Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Boeing 747 Series 136 G-AWNB
Report on the accident at approximately 4nm north-west of Prestwick Airport, Scotland, on 16 May 1975

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Department of Trade
Accidents Investigation Branch
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6 August 1976

The Rt Honourable Edmund Dell MP
Secretary of State for Trade

Sir

I have the honour to submit the report by Mr R G Feltham, an Inspector of Accidents, on the circumstances of the accident to Boeing 747 Series 136, G-AWNB, which occurred approximately 4 nm north-west of Prestwick Airport, Scotland, on 16 May 1975.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch
Aircraft Accident Report No. 13/76
(EW/C520)

Operator:	British Airways
Aircraft:	Boeing 747 Series 136
	British G-AWNB
Engines:	Four Pratt & Whitney JT9D-7
Place of Accident:	Approximately 4nm north-west of Prestwick Airport, Scotland Latitude 55°31′ North. Longitude 4°38′ West
Date and Time:	16 May 1975 at 0733 hrs
	All times in this report are GMT

Synopsis

The accident was notified by British Airways to the Department of Trade on 16 May 1975. The Accidents Investigation Branch of the Department of Trade carried out an investigation and the following groups were established: Operations; Engineering; Flight Recorder.

The State of Manufacture was notified of the accident but declined to appoint an accredited representative to participate in the investigation.

The accident happened when the aircraft was engaged on crew training involving circuits and landings at Prestwick Airport. During the third approach after two uneventful 'touch and go' landings a bang was heard and it was determined that No. 4 right main cabin door was damaged and had failed inwards. After landing, ground examination revealed that the door had been struck by the outboard end of the right inboard wing trailing edge foreflap which had become detached during flight. No injury was sustained by the occupants nor by anyone below the flight path. The detached foreflap fell into the sea. It is concluded that the foreflap detachment was caused by failure of its outboard sequence carriage attachment fitting due to fatigue.

1. Factual Information

1.1. History of the flight

The aircraft was engaged on pilot and engineer officer training and was making right-hand circuits and landings on runway 13 at Prestwick Airport. It took off in daylight at 0712 hours. The weather was fine with ceiling and visibility unlimited and light and variable winds. The handling pilot was a First Officer under instruction whose experience of flying the Boeing 747 was 1 hour on the aircraft and approximately 20 hours on a simulator. He was flying the aircraft from the right hand seat whilst the Training Captain (the Commander) was supervising from the left hand seat. All the approaches were being flown manually. Having successfully completed two 'touch and go' landings, it was intended that the third approach should be terminated in a full stop. During this approach, while turning on to the final approach heading at an altitude of about 1,300 feet, the handling pilot asked for the flaps to be selected from 20^{o} to the landing flap setting of 30^{o}. At 0733 hours, shortly after the flap selection was made, a bang was heard and a slight pressure change was sensed by two of the crew members. The Flight Engineer, who was also under instruction, checked the engine instruments but found no evidence of engine malfunction. He noticed, however, that No. 4 door right warning light was illuminated and reported this to the Commander. The supervisory Flight Engineer went to the passenger cabin to inspect the door and found that it had failed inwards and was displaced approximately 2 inches from the door surround. There was debris from the door on adjacent passenger seats and further debris, including an escape chute gas generator, on the cabin floor. After this preliminary inspection he returned to the flight deck and reported the extent of the damage to the Commander.

While the aircraft was still turning the handling pilot did not notice any change in handling characteristics. However, after levelling out, it was evident that about 15^{o} to 20^{o} of control wheel displacement to the left was required to maintain the wings level and a small amount of buffet was also felt. The Captain, on confirming that this amount of aileron deflection was necessary, took control of the aircraft at about 600 feet. He aligned the aircraft with the runway centre line, applied sufficient rudder control to offset the lateral out of trim condition, and increased the airspeed slightly to 149 knots, this being the landing reference speed (V_{REF}) + 10 knots at landing weight of 243,000 kg. He was under the impression that more than normal control movements were necessary, both laterally and longitudinally, to achieve the desired flight path but no problem was experienced during the flare-out and landing. Normal drills were carried out after landing on the assumption that a door failure was the only fault.

Since the flaps had been retracted during the after landing checks, the cause of the problem was not immediately apparent. However there were various score marks on the right hand side of the fuselage leading to the damaged door which indicated some form of impact from behind the right wing trailing edge. Further investigation established that the foreflap section of the right inboard trailing edge flap was missing, and had become detached in flight.

Sections of the foreflap were later recovered from the sea, about three miles north-west of the airfield.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Non-fatal	–	–	–
None	5	–	

1.3 Damage to aircraft

The right inboard trailing edge foreflap had separated from the aircraft (Figure 1).

There was some minor skin damage on the right wing inboard trailing edge mid flap upper surface, inboard spoiler undersurface and more severe damage on the fuselage side forward of the No. 4 right main door. (Figure 2).

Number 4 right main door had been forced about 12 inches into the cabin. Three of the four door latches had been fractured. The door had been pierced in its upper part and the gas generator for the escape slide had been ejected from its mountings and rendered ineffective. (Figure 2).

The rear cabin of the aircraft contained a considerable scattering of debris from both the foreflap and door structures.

1.4 Other damage

There was no other damage

1.5 Personnel information

1.5.1 *Flight crew*

1.5.1.1 Commander

Age: 51	Male
Licence:	Airline Transport Pilot's Licence. Valid until 28 April 1980
R/T Licence:	Restricted
Instrument rating:	Valid to 22 January 1976
Aircraft rating:	Boeing 747 (In command)
Total flying experience:	12,246 hours
Total flying on type:	284 hours
Medical certificate:	Valid until 30 June 1975
Last competency check:	9 January 1975

1.5.1.2 First Officer

Age: 42	Male
Licence:	Airline Transport Pilot's Licence. Valid until 17 December 1975
R/T Licence:	Restricted
Instrument rating	Valid to 7 May 1975
Aircraft rating	VC 10 (In command)
Total flying experience:	5,203 hours
Total flying on type:	1 hour under instruction
Medical certificate	Valid until 31 August 1975
Last competency check:	(VC 10) 28 November 1974

1.5.1.3 Engineer Officer

Age: 49	Male
Licence:	Flight Engineer's Licence. Valid until 14 June 1978
Aircraft rating:	Boeing 707
Total flying experience:	10,154 hours
Total flying on type:	35 hours under supervision
Medical certificate:	Valid until 30 June 1975
Last competency check:	(Boeing 707) 1 October 1974

1.5.1.4 Engineer Officer (Supervisory)

Age: 47	Male
Licence:	Flight Engineer's Licence. Valid until 31 March 1978
Aircraft rating:	Boeing 747
Total flying experience:	4,482 hours
Total flying on type:	1,206 hours
Medical certificate:	Valid until 31 March 1976
Last competency check:	5 November 1974

1.5.1.5 First Officer (Supernumary) — This officer was flying in a non-operating capacity as an observer.

1.5.2 *Cabin Crew*

Nil

1.5.3 *Passengers*

Nil

1.6 Aircraft information

1.6.1 *General*

Type:	Boeing 747 Series 136
Manufacturer:	The Boeing Company, Seattle, USA
Year of manufacture:	1970
Ownership:	Delivered to British Overseas Airways Corporation 23 May 1970 Re-registered in name of British Airways Board on 1 April 1974
Certificate of Airworthiness (C of A):	UK Civil Aviation Authority (CAA) No. 2823. Valid until 19 May 1977
Certificate of Maintenance Release:	Issued, following last Intermediate Check on 12 December 1974 at 11,999 airframe hours and valid for 2,250 hours.

Total Airframe hours:	13,732
Total landings:	5,507
Airframe hours since C of A renewal:	4,014
Landings since C of A renewal:	1,515

1.6.2 *Aircraft loading*

The calculated weight of the aircraft at the time of the accident was 245,000 kg. The maximum authorised landing weight was 265,300 kg. The centre of gravity of the aircraft was within the prescribed limits.

1.6.3 *Recent utilisation*

The aircraft was flown to Prestwick on 9 May 1975 for an extended crew training detail. Before departure the aircraft had accumulated a total of 13,666 hours and 5,187 landings. During the training period the aircraft accumulated a further 66 hours and 320 landings.

1.6.4 *Trailing edge flaps and foreflaps – Description*

The Boeing 747 trailing edge flap system consists of four triple slotted trailing edge flaps positioned by independent drive systems. Each flap is supported by two flap carriages which travel on tracks attached to the lower surface of the wing. A transmission assembly attached to each carriage extends or retracts the flap. Each trailing edge flap consists of a foreflap, midflap and an aftflap, the three flap segments being mechanically separated to form three slots as the flaps are extended (Figure 5).

The foreflaps are supported by a track which extends into the midflap where it runs on rollers. The position of the foreflap is established by sequence carriages attached to this surface. The foreflap extends with the midflap until its sequence carriage contacts detents in the flap tracks, at which point the foreflaps and midflaps separate, the foreflaps remaining fixed until the flaps are retracted (Figures 6 and 7).

1.6.5 *History and relevant inspections of right inboard trailing edge foreflap*

The right inboard trailing edge foreflap, Serial No. 000053, fitted to the aircraft at the time of the accident was installed on G-AWNB at the time of delivery of the aircraft to the operator. The records show that the foreflap had been removed from the aircraft for a short period only in February 1973 for the purpose of incorporating approved modifications.

At the time of the accident the maintenance schedule called for routine inspections of the trailing edge flap assemblies at the following intervals: every 250 hours – walkround inspection, every 850 hours – scan inspection, every 2,250 hours – zone inspection, all inspections to be with flaps lowered. The records show that these inspections had been carried out at the required times.

In addition certain special checks had been called for and completed. The two most recent checks of this nature were carried out under the operator's references Special Check (SC)747/74/70 and Aircraft Maintenance Work Requirement (AMWR) 747/75/1031.

SC 747/74/70 related to Boeing Service Bulletin 747-57-2119 (Issued 31 May 1974 and revised 24 September 1974) and called for an inspection, for cracking, of the inboard foreflap outboard sequence carriage attachment fitting and, subject to a defined cracking

limit being exceeded, its replacement. The foreflaps of G-AWNB were subjected to this check on 27 September 1974 at which date the aircraft had accumulated 11,273 hours and 4,295 landings. No defect was recorded.

AMWR 747/75/1031 was raised by the operator following the loss of a foreflap from another B.747 of its fleet at Toronto on 22 March 1975. This check was a repeat application of Boeing Service Bulletin 747-57-2107 (Issued 3 November 1972) which called for a once only inspection of foreflap tracks for signs of galling and rollers for seizure. The foreflap assemblies on G-AWNB were subjected to this check on 25 March 1975 at which date the aircraft had accumulated 13,150 hours and 5,082 landings. No defect was recorded.

1.7 Meteorological information

The weather observation for Prestwick at 0730 hrs on 16 May 1975 was:

Weather	Nil
Surface wind	Light and variable
Visibility	40 nm
Cloud	Nil
Temperature	+ 6°C
QNH	1017 mbs

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome and ground facilities

Not applicable.

1.11 Flight recorders

The aircraft was equipped with a Plessey PV 740 digital flight data recorder system which provided information to a mandatory crash-protected recorder and to the Aircraft Integrated Data System (AIDS) recorder. A read-out of both recorders was attempted subsequent to the accident but the mandatory recorder was found to be unserviceable and contained invalid data relevant to the accident flight.

Subsequent investigation revealed intermittent failures in certain integrated circuits of the Logic Unit of the airborne system to which the invalid recording was attributed. The AIDS recorder was replayed and valid data were obtained although certain parameters contained identifiable errors.

Analysis of the information from the AIDS recorder showed that the aircraft had completed a take-off followed by two 'touch and go' landings and was on a third approach, when a flap selection from 20° to 30°was recorded. This selection was made whilst the aircraft was in a 25° banked turn to the right and, as the flaps were travelling through 25°, a lateral out of trim condition arose which was immediately corrected by the application of between 20 and 30 per cent left aileron control. The aircraft was established on final approach with the lateral out of trim condition persisting until touchdown. The recording showed that the flaps had only been selected fully up after the entire training detail had been completed.

The aircraft was also equipped with a Fairchild Model A100 cockpit voice recorder (CVR). This recorder operates on a recycling principle so that, when it is under power, all information recorded prior to the previous 30 minutes is automatically erased. As part of the 'leaving aircraft' drill after landing, the CVR manual erase button was operated. This resulted in erasure of the entire recording. There was no legal or Company requirement to retain the recording in these circumstances.

1.12 Wreckage

Examination of Aircraft

1.12.1 *Initial examination*

Inspection of the aircraft showed that the right inboard trailing edge foreflap had separated from the aircraft. Inspection of the foreflap attachments remaining on the aircraft showed that all failures had pure overload characteristics except those on the outboard sequence carriage attachment fitting which exhibited evidence of a combination of fatigue and overload failure.

There were indications of contact between the foreflap and inboard spoiler and between the foreflap and midflap during the initial separation of the foreflap from the aircraft.

There was severe damage to the right hand side of the aircraft fuselage, on, and just forward of the No. 4 main door. There was also minor damage to the aft end of the wing fuselage fairing.

The No. 4 door had been forced into the cabin and three of the four latching rollers had been broken off in overload.

There was a large scattering of debris throughout the aft cabin which was all identified as coming either from the foreflap or from the door and its surrounds.

1.12.2 *Examination of foreflap structure*

The foreflap main structural box with some of the leading and trailing edge honeycomb structure still attached was recovered, in two pieces, from the sea under the approach path. Another part of the trailing edge honeycomb was recovered from the sea some days later. The main foreflap box had broken at its structural joint between the inboard sequence carriage attachment and the centre foreflap track. The inboard end section had suffered severe post separation damage, all of the leading edge and most of the trailing edge having broken off the main box. It had also suffered severe damage to the outboard end of the box structure, the outer closing rib being one of the identified pieces found in the aft cabin. The foreflap outboard track attachment had been wrenched from the structure but was not recovered. The inboard section of the foreflap suffered much less damage. The leading edge had been struck between the inboard track attachment and the inboard sequence carriage attachment, and the trailing edge honeycomb had separated at the inboard and outboard ends of the section. The expanding body seal attached to the inboard end had also suffered damage to its leading edge.

1.12.3 *Examination of right inboard foreflap attachments and associated tracks*

1.12.3.1 Inboard sequence carriage attachment fitting.

This fitting showed evidence of having failed in torsional overload the major failure having occurred in the vertical leg of the attachment fitting adjacent to the sequence carriage lug. Contact marks on the pick-up mounting in the foreflap and evidence on the outer bearing of this fitting indicated that the inboard end of the foreflap pivoted aft about the inboard sequence carriage at the time and that the flap moved outboard at the time of failure. No evidence was found of a pre-existing defect.

1.12.3.2 Outboard sequence carriage attachment fitting

This fitting was found to have had major failures through its horizontal flange and through its vertical channel member.

Initial examination revealed extensive fatigue cracking in the horizontal flange portion around the base of the main attachment lug and around three of the four bolt holes. Fatigue cracking was subsequently found to exist in the vertical channel portion of the fitting between the horizontal flange and the first foreflap spar attachment bolt and also adjacent to the second attachment bolt.

Examination of the portion of the flange remaining attached to the foreflap revealed that heavy fretting of the mating surface of the flange had occurred around the attachment bolt holes but that between the bolt holes there were areas where no fretting had occurred. There were no shims between the mating surface of the horizontal flange of the fitting and the lower surface of the foreflap.

The fitting was subjected to a detailed metallurgical examination in order to establish the mode and characteristics of failure (see 1.12.4).

1.12.3.3 Foreflap inboard track

This track showed evidence of having been extended from the midflap until the forward limit stops were reached, a condition not normally achieved in the extension cycle. There was also evidence that there had been contact between the track and the attachment fork.

1.12.3.4 Foreflap centre track

This track had been twisted, the forward end having been rotated clockwise as viewed from the front. There was evidence of contact between the track and the foreflap attachment fork above its centre line similar to that on the inboard track.

1.12.3.5 Foreflap outboard track

The forward end of this track and its foreflap attachment fitting were not recovered. The aft portion of this track some two feet in length, remained in the midflap. Examination of the failure on this part of the track showed that the inboard upper flange of the I section track had failed in compressive buckling and the remainder of the section had failed in tensile tearing.

1.12.3.6 Foreflap inboard and centre track attachments

The attachment fork ends of both these fittings had failed. Both fittings and their associated tracks showed evidence of contact between the upper edge of the fork centre and the front edge of the track. The failure of both fork lugs on each fitting consisted of a lug shear failure of the lower arc of the lug and a bending failure of the upper arc and in both cases were considered to be the result of prising loads induced by nose-up pitching of the foreflap.

1.12.3.7 Foreflap track flight load rollers

All foreflap track flight load rollers were visually inspected for freedom of movement. Each roller was found to rotate freely by manual rotation.

1.12.4 *Metallurgical examination of right inboard foreflap outboard sequence carriage attachment fitting*

This fitting was manufactured as a die forging from 7075 – T73 aluminium alloy. The bore, general process requirements for the fitting after final machining were as follow:

(i) penetrant inspection,

(ii) shot peening over all surfaces except in the bearing housing bore,

(iii) chemical conversion coating or chromic acid anodized,

(iv) primed with one coat epoxy primer except in the bearing housing bore.

Initial inspection showed that the fitting had fractured in two positions, as shown in Figure 3, namely through the vertical channel member and through the horizontal flange. Subsequent examination confirmed the presence of fatigue cracks in both fractures.

Considerable distortion was evident in the tapered portion of the vertical channel in the region of the first and second bolt holes. This distortion was consistent with forward bending loads being applied to the channel via the lug and was indicative of the fitting having pulled away from the flap. Examination of the fractures and cracks in the contacting face of the vertical channel revealed evidence of fatigue in the positions shown in Figure 3. Radial cracks, initiated at the edges of holes, had developed under the influence of stresses induced by the distortion and a circumferential crack round the first bolt hole had grown in plane bending from multiple origins. The high strain nature of the fatigue striations and the distortion characteristics of the vertical channel indicated that these failures were secondary to those in the horizontal flange.

Examination of the horizontal flange showed that a major fracture had occurred across its entire width involving three of the four bolt holes as shown in Figure 3. Evidence of fatigue was found both on the fracture surfaces adjacent to the bolt holes and on the fracture involving the blending radius to the lug. The major fracture through the flange resulted from the growth of fatigue cracks from multiple origins along the toe of the blending radius. These origins were particularly concentrated to one side of the lug and could be linked to a large number of stress cracks which existed in the surface finish in the same area. Examination of the fracture surfaces in the scanning electron microscope revealed the presence of high cycle fatigue striations over most of the section. The fatigue cracking near the bolt holes was initiated by fretting at the mating face at points approximating to the positions of the rims of the bolt heads on the outer surface. There was evidence of distortion of the flange at these points which appeared to be associated with stresses introduced by the clamping effect of the bolts.

Metallographic examination of microsections taken through the region of surface finish cracking on the lug blending radius revealed numerous short cracks in the underlying metal as typically shown in Figure 4. Although the distribution of the fatigue cracks followed the stress pattern as revealed by the surface finish cracks, the short cracks in the underlying metal had originated from surface discontinuities. These discontinuities took the form of mechanical laps introduced in the shot peening process and were indicative that overpeening had occurred.

Tests of the material for tensile strength and chemical composition revealed no significant deviation from specification requirements.

1.13 **Medical and pathological information**

Not applicable.

1.14 **Fire**

No fire occurred.

1.15 **Survival aspects**

Not applicable.

1.16 Tests and research

1.16.1 *Outboard sequence carriage attachment fitting on foreflap previously removed from G-AWNB.*

The foreflap with this fitting attached had been earlier removed from G-AWNB and fitted to the inboard position of another aircraft in the fleet. On 16 April 1975 during an inter-supplement check, this fitting was found to be cracked and was removed from this other aircraft.

Subsequent to the accident to G-AWNB on 16 May 1975 the fitting was re-examined for comparision purposes. It was found that the cracking was caused by fatigue, and that its characteristics were very similar to those found on the subject fitting from G-AWNB. The fitting also exhibited the same type of subsurface cracks together with surface mechanical laps attributed to overpeening. The surface had been anodised and the mechanical laps had consequently widened due to anodic attack. Fretting marking, similar to that on the failed fitting, was also found on the mating surface of the horizontal flange.

1.16.2 *Other outboard sequence carriage attachment fittings*

The operator supplied three other outboard sequence carriage attachment fittings of the same type for comparative examination. These fittings had been removed from other Boeing 747 aircraft to incorporate the modification introducing improved type stronger fittings (see 1.17.3).

Sections taken from these fittings showed that all three had sustained surface damage in the form of mechanical laps during the shot peening process. On one fitting, which had been subsequently anodised, the anodic treatment appeared to have worsened the damage.

1.17 Other information

1.17.1 *Previous Boeing 747 inboard foreflap losses*

Up to the time of this accident there had been five recorded instances in which an entire foreflap or a major portion of one had become detached from a Boeing 747 in flight. All of these instances occurred outside the United Kingdom and each has been the subject of investigation by a foreign investigating authority.

In each of the five cases the initial failure leading to separation of the foreflap was related to the outboard sequence carriage attachment fitting. However three different underlying causes were associated with these failures.

In one case the primary cause was attributed to migration of the bearing in the fitting. The remedial action introduced for this type of failure is detailed in Boeing Service Bulletins 747-27-2070, which called for the fitting of bearing retainers at foreflap attachments, and 747-57-2088 which called for the modification of the inboard sequence carriage attachment fitting by replacement with a self aligning fitting designed to eliminate the spanwise loading which was considered to be aggravating the bearing migration. These modifications had been introduced by British Airways on G-AWNB and, where applicable, on other aircraft in the fleet.

In another case the primary cause was attributed to the disconnection of part of the flap drive system leading to uneven deployment of the flap.

In each of the remaining three cases the primary cause was attributed to seizure of the foreflap track flight load rollers. This induced excessive loading on the outboard sequence carriage attachment fitting. In two cases this led directly to overload failure and in the third to overload following partial fatigue. As a result of the first of these three incidents

Boeing Service Bulletin 747-57-2107 was issued. This called for a one time inspection of all foreflap flight load rollers for lubrication and freedom. A repeat of this inspection was called for after the second incident of this type. The third incident occurred very shortly after the second.

1.17.2 *Subsequent Boeing 747 inboard foreflap loss*

Approximately four months after this accident a foreflap was lost from another Boeing 747 aircraft during flight. A seized flight load roller was found on the subject foreflap. This accident also occurred overseas and is the subject of investigation by a foreign investigating authority.

1.17.3 *Redesigned outboard sequence carriage attachment fitting*

During the aircraft manufacturer's fatigue test programme, a fatigue crack was found in the fillet radius between the lug and the horizontal flange of a foreflap outboard sequence carriage attachment fitting on the fatigue test specimen airframe. Analysis indicated that crack initiation occurred at approximately 12,000 simulated flights. The manufacturer subsequently introduced a redesigned and strengthened fitting, the design aim being to eliminate the possibility of fatigue failure of the horizontal flange with all rollers rolling and to increase the tolerance to damage with sliding rollers.

The redesigned fitting is also a die forging manufactured from 7073-T73 aluminium alloy but has different dimensions and a solid vertical member. The specified surface treatment, process and quality control requirements for the stronger fitting are the same as those for the original fitting.

1.17.4 *Boeing Service Bulletin 747-57-2119*

This service bulletin was issued on 31 May 1974 as a result of the discovery, by the manufacturers, of fatigue cracking of the outboard sequence carriage attachment fitting on their fatigue test specimen airframe. A revision to the bulletin was issued on 24 September 1974 as the result of two operators finding cracks in this fitting in a different place to that on the fatigue test specimen.

The revised bulletin highlighted the possibility of the total loss of a foreflap and its subsequent damage to other parts of the aircraft. It also acknowledged the possible existence of a fit up problem at the horizontal flange of the outboard sequence carriage attachment.

The revised bulletin called for a one time inspection for cracking throughout the Boeing 747 fleet and for all results to be transmitted to Boeing. It laid down a frequent inspection cycle if cracking within specified limits existed and called for replacement of the fitting if these cracking limits were exceeded. It further called for checking of the fit up of the horizontal flange of the outboard sequence carriage attachment for correct shimming on those aircraft from which the flange attachment bolts were readily removable.

Because of difficulties of access G-AWNB was one of the early aircraft exempted by the bulletin from this shimming check at the time.

1.17.5 *Airworthiness Directive (AD) 75-20-05*

As a result of the significant history of foreflap problems on the Boeing 747, the US Federal Aviation Administration (FAA) issued an Airworthiness Directive (AD 75-20-05). A subsequent amend to this AD became effective from 12 December 1975.

The general requirements of the directive (as amended) are that, within 100 flights of the AD coming into force and at 350 flight intervals thereafter, foreflap rollers, tracks and

sequence carriage attachment fitting must be inspected, and, if necessary, replaced. It also instructs that the rollers and attachment fittings must be replaced before 31 December 1976 at which point normal inspection intervals may be resumed.

1.17.6 *Safety Recommendation A-75-79*

This Safety Recommendation was issued on 6 October 1975 by the US National Transportation Safety Board (NTSB) indicating the Board's recognition of the possible hazard to the safety of passengers in an aircraft or to persons on the ground following the loss of a foreflap. The board recommended that AD 75-20-05 be amended to require that the inspection of the inboard foreflaps be conducted within the next 25 flights, effective on the date of issue of the amended AD.

1.17.7 *Inspection requirements for aircraft used for crew training*

At the time of the accident no special inspection cycle on the flaps was called for whilst an aircraft was being used for crew training.

Subsequent to this accident the CAA called for a special inspection programme for UK registered Boeing 747 aircraft engaged in this role. This consists of an eddy current check of the foreflap attachment fittings immediately before and after the allocation of an aircraft for crew training, and a visual inspection of the fittings after every 80 approaches during training. The operator's maintenance manual was amended in June 1975 to include this.

1.17.8 *Operator's modification programme*

As a result of the second issue of Service Bulletin 747-57-2119, the operator introduced a modification programme on 17 December 1974 to install the stronger type of outboard sequence carriage attachment fittings (1.17.3 refers) on all their aircraft before they had completed 5,500 landings. This figure was decided upon taking into account the lead time required to acquire the fittings, the expected frequency of landings in the fleet, and the availability of aircraft at a suitable point in the maintenance cycle. At the time of its introduction there was no directive from either the manufacturer or the airworthiness authorities making the modification mandatory.

1.17.9 *Frequency of landings*

Reference is made in the previous paragraph to expected frequency of landings as a factor in determining the time at which improved type sequence carriage attachment fittings were to be fitted. The figure used by the operator was based on the fleet average of landings between intermediate checks. At the time of the accident the fleet average showed that about 500 landings could be expected although individual aircraft landing figures might diverge considerably from the norm. Because G-AWNB had been used extensively in the training role since its last intermediate check it had accumulated landings at almost three times the fleet average rate.

1.18 New investigation techniques

None used

2. Analysis

2.1 Separation sequence of foreflap from aircraft

Fracture analysis of the separated flap components enabled a sequence of failure of the parts to be established which indicated that the failure of the outboard sequence carriage attachment fitting constituted the primary failure. Furthermore, examination of the foreflap attachments and the foreflap drive and sequencing mechanisms revealed no evidence of a pre-separation defect except the fatigue failure observed on the outboard sequence carriage attachment fitting. The absence of any evidence of interference or jamming of the foreflap and its controlling mechanism, which could have given rise to abnormal forces being applied to the foreflap, indicated that the outboard sequence carriage attachment fitting was weakened by fatigue cracking to the point at which it failed under normal operational loads.

The foreflap separated when the aircraft was established on final approach to land and whilst the flaps were being extended from the 20^{o} position to 30^{o}. The loads applied to the outboard sequence carriage attachment fitting had previously been measured during flight testing by the manufacturer. The tests showed that, during the extension of the flaps from 20^{o} to 30^{o}, although the lift loading on the fitting decreased, the drag loading increased. The character of the final overload failure of the fitting on G-AWNB indicated that drag load was the predominant influence.

The failure of the outboard sequence carriage attachment fitting, with the flaps extended beyond 20^{o}, is considered to have had two immediate results. Firstly, the re-distributed load on each of the four remaining attachments was increased. Secondly, the loss of this attachment caused the outboard end of the foreflap to twist nose up, increasing the load on the outboard track attachment in particular. The load on the outboard foreflap track was thus increased to the point at which the track failed in bending. The outboard end of the foreflap was then left unrestrained allowing it to sail upwards, breaking the foreflap at its structural joint between the centre track and the inboard sequence carriage attachment, twisting the centre foreflap track and failing the attachment of the foreflap to the centre track. When the outer end of the foreflap had become totally detached from the aircraft it was orientated in such a way that it travelled inwards and struck the fuselage side causing the damage to the No. 4 right main door before falling clear of the aircraft. The inboard end of the foreflap, being left ineffectively retained, broke free of its attachments and fell away from the aircraft, giving a glancing blow to the rear of the wing/fuselage fairing.

2.2 Failure of outboard sequence carriage attachment fitting

The loss of the foreflap from G-AWNB was the sixth failure of its kind up to that time. It was unusual, however, in that no defect was found in any other part of the flap system. In all other cases of foreflap loss a defect in the flap system had given rise to abnormal loading on the attachment fitting. In this case there was no evidence of abnormal loading being present at any time.

Examination of the fractured fitting showed that fatigue cracking had started at several origins in the horizontal flange. Most of these were around the base of the main sequence carriage attachment lug, the remainder being at or near three of the four flange attachment bolt holes. The fatigue cracking eventually advanced to the point at which the remaining area of the horizontal flange failed in overload.

Up to the time of its failure, the horizontal flange of the fitting would have transmitted all of the drag loading imposed on the fitting, being the stiffest load-path in that sense. After failure of the flange, the drag loads would have been transmitted by bending of the vertical channel. The manufacturer has stated that the vertical channel would not be

a wider consideration, there is little doubt that components of such size detached in flight are capable of inflicting severe injury to persons below the flight path. The concern of the NTSB on this point in their Safety Recommendation is, therefore, fully supported.

In relation to the risk of foreflap loss the relevant FAA. Airworthiness Directive calls for early and frequent inspections of all foreflap components which have caused malfunction in the past and calls also for the replacement of any unsatisfactory parts found on inspection. The most recent amendment dated 12 November 1975 requires the replacement of all rollers and attachment fittings before 31 December 1976. The provisions of the directive undoubtedly will assist in containing the problem at the present time. It is considered, however, that the risk of foreflap loss will only be fully minimised when all operators have been able to complete the replacement of the outboard sequence carriage attachment fittings with the improved type.

2.7 Flight recorders

The crash-protected flight data recorder did not function correctly on the subject flight and, for the purposes of the investigation, it was necessary to recover recorded information from the AIDS non-protected recorder cassette. If the accident had been of a catastrophic nature it is considered probable that the latter recording would not have survived and essential data would then have been lost. These circumstances suffice to demonstrate the need for the mandatory crash-protected recording system to be maintained, at all times, at the highest possible level of serviceability.

The cockpit voice recording was erased by the crew as part of the leaving aircraft drill. The evidence on the CVR may not have been of high significance in this investigation. Nevertheless it is considered desirable that, following an incident or accident, crews should take such steps as are practicable to preserve the cockpit voice recording as soon as possible when the aircraft is on the ground so that any subsequent investigation may benefit from an analysis of the recorded audio information. Such steps would normally include refraining from operating the manual erase facility and immobilising the CVR by tripping the appropriate circuit breaker, thus cancelling the automatic erase function.

3. Conclusions

3.1 The crew were properly licensed and competent to carry out the flight.

3.2 The aircraft was properly certificated and had been maintained in accordance with approved requirements.

3.3 The aircraft was being operated within its prescribed limitations.

3.4 The right inboard trailing edge foreflap separated from the aircraft in flight, whilst the flaps were extending between 20° and 30° (full) deployment.

3.5 Separated parts of the foreflap struck the right side of the fuselage and the No.4 Right door. Most of the parts then fell into the sea.

3.6 Three of the four latches on the No. 4 Right door were fractured by the impact of the foreflap on the door, and the door and some flap debris was forced into the cabin.

3.7 The foreflap separated from the aircraft as a result of failure of its outboard sequence carriage attachment fitting.

3.8 The outboard sequence carriage attachment fitting failed because extensive undetected fatigue cracking had developed in part of it.

3.9 No pre-existing defect was found in any other part of the trailing edge flap system.

3.10 There were no injuries either to the occupants of the aircraft or to persons below the flight path.

Cause

The right inboard trailing edge foreflap became detached from the aircraft, during flight, because its outboard sequence carriage attachment fitting failed.

The mechanism of the fitting failure was the undetected growth of fatigue cracking in the horizontal flange leading to overload failure of the remainder of this flange. This was followed by fatigue cracking in the vertical channel portion of the fitting leading to its overload failure.

4. Safety Recommendations

It is recommended that:

4.1 Operators be urged to complete the installation of the improved type of foreflap outboard sequence carriage attachment fitting on their Boeing 747 fleet at the earliest possible date.

4.2 The attention of aircraft manufacturers, maintenance and repair organisations and operators is drawn to the dangers which may be involved by the introduction of super-imposed clamp-down stresses during the assembly of highly stressed components with non-parallel mating faces.

4.3 Further research be conducted into the surface peening processes used in the aerospace industry to determine whether improvements can be made in methods, material or process control.

4.4 Flight crews be urged to take such action as is practicable to preserve the cockpit voice recording following an incident or accident including immobilisation of the CVR as soon as possible when the aircraft is on the ground to prevent its automatic erasure.

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Inspector of Accidents

Accidents Investigation Branch
Department of Trade

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