receiver	Collins 51 V-4
	1 marker receiver	Bendix MKA-7A-1
	2 ADF receivers	Collins 51 Y-3
	2 instrument amplifiers	Collins 344 C-1
	1 DME interrogator	RCA (AVQ 70)
Radar:	1 ATC transponder	RCA AVQ 65
	1 weather radar	RCA AVQ 10
Also:	2 approach horizons	2 altimeters
	2 course indicators	2 weather radar indicators (cannot be used for collision avoidance)
	2 turn and bank indicators	
	1 DME indicator	2 marker indicators
	3 RMI (VOR/ADF)	1 magnetic compass
	2 airspeed indicators	1 standby horizon
	2 rate of climb indicators	1 clock (no stopwatch)

1.7 Weather

1.7.1 *General meteorological situation*

A strong cold air current was flowing from the North Sea area into the Western Mediterranean area. In the upper Rhine valley area this led to an intensive upward motion of the wedged-in warm air there with cloud formation and considerable falls of snow even in low lying areas. This meant that the meteorological conditions were unfavourable for flight operations owing to:

– severe icing and moderate turbulence in cloud

– strong northerly winds almost to ground level

– low cloud bases and poor visibility, approaching the minima at times, at the airport of destination Basel-Mulhouse.

1.7.2 *Meteorological conditions at Basel-Mulhouse*

The official meteorological observations at Basel around the time of the accident were as follows:

0815 wind 340/5 Met visibility 0.7 km, runway visual range 500 m (RVR), moderate snowfall, 8/8 stratus at 300 ft, temperature 0°C/dewpoint 0°C, visibility: trend increasing to 1000 m.

0845 wind 360/9, Met visibility 1 km, runway visual range 1300 m, light snowfall, 8/8 stratus at 400 ft, temperature and dewpoint 0°C, visibility: trend increasing to 1500 m.

0915 wind 340/10, Met visibility 1200 m, runway visibility 1200 m, runway visual range 1700 m, light snowfall, 8/8 stratus at 500 ft, temperature and dewpoint 0°C, visibility: trend increasing to 1500 m.

0945 wind 320/9, Met visibility 700 m, runway visual range 500 m, moderate snowfall, 8/8 stratus at 400 ft, no significant change.

These changes in the meteorological situation are largely consistent with the weather forecast for Basel which was given to the crew before take-off:

0700-1600 wind 020/15, visibility 2 km, moderate rain, 6/8 stratus at 800 ft, 8/8 stratocumulus at 2000 ft, temporary 0600-1200 hrs visibility 1500 m, heavy rain and snow, 8/8 stratus at 400 ft, intermittent 0600-1000 hrs visibility 1200 m.

The meteorological data transmitted to the aircraft by approach control were also similar:

0849 wind 360/9, visibility RVR A 700 m, RVR B 1300 m, snow, 8/8 120 m, temperature and dewpoint 0°C.

The runway visibility values (RVR) were measured with 2 transmissometers. (See 1.10.2). A and B varied between 500 and 1900 m from the first weather report to the aircraft up to the time of the accident, with the decisive 'A' values remaining for some time at 500-550 m (0903–0909 hrs).

The recorded cloud base was 120-170 m.

The ground was covered with fresh snow, the instrument runway 16 was, however, cleared of snow.

Zurich's weather radar picture showed no stormy cloud areas in the Basel area at the critical time.

1.7.3 *Meteorological conditions in the accident area*

According to statements made by competent witnesses the accident site was in cloud, the wind was blowing from a northerly direction at approximately 15 kts. Visibility was reduced to less than 50 m by heavy snowfall.

1.7.4 *Meteorological conditions at the alternate airport, Zurich*

The development of the current meteorological situation in Zurich suggested that the meteorological conditions would be just good enough for a possible diversionary landing.

1.7.5 *Meteorological conditions at the alternate airport, Geneva*

The meteorological broadcast (VOLMET) from Geneva apparently heard on the VHF-COM 1 (this is also transmitted by Zurich and Basel weather services, among others, in addition to Geneva) gave good meteorological conditions for a possible diversionary landing at the critical time.

1.8 Ground aids to navigation

1.8.1 *Airways*

The Bristol-Basel route flown is marked by several NDBs and VOR. They were operational and IM 435 gave the appropriate air traffic services units routine reports when they were passed. Over France G–AXOP's flight path was also tracked and recorded by military radar. The analysis showed that the aircraft kept accurately to the airway as far as Rolampont. While proceeding to Luxeuil VOR an unreported deviation of approximately 10 nm to the right of the airway centre line was observed. The recorder picture extends just into the Hericourt area.

1.8.2 *Basel-Mulhouse TMA*

List of the navigational aids according to AIP France, approach charts dated 20 July 1972 (Annex 2a).

There were 3 crystal-controlled, non-directional medium wave beacons (NDB) available for area navigation.

NDB	BN	306.5 KHz, type of emission		AO/A1
	MN	335.5	”	AO/A1
	BS	276	”	AO/A2

- There is a VDF on the Approach Control frequency 121.25 MHz and on 119.7 MHz with the aid of which the bearings of aircraft in the control zone can be taken automatically during their radio transmissions.
- There is also surveillance radar (SRE) in the airport area which operates in the 10 cm band and according to the French AIP can be used for surveillance and information up to FL 100. It was therefore not used for radar vectoring but only to speed up the traffic flow and to prevent inadvertent entry into the bordering military sectors.
- It was difficult to determine the accuracy of the geographical position of an aircraft echo observed on the radar scope as at that time the installation was not equipped with video-mapping, ie representation of the structure of the airways and TMA and the positions of the NDBs.
- Owing to the position of the antenna the installation shows a large blank cone in the approach and take-off climb areas between the two NDBs BN and BS and is neither intended nor suitable for monitoring the last phase of the final approach to runway 16.

1.8.3 *Approach aids*

ILS runway 16: Basel airport had a complete ILS facility for runway 16 which had been approved for ILS Precision Category 1 approaches. The localizer centre-line was on 158°; the glide path was 2.5°.

The frequencies were: 109.5 MHz (LOC), 332.6 MHz (GP), the identification was ‘MH’.

The accompanying 75 MHz markers are:

Outer marker (OM)	sited 3.7 nm from the approach end of the runway
Middle marker (MM)	sited 0.6 nm from the approach end of the runway
Inner marker (IM)	sited 0.05 nm from the approach end of the runway

(the Inner marker (IM) is non-mandatory).

Approach procedures: see Annexes 2a and 2b. Approach minima see 1.17.

NDB runway 16: In addition to the ILS approach, an approach procedure using the NDBs BN and MN was also promulgated for Basel airport and was authorised with the following minima:

Minimum height:	387 ft/AGL
Minimum visibility:	1000 m

1.8.4 *ILS checks*

The routine daily check before the accident and the inspection flights by the French authorities after the accident found no relevant defects in the ground aids to navigation.

1.8.5 *Characteristics of the ILS installation*

The non-transistorized ILS installation of British design used in Basel also radiates for the localizer a so-called 'back beam', ie a course beam, in the opposite direction to the approach. This is customary in installations of this kind unless it is technically necessary to suppress the back beam.

In addition to the main glide path beam in the approach area the glide path transmitter radiates various steeper and very narrow secondary beams which therefore cannot be bracketed. The same applies to the back zone where, among other things, a weak glide path of approximately 1°55″ can be observed.

No ILS back beam procedure has been promulgated. Nowhere is specific reference made to the secondary localizer and glide back beams which exist; nor is this required under international regulations.

1.8.6 *The MF beacons in the TMA*

Complaints about the quality of the medium wave beacons in the TMA were made sporadically both before and after the accident. Fault was chiefly found with the main approach beacon BN on approaches from the direction of Hericourt and in the holding pattern at a fairly high altitude. However, no complaints about BN were made during final approach on the ILS.

The projected installation of a VOR transmitter, which had been procured even before the accident and which would have decidedly improved the situation in the TMA as it is not affected by static, had been delayed owing to difficulties in procuring the land.

The measured range of the beacons after the accident was generally small. During the emission of the identification signal the indication from beacons BN and MN was, as expected, unstable. The type of emission (AO/A1) of these two beacons does not comply with the ICAO standard (see also 1.17).

1.9 **R/T communications**

Analysis of the tape recording of the R/T conversations conducted in English between the ATC unit of Basel-Mulhouse airport and the crew of the accident aircraft had shown that the conversations proceeded normally. No difficulties of transmission or of communication could be detected.

The voices of both pilots were identified by the airline's chief flight instructor: both Captain Dorman and Captain Terry had taken part in the R/T communications. A detailed correlation of the R/T messages is given in Annex 5a.

1.10 Aerodrome ground facilities

1.10.1 *General*

Basel-Mulhouse is a communal French-Swiss airport on French territory. The technical services comprising ATC, weather and runway services and maintenance of the technical equipment and installations, are under French control.

1.10.2 *Instrument runway 16*

Basel-Mulhouse airport is at an altitude of 269 m, 5 km NW Basel, on the left bank of the Rhine. The instrument runway 16 measures 2370 x 60 m. The runway threshold is 260 m (873 ft) amsl. The lighting in the approach area consists of a string of lights 900 m long with 3 crossbars.

Runway visual range is measured using 2 transmissometer units, one level with the ILS touchdown point to the west of the runway, the second unit also to the west of the runway approximately halfway down the length of the runway. The runway visual range, which is calculated by computer, is shown in the control tower in illuminated figures.

The heavy snow may have led to the measurements being impaired owing to the pockets of snow on the transmissometers, all the more so with the prevailing strong north wind. If this effect existed at all then it must be assumed for the whole period of time that G–AXOP was in contact with the control tower, because the conditions remained roughly the same.

1.11 Flight data recorder

The aircraft was equipped with a MIDAS CMM/3RB magnetic tape flight data recorder system which mainly consisted of the actual crash recorder (secondary recorder) and an electronic unit (primary recorder). After the accident the device was recovered intact from the wreckage. The analysis took some time, as it was a long time before the errors in the analysis were eliminated (see item 1.16.1).

A cockpit voice recorder was not installed in the aircraft, since there was no requirement to do so in the United Kingdom at the time of the accident.

1.12 Aircraft wreckage

The aircraft was destroyed in the accident. Seen from the direction of approach, one of the main pieces of the wreckage, the centre section of the aircraft, was in an inverted position. It comprised the left wing up to and including engine No 1, the inner part of the right wing with fractures and burnt patches between engines Nos 3 and 4 and the centre section of the fuselage.

The detached after-section of the fuselage with the control surfaces was also in an inverted position.

Numerous pieces of fuselage wreckage lay among the main pieces of wreckage. Important parts of the engines and the forward section of the fuselage were scattered over a wreckage area of approximately 1000 m^2 in front of the main wreckage, looking in the direction of flight.

Among other items, the following parts or instruments were identified for later examination:

- Flap actuating cylinder in the inner right wing
- Flap selector box
- Cockpit pedestal
- The 4 engines including propellers
- Autopilot: pedestal controller
- Autopilot: computer amplifier
- VHF-COM: receivers 1 and 2, transmitters 1 and 2
- De-icing equipment: 2 push rods
- Altimeters 1 and 2
- RMI-VOR/ADF 1 and 2
- Course indicators 1 and 2
- Horizons 1 and 2
- ADF control panel, receiver, systems 1 and 2
- Marker receiver
- Glideslope receivers 1 and 2
- VHF-NAV receivers 1 and 2
- VOR instrumentation units 1 and 2

1.13 Medical and pathological findings

The autopsies on the two pilots showed that there is no reason to believe that any changes had occurred in the organs which might have hindered them in their work. The onset of death was due to purely traumatic causes and can be attributed entirely to the bodily injuries sustained in the crash.

At the time of the accident the pilots were not under the influence of alcohol or drugs. The measured CO-Hb concentration of 7% and 7.6% respectively is normal in smokers.

On the basis of the blood particles taken from the left hand control column which were ascribed to Captain Dorman the assumption that he was sitting in the left hand pilot's seat is confirmed.

1.14 Fire

Following the crash fire broke out on the right wing but it remained localized and the first helpers on the scene were able to extinguish it.

1.15 Survival aspects

Thirty seven occupants survived the accident. This is mainly due to the fact that the rear section of the fuselage remained intact to a large extent and no serious fire broke out.

1.16 Tests and special investigations

1.16.1 *Flight path reconstruction*

The parameters recorded by the flight data recorder were the indicated airspeed (IAS), altitude, (vertical) acceleration, magnetic heading, pitch attitude and time signals..

The special equipment needed for the analysis was only available in Bournemouth, England. After the first rough analysis an analysis was made in several refinement stages with the help of a computer which led to all parameters being determined with a very narrow margin of error. In order to define the main source of error in the wind a read-out regarding this was also undertaken from the flight data tape of an aircraft approaching Basel during the same period of time.

The plots of the flight path thus obtained give a qualitatively good picture of the movements of the aircraft from the first time it passed the beacon BN until the crash. Owing to the fact that only an average value for the wind effect is known the greatest inaccuracy must lie in the middle section of the reconstructed flight path where, compared with the eye witness reports, a lateral deviation of approximately 800 m can be observed.

1.16.2 *ILS inspection flights*

On 21 November 1973 a Federal Air Ministry inspection aircraft calibrated the ground aids to navigation, in particular the ILS. No defects in the equipment were found. The characteristics of the ILS installation described in 1.8.5 were confirmed. LOC back beam and glideslope secondary beams are given in Annexes 6a and 6b

1.16.3 *Airframe*

Examination of the flap actuating cylinder in the inner right wing and the flap selector box showed that the flaps were extended approximately 20° on impact.

The elevator trim indicator was at 1.0 division 'nose up', the directional trim indicator at 0.5 division 'left' and the aileron trim indicator at 'O' (neutral).

1.16.4 *Engines*

The damage to the compressors and propellers shows that the engines were under power on impact; a quantitative assessment is not possible.

1.16.5 *Radio and navigational equipment*

VHF/COM transmitters

Transmitter 1 was tuned to 126.80 MHz (corresponds to Geneva Met broadcast),
Transmitter 2 was tuned to 118.30 MHz (Basel Tower).

VHF/COM receivers

Receiver 1 was tuned to 126.80 MHz (Geneva Met Broadcast), receiver 2 was tuned to 118.30 MHz (Basel Tower).

VHF/NAV receivers

Both receivers were tuned to 109.5 MHz (Basel ILS).

VOR instrumentation units

Unit Serial No 398: (belonging to No 1 system, according to the entry in the technical log of 11 May 1972).

It was found that inexpert repairs had been carried out on the unit but they did not affect its performance.

The VOR flag alarm circuit had been set at a slightly too high flag current.

The LOC alarm circuit showed values which at 950 μA instead of 350 μA and 360 μA instead of 130 μA respectively are far above the nominal values. The flag does not appear with such a setting even when unusable signals are received.

The deflection sensitivity is set approximately 50% too high.

Unit Serial No 1169: (belonging to No 2 system according to the above entry).

A modification recommended in Service Information Letter 12-63 of 6 June 1963 had not been implemented, although the British ARB (now CAA) stated in its list of 1 January 1969 that it should be applied to the equipment in question. Non-implementation of this modification did not affect the performance of the equipment in G–AXOP.

Glideslope receivers

Receiver 1:

No irregularities were found.

Receiver 2:

The glideslope alarm circuit showed values of 950 μA instead of 350 μA and 465 μA instead of less than 200 μA respectively. The flag does not appear with such a setting even when unusable signals are received.

The deflection sensitivity is set approximately 50% too high.

Marker receiver

This equipment was live at the time of the crash.

ADF receivers

Receiver 1:

There may have been intermittent electrical interruptions in the loop servo amplifier caused by poorly soldered joints (Annex 4a).

At the time of the crash the receiver was working in the ADF mode and was tuned to 335 kHz.

Inexpertly carried out repairs were found in the loop servo amplifier (Annex 4b).

Receiver 2:

At the time of the crash the receiver was live, working in the ADF mode and tuned to 306 kHz. (MF Beacon BN = 306.5 kHz).

Autopilot

The Heading mode had been selected for the integrated flight system and the autopilot. It could not be determined whether the autopilot was being used and what IFS system was selected.

De-icing equipment

The position of the push rod of the jet pipe flap and of the air shutter indicates that the wing leading edge de-icing system was switched off at the time of the crash.

Altimeters

Altimeter 1 had a setting of 967 mb (effective QFE at the time of the accident was 967.5 mb) and altimeter 2 a setting of 997 mb (QNH at the time of the accident was 998.5 mb).

RMI VOR/ADF

The compass card of instrument No 1 was jammed at 200°, which roughly corresponds to the course at the time of the crash.

Course indicators

In both instruments the track arrow was jammed at 158°, which corresponds to the QFU of the instrument runway at Basel-Mulhouse airport.

1.16.6 *History of the ILS airborne equipment in G–AXOP*

On the day before the accident, in the evening of 9 April 1973, an ILS approach to Luton was made in the aircraft. During final approach the co-pilot observed a discrepancy between the instrument indications of the pilot-in-command and the co-pilot. Whereas the co-pilot's ADF and localizer needle showed a definite deviation to the left of the approach path, the PiC's instruments showed the aircraft exactly on the centre line. It could not be ascertained whether this discrepancy to the left was observable only in the flight director system in the horizon or also in the localizer needle (beam bar). Shortly after this discrepancy was reported by the co-pilot the crew established visual contact with the ground. Both pilots then saw that the aircraft was in fact approaching well to the left of the centre line.

After landing the IFS and ILS instruments showed the same indications, so the PiC did not make the prescribed entry in the technical log. However, he maintains that he informed the duty engineer at Luton verbally of the incident. The engineer cannot, however, recall this. In addition to this the PiC instructed his co-pilot to inform the new crew the following morning. The co-pilot, who flew on as a passenger from Luton to Bristol, maintains that he accordingly reported the incident to the pilot in the cockpit before take-off from Luton.

The two pilots who operated the flight into Luton reported the incident to their superiors after the accident, but the UK accident investigation authorities did not learn of this until about six months later when one of the pilots reported it to them direct.

Further investigations showed that as long ago as 11 months earlier a similar fault in the left hand ILS instrumentation had been observed and reported. As the fault did not recur on subsequent flights, no futher technical inquiries were made.

1.16.7 *Integrated flight system (IFS)*

The IFS equipment installed in G–AXOP supplies computed control signals for the bank required in order to establish and maintain the desired course. This information is shown either on the left or on the right horizon.

The IFS may be used in the Heading, NAV/LOC or Approach modes.

Heading Mode:

The position of the steering pointer depends on the difference between the heading selected and that flown, the instantaneous bank and the yaw rate. The control signal is at zero when the sum of the instantaneous values is identical as regards magnitude and direction. For example, if the actual heading is consistent with the selected heading, the bank and the yaw rate must also be zero before the steering pointer shows zero.

NAV/LOC:

This mode can be used for VOR or for localizer. The position of the steering pointer depends on the difference between the selected course (LOC or VOR) and the actual heading, the instantaneous deviation from the beam, the instantaneous bank and the yaw rate. If the aircraft is on the beam, a constant intersection angle is eliminated as a function of time. The control signal is zero if the instantaneous values of all the signals added together are identical as regards magnitude and direction. Any deviation from the nominal flight path immediately gives rise to an appropriate control signal.

Approach Mode: (See Annex 7)

This is selected as soon as the aircraft is on the LOC beam and the glide path pointer has reached zero. The position of the steering pointer depends upon the change in the intersection angle to the LOC beam, the lateral deviation from the LOC beam and the instantaneous bank. The control signal is zero when the instantaneous values of all the signals added together are identical as regards magnitude and direction. Any deviation from the nominal flight path immediately gives rise to an appropriate control signal.

Flag alarm for the steering pointer:

The flag alarm in the horizon becomes visible if one of the following conditions is met:

(a) Mode switch in GYRO position
(b) Loss of heading power 115 V ac
(c) Loss of attitude power 28 V dc
(d) Loss of attitude power 115 V ac

The flag alarm is not visible in the Heading, NAV/LOC, or Approach modes, provided the above mentioned power supply is in order.

The steering pointer is not visible if the GYRO mode is selected, provided the power supply is safeguarded.

If the IFS switch is on 1, the steering pointer in the captain's horizon can be used and the steering pointer in the co-pilot's horizon is not visible. If the IFS switch is on 2, the steering pointer in the co-pilot's horizon can be used and the pointer in the captain's horizon is not visible.

Pitch bar:

The pitch bar shows the pitch of the aircraft. If the mode switch is selected to Approach, the pitch bar moves into a pre-set datum position for approach by means of a servo-system. No signals from the ILS glide path receiver are therefore introduced into the IFS.

1.16.8 *History of the ADF equipment*

Records kept from 18 September 1965 to 23 February 1971 by Trans Canada Airlines (the previous operator of G–AXOP) show that receiver No 2252 failed several times a year owing to malfunctions and had to be replaced prematurely.

On 31 May 1972 and 2 June 1972 the Invicta crews complained about ADF system 1. However, according to the records system 2 was replaced. The receiver with serial No 2252 had been repaired on 25 February 1972 and 16 June 1972 and was installed in G–AXOP as system No 2 on 2 July 1972.

On 21 July 1972 a complaint was made about system No 1, but no fault was found on the ground, whereupon systems 1 and 2 were interchanged.

Irregularities were found at the last 'M' check during the ground test of ADF system No 2, which gave rise to an in-flight check being made on both ADF receivers. Although there is a note of it in the flight authorisation, there is no corresponding entry in the report of the test flight of 24 March 1973. The test report was not drawn up until 4 May 1973, ie after the accident.

1.16.9 *Maintenance work on the radionavigational equipment*

Maintenance work on G–AXOP was carried out by Invicta and by Aviation Traders (Engineering) Ltd (ATEL). As Invicta was not licensed by the British authorities to carry out repairs on radio equipment independently, this work was carried out there under the supervision of qualified ATEL technicians. The appropriate quality control was carried out every 3 weeks, on average, in the Invicta workshops in Manston and somewhat less frequently in Luton.

Whilst G–AXOP was owned by Trans Canada Airlines, maintenance of the radio-navigational equipment was changed from the 'fixed period' to the 'on condition' system (servicing or repairs being carried out as and when required); this system was also used when the aircraft was operated by Invicta.

G–AXOP's technical logs give no indications as regards when and where either the incorrect presetting of the VOR instrumentation unit 1 and glideslope receiver 2, or the botched repair work, were carried out.

Invicta was responsible for carrying out the in-flight check following completion of an 'M' check by ATEL. On 23 March 1973 ATEL completed an 'M' check on G–AXOP. The in-flight check was made on 24 March 1973 during a non-stop transit flight from Southend to Manston.

1.17 Miscellaneous

(Citing of the regulations does not constitute a legal appraisal of the events leading up to the accident.)

1.17.1 *Valid approach minima*

Official minima

According to AIP France the aircraft type Vickers Vanguard belongs to aircraft category II. In Basel the following lowest minima are authorised for a 'standard' ILS approach by these aircraft (a 'precision' approach was not applicable as the aircraft was not equipped with a radio altimeter):

Minimum height 65 m
Minimum visibility 600 m

The increases of 60% required in the publication if no exceptional authorisation has been given only apply to single flights according to the competent French authorities, and not to airlines which often fly into Basel.

An approach may only be initiated and continued to final approach if the runway visual range (the visibility value of transmissometer A determines this) is equal to or exceeds the authorised minimum value. It is the airline's responsibility to prescribe any increases on the minima mentioned according to the aircraft's equipment and the pilots' level of training. The airline or alternatively the pilot is responsible for adhering to the national and the airline's minima. The French supervisory authorities merely reserve the right to check that the regulations are being observed by means of spot checks.

Company minima

There are various specifications in the Invicta Flight Operations Manual:

- Volume 6, Part 1, Section 9, p 1 (Edition of 11 June 1971)
  ILS min for Basel 250 ft/600 m
- Volume 6, Part 2, Section 1, p 1 (Edition of 27 June 1972)
  ILS min 250 ft/650 m for airports such as Basel, with a runway of 6500 ft or more and approach lighting with less than 5 crossbars (Basel has 3).

In the Jeppesen manual also carried in the aircraft a minimum of 200 ft and visibility of at least 750 m RVR is required for a complete ILS installation and procedure (approach chart dated 9 March 1973).

1.17.2 *Company regulations*

According to volumes 1-6 of the Invicta Flight Operations Manual (FOM) approved by the British Civil Aviation Authority:

Instrument approaches under critical meteorological conditions are to be carried out by the PiC.

Before the approach the PiC briefs the co-pilot accordingly and he, as assisting pilot (a/p or P2), reads through the check list and, at the PiC's command, makes all preparations to land and reports any deviations from the prescribed procedures immediately.

When beginning to approach the minimum permissible decision height the co-pilot calls out every 100 ft and when the approach lights and/or runway are in sight.

The PiC decides whether to overshoot or land and carries out the selected procedure himself.

The radio aids are selected and checked by the co-pilot at the PiC's command, whereupon the PiC for his part must make sure that the navigational aid is correctly set.

It is permissible to use 2 captains – the PiC is specified before each route segment is flown and he sits in the left-hand pilot's seat.

Basel was one of the airports to which a PiC may make an approach without prior briefing or introductory flight as it is considered to be operationally simple.

Maximum permissible speed:

The graph for the maximum permissible speed (V_{NO}) shown in Chapter 1 of volume 2 of the Invicta Vanguard Aircraft Flight Manual (AFM) gives some values which are higher than the permissible limits quoted in the manufacturer's AFM. This discrepancy is explained by the fact that the Invicta AFM is the same as the AFM of the first owner of the aircraft, Trans Canada Airlines, whose aircraft had been certificated for higher maximum speeds.

After Invicta had bought the aircraft the British supervisory authorities ordered that all Vickers Vanguard aircraft types registered in the United Kingdom were to be operated according to standard values which are slightly lower than these. However, this correction was not noted in all Invicta publications. The high speeds noted over quite a time during the descent to Basel were within Trans Canada Airlines' permissible maximum speeds at that time.

1.17.3 *Method of operation of the NDBs in the Basel-Mulhouse TMA*

According to ICAO Annex 10, volume 1, item 3.4.6.1 non-directional radio beacons serving as holding beacons, approach, or landing aids shall be operated on the AO/A2 type of emission (modulated carrier). The two beacons BN and MN are, however, operated on the AO/A1 type of emission with unmodulated carrier, which causes the radio compass (ADF) needle to oscillate during keying of the station identification. The French authorities' justification for this deviation from the ICAO standard is the narrower band width of AO/A1 emissions, which makes it possible to have more radio aids within the allotted frequency band. This is said to more than compensate for the disadvantage of the oscillating ADF needle.

1.17.4 *Operating regulations of Basel-Mulhouse airport*

The operating regulations for approach and aerodrome control at Basel airport are laid down in the 'Manuel due Controleur d'Approche et d'Aerodrome', which is issued by the Airport Director and supplemented by instructions.

Transfer procedure In II-2-1-5 of the above mentioned Manual the following procedure for transferring from approach to aerodrome control is laid down, which applies to aircraft flying under IFR:

'**II-2-1-5 Coordination between approach control and aerodrome control**

When traffic is light, aerodrome control may operate the approach control service after agreement by the competent controllers regarding the way in which the service should be operated.

When traffic is heavy, approach control and aerodrome control must operate separately.

The methods of transferring from one control unit to the other are laid down in RAC-2-3-03, namely:

(1) **Arriving aircraft**

The control of an aircraft making an approach shall be transferred to aerodrome control when the aircraft is in sight of the aerodrome and the approach and landing may be made visually (IMC conditions permitting visual approach). As the aircraft is not necessarily able to apply the collision avoidance rules, it must first be separated from other aircraft manoeuvering under IMC by approach control.

Regulation III.2.9 PPI radar

PPI radar enables the following radar services to be used:

Radar information

Radar surveillance'

The aircraft G–AXOP was referred to the aerodrome control frequency immediately after it first established contact with approach control, which seems to be contrary to the regulation quoted above. The French authorities point out the admissibility of this procedure, as it only involves a change of frequency but not work on the part of approach control. The aerodrome controller is also trained as an approach controller and, when traffic is light, fulfils both functions on the same frequency. He is said to be all the more able to do this, as he also has a radar set at his disposal with the surveillance radar already described and he works in the same room as the approach controller.

The change to the aerodrome control frequency of 118.3 MHz meant that the air traffic controller no longer had the automatic R/T direction finder at his disposal. The VDF in Basel can only be used on two frequencies, the approach frequency of 121.25 MHz being selected to assist the identification of IFR aircraft and for any VDF approaches, and the general and military frequency of 119.7 MHz being selected to locate light aircraft which often fly low and below the range of radar.

1.17.5 *Meteorological reports to approaching aircraft*

According to ICAO document 4444-RAC/501/10 'Rules of the Air and Air Traffic Services' approach control shall transmit the following Met information to aircraft approaching under IFR:

PART IV – Approach Control Service

'13

Information for arriving aircraft

Note. – See Part VIII, 3.3 regarding flight information messages.

13.1

As early as practicable after an aircraft has established communication with the unit providing approach control service, the following information shall be transmitted to the aircraft, except when it is known that the aircraft already has received the information:

(a) runway-in-use;

(b) current meteorological information, as specified in Part VIII, 3.3.2.2 and 3.3.2.3;

(c) current runway surface conditions, in case of precipitants or other temporary hazards;

(d) changes in operational status of visual and non-visual aids essential for approach and landing.

13.3

At the commencement of final approach, the following information shall be transmitted to aircraft:

(a) significant changes in the mean surface wind direction and speed;

Note – Significant changes are specified in Table I of the Pans-Met. However, if the controller possesses wind information in the form of components, the significant changes are:

– Mean head-wind component:	10 knots
– Mean tail-wind component:	2 knots
– Mean cross-wind component:	5 knots

(b) the latest information, if any, on vertical wind shear and/or turbulence in the final approach area;

(c) the current visibility representative of the direction of approach and landing or, when provided, the current runway visual range value(s) and the trend, if practicable, supplemented by slant visual range value(s), if provided.

13.4

During final approach, the following information shall be transmitted without delay:

(a) the sudden occurrence of hazards (eg unauthorised traffic on the runway);

(b) significant variations in the current surface wind, expressed in terms of minimum and maximum values;

(c) significant changes in runway surface conditions;

(d) changes in the operational status of required visual or non-visual aids;

(e) changes in observed RVR value(s), in accordance with the reporting scale in use, or changes in the visibility representative of the direction of approach and landing.

PART VIII. – Air Traffic Services Messages

3.3.2.2

Messages transmitted to arriving aircraft in accordance with Part IV, 13.1 shall, except as provided in 3.3.2.2.1, contain the following meteorological information in the order given:

(a) mean surface wind direction and speed and significant variations therefrom;

(b) visibility, including significant directional variations, or, when provided, runway visual range;

(c) present weather;

(d) amount and height of base of low cloud;

(e) air temperature, if requested by the aircraft;

(f) dewpoint, if requested by the aircraft;

(g) altimeter setting(s);

(h) other significant information;

(i) if appropriate, information regarding expected changes as indicated in landing forecasts.

3.3.2.3.3

Runway visual range

Runway visual range values up to 800 metres shall be given in increments of 30 to 60 metres, in accordance with available observations, and values above 800 metres shall be given in increments of 100 metres. Runway visual range values which do not fit the reporting scale in use shall be rounded down to the next (lower) step in the reporting scale. If runway visual range is observed from more than one location along the runway, the value for the touchdown zone shall be given first and shall be followed by all the values for successive locations whenever one of these values is lower than the value for the touchdown zone and less than 800 metres. The respective locations shall be identified in a concise and unambiguous manner.

ICAO-Document 7605-Met/526/5

'Procedures for Air Navigation Services/Meteorology'

2

Meteorological Service for Air Navigation

2.2.4.2

When observations of runway visual range are required for inclusion in reports for take-off and landing, the runway visual range should be reported to the appropriate local air traffic services unit whenever there is a change in the value to be reported in accordance with the reporting scale in use. Arrangements for the transmission of such reports to air traffic services units concerned should be such that transmission is normally completed within 15 seconds after the termination of the observation which gave rise to the report.

Note 1 – The steps to be used in the reporting scale for runway visual range are given in 2.7.2.5.2.2.(f).

Note 2 – Attachment I gives guidance concerning constants for conversion of transmissometer indications into runway visual range.

2.2.5

Reports to aircraft for a take-off or an approach-to-land

2.2.5.1

Reports of meteorological conditions at aerodromes for aircraft taking off, holding or making an approach-to-land should be based on observations which are representative of conditions existing immediately prior to the transmission of the report.'

Comparison of the meteorological documents available and extracts from the record of the R/T communications showed the following:

1 In accordance with the regulations approach control transmitted the necessary meteorological data to G–AXOP when it first established contact.

2 The obligatory notification of the runway visual range at the commencement of final approach was not given when either approach was attempted.

3 The deterioration in the runway visual range ascertained from the RVR recording, which for some time was below the RVR value of 700 m first notified and even below the national permissible minimum value for Vanguards, was not reported to the aircraft.

4 The aerodrome controller confirmed in French to another aircraft approaching at the critical time that visibility on the runway itself was good but was poor ('bouche') in the approach area.

5 During the long approach period the crew made no further enquiries about the development of the weather, which must have been very critical, as the visibility value transmitted to them was after all only 50 or 100 m above the company minimum.

2 Analysis and Conclusions

2.1 Analysis

2.1.1 *Technical analysis*

2.1.1.1 AIRFRAME AND ENGINES

The position and condition of the wreckage at the accident site suggest that all the damage found on the airframe and the engines was due to the crash. No sign of previous defects was found.

Just before the crash the undercarriage was in all probability raised and locked and the flaps were at the 20° extension.

This configuration and the trim settings are consistent with a normal climb, as for example after a missed approach. It can also be inferred from this that the engine power was in all probability distributed symmetrically.

2.1.1.2 RADIONAVIGATIONAL EQUIPMENT

ADF

The settings found in the receivers correspond to the radio beacons in the Basel area:

Receiver 1	335 kHz/Beacon MN:	335.5 kHz
Receiver 2	306 kHz/Beacon BN:	306.5 kHz

The poorly soldered joints found in the loop servo amplifier of system No 1 might have led to interruptions in individual electrical connections in the amplifier; above all, intermittent interruptions were probable as a result of jolts, which could also be reproduced during the investigation. These irregularities would not have been readily observed by the crew.

It was possible that no faults were found during tests in the aircraft on the ground or in an electronic workshop. No thorough examination of the receivers was ordered after there had been repeated complaints about the ADF equipment.

The interchanging of systems 1 and 2 on 27 July 1972 suggests that no definite explanation of the cause of the faults reported by the crews was found.

VOR instrumentation units:

The faults found in system No 1 made it impossible as such for it to be used as primary approach aid. The fact that the VOR flag alarm circuit was set too high is not significant in this case, as there was no VOR unit on the ground. The fact that the deflection sensitivity of the LOC indication was 50% too high did not prevent the system being used but was rather exacting for the pilots.

The faulty settings of the LOC alarm circuit prevented the appearance of the flag until the two signals were unusable or not received.

It is conceivable that, if the unit was receiving unsatisfactory signals, the steering pointer returned to the mid-position without the pilot in the left hand seat being made aware of this dangerous situation. This fault could only have been discovered by cross checking with system No 2. With the actual arrangement of the instruments, either pilot could monitor the LOC flag of system No 2.

The reconstruction of the flight path on the basis of the flight recorder data shows that in practice G-AXOP never flew into a zone in which one or both the LOC signals were unusable.

Glideslope receivers:

The investigation uncovered faults in system No 2 which were similar to those in the VOR instrumentation unit No 1: the setting of the flag alarm circuit was far outside the tolerances and the deflection sensitivity was too high. The system therefore did not meet the requirements for a primary approach aid.

The incorrect setting of the glideslope alarm circuit prevented the appearance of the flag until both glideslope signals were unusable or not received. If unsatisfactory signals were received, the glideslope indicator returned to mid-position without the flag appearing, so that the pilot could assume that he was on the correct glide path.

The reconstruction of the flight path shows that during the last stage of the flight G-AXOP had flown into an area where a misleading indication of this kind could have occurred. This grave fault could only have been uncovered by comparing this indication with the indication of system No 1 (Cross check), which, having regard to the arrangement of the instruments, was not readily possible for the pilot in the right hand seat.

Airworthiness of G-AXOP as regards the radionavigational equipment:

The faults found in the ADF and ILS equipment were such that the safety of ILS approaches was doubtful.

Maintenance and repair of the radionavigational equipment of G-AXOP:

Although on the one hand the firm ATEL was equipped and operated in accordance with the British Civil Aviation Authority (CAA) and on the other hand Invicta's unlicensed workshop carried out its work under ATEL's supervision, the investigation found several faults, some of them serious, in the aircraft equipment.

The botched solder work found in the equipment was carried out during repairs and partly perhaps even when the equipment was manufactured.

The technical records of G-AXOP provide no indication as regards when and where the faulty work was carried out.

It is noteworthy that G-AXOP was recertificated several times without the cause of the defects in the ILS or ADF equipment reported by the crews being found.

It is doubtful whether the maintenance of and repairs to G-AXOP's radionavigational equipment fulfilled the conditions for commercial IFR operations.

2.1.2 *Operational analysis*

2.1.2.1 CREW

The pilots commenced the flight obviously rested and fit. The short, at first problem-free flight, from Luton via Bristol to Basel should not have seriously tired the crew. There was also nothing of a medical or physiological nature which could have impaired the pilots in their work.

Both pilots held the necessary training certificates and were familiar with Basel from earlier approaches with the same aircraft type. The investigations in the United Kingdom showed that the crew had the necessary documents for an IFR flight from Bristol to Basel.

Both pilots held the rank of captain. Captain Terry was, however, senior and had more flying experience. In accordance with the usual practice, Captain Terry flew from Luton to Bristol, ie the first route segment, as aircraft commander, while it may be assumed on the basis of witness statements, the signature on the load sheet, the record of the R/T communications and the traces found, that Captain Dorman flew from Bristol to Basel as aircraft commander in the left-hand seat. Experience has shown that a crew combination of this kind has undesirable consequences, especially when it is not a training captain who is flying in the right-hand pilot's seat. The pilot in the right-hand seat then generally has insufficient experience of performing the co-pilot's real duties and thinks like a captain rather than a co-pilot. The aircraft commander is irritated by the presence of a pilot of the same rank, so that there is a danger of a crew made up in this way not acting as a normal crew does.

2.1.2.2 METEOROLOGICAL CONDITIONS

The meteorological conditions in the Basel area were characterised in the main by heavy cloud, heavy snow at times and moderate north wind. This was consistent with the meteorological documents handed to the crew before take-off in Bristol, it is true, but it might nevertheless have surprised them to some extent, as the violence of the meteorological phenomena at the start of spring was atypical.

Disturbances due to static are customary in the reception of non-directional medium wave radio beacons in an active snowfall area.

During the approaches made by G-AXOP the runway visual range at the relevant measuring point of transmissometer A fell for some time below the value of 700 m first reported to the aircraft. From 0903–0909 hrs the RVR was, at 500–550 m, even below the official permissible approach minimum for aircraft in the Vanguard category. On the basis of a weather report of this kind the aircraft would have had to have discontinued the approach and waited for better meteorological conditions or made an approach to another airport with better meteorological conditions.

The explanation given by the aerodrome controller in Basel-Mulhouse, namely that visibility was distinctly better and therefore no further visibility reports were given, is not convincing. The asserted reduction in the RVR measurements owing to snow drifts would not only have applied to the unreported lower RVR values but also to the value of 700 m first reported to the aircraft, as snow was falling for some time. The aerodrome controller also reported to a French aircraft that visibility conditions in the approach area – which are important for the success of the approach – were worse than on the aerodrome itself. The international regulations require meteorological data to be given by authorised meteorologists or facilities; being an ATC specialist the aerodrome controller does not belong to this category. He therefore has to report obvious discrepancies to the weather specialist and cannot decide himself the validity of the meteorological reports available. Failure to give low visibility reports is of no direct relevance to the occurrence of the accident, especially as it happened far from the approach area. Transmission of the RVR values read might perhaps have resulted in the approach attempts being discontinued and thereby prevented the accident.

In the accident area the cloud was continuous and the visibility conditions were so poor that, combined with the snow covered ground without contrast, the crew could not see in time whether they were approaching ground obstacles, particularly since the aircraft was not equipped with a ground proximity warning device.

2.1.2.3 NAVIGATIONAL AIDS IN THE TMA

The meteorological conditions already described and the fact that the modulation of the most important approach beacons in the Basel-Mulhouse area did not comply with ICAO requirements caused crews of all approaching aircraft some difficulties. Under such conditions the ADF indications are still usable, it is true, but they are not reliable enough, so that it is essential for the aircraft position to be monitored by additional static-free navigational aids or by radar monitoring from the ground.

During the critical period from 0400–1030 hrs ten aircraft landed safely in Basel-Mulhouse; two aircraft landed on another aerodrome owing to the poor weather conditions.

The reconstruction of the accident flight shows that there was a usable ADF indication on individual instruments at least part of the time: for example, the Hericourt beacon (HR) was passed apparently normally, the maintenance of the course between HR and BN is characterised by its constancy, and during initiation of the first approach attempt BN was correctly passed twice. This possibly also applies to the aircraft's apparent heading for the BS beacon (possibly confused with MN) during the second approach attempt.

Monitoring of positions in the area and on the ILS, including markers, would have been possible using radio aids (VOR or DME) with no electrostatic interference; also on request, a cross check could have been made with the Basel approach control office (VDF radial). However, no such request was made, although the fact that a VDF is available is noted in the Jeppesen approach chart used.

2.1.2.4 BASEL ATC

The competent control and supervisory authorities of Basel approach control were aware of the, in itself, critical meteorological situation. They also knew about the shortcomings in the medium wave radio beacons in the TMA, as they were, after all, well aware of the lengthy endeavours to acquire an electrostatic-free navigational aid (VOR).

A further real incentive to greater alertness was given by the repetition of the procedure turn over BN; this is something which rarely happens and is usually caused by navigational inaccuracies or technical defects on board the aircraft.

The former captain's report of the low-flying aircraft over Binningen should also have had a disquieting effect, as also should the reported overshoot in view of the meteorological situation over the aerodrome which the controller had not considered critical.

A report from Zurich Area Control Centre which was very alarming and was confirmed by his own radar display did not prompt the controller to take immediate and determined action, although no other aircraft could have been operating uncontrolled in the area with the meteorological situation as it was. He did not intervene with specific information until it was too late.

When considering this behaviour it must be borne in mind that:

(a) the aids (radar and VDF) available would have made it possible for the controllers, at least to some extent, to detect the incorrect flight paths and to take early action to help the cockpit crew,

(b) the ATS facilities available were in general not designed to give a warning when aircraft infringed the required minimum height above ground level,

(c) no international or national regulations or ATC procedures are known which require ATC to perform such services if, as at Basel, no precision approach radar is available.

The Federal Commission of Inquiry into Aircraft Accidents believes, however, that it is evident from the idea and conception of the whole ATC system and from the object of ground radar (information and surveillance) that everyone concerned has an unwritten inherent duty to draw the attention of other users of the system to obviously dangerous situations even though the duty to warn is not part of his primary duty. In this sense greater attentiveness and active helpfulness would have been expected, not only with hindsight, from ATC which, in view of the accumulating danger signs would then have taken early active warning action, thereby possibly preventing the accident.

2.1.2.5 OPERATIONAL SUPERVISION

In general, the airline's training and operating regulations seem to be in order. However, the statements regarding the method of operation of the flight director system, some of which are conflicting, raised some doubts as to familiarity with the system, which is vital in critical situations with equipment such as this.

The dubious basic training of Captain Dorman cannot just be blamed on the airline, as they could not uncover the discrepancies in his flying log book and, under the UK Civil Aviation Act 1971 (Section 36 (1)), only with the pilot's consent could they have found out from the UK Licensing Authority the difficulty with which Captain Dorman obtained the British instrument rating.

It is open to doubt whether the generous regulation relating to applications to make instrument rating test flights takes too little account of general interests of safety. It is certain that repeated failure to pass a test of this kind indicates a lack of suitability on the part of a candidate.

2.1.2.6 FLIGHT PATH INTERPRETATION

The analysis of the flight data recorder produced a qualitatively good picture of the flight path which, when verified by additional spot checks, may be described as established and sufficiently exact for operational interpretation.

The flight seems to have proceeded according to routine until the commencement of the approach to Basel. The unreported deviation from the airway centre line between Rolampont and Hericourt may have been due to more favourable conditions for descent to the south of the airway. The high airspeed established during the same period, which might be explained by a descent in a cloud gap, would also be consistent with this.

It may be assumed that the aircraft passed the Hericourt and BN beacons normally during descent, which is confirmed by the Basel-Mulhouse radar controller's statement and the plot of the flight path.

Beginning with the initiation of the actual approach, great flying and navigational difficulties are immediately in evidence which finally resulted in complete disorientation and led first to a near-accident and then, on the second approach attempt, to the disaster.

In detail, the following interpretations, above all, are possible for the various approach phases:

Preparation for the first approach attempt:

The first procedure turn is characterised by an inaccurate course selection (wrong intersection angle) and therefore did not lead to the prescribed MN beacon but – probably unnoticed at first – across the localizer to the other side of the holding area. When roughly abeam of MN the aircraft reported passing it. After attempting to intercept for a short time the localizer expected to the west, a consistent intercept course to BN was maintained. During this turn the maintenance of height was poor, fluctuating between approximately 2200 and 2900 ft, the assigned height being 2500 ft. Possible turbulence cannot explain this deviation, as the acceleration recording by the flight data recorder indicated only slight turbulence and the aircraft is in general considered to be very stable under such conditions.

As the first procedure turn was unsuccessful and first took them far beyond the ILS glide path to the ILS localizer, a second one was unavoidable. During the second procedure turn the crew must have made a crucial navigational error, quite obviously confusing beacons MN and BN. In an extremely tight turn deviating 950 ft from the assigned height they headed straight for beacon BN again and passed it at a height of approximately 3200 ft (assigned height 1923 ft).

First approach attempt:

After passing BN the aircraft descended with a remarkably constant rate of descent, flying as first considerably to the right and later to the left of the ILS approach centre line. When the aircraft was roughly abeam of the NDB BS it reported passing BN at approximately the assigned height which could suggest that beacons BN and BS were confused. The aircraft then continued to descend to 1400 ft at a constant rate. First overshoot: the approach was discontinued over the city of Basel, where the aircraft was sighted by several witnesses on the ground. It is to be assumed that the crew, like many of the surviving passengers, could see the ground, above all through the side windows, and therefore initiated the overshoot after some hesitation before reaching the ILS minimum of 1133 ft.

Second approach attempt:

Coincident with the commencement of the overshoot there was a change in the operator of the R/T equipment (Captain Dorman instead of Captain Terry), which implies that the pilot flying the aircraft was changed. Afterwards the flight path is much smoother as regards course and height. The flight proceeded in a wide turn to the right in the direction of the beacon BS and at a height of approximately 3200 ft which was then slowly reduced to the assigned height of 2500 ft and maintained for a long time. In the vicinity of BS position MN was reported and a left-hand turn was initiated to the west side of the localizer which was approached from this (as such wrong) side in a clean intercept. The localizer (back beam) once reached was accurately maintained and the second final approach was initiated. The rate of descent was at first the same as on the first approach attempt but became noticeably shallower after the back glide path was crossed. At roughly the same time the aircraft also reached the area where the glide path warning flag had to be visible the whole time (at least on the captain's instrument), as the glide path signal was too weak in this area. When the aircraft reached approximately 1400 ft an abrupt overshoot was initiated – which according to statements was clearly felt by all the surviving passengers – and the aircraft climbed at optimum rate. The initially high rate of climb soon decreased somewhat, so that the aircraft crashed into the upper slopes of the range of hills and was wrecked.

2.1.2.7 SUMMARY

The flight path during the descent from HR to over BN was normal, it then becomes highly erractic with regard to navigation and maintenance of height, deviating considerably from the prescribed flight path and prescribed height.

During the second procedure turn before the first final approach a navigational error was obviously made, as the aircraft headed straight for BN again instead of beacon MN. One cannot say whether this was due to the fact that the two beacons were not set on the ADFs in the normal sequence (ADF 1 to BN, ADF 2 to MN; the opposite settings were found in the wreckage).

Following the second procedure turn a continual descent begins from a height of approximately 3200 ft, as if they had a definite glide path indication. This could not, however, have come from the ILS glade path transmitter, as the flight path led over the glide path station with its many weak and steep secondy glide path beams. The flight director system could offer an explanation for the regular rates of descent. At approximately 3200 ft over BN a spurious glide path was crossed during the second procedure turn. Now if on the basis of this indication, which might also have coincided with a localizer indication, the flight director was set to the approach mode in order to follow both pointers on this, the subsequent approach might be explained but only if the two pilots neglected to keep the normal, continuous, mutual check on the basic navigational instruments and the marker control. The artificial horizon pitch bar which is not integrated with the ILs glide path signals requires an average rate of descent of approximately 500 ft/min to maintain a 2.5° glide path without wind correction. In this instrumentation the ILS glide path indication takes the form of a small triangle in the artificial horizon.

The reason for the poor tracking of the ILS localizer during the first approach attempt can be explained by the defect found in the captain's ILS equipment. The flag current which was set too high is not of significance here, as the aircraft never flew in an area where this licalizer flag would normally have had to respond. There should have been a localizer indication the whole time. On the other hand, it was extremely disturbing that the deflection sensitivity of the localizer had been set more than 50% too high. Because of this the localizer indication and therefore the IFS steering pointer too were so 'jittery' that they could hardly be followed any more. In addition, it was easy to miss crossing the localizer, as this only lasted 3-4 seconds after the second procedure turn, which was completely unsuccessful, instead of the usual 10 seconds. The difficulties in intercepting and following the localizer up to the first overshoot, which is the latest time that a change of pilot and therefore also a change of the primarily used blind flying instruments may be assumed, become evident if one compares the flight path of the first section with that of the second.

As an unrectified, at least temporary defect in the captain's ILS equipment had also led to a final approach to the left of the approach path the day before, the approach path on the first approach attempt, which was obviously too far to the left, possibly indicates that this technical defect had recurred.

Despite the prevailing unfavourable conditions as regards the weather, instability of the ADFs and oversensitivy of the ILS localizer indication on the instruments of the pilot flying the aircraft, the first approach attempt following the confusion of the beacons need not necessarily have led to the dangerous flight path established. These conditions, some of which the crew was aware of, could be expected to have prompted them to make a careful, repeatedly verified approach, with continual mutual monitoring, in the course of which any discrepancies would soon be discovered and ATC help requested in case of doubt. But nothing of the kind occurred.

The maintenance of height was erratic and should have been reported to the ATC. The inference of the values recorded by the flight data recorder is that the considerable deviations in height did not result from turbulence or vertical gusts.

The markers were not used to identify the beacons and the correct glide path altitude.

The crew's conduct following discontinuation of the first approach attempt is inexplicable. Although it must be assumed on the basis of the witness statements and the plot of the flight path that the crew realised what a dangerous manoeuvre they had carried out – instead of the unbuilt-up and flat outlying ground of the aerodrome a densely populated and hilly area came into view even before the normal ILS approach minimum was reached – no fundamentally new safety measures were taken. Apparently only the certainly expedient change of pilot and, consequently, instruments took place, which admittedly resulted in accurately flown turns and courses but still did not rely on the marker beacon emissions which were essential for an ILS in view of the atmospheric disturbances. Instead of requesting the help of Air Traffic Control who were only intermittently occupied with other aircraft, or diverting to an alternate aerodrome, they may well have attempted, according to a possible interpretation of the tape recording, to make the second approach using only localizer and glide path and time and course navigation, which could not succeed in view of the 'bungled' situation. The fact that the second approach was initiated with position report MN in the immediate vicinityof the BS beacon could be looked upon as a further confusion of navigational aids.

It is not possible to say what happened in the cockpit and how the various mistakes and wrong decisions and the shortcomings in the pilots' monitoring of each other came about, as no cockpit voice recorder was carried which would doubtless have been able to provide many clues, thereby making it easier to recommend what action should be taken to prevent similar accidents. There are no clues or explanations as to what had distracted the crew from their work to such an extent or had hindered their monitoring of each other.

2.2 Conclusions

2.2.1 *Findings*

The licences of the crew were in order and valid

The crew was authorised to operate the flight and had landed in Basel-Mulhouse several times before.

There was no reason to believe that the pilots had any medical disorders during the accident flight.

The aircraft had been declared airworthy and was certificated.

No signs of structural failure, fire on board, failure of the engines or the controls during the flight could be found.

There were several faults in the aircraft's radionavigational equipment resulting from poor maintenance which made the crew's navigational orientation much more difficult.

In the prevailing meteorological conditions in the Basel area only an instrument approach was possible. The atmospheric disturbances impaired the reception of the medium wave navigational beacons, but they still gave usable indications at least part of the time.

According to the data record by the automatic equipment the visibility conditions on the instrument runway were at times below the minimum values permissible for the aircraft. They were not communicated to the crew.

The flight from Bristol to Basel proceeded apparently without operational or navigational difficulties as far as the Basel-Mulhouse terminal control area.

Even during the first procedure turn over the starting point for the approach beacon BN, navigational difficulties arose which led to the procedure turn being repeated.

The first final approach resulted in a near-accident far from the aerodrome after the crew had established visual contact with the ground.

The second approach attempt was made to the south of Basel airport and without using the marker beacons of the ILS.

The overshoot during the second unsuccessful approach was initiated too late, so that G–AXOP, while still airworthy, crashed into steep wooded terrain.

2.2.2 *Probable cause of the accident*

The Federal Commission of Inquiry into Aircraft Accidents came to the following conclusion:

The accident is attributable to:

loss of orientation during two ILS approaches carried out under instrument flight conditions.

The following factors contributed to the occurrence of the accident:

inadequate navigation, above all imprecise initiation of final approach as regards height and approach axis,

confusion of navigational aids and

insufficient checking and comparison of navigational aids and instrument readings (cross and double checks).

The poor reception of the medium wave beacons, the technical defects in LOC receiver No 1 and glideslope receiver No 2 made the crew's navigational task more difficult.

3 Recommendations

1 In view of the civil/military traffic conditions and the topographical situation the ATC technical and operating facilities in Basel-Mulhouse TMA should be re-examined and radar vectoring in particular provided.

2 All medium wave radio beacons in the Basel TMA should be readjusted to a modulation in conformity with ICAO.

3 International regulations should require the suppression of unpublicized ILS backbeams, especially glide path backbeams.

4 Official approach charts should – as far as possible – contain indications for cross checking the main approach beacon with other electrostatic-free radio aids.

5 All commercially operated aircraft having an all-up weight of more than 5700 kg should be equipped with flight data and cockpit voice recorders.

6 All commercially operated aircraft having an all-weight of more than 5700 kg should be equipped with a ground proximity warning device.

sig Dr Th Kaeslin
sig J –P Weibel
sig F Dubs
sig Dr H Hafner
sig Dr Ch Ott

Bern, 30 May 1975

Abbreviations

ADF	Automatic direction finding equipment
AFM	Aircraft flight manual
AIP	Aeronautical information publication
ATC	Air traffic control
CAA	Civil Aviation Authority
COM	Communications
DME	Distance-measuring equipment
FOM	Flight operations manual
GP	Glide path
ICAO	International Civil Aviation Organisation
IFR	Instrument flight rules
IFS	Integrated flight system
ILS	Instrument landing system
IMC	Instrument meteorological conditions
LOC	Localizer
MF	Medium frequency
NDB	Non-directional radio beacon
QFE	Atmospheric pressure at aerodrome elevation or at runway threshold
QFU	Magnetic orientation of runway
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RMI	Radio magnetic indicator
VDF	Very high frequency direction-finding station
VHF	Very high frequency
VOLMET	Meteorological information for aircraft in flight
VOR	VHF omnidirectional radio-range