ACCIDENTS INVESTIGATION BRANCH
Department of Trade and Industry

Trident 3B G-AWZA and Comet 3B XP 915

Report on the accident at Thurleigh Aerodrome, Bedford on 19 January 1971

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Civil Aircraft Accident Report 4/72

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Bedford on 19 January 1971

CORRECTION

Page 10: Last sentence on page should read

'He keeps his left hand resting on the throttles which are under automatic control and his right hand on the control column with his thumb close to the auto-pilot disengage button.'

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Department of Trade and Industry
Accidents Investigation Branch
Shell Mex House
Strand
London WC2

21 December 1971

The Rt. Honourable the Lord Carrington
Secretary of State for Defence

The Rt. Honourable John Davies MBE MP
Secretary of State for Trade and Industry

Sir,

I have the honour to submit the report by Mr N S Head, an Inspector of Accidents, on the circumstances of the accident to Trident 3B G–AWZA and Comet 3B XP 915 which occurred at Thurleigh Aerodrome, Bedford, on 19 January 1971.

I have the honour to be
Sir,
Your obedient Servant,

V A M Hunt
Chief Inspector of Accidents

Accidents Investigation Branch
Civil Accident Report No EW/E14/01

Aircraft:	Trident 3B G–AWZA	
Engines:	3 RR Spey 512–5W/50 and 1 RR 162–86/05	
Owner:	Hawker Siddeley Aviation Limited Richmond Road, Kingston-on-Thames, Surrey.	
Operator:	British European Airways Corporation, Bealine House, Ruislip, Middlesex.	
Crew:	Pilots:	
	Instructor – Captain A J Angus	– Uninjured
	Trainee – Captain L Wallis	– Uninjured
	Trainee – First Officer J A Passmore	– Uninjured
	Supernumary Crew: Two	– Uninjured
Passengers:	Nil	

MAS Aircraft:	Comet 3B XP 915	
Engines:	2 RR Avon 524 and 2 RR Avon 504	
Crew:	Commander – Flight Lieutenant B M Barclay RAF	– Uninjured
	Co-Pilot – First Officer I L McGrath BEA	– Uninjured
	Flight Engineer – Flight Lieutenant R E Anstee RAF	– Injured
	Supernumary Crew: Four	– Uninjured
Passengers:	Nil	

Place of Accident:	Runway 27 at Thurleigh Aerodrome, Bedford.
Date and Time:	19 January 1971 at 1355 hrs.
	All times in this report are GMT.

Summary

Trident G–AWZA was making an approach to Runway 27 at Thurleigh Aerodrome using the Instrument Landing System for Crew training purposes. It was the intention of the Commander to make an approach down to 100 feet and then overshoot over a Comet aircraft which he could see on the runway awaiting take-off clearance. However, the Trident descended below 100 feet and during the overshoot struck the fin and rudder of the Comet with the underside of its port wing and port inner flap.

1. Investigation

1.1 History of the flight

The Comet aircraft, XP 915, operated by the Blind Landing Experimental Unit (BLEU), was about to make a training flight, and was in the take-off position on Runway 27, on the centreline, about 500 feet in from the end of the runway, awaiting take-off clearance. The role of the Comet aircraft in the subsequent accident was completely passive and therefore further references to it in this report are confined to the damage it received and the injury to one of its crew members.

The Trident aircraft, G–AWZA, operated by British European Airways Corporation (BEA) was one of a number of civil aircraft flying in the Bedford aerodrome circuit and making use of the Instrument Landing System (ILS) of Runway 27, for training. These aircraft were operating under radar surveillance and were being positioned and sequenced by the Bedford approach controller as required for the various exercises on which they were engaged.

The local weather throughout the relevant period was reported as visibility 4 to 6 nautical miles, cloud base varying from 1,500 to 2,000 feet and surface wind varying from 190° (T) to 210° (T) at speeds from 10 to 15 knots. There were occasional flurries of light rain.

Trident G–AWZA was engaged in conversion training to an approved BEA syllabus. At the time of the accident the particular manoeuvre being practised, in simulated Category III weather conditions, was designed to familiarise crew members with various failure situations during an automatic approach to land using ILS. A screen in front of the left-hand pilot was being used to simulate Instrument Meteorological Conditions (IMC) and an aperture in this screen was being opened and closed at the relevant heights to simulate the appropriate visual reference limitations.

The operating crew consisted of a training captain who was in overall command and was occupying the P2 position (right-hand seat), a captain under training occupying the P1 position (left-hand seat) and a first officer under training in the P3 position (centre seat). Although P1 and P3 were under training in G–AWZA (which is a Trident 3B aircraft, a type just coming into service with BEA), both of them had considerable previous experience of Trident 1 and 2 operations and of auto-approach procedures. In addition to his instructional role the training captain was fulfilling the P2 function appropriate to the various cockpit drills and procedures involved; elements of the BEA crew procedures which are considered relevant to this investigation are given in section 1.16 of this report.

The two extra crew members, who were also on the flight deck, were another BEA training captain and a Hawker Siddeley flight engineer. The latter was operating the shutter of the blind flying screen as directed by the training captain in command but except for this neither of the two extra crew members took part in the operation.

Prior to the approach on which the accident occurred four exercises had been successfully completed. These had involved automatic approaches down to a height of about 12 feet, each followed by an automatic overshoot; the last three exercises had included a simulated engine failure during the overshoot phase.

In the fifth exercise the overshoot was originally planned to be initiated at a height of about 70 feet, the visibility shutter in the screen in front of P1 being closed at about this height, thus triggering P1 into calling for overshoot action as defined in the relevant BEA crew procedures. Almost simultaneously with overshoot initiation there was to be an auto-pilot 'failure'. The training captain had briefed P1, P3 and the flight engineer on the details of this intended exercise.

When the aircraft was inbound at the outer marker, approximately 3 nautical miles out on the approach, the Trident pilot reported that he was on finals for a low approach and overshoot. The controller acknowledged this by informing the pilots that the Comet aircraft was back-tracking on the runway and that they were therefore cleared only to make an overshoot; the Trident pilot replied with the word 'understood'. At about 900 feet the training captain introduced a 'failure' by switching off one of the roll channels of the auto-pilot system; both P1 and P3 noted it and took account of its consequential effects. In this case the primary consequence was to increase the decision height (DH) from the 12 feet which is permitted with a fully triplicated auto-pilot system to a height of 100 feet which is appropriate for an auto-pilot system operating only in duplex. (The BEA use of decision height is explained in Section 1.16 of this report.) The training captain said subsequently that from 500 feet downwards there was some turbulence but not to the extent that he considered abandoning the exercise on this account. It was raining but forward slant visibility was good and he could see the Comet lined up on the runway near to the threshold. His own vision was not impaired by the screens in front of P1 and as the aircraft seemed to be correctly aligned both laterally and vertically he was satisfied to continue the approach. Having established the Comet's position on the runway he decided not to continue the exercise down to the originally intended 70 feet (R) but to overshoot at 100 feet (R). He did not consider it necessary to inform the crew of this change and decided that he could still get some value from the exercise by having P1 overshoot from 100 feet (R).

At 500 feet (R),((R) = as shown by the radio altimeters) P3 called '500 – RADIO' there by indicating to P1 and P2 that subsequent height calls would be given by reference to the radio altimeters. At 300 feet (R) P3 called 'AUTOLAND – 100 feet' to indicate that the status of the relevant equipment was satisfactory for the approach to be continued to a landing on automatics subject to P1 making his decision by 100 feet (R). P1 repeated '100 feet' to acknowledge this call from P3.

At about 190 feet (R) P1 went 'head up' preparatory to seeking external visual reference and at 150 feet the screen shutter was opened thus giving him the appropriate 'visibility'. At 130 feet (R) P3 called '30 ABOVE'; almost immediately P1 called 'LAND' and the Training Captain (P2) said subsequently that immediately following this he had called 'OVERSHOOT' and opened the throttles fully. P1 said that when P2 called 'OVERSHOOT' he went 'head down' and reverted immediately to his flight instruments checking speed and attitude and noted that the aircraft had rotated to about 9° nose-up attitude; however all crew members said that they felt the aircraft continue to 'sink'.

At 70 feet the flight engineer closed the screen shutter as he had been previously briefed to do. The aircraft continued to descend and at a radio altimeter reading which P1 said subsequently was about 20 feet there was an impact; P1 disengaged the auto-pilot by pressing his thumb button, called 'AUTO-PILOT OUT', took over manual control and climbed the aircraft back to circuit height. The pilots of another Trident aircraft in the circuit then made a visual check of the damage to G–AWZA and established that it was confined to the port inner flap after which the aircraft made a successful landing at Bedford using a 'flaps up' technique as a precautionary measure.

The Comet crew were uncertain of the extent of the damage to their aircraft and after shutting down the engines, left the aircraft with the assistance of the Fire Service who were quickly on the scene in response to ATC instructions. The aircraft was towed away and the runway cleared of wreckage so that the Trident could land. There was no fire in either aircraft.

1.2 Injuries to persons

Although at the time it was not thought there had been any injury to crew members in either aircraft it appeared subsequently that the Comet flight engineer had injured his back. This appears to have occurred during impact at which time he was only loosely strapped into his seat and was bending forward and stretching out to make an adjustment to one of the engine controls.

1.3 Damage to aircraft

The Trident aircraft sustained damage to the underside of the port wing and to the port inner flap.

The fin and part of the rudder of the Comet were torn off and there was some compression damage to the fuselage structure.

1.4 Other damage

Nil.

1.5 Crew information (Trident Operating Crew)

Captain Anthony John Angus, aged 48, holds a valid airline transport pilot's licence endorsed for command of Trident aircraft. He is also a senior base training captain for Trident 3 aircraft and at the time of the accident he had a total flying experience of 13,275 hours, 3,309 of which were on Trident 1 and 2 aircraft and 48 on Trident 3.

His last medical examination was on 30 November 1970; he had flown 2 hours 20 minutes in the 24 hours previous to the accident and had not done any other flying in the 72 hours previous to the accident.

He was in command of the aircraft in his capacity as training captain and was also acting as P2 in the BEA flight crew procedure appropriate to the flight sequence taking place at the time of the accident. (See 1.15 of this report.)

Captain Leslie Wallis, aged 49 years, holds a valid airline transport pilot's licence endorsed for command of Trident aircraft; he is also assistant flight manager of No 3 Trident Flight of BEA.

At the time of the accident his total flying hours were 14,082, of which 2,337 were on Trident 1 and Trident 2 aircraft, and 2 hours 20 minutes were on Trident 3.

His last medical examination was on 4 January 1971 and his flying in the 72 hours previous to the accident was the same as that of Captain Angus from whom he was receiving conversion training on the Trident 3 aircraft. He was under training and was acting as P1 in the BEA crew procedure appropriate to the flight sequence taking place at the time of the accident.

First Officer James Alan Passmore, aged 23, holds a valid airline transport pilot's licence endorsed for co-pilot duties on Trident aircraft. His last medical examination was on 20 November 1970 and at the time of the accident he had a total flying experience of 3,128 hours, 2,885 of which were on Trident 1 and 2 aircraft, and 2 hours 20 minutes on Trident 3.

His flying in the 72 hours previous to the accident was the same as that of the training captain from whom, together with Captain Wallis, he was receiving conversion training on Trident 3 aircraft. Mr Passmore was acting as P3 in the flight sequence taking place at the time of the accident.

1.6 Aircraft information

G–AWZA was constructed by Hawker Siddeley Aviation Limited at Hatfield in 1969/70. It is a Trident type 3B , fitted with three tail-mounted Rolls Royce Spey engines and one tail booster engine; it has a maximum take-off weight of 150,500 lbs and is a larger and more recent version of the Trident 1 and 2 aircraft in service with BEA. At the time of the accident the aircraft was leased to BEA by Hawker Siddeley Aviation and was being used for crew conversion training purposes preparatory to coming into service with BEA.

The aircraft had a valid certificate of airworthiness and a current certificate of maintenance and there was no deficiency or pre-crash failure in the aircraft or its equipment. For an understanding of this accident it is considered the only relevant aircraft information is that concerning the auto-approach/auto-land system which was being used at the time of the accident.

The system consists essentially of a triplicated automatic pilot which may be coupled to the signals from the localiser and glide path transmitters of an Instrument Landing System (ILS). When so coupled and correctly switched the system is capable of controlling the aircraft through an automatic ILS approach and, together with other signals derived from three radio altimeters, through to an automatic flare and automatic landing.

The system incorporates an automatic throttle control which may be used during the approach to control power settings on No 1 and No 3 engines to maintain a required airspeed pre-set by the pilot; it automatically removes the power on No 1 and No 3 engines during the flare and landing phase of the automatic operation.

At any state of the approach an automatic overshoot may be initiated simply by the action of advancing the throttles to the fully open position. In addition to applying full power this action disconnects the auto-throttle function, uncouples the auto-pilot system from the ILS localiser and glide-path signals and rotates the aircraft into an initial 8^{o} nose-up attitude appropriate to the climb out flight path. The aircraft will then climb away under control of the auto-pilot at the same pre-set airspeed used during the approach until any appropriate adjustments are made by the pilot.

The operating status of, or alternatively, failure of, various components of the auto-pilot system are indicated by a number of visual indicators, the majority of which are of the so-called magnetic indicator type. Should the auto-pilot become disengaged as a consequence of a failure this is indicated by a warning bell audible only through the pilots' headphones. The auto-pilot may also become disengaged as the result of an excessive or unusually abrupt application of nose-up or nose-down pitch control; this will also produce the same warning signal to the pilots. The warning signal remains in operation until either of the pilots presses one of the auto-pilot disengagement button switches incorporated in each pilot's control column.

Intentional disengagement of the auto-pilot may be accomplished by pressing either of the buttons on the pilots' control columns or by means of the engage and master levers on the central pedestal. In either of these cases there is no audible warning signal in the pilot's headphones, and visual indications of disengagement are confined to certain of the magnetic indicators.

1.7 Meteorological information

Only the local weather at Bedford is considered relevant to this investigation. A special observation made immediately following the accident was as follows:

Weather	Rain
Cloud base	1,500 feet
Visibility	4 nautical miles
Wind velocity	210°(T) at 20 knots

Anemometer readings from two points, one 3½ miles south west of the touch-down point of Runway 27 and the other about 1 mile west south west, showed that during the relevant period of the accident approach there had been some gusting with the wind having averaged 15 knots with a peak value of 29 knots.

Except for any possible distraction which the training captain may have experienced where there was a minor difficulty during his attempts to switch on the windscreen wipers at a late stage of the approach it is not considered that the weather was a factor in this accident.

1.8 Aids to navigation

The only items of relevance under this heading are the ILS installation on Runway 27 at Bedford and the related receiver equipment in the Trident aircraft. Both are suitable for Category III weather minima approach purposes and both were given very thorough post-accident checks which established that they were capable of operation to full specification standards. There is no evidence to suggest that they were not so operating throughout the relevant period.

1.9 Communications

The Comet aircraft was in communication with Bedford tower on frequency 245.8 MHz. The aircraft had been cleared to enter the runway and to back-track to the take-off position and had also been informed that the Trident approaching the runway was making an overshoot and was not intending to land from its approach. This information was acknowledged.

The Trident aircraft was in communication with Bedford approach on the frequency 122.5 MHz and was being monitored on radar by the Bedford approach controller. Communications between the Trident aircraft and Bedford approach and with other aircraft in the circuit were satisfactory throughout; the exchange of messages relevant to this accident is given in section 1.1 of this report.

No minimum altitude for overshooting over the Comet aircraft was specified by Bedford approach for the Trident aircraft, nor is there any air traffic control instruction which requires that a controller should impose any such limitation. Two minutes after the accident when, from a number of R/T transmissions, it was apparent to the approach controller and to other aircraft

that the Trident had hit the fin of the Comet, another aircraft engaged in overshoot training asked the approach controller what minimum altitude he would prefer. The controller suggested 200 feet and this was agreed to and used by the overshooting aircraft.

1.10 Aerodrome and ground facilities

Bedford aerodrome is owned and operated by the Ministry of Defence (Procurement Executive), (MAS); the Blind Landing Experimental Unit (BLEU) of MAS who were the operators of the Comet aircraft involved in this accident are one of the MOD(PE) units resident at Bedford. The aerodrome facilities pertinent to this accident include Runway 27 equipped with an Instrument Landing System which together with appropriate runway and approach lighting, is of a suitable standard for Category III instrument approach purposes. The aerodrome is much used by civil airline aircraft for the purpose of familiarising pilots with instrument approach flying in simulated Category III weather minima.

Runway 27 is 3,200 metres long and 93 metres in width but has no perimeter track giving direct access to the take-off position. Consequently an aircraft intending to take-off on this runway must back-track along the runway for distances of about either 1,600 metres or 800 metres, according to its point of entry onto the runway.

As a result of the foregoing limitation it is not unusual for aircraft which are engaged in instrument approach practice on Runway 27 to make overshoots over an aircraft which is either standing in the take-off position or is back-tracking along the runway.

1.11 Flight recorder

Trident G–AWZA was fitted with a Plessey-Daval PV 726A Flight Data Recording System operating on the electro-magnetic digital recording principle and providing for a maximum of 42 analogue signals and 26 event signals to be sampled; not all channels were in use. The information was recorded simultaneously on two separate recorders, one being a crash-protected recycling type using stainless steel wire as the recording medium and the other a quick access cassette loaded recorder employing magnetic tape.

The system had been installed at the time of aircraft manufacture and had flown a total of just over 60 hours when the accident occurred. When retrieving the information relative to this accident it was found that the recording on the quick access cassette was very poor and data relating to the 3rd, 4th and 5th overshoots and the final landing could not be recovered from this source. No reason could be established for this failure, which could not be repeated during test running of the equipment, but the existence of foreign matter on the recording head which had subsequently become displaced is a possible explanation.

On examination of the wire recorder it was found that one of the wires had broken and was not winding on to its appropriate spool. However, the break was in the wire to the inactive head so that all recently recorded data, including the departure from Birmingham, the five overshoots and the subsequent landing were successfully retrieved. Comparison of the 2nd overshoot recording from the cassette tape with that from the wire established the compatibility of the recorded data from both sources.

Data recovery was made by British European Airways Corporation (BEA) using their play-back facilities at London Airport (Heathrow) and this data was analysed by BEA and, subsequently, also by RAE Bedford. For the purposes of this investigation the important features of the analyses were those which related to the event data of the final overshoot sequence. This data does not distinguish between auto-throttle disengagement by pressure of the release buttons or by the alternative of fully advancing the throttles and for this reason, and because of the sampling rates, it was not possible to obtain precise time and height values for given events. In the context of this investigation this is not considered to be important and the relevant items together with their height 'spread' and sequence were established as being within the following limits (heights are radio altimeter derivations):

(a) Auto-pilot switched to flare between 68.5 and 64 feet.

(b) Auto-throttle disengaged between 66 and 52 feet.

(c) Throttles fully advanced between 57 and 43 feet.

(d) Tailplane moved to 4.5° aircraft nose-up (ANU) between 55 and 50 feet.

(e) Auto-pilot disengaged between 51 and 49 feet.

Although the validity of the flight recorder system was established as being within the design specification, it proved difficult to derive a flight path which completely satisfied all the recorded data and other factual information including the position of the Comet aircraft and the height of the impact damage to its fin. It appears possible that the method of close analysis which RAE Bedford applied may call for a vertical accelerometer of a higher performance standard than the type at present in use. The existing type, although well within the specified requirements, may possibly be subject to some error under dynamic conditions.

Such a form of analysis could well prove to be vitally important in some accident investigations and therefore it is considered desirable to conduct an investigation into this possible accelerometer error; BEA and RAE Bedford are co-operating to this end. The error which is thought to exist would lead, inter alia, to minor revisions in the heights given above for items (a) to (e) but these are not considered material to the investigation into this particular accident.

The RAE analysis established that from at least 300 feet on the approach, except for a brief period at about 180 feet, the Trident was on a collision course with the Comet and that there was nothing in the pilot's eyepath which suggests that P2 could have been misled on this point as the situation developed. This analysis also indicated that the visibility provided by the screens being used in the Trident to produce simulated Category III visibility limitations could vary considerably as a function of the pilot's eye position and the screens were thus unsatisfactory for their intended purpose. This point, which is outside the scope of this report, has been referred to those concerned with Category III training.

1.12 Wreckage

Not relevant to this investigation.

1.13 Fire

There was no fire.

1.14 Survival

Not relevant to this investigation.

1.15 Tests and research

None.

1.16 Other information

This section contains pertinent information on the crew procedures used by BEA during automatic approaches and landings and which were being used at the time of the accident. Only the essentials of the procedures are given and only as they relate to the accident approach.

The procedures are well designed and involve closely co-ordinated teamwork between the three pilots who form the normal BEA flight deck crew. In BEA terminology the pilot in the left-hand seat is known as P1 and in normal line service he is the captain and the pilot-in-command. The pilot in the right-hand seat is P2 and is the co-pilot whilst the pilot in the centre seat between the other two is known as P3.

During the approach in normal line service, until the aircraft is nearing the decision height, which is the height by which he must decide whether or not to continue through to a landing, P1 is responsible for overall supervision of the operation. He monitors his flight instruments and the activities of the other two pilots and deals with R/T communications.

During this same period P2 is responsible for direct control of the aircraft by monitoring his flight instruments and the auto-pilot and making the necessary switching selections appropriate to the various stages of the sequence. He keeps his left hand resting on the throttles which are under automatic control with his thumb close to the auto-pilot disengage button.

Throughout the entire approach P3 is responsible for monitoring certain of the engine and aircraft systems indicators, for monitoring the flight instruments of P1 and P2 and informing them of any discrepancies, and for making a number of advisory and/or warning calls. The closing stages of the operation are best shown in relation to these calls in their appropriate sequence and in the context of the auto-pilot status on the accident approach.

At 500 feet (R), ie as indicated by the radio altimeters, P3 calls '500 - RADIO' to indicate to P1 and P2 that subsequent heights will be called by reference to the radio altimeters.

At 300 feet (R) P3 calls 'AUTOLAND - 100 feet' thus indicating that the system operating status is adequate for continuation to a landing subject to P1 making the appropriate decision by a height of 100 feet (R). This height value will vary according to a number of circumstances which are defined in the BEA procedures; the value of 100 feet (R) given here was applicable because of the 'failure' which the training captain had introduced at about 900 feet in the approach. This had the effect of reducing the auto-pilot from triplex operation to duplex operation for which BEA requires a decision height of 100 feet.

Before reaching the decision height P1 goes 'head-up' to seek external visual reference and 30 feet before decision height, ie at 130 feet (R) in this case, P3 calls '30 ABOVE'; this call serves two purposes. It warns P1 that he must now make his decision whether or not to land and announce it by calling 'LAND' or 'OVERSHOOT'; he acts accordingly. If P1 calls 'LAND' the approach continues but if P1 calls 'OVERSHOOT' P2 must immediately initiate overshoot action by fully advancing the throttles. He will also take this action if P1 says nothing at all.

If P1 calls 'LAND', as he did in the accident case, in addition to indicating that the approach will continue to a landing, it also indicates that he has taken over control of the aircraft and will make any commands which subsequently may become necessary; he keeps his hands on the control column from this point onwards. P2 remains firmly 'inside' the aircraft monitoring the auto-pilot and his flight instruments down to the touchdown, keeping his left hand on the throttles and his right hand on his control column.

Should P1 subsequently decide to overshoot for any reason he calls 'OVERSHOOT' and P2 immediately fully advances the throttles to initiate this whilst continuing to monitor the auto-pilot and his flight instruments as before. It will be apparent that P2 has considerable responsibility during the operation and, in particular, that it is he who must take the action of advancing the throttles to initiate an overshoot whether this is made before or after the decision height. P2's reaction to a call of 'OVERSHOOT' could therefore be expected to be the immediate advancing of the throttles whenever such a call is made whereas, except in some form of emergency, this action would not be expected of P1.

2. Analysis and Conclusions

2.1 Analysis

From the flight crew evidence, from the flight recorder evidence, from post accident checks of the Bedford ILS and from checks of all the relevant aircraft systems in G–AWZA, it has been established that:

(a) Both the ground ILS installation and the relevant equipment in the aircraft itself were capable of operation to full specification standards and were so operating.

(b) The aircraft had been on the correct glide slope for at least the final 400 feet of the approach and although there had been minor variations in pitch attitude and rate of descent none of these were of sufficient magnitude to have misled the training captain into a belief that he was on anything other than a 'collision course' with the Comet. Only an overshoot made at sufficient height could have prevent the collision.

(c) The throttles were not fully advanced to initiate overshoot until the aircraft was at a radio altimeter height of between 57 and 43 feet. Energy height calculations show that throttle advancement was virtually coincident with auto-throttle disengagement.

(d) Unknown to the flight crew the auto-pilot was disengaged at a radio altimeter height of 50 feet ± 1 foot.

(e) Virtually coincident with auto-pilot disengagement there was a nose-up pitch control input applied at a rate well beyond the capability of the auto-pilot and thus, necessarily, made by either P1 or P2.

Consideration of item (c) above indicates that the pilots were mistaken in their assessment of the height at which overshoot action had been initiated and that there had been a time delay between the call 'OVERSHOOT' and the action of opening the throttles fully. Items (a) and (b) show that the fundamental cause of the accident was the failure to overshoot sufficiently early in the approach. It is relevant to consider whether there were any specific circumstances which could have led to this.

When he made his call of 'LAND' just before reaching the decision height of 100 feet (R) P1 was conforming correctly with his briefing for the exercise on which he was engaged. He was well aware of the Comet aircraft on the runway and that a full landing procedure was therefore impossible but he assumed, quite properly, that the training captain who was in command of the operation would ensure overshoot action with an adequate margin over the obstruction.

During the approach, and after establishing the Comet's position on the runway, the training captain had revised his originally intended overshoot height from 70 feet (R) to 100 feet (R). He did not inform P1 or P3 of his revised intentions nor was there any need for him to do so. He said subsequently that it was at or fractionally before 100 feet (R) that he gave the command 'OVERSHOOT'; whenever this command was given the aircraft was below 60 feet (R) by the time the throttles were fully advanced. At the rate of descent then applying this represents a time lapse of about three seconds between the command and the required action; in the context of such an operation, this was an unacceptable delay.

It has not been possible to establish with absolute certainty whether there was such a delay between the command and the action, or whether the training captain had in fact subconsciously reverted to his originally planned overshoot height of 70 feet (R). On balance the former seems more probable. There can be no doubt that a cockpit voice recorder would have been of very considerable value in clarifying this aspect of the investigation.

The duties of P2 in the final stage of such low approaches are demanding in themselves and the addition of the instructional and safety monitoring roles required of a training captain may well lead to an overall demand which is excessive. As P2 the BEA crew procedures require him to be firmly 'inside' the aircraft closely monitoring the auto-pilot and his flight instruments; as training captain he is further required to be simultaneously 'outside' monitoring safety and 'inside' monitoring the activities of P1 and P3. In a case such as this where the 'outside' circumstances were somewhat unusual, and became critical, there could well have been a delay between his call of 'OVERSHOOT' as training captain and his realisation that as P2, it was his personal duty to advance the throttles fully, carry out the overshoot drills and monitor the overshoot.

Automatic overshoots in Trident aircraft, initiated before the flare phase of the automatic landing, involve an average height loss of the order of 40 feet. Allowing for this, and for the fact that overshoot initiation at 100 feet (R) in circumstances of level ground will take place about 1,000 feet before the runway threshold, it is apparent that had the throttles been advanced at the intended 100 feet (R) the aircraft could have been expected to pass over the Comet aircraft with at least 100 feet clearance and established in the climb out flight path. Superficially a decision height of 100 feet (R) may therefore seem to offer an adequate margin. It does not however contain any allowance

for either a possible equipment failure or for a crew procedural failure leading to a delay in overshooting such as occurred on this occasion. Its use must therefore be considered an error of judgment by the training captain.

In the final stages of the approach, and in conformity with his duties as P2, the training captain had his right hand on his control column and although he does not recollect doing so there can be little doubt that it was he who applied the abrupt pitch-up control input at about 50 feet (R). It has not been possible to establish whether this action did in itself disengage the auto-pilot. Because there was no audio warning signal it is apparent that one of the auto-pilot disengagement buttons must have been pressed virtually simultaneously with the application of the pitch-up control force. Although almost certainly it was the training captain who took this action he has no recollection of having done so.

From 50 feet (R) down to impact with the Comet the aircraft was certainly not under auto-pilot control and there is no indisputable evidence that it was being flown manually in the full sense of the word. P1 had his hands on his control column and was monitoring his flight instruments whilst following control movements which he thought were being made by the auto-pilot. The training captain said that although he had no conscious recollection of flying the aircraft manually he felt it would have been illogical for him to have applied the pitch-up control input which he apparently did and then immediately to release control of the aircraft completely. There is some validity in this contention and in any case the doubtful period until P1 took full control on impact at 20 feet (R) was only about three seconds; it would be quite unrealistic to expect the pilots to retain a detailed memory of events in such a brief period of time, more particularly against the over-riding distractions of the accident.

The fact remains that for some hours following the accident and until presented with the flight recorder evidence all five experienced crew members were firmly convinced that the overshoot had been made under auto-pilot control until the point where P1 disengaged it at impact with the Comet. This is indicative of an unsatisfactory design feature in the auto-pilot disengagement warning system and one which is now to be remedied. A modification will be made so that there will be an audio warning signal whatever the manner of disengagement; this signal may then be cancelled by pressing the thumb release after a suitable built-in time delay.

There are certain aerodromes at which it has been the practice to overshoot over an aircraft on the runway and thus minimise delays which might otherwise become economically punitive to training activities. For certain types of training, provided that all concerned act prudently, there does not appear to be any reason why such a practice should not be acceptable. The crux of a safe procedure lies in the height clearance over the obstructing aircraft.

In the past an adequate height clearance has been assumed to be a matter of common sense and consequently no minimum clearance is defined in existing legislation. Immediately following this accident, and whilst the Comet was still on the runway, the Bedford controller suggested that another aircraft then making an approach should overshoot from a height of 200 feet. Since the accident BEA have also required their training aircraft to overshoot at 200 feet in such circumstances. An overshoot which is initiated at 200 feet above threshold elevation will begin about half a mile before the threshold and during the overshoot the aircraft will pass over the threshold at a height of 350 to 400 feet on the climb out. It is therefore apparent that a 200 feet minimum overshoot height would provide an adequate safety margin over an aircraft standing on the runway threshold.

Such an overshoot height would however nullify the very low level overshoot requirements inherent in Category III training and it follows logically that such training entails an unobstructed runway. This type of training will greatly increase in the future and the necessary arrangements to ensure a satisfactory combination of safety and training economy would appear to be a matter for collaboration between ATC and the operators concerned with Category III training.

2.2 Conclusions

a. *Findings*

(i) The documentation of both aircraft was in order.

(ii) There was no pre-crash failure or malfunction of either the aircraft or the ILS ground installation.

(iii) The Trident crew were properly licensed and very experienced in auto-land procedures with Trident 1 and 2 type aircraft.

(iv) The Trident crew had been informed of the presence of the Comet on the runway; this information and the instruction only to make an overshoot had been acknowledged by the training captain.

(v) Although there was some gusting the weather conditions were suitable for the training exercise on which the Trident was engaged; the Comet aircraft was visible to the Trident training captain throughout the approach.

(vi) The height of 100 feet (R) which the Trident training captain chose as the decision height for the overshoot did not contain a prudent margin to allow for an error in the crew procedure or a malfunction of equipment.

(vii) Although the call 'OVERSHOOT' was apparently made at about 100 feet (R) the throttles were not fully advanced to initiate overshoot until between 57 feet (R) and 43 feet (R), ie a delay of about 3 seconds.

(viii) 0.5 seconds after the throttles were fully advanced there was a nose-up pitch control input beyond the capability of the auto-pilot; this was almost certainly made by the training captain.

(ix) At a height of between 51 feet (R) and 49 feet (R), and simultaneously with the application of nose-up pitch control the auto-pilot was unintentionally disengaged. Neither the training captain nor any of the other crew members realised that the auto-pilot had been disengaged.

(x) Despite the application of engine power and the nose-up pitch control input which had been made the aircraft continued to descend and struck the Comet fin and rudder when at a wheel height of 18 feet above the runway.

(xi) The delay in taking overshoot action and the unintentional auto-pilot disengagement may be attributable to the training captain's pre-occupation as a consequence of combining the instructional and safety duties with those entailed by his simultaneous function as P2.

b. *Cause*

The cause of the accident was that the training captain did not ensure that the overshoot was made at the intended height of 100 feet (R).

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