Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Boeing 747 - 136 G-AWNJ
Report on the incident near Nairobi Airport, Kenya, on 3 September 1974

LONDON
HER MAJESTY'S STATIONERY OFFICE
1975

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Department of Trade
Accidents Investigation Branch
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London WC2R 0DP

20 October 1975

The Rt Honourable Peter Shore MP
Secretary of State for Trade

Sir,

I have the honour to submit the report by Mr P J Bardon, an Inspector of Accidents, on the circumstances of the incident to Boeing 747 - 136 G-AWNJ which occurred near Nairobi Airport, Kenya, on 3 September 1974.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch
Aircraft Accident Report No 14/75
(EW/A247)

Aircraft:	Boeing 747 - 136 G-AWNJ
Engines:	Four Pratt and Whitney JT9D-7
Owner and Operator:	British Airways (Overseas Division)
Flight Crew:	3 - Uninjured
Cabin Crew:	15 - Uninjured
Passengers:	281 - Uninjured
Place of Incident:	Near Nairobi Airport, Kenya
Date and Time:	3 September 1974 at 0511 hrs
	All times in this report are GMT

Summary

During a coupled ILS approach in instrument conditions into Nairobi Airport (elevation 5,327 feet) 5,000 was dialled into the Altitude Selector and a descent to capture this altitude was initiated. The aircraft descended through the actual cleared altitude (7,500 feet) just before it became established on the localiser and although it was still below the glide slope the descent was continued to within sight of the ground at approximately 200 feet. During the subsequent overshoot manoeuvre the aircraft came to within 70 feet of the ground at a distance of approximately 6¾ nm from the airport. The report concludes that the incident was caused by the pilots' acceptance of a height to which they mistakenly believed the aircraft had been cleared to descend.

The failure of the ATC controller to challenge the incorrect read back of the descent clearance; inadequate crew monitoring; the relatively high speed of the aircraft's approach; and crew sickness were contributory factors.

1. Investigation

1.1 History of the flight

The aircraft was operating British Airways flight BA029, a scheduled service from London (Heathrow) Airport to Johannesburg with intermediate stops in Zurich and Nairobi. The flight from London to Zurich was uneventful and after a crew change the aircraft departed Zurich at 2136 hrs on 2 September 1974, 11 minutes behind schedule, with an estimated time of arrival (ETA) at Nairobi of 0513 hrs (0813 hrs local Nairobi time).

The flight proceeded normally with the commander in the left hand seat piloting the aircraft and the co-pilot in the right hand seat handling most of the air-to-ground communications. A flight engineer was operating the flight engineer's station. The aircraft flew at flight level (FL) 330 until about 2½ hours before ETA when it was re-cleared to FL 370. No significant weather was encountered en route and sunrise occurred at about 0330 hrs.

When the aircraft was approximately 150 nautical miles (nm) from Nairobi the commander briefed the co-pilot and the flight engineer for the approach and landing. Following normal Company* procedures he reviewed the aerodrome approach charts and noted the height of Nairobi above sea level (5,327 feet) and the appropriate safety heights for the area. He also discussed the aerodromes available for diversion. Anticipating that runway 06 would be in use and that procedure 'A' would be followed for an approach using the Instrument Landing System (ILS) (see Appendix A), the commander declared his intention of carrying out a coupled-approach on the ILS with a manual landing once the runway had been sighted. Having obtained the weather minima appropriate to both a manual approach and an auto-approach from the Company manual, the crew set the movable indices on the pressure altimeters appropriate to 5,627 feet (manual minimum altitude above sea level) and those on the radio altimeters to 200 feet (coupled-approach minimum height above aerodrome elevation).

Shortly after this briefing had been given radio communications were established with the Nairobi radar controller on frequency 119.5 MHz and the aircraft was cleared to the 'Golf Golf' non-directional beacon (NDB) at FL 150 with no delay expected for an ILS approach to runway 06. The 0430 hrs Nairobi weather observation reporting two oktas of cloud at 800 feet was also passed to the aircraft. At approximately 0455 hrs, when the aircraft was about 90 nm from Nairobi, the descent to FL 150 was commenced. During the descent a message was received informing the aircraft that a pilot who had just landed at Nairobi had reported that the cloud base was then at 300 feet.

The aircraft was recleared to FL 120 on a revised heading of 160°(M) after it had been positively identified by radar at a distance of 46 nm from Nairobi. After it levelled off at FL 120 at 0504:00 hrs and with 30 nm still to run to the 'Golf Golf' beacon, it accelerated gradually to 338 knots Indicated Air Speed (IAS). At this time the skies were clear and the Ngong range of hills, on whose summit the 'Golf Golf' beacon is installed, was clearly visible. Beyond the hills, however, the plateau surrounding the airport was covered by low cloud.

At 0505:47 hrs, when the aircraft was about 16 nm from the 'Golf Golf' beacon, it was recleared to descend to FL 100. This descent was made with the throttles closed and at a rate of about 1,000 feet per minute with the airspeed gradually reducing. At 0508:13 hrs the aircraft was instructed by radar to turn left on to a heading of 105 degs (M). During this turn the aircraft reached FL 100 and began to level off automatically under

*Throughout this report the word 'Company' refers to British Airways (Overseas Division).

the control of the autopilot. The speed at this stage was 263 knots IAS and still reducing. (NB: the maximum speed for lowering 1 degree of flap, ie the first increment, was 265 knots IAS and the minimum speed for zero flap at the aircraft's weight was 213 knots IAS).

The turn onto 105°(M) was completed at 0508:49 hrs, and the commander engaged the autothrottle 7 seconds later when the speed was about 235 knots IAS.

The No.1 very high frequency (VHF) navigation receiver had been set in the R/W 06 ILS frequency by this time and the Nairobi VOR frequency left on the No. 2 set. Both automatic direction finding (ADF) receivers were tuned to the 'Golf Golf' beacon.

At 0508:59 hrs the radar controller advised the flight: 'SPEEDBIRD ZERO TWO NINE YOU ARE PASSING THE GOLF GOLF BEACON THIS TIME DESCEND SEVEN FIVE ZERO ZERO FEET THE QNH IS ONE ZERO TWO ZERO DECIMAL FIVE.'

The crew noticed that they were passing the beacon both visually and by reference to the RMI needles. Neither pilot heard the clearance correctly and belived they had been cleared to descend to 'five zero, zero, zero feet.' The co-pilot accordingly read back without hesitation: 'ROGER SPEEDBIRD ZERO TWO NINE CLEARED TO FIVE THOUSAND FEET ON ONE ZERO TWO ZERO DECIMAL FIVE'. This message was not acknowledged by the radar controller. It was also missed by the flight engineer. He has stated that although he thought that the word SEVEN was indistinct, he was nevertheless in no doubt that the aircraft had been cleared to 7,500 feet, a height that he was expecting as it was given on the airfield approach chart as the intermediate approach altitude. However, he remained unaware that the pilots had interpreted the clearance differently.

A reconstruction of the events on the flight deck subsequent to this point has been made using the information obtained from the flight data recorder, the RTF transcript and recording, simulator studies and crew statements. No information was available from the cockpit voice recorder. The reconstruction is shown in diagramatic form at Appendix B together with a vertical cross section of the flight at Appendix C and a plot of the aircraft's track at Appendix E. From these studies, it has been deduced that as soon as the clearance was received, the commander disconnected the auto-throttle and put the aircraft into a descent. At the same time, the co-pilot dialled 5000 in the Altitude Selector on the autopilot/flight director mode selector on the pilots' light shield. The flight engineer saw this action but did not see the altitude selected as he was engaged in checking the ILS coding at the time.

At 0509:07 hrs, when the airspeed was 228 knots IAS, the commander called for 1 degree of flap and whilst this was being selected by the co-pilot, the flight engineer started the approach check. This occupied him for well over a minute and whilst he was engaged in doing this, both pilots reset their pressure altimeters to the QNH of 1020.5. The commander continued to control the aircraft through the autopilot whilst the co-pilot retuned both the ADFs to the outer and inner locators respectively. Both pilots then checked the locator beacon identifications. At this point, the co-pilot advised the commander that in accordance with the airfield approach chart, it was permitted to descend to below the sector safe altitude as the aircraft's position had been positively established over the 'Golf Golf' beacon by radar.

The flight engineer continued with the approach checks and encountered one short delay only when he found the pilots too pre-occupied with other duties to respond to his altimeter challenge until he had repeated it three times. As the aircraft passed through 8,600 feet amsl he checked the cabin differential pressure in order to cross check the aircraft's altitude.

The aircraft continued descending at about 1,900 feet per minute and soon entered the bank of low cloud when all visual reference to the ground was lost. When it passed through 2,500 feet above ground level the terrain clearance audio warning sounded and was duly noted by the crew.

At 0509:26 hrs, when the airspeed had been reduced to 220 knots, the co-pilot selected 5° flap and this took 28 seconds to achieve. At 0509:53 hrs the radar controller advised the aircraft that it had 15 nm to run to the runway and that it was cleared to lock on to the localiser which it was approaching and descend on the glide path. The commander then selected the ILS frequency on the No. 2 VHF NAV receiver himself, set the inbound QDM and switched the navigation mode switch to LAND. He then engaged the Nos. 2 and 3 autopilots in preparation for a coupled approach and at 0510:20 hrs he called for 10° flap.

At 0510:38 hrs the automatic capture of the localiser was initiated and the aircraft banked into a left turn. It was probably descending through about 7,700 feet amsl at this time at a descent rate of about 2,000 feet per minute and with the airspeed temporarily steady at 225 knots. The aircraft passed through the localiser and had to continue the turn and make further adjustments in heading before it stabilised on the inbound course. At this stage the flight engineer made a further check on the aircraft's altitude by cross reference to the cabin differential pressure.

At 6,000 feet amsl the co-pilot called 'One thousand to go' and shortly afterwards there was an audio warning alerting the crew that they were approaching their selected altitude. The ILS deviation warning light on each pilot's instrument panel then illuminated but, because it was unexpected, the commander's initial reaction was that the warning was probably false. The flight engineer also noticed the warning on resuming his instrument scan after checking the pressurisation and when he saw that the aircraft was still descending with the glide slope pointers out of view in the up position although on the localiser centre line, he called 'We have no glide slope'. The commander replied 'We have'. (Later he explained that he understood the flight engineer to mean that the glide slope had failed and that he could see no failure flag to confirm this).

At 0511:42 hrs, whilst the aircraft was still descending at 217 knots and at about 1,650 feet per minute, it reached 270 feet above ground level (AGL) and the Decision Height (DH) audio warning tone began to sound. A few seconds earlier, the ATC had advised the aircraft that it was 8½ nm from touch down and that it was cleared to land. The co-pilot began to acknowledge this message but his transmission was abruptly cut off in mid-word At this moment the flight engineer called: 'Two hundred feet decision height' and almost immediately afterwards, the aircraft broke out of the bottom of the cloud. The flight engineer called 'Give full power – give full power' followed by 'Check height – check height'. The commander, on sighting the ground, checked the rate of descent on the elevators, disconnected the autopilots and applied power for the overshoot. The time was then 0511:50 hrs. From the flight recorder read out, it was established that at its lowest point, the aircraft came to within 70 feet of the ground.

At 0512:26 the aircraft called ATC that it was overshooting and it was cleared to climb to 7,000 feet. As it had already passed 7,300 feet by this stage the radar controller amended the clearance to 7,500 feet. When the crew came to set this figure in the Altitude Selector they saw the figure 5000 which had been previously set and realised the error that had caused the premature descent and near collision with the ground. The aircraft was subsequently given radar guidance back on to the ILS and made a successful automatic landing.

The commander remained convinced that he had been cleared to 5,000 feet and after landing he went with his crew to air traffic control to find out why he had been given an incorrect clearance. This was denied by the controller and the flight crew were allowed to hear a replay of the ATC tape. This initially appeared to them to confirm that the

figure 5000 had been given in the descent clearance but after the third playback it was agreed that the words spoken by the radar controller were 'seven five zero zero feet'.

The commander completed a Company incident report form which was immediately transmitted to the Company's base at London (Heathrow) Airport. The crew were suspended from flying duties and returned to London as passengers

1.2 **Injuries to persons**

None.

1.3 **Damage to aircraft**

None.

1.4 **Other damage**

None.

1.5 **Flight Crew information**

(a) *Commander*

Age:	52 years.
Licence:	Airline Transport Pilot's Licence, valid until 5 September 1979.
Aircraft ratings:	Boeing 747, Boeing 707, Bristol Britannia.
Instrument rating:	Valid until 3 May 1975.
Medical certificate:	Valid until 31 October 1974
Last competency check:	14 April 1974.
Last route check:	24 May 1974.
Initial conversion to B747:	19 June 1971.

Flying experience

Total pilot hours:	18,845.
Total flying hours in command of Boeing 747 aircraft:	1,874.
Total flying hours in last 30 days:	57.

The commander had last flown into Nairobi on 30 July 1974. His two previous flights into the aerodrome were 10 March 1974 and 18 April 1973.

The commander had made a special and extensive study of the effects of fatigue on flight crew and had submitted evidence to the 'Bader Committee' on flight time limitations. He made available to the investigation full details of his own sleep patterns.

The commander had been employed by the Company for 32 years.

(b) *Co-pilot*

Age:	30 years.
Licence:	Airline Transport Pilot's Licence valid until 14 March 1977.
Aircraft ratings:	Boeing 747, Boeing 707, Piper PA23.
Instrument rating:	Valid until 24 April 1975.
Last competency check:	30 August 1974.
Medical certificate:	Valid until 30 September 1974.

Flying experience

Total pilot hours:	3,583.
Total flying hours as co-pilot of Boeing 747 aircraft:	171
Total flying hours in last 30 days:	39.

The co-pilot had operated into Nairobi Airport on Boeing 747 aircraft on two previous occasions – 11 August 1974 and 14 August 1974. He had also operated into Nairobi on two previous occasions on Boeing 707 aircraft in 1972.

The co-pilot completed his conversion on to Boeing 747 on 20 April 1974 and had flown about 25 sectors on the aircraft. On 30 August 1974, immediately prior to operating the service during which the incident occurred, the co-pilot carried out a simulator training detail in the capacity of P1 (First Pilot) during which the ILS Deviation Lights operated in the latter stages of an approach in Category 3 minima.

(c) *Flight Engineer*

Age:	43 years.
Licence:	Flight Engineer's Licence valid until 30 September 1978.
Aircraft ratings:	Boeing 747, Boeing 707/720.
Medical certificate:	Valid until 30 September 1974.
Last competency check:	9 May 1974.

Flying experience

Total flight engineer hours:	10,007.
Total flying hours as flight engineer on Boeing 747 aircraft:	1,336.
Total flying hours in last 30 days:	45.

The flight engineer had operated into Nairobi Airport fairly frequently, the last occasions being on 2 August 1974 and 4 August 1974.

(d) *Flight notification*

The commander received warning of this flight as part of his normal roster notification and had about a week off prior to this duty. The flight engineer was warned of a change in his roster which included this flight on 30 August 1974 and had had four days off duty before positioning to Zurich. The co-pilot had been expected to have some days off after completing a check detail in the Company's Boeing 747 simulator on 30 August 1974. While carrying out this detail he received a message from the scheduling section requesting him to remain available for a flight and later in the evening he was warned that he might have to fly on 1 September as no other pilot was

available. This commitment to operate flight BA029 was confirmed on the morning of 31 August 1974. His last flight was on 22 August 1974. Both the commander and the co-pilot had flown with the flight engineer before but had not themselves flown together previously.

(e) *Rest periods*

The flight crew met at London (Heathrow) Airport on the afternoon of 1 September 1974 and flew as passengers in a Company aircraft to Zurich arriving about 2130 hrs 2230 hrs local time). They all, therefore, had approximately 24 hours rest period before commencing duty for the flight to Nairobi.

All three crew members had a good night's sleep in a hotel in Zurich after their arrival. The commander slept for a further 2½ hours during the afternoon before the flight and the flight engineer for about 4 hours. The co-pilot slept until late in the morning and then rested in bed until he got up in the late afternoon. The crew were called for the flight at 1850 hrs and left the hotel for the airport one hour later. At the airport they performed the normal pre-flight briefing and planning duties in preparation for the arrival of the aircraft from London. The aircraft arrived a few minutes behind schedule but the hand over from the incoming crew was routine and there was no further delay.

(f) *Altimeter settings*

It was Company policy that the QNH value should be set on the altimeter barometric subscale during the final approach and landing phase on its Boeing 747 aircraft. Before converting to the Boeing 747 the commander had been accustomed to having the QFE value normally set on his altimeter, except when flying into high altitude airfields. Similarly the co-pilot had used the QFE setting both during his initial flying training and during his service with the Company on Boeing 707 aircraft, other than at high altitude airfields.

(g) *Subsequent actions*

Following the incident the Company immediately suspended the crew from flying duties and carried out an investigation into the circumstances. The Accidents Investigation Branch was also informed of the incident by the Company, although the occurrence did not fall within the definition of a notifiable accident. However, in view of its apparent seriousness, the Chief Inspector of Accidents ordered a full Inspector's investigation to be carried out, following consultation with the East African authorities.

Subsequently when the Civil Aviation Authority learned of the incident they provisionally suspended the pilots' licences under article 60(1) of the Air Navigation Order 1974 pending their own investigation. The Authority later restored the pilots' licences conditionally upon them demonstrating their proficiency on the aircraft and the co-pilot resumed his duties after further re-training. The flight engineer also returned to flying duties after successfully completing Company proficiency checks. The commander, however, did not return to flying duties with the Company and has since left its employ.

1.6 Aircraft information - Boeing 747-136 G-AWNJ

1.6.1	Manufacturer:	The Boeing Company, Seattle, USA.
	Year of manufacture:	1972.
	Owner:	Registered in the name of British Overseas Airways Corporation on 29 January 1969.
	Certificate of Airworthiness (C of A):	Renewed 23 March 1974 and current at the time of the incident.

Certificate of maintenance:	Issued in July 1974 and valid for 2,250 hours.
Total airframe hours:	10,242.
Maximum regulated landing weight:	245,000 kilogrammes.
Estimated landing weight at Nairobi:	227,664 kilogrammes (V_{REF} 134 knots IAS).
Centre of gravity:	Within the limits as shown on the Company's load sheet.

The aircraft had no defects pertinent to the incident.

1.6.2 *Minimum operating crew*

The minimum operating crew specified in the Aircraft's Flight Manual is two pilots and one flight engineer.

1.6.3 *Operational equipment*

The aircraft is equipped with a triple-channel autopilot/flight director system which among other functions has the capability for automatic capture of a pre-selected altitude; in addition it has the capability of holding airspeed, vertical speed and altitude. With this equipment it is possible to carry out either a coupled approach with one or more auto-pilots engaged or a fully automatic landing with either two or three autopilots engaged. However, before more than one autopilot can be engaged at the same time it is necessary to have both VHF NAV receivers tuned to the same ILS frequency and the navigational mode switch selected to LAND.

The autopilot/flight director mode selector panel which contains most of the control functions is situated on the pilot's light shield above the centre instrument panel and is accessible to both pilots, (see photograph at Appendix F). To pre-select an altitude, it has first to be inserted in the Altitude Selector on this panel and the system then has to be armed. The height at which altitude capture commences depends on the aircraft's actual rate of descent or climb. The barometric pressure setting to which the altitude is referenced is that set on the aircraft's left hand pressure altimeter.

There is an annunciator panel on each pilot's instrument panel which among other functions indicates either by a white or a green light when a selected facility is armed and when capture has been achieved. The functions covered by the annunciators are the Altitude Selector and localiser and glide slope capture.

1.6.4 *Navigation warning systems*

(a) *Altitude alert*

The altitude select facility has an associated alerting system which provides both an aural and a visual warning whenever the aircraft is approaching or deviating from the pre-set altitude. This alerting system is referenced to the barometric setting which has been selected on the right hand (co-pilot's) pressure servo altimeter.

An aural tone of approximately 2-3 seconds duration sounds when the aircraft is approaching (900 feet above or below) the selected altitude and at the same time the amber alert light on each pilot's panel comes on and remains on until 300 feet above or below the selected altitude when it goes out. The lights remain off when the aircraft is within 300 feet above or below the selected altitude. When the aircraft deviates outside this range the lights flash and the 2 second aural tone sounds. The lights continue to flash until 900 feet above or below the reference height when they go out.

(b) *Terrain warning*

A terrain aural warning is incorporated in the low range radio altimeter system (LRRA). Provided that the decision height (DH) pointer is set at or below 2,500 feet and is not below zero, the aural tone will be heard in the headsets and the cockpit speakers when the aircraft descends through 2,500 feet on the radio altimeter.

(c) *Decision height warnings*

These warnings, both aural tone and lights, are also incorporated in the LRRA system and the aural tone is the same as that used in the terrain warning. The tone sounds when the radio altimeter indicates between 75 feet above DH altitude and DH. When descending towards DH the note gradually increases in volume.

An amber DH warning light is positioned on each pilot's Attitude Director Indicator (ADI) and illuminates when the radio altimeter indicates at or below the altitude at which the DH pointer is set.

(d) *ILS deviation warning lights*

There are two red warning lights on each pilot's instrument panel which are operative when at least one autopilot is engaged and when either ILS or LAND mode is selected. Both illuminate if the aircraft deviates from the ILS localiser by ¼ dot or more or from the glide slope by 1 dot or more when 500 feet or less is indicated on the radio altimeter.

1.6.5 *Altimeters*

(a) *Pressure Servo altimeters*

There is a pressure servo altimeter on each pilot's instrument panel. These altimeters are of the digital pointer type in which the digital counter displays the height in hundreds and thousands of feet. Heights between each thousand are indicated by a pointer which makes one revolution of the instrument per thousand feet. There is a movable index (bug) which can be moved by hand round the periphery of the dial to indicate any height between zero and one thousand. It is impossible to reference thousands on the digital counter and therefore a height such as 5,627 can only be indicated as 627 on the pointer scale. The range of the sub-scale setting is 950-1050 mbs. It would therefore be impossible to set the QFE on the altimeter when operating into a high level airfield such as Nairobi, where the QFE is normally of the order to 830-840 mbs.

(b) *Low range radio altimeters (LRRA)*

There is an LRRA indicator on each pilot's instrument panel between the ADI and the pressure altimeter. A third LRRA is positioned below the pressure altimeter on the right hand instrument panel.

The LRRA pointer indicates height above ground level from 2,500 feet down to zero on an expanding scale. A movable index serves as a reference for the aural and light warning systems associated with the radio altimeters.

1.7 **Meteorological information**

The incident occurred in daylight about 1¾ hours after sunrise and throughout this period the sun was shining into the flight deck through the Captain's side and front windows.

The following weather report was passed to the aircraft at approximately 0448 hrs:

Nairobi 0430 hrs:	
Wind	190° less than 5 knots
Visibility	Better than 10 kilometres.
Cloud	2/8 at 800 feet.
Temperature and Dew Point	11°C
QNH	1020.5
Tempo cloud	3/8 at 800 feet.

Later during the descent a report from a landing pilot giving the cloud base as 300 feet was passed to the aircraft.

The plateau immediately surrounding Nairobi Airport was covered in low stratus with a varying base and with tops which have been estimated to be about 8,000 feet amsl. Beyond the area of the low cloud the weather was clear and the aircraft was flying in visual contact with the ground from the latter part of its descent until after leaving the 'Golf Golf' beacon when it entered cloud during its final descent.

1.8 Aids to navigation

The airport was equipped with an ILS on runway 06, a VOR station co-located with Distance Measuring Equipment (DME), and radar. All the appropriate radio navigational aids were serviceable and in use at the time of the incident. The radar unit was not equipped with secondary surveillance radar (SSR) or Height Finder equipment nor could it monitor the aircraft's height on its final approach path. The Distance Measuring Equipment (DME) was frequency paired with the VOR station and not the ILS.

There were two alternate approach procedures published for an ILS approach from the 'Golf Golf' beacon to runway 06. Procedure 'A' (see Appendix A) included the following warning in a printed note on the chart:

> 'Descent from NDB 'GG' below FL 100 not authorised unless position over NDB confirmed by visual reference or radar.'

Since the aircraft's position over 'Golf Golf' was confirmed both visually and by radar it was permitted to use procedure 'A'. This procedure allows for a descent to 7,500 feet amsl after leaving the beacon and then further descent only after the glide slope has been intercepted. The altitude over the outer marker when on the glide slope should be 6,520 feet amsl.

The glide slope angle of the 06 ILS was 2.75°. This angle suitably extended would intercept the vertical plane over the 'Golf Golf' beacon at an altitude of approximately 10,300 feet amsl. This compares with the aircraft's actual altitude over the beacon of 10,347 feet amsl (FL100).

The British Airways progress log listed the minimum safe altitude for each sector of flight and that given for the sector Nakuru direct to Nairobi was 15,200 feet. However, it is permissible for an aircraft intending to land at Nairobi to descend below this altitude if its position has been established by Nairobi radar. It can then be directed to descend in steps to FL100 which must be maintained until passing the 'Golf Golf' beacon. The approach chart which the crew were using gave 10,200 feet as the minimum safe altitude within 25 nm of Nairobi Airport in the North West sector.

1.9 Communications and Air Traffic Control

(a) *Air Traffic Control*

The aircraft first established radio contact with Nairobi control on the radar control frequency 119.5 MHz. As there was very little other traffic it was decided to keep the aircraft on that frequency in order to give experience to a controller who was under supervision and receiving radar training. Initially the aircraft was given the normal procedural clearance to proceed to the 'Golf Golf' beacon and descend to FL150. The aircraft was identified on radar when it was 46 nm from the airport and was given vectors to the beacon and further progressive descent clearances to FL120 and FL100.

At this point the supervising controller left the radar room for about 4 minutes in order to go to the tower. He returned after the aircraft has passed over the 'Golf Golf' NDB and had been given further descent clearance to 7,500 feet and was therefore not present when the aircraft read back this altitude incorrectly. The trainee himself did not notice the incorrect read back. His duties required him to inform the tower controller when the aircraft had left the beacon and this he did using the internal intercom system. The aircraft was retained on the radar frequency during the approach according to normal procedure and at 8½ nm from touchdown was passed the surface wind and clearance to land.

The trainee radar controller carried out all the communications with the aircraft with the exception of two transmissions by the supervisor after the incident had occurred. There was no other traffic on the frequency during the approach and there appeared to be no difficulty in communications between the controller and the aircraft apart from the misunderstanding of the clearance to 7,500 feet.

(b) *Controller information*

(1) *The Supervisor*

The duty radar controller commenced his training in Air Traffic Control in mid 1968. He became a qualified Air Traffic Control Officer in the United Kingdom with ratings for aerodrome, approach radar, area radar and precision approach radar control. He was posted to Nairobi Airport in April 1973 and at the time of the incident held a valid East African Controller's licence endorsed with aerodrome, approach and radar validations.

The controller reported for duty at 0400 hrs on 3 September 1974 (0700 hrs local time). On the previous day he had completed an afternoon watch starting at 0930 hrs and terminating at 1630 hrs (1230-1930 hrs local time).

(2) *The Trainee*

The officer under supervision was receiving on-the-job radar training after successfully completing a radar training course. At the time of the incident he had conducted 151 radar runs, including 5 surveillance radar approaches at Nairobi Airport. He started his training in air traffic control in November 1971 and became a qualified Air Traffic Control Officer in May 1973. His licence was subsequently validated for aerodrome and approach control. He was passed medically fit to carry out his duties on 20 December 1973.

He reported for duty on 3 September 1974 at 0410 hrs (0710 hrs local time) having worked the previous day up to 0920 hrs (1220 hrs local time).

(c) *Transcripts*

The VHF/RTF recordings were initially transcribed in Nairobi. A copy of the original tape was then sent to London and a further transcription was prepared by the Civil Aviation Authority transcription unit at Heston (Appendix D). The copy tape did not include the original injected time signals and the time intervals on this transcript are those which have been deduced from the available information.

Because of the flight crew's difficulty in interpreting the altitude to which they were cleared, this part of the transmission was carefully examined. There is no doubt that the controller spoke the words 'SEVEN FIVE ZERO ZERO FEET'. However, certain observations could be made on the manner in which the phrase was spoken. The word 'SEVEN' was pitched at a slightly lower volume than the rest of the transmission whereas the word 'FIVE' was stronger and received more emphasis.

(d) *Phraseology*

The following is an extract from the East African AIP and Manual of Air Traffic Control which is in accord with ICAO procedure:

> 'All numbers except whole thousands should be transmitted by pronouncing each digit separately. Whole thousands should be transmitted by pronouncing each digit in the number of thousands followed by the word 'thousand''.

Both the controller in his use of 'SEVEN FIVE ZERO ZERO' and the co-pilot with his 'FIVE THOUSAND' was therefore in accord with the recommended phraseology.

(e) *Acknowledgement and read back of messages*

Annex 10 Volume 2 to the ICAO Convention (Aeronautical Telecommunications) states that:

> 'An aircraft station acknowledges receipt of ATC instructions and altimeter settings by reading them back and terminating the read back by its radio call sign. The ground station denotes the accuracy of its read back by transmitting its call sign'.

It is also Company policy that all such messages be read back by the aircraft.

(f) *Company communications policy*

On Boeing 747 aircraft communications and the tuning of radio navigation aids are the responsibility of the two pilots. However, the flight engineer as part of his integration into the flight crew was expected to listen in to the radio and check the identifications of the selected aids. This the flight engineer on BA029 did. He heard the descent clearance given by the controller after 'Golf Golf' and though he found that the word 'seven' in the clearance was indistinct he assumed the controller had said 'seven five zero zero' as this was the clearance he was expecting because it was published as part of the ILS approach procedure. For some reason, which may have been that he switched to a beacon identification, he did not hear the co-pilot's read back.

1.10 Aerodrome and ground facilities

The elevation of Nairobi Airport is 5,327 feet. The aerodrome lies on a fairly level plateau which is surrounded by hills. The terrain to the West South West of the Airport is open savannah type countryside which rises gradually over a distance of about 12½ nm to a height of 6,000 feet. After the ground rises quickly to the Ngong hills, a steep ridge of high ground running approximately North and South. The ridge is about 6 nm long

and is 8,074 feet at its highest point. The 'Golf Golf' NDB is installed on top of the ridge at its northern end.

The elevation of the ground in the area where the aircraft reached its lowest point during the overshoot is about 5,400 feet amsl.

1.11 Flight recorders

The aircraft was equipped with a Plessey PV 740 Integrated Flight Recorder System which fed information to the mandatory crash protected recorder and the Aircraft Integrated Data System (AIDS). Both recordings were read out but as the AIDS recorder contained most information its data was used exclusively during the investigation. No correction or calibrations were made to the raw data which was used mainly to identify flight deck activities so that a picture could be constructed of the workloads of the crew during the approach (Appendix B). A ground plot of the aircraft's movements was prepared by means of a computer controlled plotter from information from the AIDS recorder, (this is shown at Appendix E). This showed that the aircraft was about 6¾ nm from the runway when the overshoot was initiated.

The recorder read-out showed that there was nothing abnormal in the operation of the aircraft during the approach with the exception of the height to which it was allowed to descend. Once the descent had been started after passing 'Golf Golf' the rate at which the aircraft lost height was fairly constant averaging about 1,800 feet per minute and this was maintained until the aircraft was about 110 feet above the ground when the overshoot was commenced. The aircraft continued to descend momentarily during the overshoot and came to within about 70 feet of the ground at its lowest point.

The aircraft was equipped with a cockpit voice recorder (CVR) although this equipment was not mandatory. The CVR recorded on a 30 minute cycle and would run while there was electrical power on the aircraft. In order therefore, to preserve the recording of the incident it would have been necessary for the crew of the aircraft to have pulled the appropriate circuit breaker to stop the recording. This was not done and neither was there any legal requirement or Company procedure which required this to have been done.

1.12 Wreckage

Not applicable.

1.13 Medical information

There was no medical evidence in the case of the commander and the flight engineer which could have had a bearing on the incident. The co-pilot, however, was still suffering from the effects of a bowel infection which he initially contracted over a month before the incident. He had lost nearly a stone in weight and according to the commander looked pale when he reported for duty at London (Heathrow) Airport.

1.13.1 *History of the co-pilot's illness*

The co-pilot became ill with a stomach disorder in New Delhi on 29 July 1974 and after feeling very ill and feverish for about two days during which time he received medical treatment, he returned as a passenger to London. In London he reported to the Company's doctor and, after stating that he felt much better, was declared fit on 1 August. On 2 August he flew to New York and again experienced a stomach upset which, however, was much milder and did not incapacitate him. He subsequently operated a week long trip to Johannesburg, followed by another Atlantic crossing and

felt fit although still suffering from a low grade gastro-enteritis. He then began to feel very lethargic with a tendency to sleep longer than normal and so realising that he needed further medical assistance, he consulted his own private doctor on 28 August. He was prescribed some medicine in tablet form for the treatment of his illness but nothing was said to suggest that he should not fly. In any case he was, at this time, expecting to have a number of days off before being required for flying again. He completed a training detail in the Company's Boeing 747 simulator on 30 August and although he still felt tired his performance was satisfactory.

The co-pilot took one of the tablets prescribed by his doctor in Zurich on the morning of 2 September but could not remember whether he took another one just prior to the incident flight.

On returning to London after the incident at Nairobi the co-pilot was examined by the Company doctor. The cause of the disorder was diagnosed as Oiardia, a tropical infection, and the co-pilot was taken off flying duties while he received further medical treatment.

1.13.2 *Medical treatment*

The opinion of the Civil Aviation Authority's Medical Branch was sought on the effects that the medicine which was being taken by the co-pilot might have had on his performance.

The preparation used was Lomotil, a drug which is commonly used in the treatment of mild diarrhoea. The drug has side effects which vary widely in their nature and magnitude and which have been quoted as including depression of the central nervous system, slow respiration, drowsiness, insomnia, dizziness, restlessness, euphoria, and nausea.

The drug has been used widely in aviation and has been prescribed for astronauts on space missions. Opinion varies on its use but the Royal Air Force has apparently had no problems with it. The Federal Aviation Administration in the United States, however, suggests that 'airman duties are contra-indicated for 24 hours' after its use.

It was the opinion of the Civil Aviation Authority's doctors that the medicine could have affected the co-pilot's alertness and that the combination of this and the effects of his debilitating illness and the physiological state of low arousal which normally exists at the time of day when the incident occurred, could have resulted in a level of performance well below his normal. This opinion was shared by the Company doctor who examined him on his return to London.

1.13.3 *Medication and flying*

Warnings and advice to aircrew about flying when either suffering from an illness or while taking medication have been issued from time to time in Aeronautical Information Circulars. The latest circular on this subject (14/1974) was issued by the Civil Aviation Authority on 25 February 1974.

Similar instructions are also contained in the Company's Flight Operations Divisional Orders.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 *Simulator tests*

A test programme was carried out in the Company's Boeing 747 simulator to try to evaluate the circumstances of the incident. The programme was based on the diagram of the crew's activities (Appendix B) which had been constructed from information derived from the flight data recorder readout, the RTF transcripts and the crew's statements. Because the simulator was not programmed to include the Nairobi procedures, the approach was modified to that of another airfield of a similar elevation. The pre-knowledge of the events by those flying the simulator precluded any possibility of simulating the circumstances which caused the original confusion over the clearance. Several approaches, however, were carried out which satisfactorily repeated the pattern of events that occurred during the incident.

The simulator tests confirmed that there was a high level of flight deck activity during the approach especially in the period immediately following the receipt of the descent clearance. It was shown that there was a peak in the work load of both pilots at this time and that very little delay could be tolerated in starting the descent if the aircraft was to remain ideally below the glide slope. The approach checks took on average about one minute to perform even with no delays or interruptions and during this time the flight engineer's attention was diverted from the operation of the aircraft.

Although the automatic pilot was flying the aircraft a high degree of concentration was still required to supervise its progress and monitor the correct operation of the automatic systems such as the localiser capture and the acquisition of the selected altitude. This particularly applied in the case of the commander who, in addition to regulating the rate of descent and monitoring the decaying airspeed, also made the requisite selections for programming the system for an autoland. There appeared to be little time for referring to the aerodrome approach chart and cross checking the approach procedures against ATC clearances. There were no conspicuous clues or warnings during the approach to alert the crew to the fact that they had mis-set the Altitude Selector and had passed through both the correct procedure altitude (7,500 feet) and the outer marker altitude (6,520 feet).

The tests showed that when the aircraft was approaching ground level the illumination of the ILS deviation lights and the audio warnings from the altitude alerting system and the radio altimeter decision height followed one another in rapid succession. A confusing situation developed which would have been difficult to analyse by somebody who was unaware of the danger of his position.

Other approaches were made during the test programme in which the initial speed was reduced and stabilised with the flaps lowered and approach checks commenced before reaching the 'Golf Golf' beacon. This served to reduce the peak load which occurred at the start of the final descent and generally gave the crew more time in which to carry out their duties. The simulator programme, however, revealed nothing that would have prevented a satisfactory approach from being completed if the correct procedure had been followed.

1.16.2 *Analysis of the Audio Tone heard on the RTF Tape Recording*

An analysis of an aural tone heard very briefly when the co-pilot made his transmission at 0511:45 hrs (Appendix D, Line 197) was made in order to establish its source. The nominal frequency of the radio altimeter warning tone is 800 Hz. The frequency of the tone heard on the RTF tape of the incident was 833 Hz. For comparison, a test transmission was made for the purpose of this analysis from a B 747 parked on the ground at London Heathrow Airport. The frequency of the tone transmitted on this occasion was 769 Hz. Allowing for likely differences in the speeds of the recorders in London and Nairobi, it is considered that the tone heard on the RTF tape of the incident was

sufficiently close to 800 Hz to justify the conclusion that its source was the radio altimeter and not some other source such as a marker beacon identification signal, which operates at the much lower frequency of 400 Hz.

The results of this analysis therefore confirm that at the time of the co-pilot's truncated transmission at 0511:45 hrs, the aircraft was at 200 feet agl.

1.17 Other information

1.17.1 *Ground Proximity Warning System (GPWS)*

Since the incident, the Company has decided to install a Ground Proximity Warning System in its Boeing B747 fleet.

The purpose of the equipment is to prevent aircraft from inadvertently flying into the ground in circumstances when the crew is unaware of its close proximity. The system is designed to give both a light signal and an aural warning when the aircraft approaches dangerously close to the ground and it is intended that the warnings will be backed up by operational procedures which will require the pilot to pull back on the control column immediately and unquestioningly whenever the warning is given. The equipment has five warning modes which cover the following circumstances:

Mode 1	An excessive descent rate when the aircraft is within 2,450 feet off the ground.
Mode 2	An excessive closure rate with respect to the ground when the aircraft is less than 1,500 feet above the ground.
Mode 3	A negative rate of climb after take-off or missed approach before reaching 700 feet.
Mode 4	An unsafe ground clearance when the aircraft is below 498 feet above ground and not in the landing configuration.
Mode 5	An excessive excursion below the ILS glide slope when within 650 feet off the ground.

There was no GPWS equipment approved for use at the time of the incident, but had the model then in existence been installed in the aircraft, it would have operated as follows:

(a) Mode 1. Depending on the actual descent rate the warning would have probably been given between 700 feet and 580 feet above ground level (agl).

(b) Mode 4. There would definitely have been a warning at 498 feet agl.

(c) Mode 5. Depending on the ILS signal strength there might have been a warning at 650 feet agl.

Several changes to the parameters for all the modes have been made in the latest model of the equipment. However, only the warning given by Mode 5 would have been affected by the changes. It would be expected that Mode 5 would now give a 'soft' warning in the form of an amber light at 1,000 feet agl and a 'hard' warning at 300 feet agl.

GPWS equipment has been fitted into an HS 748 aircraft operated by the Civil Aviation Flying Unit (CAFU) from Stansted, Essex for the purpose of carrying of a series of evaluation trials. On the basis of these trials the Civil Aviation Authority has concluded

that a mandatory requirement to carry GPWS should be introduced as soon as practicable, initially for aircraft having a maximum certified take-off weight in excess of 15,000 kg or authorised to carry 30 passengers or more. It is expected that the date for compliance will be mid-1976 for turbo-jet aircraft and mid-1977 for other types.

1.17.2 *Monitoring procedures and allocation of crew duties*

At the time of the incident, the information concerning Aircraft Handling and Crew Drills was contained in Section 101 of the Company's B747 Flying Manual, the first part of which was entitled 'Flight Deck Drills and Procedures'. This was further sub-divided under a number of headings, one of which was entitled 'Check Lists' and the other 'Cross Checking, Monitoring and Call Outs'.

Under 'Check Lists', instructions were given in general terms as to how the check lists, contained elsewhere in the Manual, were to be used. It was stated that each check list item was annotated C, P, E (ie Captain, Co-pilot, Flight Engineer) indicating which crew member was to carry out the particular check. No specific requirement was stated in the 'Before Descent Check List' or the 'Approach Check List' to check the settings of the Altitude Selector as the Company did not consider it practicable to do so. However in a later issue of this section, produced since the incident, the following note has been added to the paragraph entitled 'Altimeter Setting Procedure' where it details the procedure to be used for setting the Altitude Selector:

> 'Note - Either pilot may change the altitude selector. The pilot who does so MUST ENSURE THAT THE SETTING IS CHECKED AND CONFIRMED AS CORRECT BY AT LEAST ONE OTHER CREW MEMBER'.

Under the section entitled 'Cross Checking, Monitoring and Call Outs', it was stated that 'the occupants of the pilots' and E/Os seats must operate as an integrated crew, monitoring and cross checking each others actions in so far as is practicable .....' Later in the same section it was stated that:

> 'The navigation and flight progress indications must be cross checked and monitored continuously: any crew member must advise the Captain immediately if:
>
> (a) it appears that the aircraft is departing significantly from its intended flight path OR
>
> (b) any abnormal instrument indications, comparator, annunciator, flag or light warnings are observed;
>
> (c) any hazardous situation may be developing.
>
> During take-off, climb and approach to land phases of flight, the Co-pilot will necessarily be largely responsible for monitoring and cross checking the flight instruments, and calling out appropriate information; the ensuing list covers the more important items under these headings.'

Since the incident, this last paragraph has been amended and the words 'the Co-pilot will necessarily be largely .....' have been deleted. The paragraph now reads as follows: '..... the non handling pilot will be responsible .....'

The list of call outs referred to was contained on pages 101-10-03 to 05 of the Flying Manual. It applied only to a manual approach but referred to a further list on page 101-66-04 which detailed the additional call outs to be made during an auto-approach.

Also since the incident, a further paragraph has been added to the section entitled 'Cross Checking, Monitoring and Call outs' and this is as follows:

'The radio altimeters must be monitored by both pilots at all times that they are active - ie below 2,500 feet AGL. On the approach the signal that the radio altimeters are active is given by the terrain warning tone'.

Additional information on operating procedures is contained in the Company's Crew Training Manual Part I, which is issued to all flying personnel. This contains a considerable amount of amplifying material as regards the duties and monitoring functions of the flight engineer for each phase of flight but nothing of an equivalent nature in the case of the pilots. One of the duties of the flight engineer stated in the Crew Training Manual is the requirement to check Altitude Selector settings during the descent.

1.17.3 *Recommended speeds*

In Section 101 of the company's Flying Manual, the following advice is given as regards the speeds that should be flown during the descent and approach phases:

'With flap at 0, 1 or 5 the quoted minima of V_{REF} +80, 60 or 40 are comfortable speeds to maintain; minima for flap 10 and 20 ie V_{REF} +20 and V_{REF} +10 are both well below Vmd and, although safe in terms of stall margin, they are uncomfortable speeds. For the intermediate approach procedures a speed of V_{REF} +30 is recommended for both configurations.'

At the time of the incident the V_{REF} for the aircraft's weight was 134 knots IAS. Consequently, the recommended speed during the intermediate approach phase after 10 flap had been selected was 164 knots IAS.

2. Analysis and Conclusions

2.1 Analysis

This was a very serious incident which only avoided becoming a major catastrophe by the narrowest of margins. Superficially, the incident occurred simply because both pilots misheard an ATC instruction to descent to 7,500 feet. In all probability, had they not done so, the approach and landing would have been a well planned and well executed manoeuvre involving the minimum wasteage of time and fuel; or at least would have appeared so. But on closer examination it is apparent that there was present a number of inter-related factors, involving environmental conditions, sickness, operational procedures and flight deck management, which made it highly likely that the crew would not be alert to errors made by themselves or others.

Obviously the central question is why the mistake over the clearance was not noticed in good time by the crew or the ATC. This aspect will be fully explored later, but first, an attempt is made to establish the reason for the error itself.

Air Traffic Control

The way in which the clearance was given, that is 'DESCEND SEVEN FIVE ZERO ZERO FEET' was quite correct and wholly in accordance with international procedures. Probably the pilots' hearing of the clearance as 'five zero zero zero feet' was because the word 'seven' was apparently received so indistinctly as to be unheard and the word 'five' appeared to be given greater emphasis. By concentrating on the number of zeroes being given in the clearance, the pilots obviously overlooked the first figure. The fact that the co-pilot's readback was unchallenged by the ATC may well have submerged any subconscious doubts that he may have had about the correctness of it.

According to the ICAO Annex 10 volume 2, the controller's instruction to the aircraft to descend was one for which a read back was required. This implies that the controller should therefore have listened for the read back and challenged it when he heard that it was incorrect. Equally the pilots should have also requested an acknowledgement if they were in any doubt. It is self-evident that had the controller picked up the incorrect read back, the incident would not have happened, but his failure to do so cannot be explained solely on the grounds that he was under training. He was, in fact, a fully qualified air traffic controller who was simply being checked out in that particular position. The most probable reason for his failure to pick up the incorrect read back was that at the time, he was talking to the tower on the internal intercomm to report that the aircraft had left the 'Golf Golf' beacon. Also as the readback was spoken confidently and without hesitation, there was nothing in the co-pilot's tone of voice to alert the controller that there was any doubt about the clearance.

Terrain awareness

The reason why the pilots saw nothing wrong with a supposed clearance to descend to 5,000 feet in the Nairobi area is more difficult to determine. Presumably they both believed that the aircraft had been cleared to descend to 5,000 feet above ground level. This could possibly have been because they momentarily overlooked that Nairobi is not a sea level airfield.

This possibility would have been considerably lessened, as would any possible confusion over altitude clearances, had the crew been provided with log sheets on which to record QNH and other ATC instructions in a way that would enable a direct comparison to be made with airfield elevation and local safety heights.

Environmental factors affecting the crew

By the time of the incident, the crew had been on duty for 9 hours during what was otherwise their normal sleep period. Moreover, at 0500 hrs their biochemical, physiological and psychological functions would have been at their lowest point on the normal circadian rythmmic cycle. Thus each of them would have been in a lower state of arousal than normal and therefore less likely to notice errors, particularly if made by one of themselves.

In the case of the co-pilot, there were additional factors which undoubtedly would have affected his overall performance, foremost among which was his state of health. It seems clear that he was more affected by his bowel infection than he himself realised, which, coupled with the medication he was taking, most probably lowered his general level of alertness and his ability to assimilate the normal amount of information. There is no doubt that the co-pilot should not have been flying in this condition, but the reason for his doing so can be appreciated. Not only did he believe that the infection was clearing up, but also he had been given no indication by his local doctor that he should not fly. When he was called out at the last moment over the weekend for the flight, which he was keen to make, he did not consider it necessary to let the company know that he had been prescribed medication for his condition. It has since transpired that the drug he was using can have side effects, which the United States Federal Aviation Administration, for one, consider incompatible with flying duties.

Last but by no means least was the co-pilot's relationship with the commander as an additional stress factor. They had not flown together before, and the co-pilot would therefore have been keen to make a good impression, particularly in view of the commander's considerable seniority. As a consequence of this, it is likely that the co-pilot tried to convey the appearance of alertness by carrying out his duties briskly, but due to his physical condition did so without much thought as to the implications of what he was doing.

From the foregoing therefore, it is reasonable to deduce that the physical and mental state of the crew was such as to make them prone to error, especially when faced with a sudden demand for activity after a long period in a state of relatively low arousal. This would have been particularly so in the case of the co-pilot.

Crew activity

The clearance to descend from FL 100 appears to have triggered off a period of intense activity by all three crew members. This is illustrated in the diagram at Appendix B, which shows that the crew were left with a considerable amount to do in the time available. The result of this was that each crew member became wholly absorbed in his own task to the exclusion of all else. The flight engineer was engaged in reading out the approach check list, which not only occupied him for well over a minute, but also required him to turn away from the pilots' panels in order to attend to his own. The co-pilot also participated in the approach check as well as monitoring the extension of the flaps and talking to ATC. It was also at about this time that he inserted 5000 in the Altitude Selector. The commander appears to have been mainly pre-occupied with initiating the descent. It therefore seems likely that he reacted as soon as he heard the word 'Descend .....' and did not pay the same regard to the second part of the clearance. A further indication of the extent to which each crew member was occupied with his own tasks was when, a short while later, the commander found it necessary to tune the No. 2 VHF Navigation Receiver to the ILS frequency himself, which he needed to do in order to engage Nos. 2 and 3 autopilots. Similarly the flight engineer states that he had repeatedly to request the pilots to check their altimeter settings.

Aircraft speed

The unusually high work load of the crew after the aircraft had passed the 'Golf Golf' was undoubtedly related to the speed of the aircraft during the descent from FL 100. This seems to have been unnecessarily high and considerably above the recommended speeds appropriate to each flap setting (though not, it should be said, in excess of the relevant limitations). The speed could in fact have been reduced progressively to 164 knots as the flap was lowered in stages to 10 degrees, but in fact the commander never allowed it to fall below 210 knots IAS and most of the time it was higher than that. This resulted in the crew having considerably less time than they might otherwise have had for preparing the aircraft for the approach and monitoring the progress of the flight.

In view of the deteriorating weather conditions that were reported by the pilot of a preceding aircraft, it might have been expected that the commander would have considered it prudent to have slowed the aircraft down and perhaps have started the approach check before reaching 'Golf Golf'. Admittedly this check would not have progressed beyond the altimeter check whilst the aircraft was still above FL 100, but at least it would have spread the work load and given the crew more time to monitor the progress of the flight after the aircraft had passed 'Golf Golf'. As it was, the commander allowed the speed to build to as high as 338 knots when the aircraft levelled off at FL 120, so that when the aircraft reached 'Golf Golf' at FL 100, he had only managed to reduce the speed to 235 knots. He then had to initiate the descent immediately at a fairly high rate, thus making any further speed reduction more difficult to achieve.

The commander's decision to keep the speed higher than desirable appears to have been based on commercial considerations as it appeared to him that by so doing, the aircraft would arrive at Nairobi on or within five minutes of the scheduled time. It is not uncommon practice for commercial or ATC reasons for the speed to be kept close to the maximum for small flap extensions during the initial and intermediate approach phases. There can, of course, be no objection to this provided that the consequences in terms of increased workload on the flight deck are appreciated.

Monitoring procedures

The main reason why the commander did not properly evaluate the supposed clearance to 5,000 feet seems to have been because he was attempting to do too much himself. He appears to have placed too much reliance on the system of monitoring used by the Company, not realising that this sytem had in fact ceased to function during a period of increased crew activity. If any of the crew gave any thought as to who was monitoring the flight after it had passed the 'Golf Golf' beacon, it can only be supposed that each thought the other was. The disturbing conclusion to be drawn from this is that there could well be other occasions when, without the crew realising it, no monitoring takes place.

The Company lays great stress on monitoring and has gone to considerable lengths to ensure that its B747 pilots and flight engineers operate as intergrated crews. It must therefore be of some concern that the system of monitoring allowed a comparatively simple error to remain undetected whilst the crew was under pressure, especially as that pressure was neither exceptional nor sustained.

In the light of this incident, it would seem therefore that a re-examination by the Company of its monitoring procedures is called for, particularly to ascertain if any measures can be taken that would enable the commander to devote more of his attention to his overall supervision of the flight during an approach in instrument conditions.

The Company's decision, made since the incident, to introduce a procedure for monitoring all changes of setting to the Altitude Selector will obviously go a long way towards preventing a recurrence of this type of incident.

Failure of the crew to respond to warnings and other indications

The greater part of this analysis has of necessity been concerned with examining the possible reasons for the clearance being misheard and why it was not noticed by the crew. It is also necessary to examine why, once the error was made, various warnings and other indications did not alert them to the fact that the aircraft had been programmed to descend into the ground.

Firstly it is necessary to appreciate that most probably both pilots were utterly convinced of the correctness of their actions thus far. Their conviction was quite unshaken by the terrain audio warning which occurred at 2,500 feet above the ground (ie at an indicated altitude of 8,200 feet) and they did not in any way relate this warning to the intermediate approach altitude of 7,500 feet given on the approach chart and which they must have discussed at the top of the descent. It transpires that this warning makes comparatively little impact on crews, because it occurs on each approach at least once. In particular it appears to have little significance when it is heard at the time it is expected, as happened on this occasion. It is thus understandable why no action was taken when the warning sounded. However, from this point on, the radio altimeters were indicating but only the flight engineer appears to have paid them any attention. He states that though he was concerned by the aircraft's apparent deviation from its expected flight path, he could not see the reason for it. Subconsciously, he was probably trying to relate the inconsistency of the aircraft's low altitude with the fact the landing check had not been carried out and that the aircraft was not on the glide slope. His inability to understand what was happening was probably due to his having been out of the monitoring loop for a period of a minute or more whilst he was reading out the approach check. He was probably reluctant to communicate his unease to the commander when he suspected that it may have been himself that was wrong and not the pilots. He clearly thought it best to say nothing until he had re-orientated himself to the approach.

The next two warnings came within two seconds of each other, namely the ILS deviation lights and the altitude alert. Also coincident with these warnings was a call from ATC clearing the aircraft to land. At this stage the aircraft was descending through 500 feet above the ground and it was also at this point that the flight engineer advised the commander that there was no glide slope and received the commander's denial of this.

The altitude alert does not indicate proximity to the ground but only that the aircraft is approaching the selected altitude, which in this case was 5,000 feet. As both pilots were convinced that there was nothing wrong with descending to 5,000 feet although it was in fact 327 feet below airport elevation, the warning that the aircraft was approaching that altitude clearly had no implications of danger for them. The pressure altimeter bug was similarly of no value, even though it had been set to the minimum decision height, as it can only be set to between 0 and 999 feet.

The ILS deviation lights illuminate when the aircraft is displaced from the localiser or glide slope and when it is below 500 feet above the ground, though terrain warning is not their function. The pilots' immediate reaction to the illumination of the ILS deviation lights was that it was a false warning. This was doubtless because it did not conform to what they believed the aircraft to be doing at this stage, namely, descending to the intermediate approach altitude. The co-pilot's reaction may well have been conditioned not only by the fact that there was very little time in which to determine the reason for the warning, but also because he had only once before seen the lights operate and that was at a very late stage in the approach during a simulator detail in circumstances totally different to that of the incident.

From the foregoing it can be seen that the reason why the crew apparently ignored the three indications of the aircraft's close proximity to the ground was because only one of these specifically related to aircraft height namely the terrain warning at 2,500 feet agl and that this occurred when it was expected. The other two were not primarily intended to warn when the aircraft was coming close to the ground and therefore did not cause the crew any undue concern. When the minimum decision height (MDA) warning sounded at 270 feet agl the flight engineer seemed to be the first to realise what was happening, probably because he had just previously been alerted by the operation of the ILS Deviation Lights. He immediately responded by calling that the aircraft was at a low altitude. Even then, it was only when the aircraft broke cloud that the commander at last appreciated the aircraft's danger and took overshoot action.

Ground Proximity Warning System

Although no GPWS equipment had been approved for use at the time of the incident, it is instructive to consider what effect the equipment would have had on the outcome had it been available. As has been shown, even if the earlier type had been installed in the aircraft at the time of the incident it would probably have warned the crew of the hazardous situation that was developing as high as 700 feet agl and certainly no later than 498 feet agl. Although these warnings would only have occurred seconds before the existing warnings on the aircraft operated, they would have served to prompt the crew into immediate action. Thus the mental block that appeared to exist in the minds of all three crew members as to what was actually happening would have been broken much earlier than was the case, and the aircraft would not then have come so dangerously close to the ground. As it was, it required an actual sighting of the ground at the very last moment to persuade the commander to take recovery action.

Notwithstanding the above, it should still be said that even if a GPWS had been installed in the aircraft and had operated correctly, a substantial departure from the intended flight path would still have occurred. The implications of this in terms of a failure of flight deck procedures would therefore have been no less serious.

Cockpit Voice Recorder (CVR)

The investigation would have been considerably aided had the CVR recording for the period of the incident not been subsequently lost due to the recorder being erased during the normal shut down procedure after the aircraft had landed. It is considered that every effort should be made to encourage crews when practicable to pull the CVR circuit breaker as soon as possible after an incident or accident when the aircraft is on the ground so that essential evidence may be preserved.

The effect on incident reporting of the action taken against the crew

The incident first came to light because the commander reported it immediately. This was clearly a highly responsible action on his part and one which he took without thought of the possible consequences to himself. It is, of course, impossible to predict what effect the action taken against the crew will have on the future of incident reporting by flight crews, but it would seem likely that it may well be discouraging.

2.2 Conclusions and findings

(a) *Findings*

(i) The crew members were properly licensed.

(ii) The aircraft was free of defects and its documentation was in order.

(iii) The crew was properly rested prior to the flight and at the time of the incident had been on duty overnight for approximately 9 hours.

(iv) The co-pilot had been suffering from a persistent bowel infection for five weeks and this had had a debilitating effect on him. He did not inform the Company that he had been prescribed medication for the complaint by his own doctor. The drug which the co-pilot was using may have had undesirable side effects on the performance of his duties and his general level of alertness.

(v) The co-pilot's previous experience of seeing the ILS Deviation Lights operate was confined to one simulator detail and in circumstances totally different to that of the incident.

(vi) The performance of the crew was partly affected by the loss of a night's sleep and the reduced physical and mental responses associated with the early hour of the morning.

(vii) The word 'seven' in the ATC clearance was received less distinctly than the remainder of the message and accordingly the pilots misheard the clearance as one to descend to 5,000 feet.

(viii) The co-pilot's read-back of 5,000 feet was not acknowledged or corrected by the trainee radar controller.

(ix) Following the receipt of the clearance, the co-pilot inserted 5000 in the Altitude Selector and the commander was aware that he had done so.

(x) The flight engineer also had difficulty in hearing the clearance to descend, but he nevertheless interpreted it to mean that the aircraft was cleared to descend to 7,500 feet. However he was unaware that the pilots had misheard the clearance and had interpreted it differently, nor did he see the atltiude that was inserted in the Altitude Selector.

(xi) The speed at which the aircraft was flown during the initial approach phase was greatly in excess of the recommended speeds. This resulted in a high work load on the crew and directly affected their ability to monitor the flight.

(xii) The commander initiated a descent which was continued at an average rate of 1,800 feet per minute to within sight of the ground at approximately 200 feet agl.

(xiii) During the subsequent overshoot manoeuvre, the aircraft came within 70 feet of the ground at a distance of approximately 6¾ nm from the airport on the localiser centre line.

(xiv) The pilots believed that the altitude to which the aircraft was descending was an intermediate approach altitude prior to glide slope capture and had overlooked the fact that the altitude pre-selected by the co-pilot was below the elevation of the airfield.

(xv) The flight deck instrumentation and warnings correctly indicated the aircraft's actual flight path towards the ground, but the significance of these was not appreciated by the crew.

(xvi) No specific instructions were given in the Company Flying Manual, current at the time of the incident that the settings to the Altitude Selector should be cross checked, though it was stated in the Crew Training Manual Part I that the flight engineer should do so during the descent.

(xvii) The pilots did not cross refer the altitude to which they believed the aircraft had been cleared to descend against the intermediate approach altitude published on the aerodrome approach chart for Nairobi.

(xviii) There was no provision made by the Company for crews of the B747 fleet to record altitude clearances received during the approach phase to enable a direct comparison to be made with airfield elevation.

(xix) Had an approved Ground Proximity Warning System been available at the time of the incident, it would probably have given a warning of the aircraft's proximity to the ground at a height of 700 feet agl and certainly no lower than 498 feet.

(xx) The commander's planning and conduct of the approach gave himself and his crew too little time to monitor the progress of the flight properly.

(xxi) The commander's overall supervision of the approach was adversely affected by his personal preoccupation with the control of the aircraft.

(xxii) The system of monitoring used by the Company on its B747 fleet did not function properly during the aircraft's approach to Nairobi at a time when the cockpit workload was high.

(b) *Cause*

The incident was caused by the pilots' acceptance of a height to which they mistakenly believed the aircraft had been cleared by ATC to descend and which was below the level of the surrounding terrain. Contributory factors were: the failure of the ATC controller to challenge the incorrect read back of the descent clearance by the co-pilot; inadequate crew monitoring; the relatively high speed of the aircraft's approach; the crew's low arousal state and the ill health of the co-pilot.

3. Recommendations

It is recommended that:

(1) Consideration be given by the Company to a re-examination of its B747 flight deck procedures with particular regard to the allocation of crew duties and monitoring responsibilities during the descent and approach phases of flight so as to enable the commander to exercise his supervisory function to greater effect.

(2) Consideration be given to ensuring that settings to the Altitude Selector in the B747 and similar devices in other types of aircraft be cross checked by all flight crew members when descents to the sector safe altitude and below are involved.

(3) Consideration be given by design and airworthiness authorities to the provision of a mechanical or electronic lock on the Altitude Select facility, which can be preset, so as to prevent the subsequent selection of heights to below a safe minimum.

(4) Flight crews be provided with log sheets on which altitude clearances can be recorded during the approach phase which will enable a direct comparison to be made with airfield elevation. Additionally provision should be made on the log sheets for recording ATC clearances during the approach phase.

(5) Consideration be given by the Company to ensuring that crews of B747 aircraft receive adequate simulator refresher training in operating into high altitude airfields.

(6) Consideration be given to requesting crews to switch off the Cockpit Voice Recorder as soon as possible after an incident or accident when the aircraft is on the ground so that essential evidence may be preserved.

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Accidents Investigation Branch
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