No: 1/91	Ref: EW/A342	Category: 1a

Aircraft Type and Registration:	Boeing 747-287B, G-VIRG
No & Type of Engines:	4 Pratt & Whitney JT9D series turbofan engines: 2 model 7A, 1 model 7F, 1 model 7J
Year of Manufacture:	1975
Date and Time (UTC):	17 October 1990 at 2350 hrs
Location:	New York Kennedy Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 21 Passengers - 284
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to left inboard flap unit, left inboard aileron, Nos 3 & 4 canoe fairings and left inboard aft flap drive mechanism
Commander's Licence:	Airline Transport Pilot's Licence[1]
Commander's Age:	44 years
Commander's Total Flying Experience:	Approximately 14,300 hrs (of which 1,300 were on type)
Information Source:	AAIB Field Investigation

The first officer was handling the aircraft as it made a visual approach to runway 13 Left in good visual conditions and a surface wind of 220°/15 knots. The handling pilot had briefed for a visual landing in cross-wind conditions. The approach was normal in all respects and the aircraft crossed the landing threshold at reference threshold speed plus 10 knots. The first officer stated later that he believed he had checked the descent at 50 feet agl and remembered closing the throttles quite quickly at 30 feet. The captain thought he saw the first officer start the flare manoeuvre and, realising that the flare was insufficient, called 'flare-flare' before the aircraft landed heavily.

When the flaps were retracted after landing all cockpit indications were normal. However, when the crew disembarked, they discovered that the left wing flaps had retracted unevenly, sustaining light damage and causing light damage to the left aileron.

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1 The nominated aircraft commander was a training captain who was conducting a line check on the flight engineer and did not occupy either pilot's seat. In this report references to the aircraft commander and the aircraft captain relate to the captain who occupied the left pilot's seat.

The read out from the flight data recorder confirmed that the approach had been stable, that the speed over the threshold had been V_{ref} + 10 kt and that the aircraft had touched down with wings level and on the runway heading. The record showed that control column position and aircraft pitch attitude were normal over the latter stages of the descent. It showed a rearward movement of the control column at 40 feet radio altitude, some 3 seconds before touchdown, followed by a much greater rearward movement one second later, when the aircraft was about 15 feet above the runway. The pitch attitude lagged the control column movement and was increasing only as the aircraft touched down. There was no evidence on the flight recorder of the abrupt power reduction referred to by the pilot.

The flight recorder records of two earlier, normal landings were analysed and compared with the record from the hard landing. The differences in control column movement and pitch attitude were very small indeed. The rate of descent at 50 feet radio altitude, however, differed considerably. Engine power, measured in terms of engine pressure ratio (EPR), also showed little difference but, measured in terms of low pressure shaft rpm (N1), showed that the mean engine power of G-VIRG in the 16 seconds prior to touchdown had been between 3.2% and 4.7% less than that recorded for the normal landings. The two normal landings showed rates of descent of 550 fpm and 700 fpm, which then reduced to low values before touchdown. The rate of descent at 50 feet prior to the hard landing was 940 fpm and was still around 700 fpm on touchdown.

Engineering examination

Initial inspection by the operator at Kennedy Airport revealed that damage had occurred to the aerofoil surfaces of both the No 2 aft flap and the adjacent left inboard aileron, the Nos 3 and 4 canoe fairings and the aft flap drive mechanisms at the Nos 3 and 4 track positions.

The inspection detailed in the Boeing 747 Maintenance Manual as the Hard Landing or High Drag/ Side Load Landing Condition Inspection was also carried out. This inspection consists of a series of individual items and is divided into two phases. If none of the phase 1 inspections reveals any damage, there is no requirement to progress to phase 2. Inspection of the aft flap drive mechanism is included in the phase 1 inspection and, in view of the damage noted in this area, the operator carried out the phase 2 inspection with the remainder of the phase 1 items. No other damage was reported. Repairs were then carried out at Kennedy Airport to the aft flap unit and inboard aileron. All four operating rods and both bellcranks of the No 2 aft flap drive (Geneva Mechanism) were replaced and the two damaged canoe fairings were exchanged for new items. The damaged fairings were sent for repair within the United States.

The failed operating rods and bellcranks were returned to the UK and were subsequently received by the AAIB, who were able briefly to examine the aircraft during a stopover at Gatwick, 2 days after its return to service. In addition to the repairs described above, recent repair work was found to the trailing edge area of the aft flap. It was established that the trailing edge had been damaged during third-party maintenance activity approximately one week before the incident at Kennedy Airport, when the flaps were inadvertently lowered and the No 2 aft flap struck ground equipment.

The failed operating rods were examined by AAIB. Since they bore no visible identification, it was necessary to re-assemble them, measure their original lengths, and compare these with the lengths of operating rods on a similar 747 aircraft. It was then established that a section of the inboard aft rod was missing. Although some photographs of the damaged area had been taken by the operator at Kennedy Airport before the repairs were made, they were sufficient only to establish the orientation of the inboard pair of rods. Later photographs of the operating rods and bellcranks taken at the AAIB are in the Appendix; View A shows the position of the mechanism with flaps extended to approximately 30° and View B shows the mechanism overextended, following failure of the forward rods.

Examination of the rods and bellcranks revealed that both forward rods had failed in a complex fashion, initially in compressive buckling. The aft outboard rod had remained intact but its attachment lug on the bellcrank had failed. The inboard aft rod had broken into three segments, which were:

Segment 1 - forward section (approximately 50% of the complete rod length including the forward eye end)

Segment 2 - aft eye end attached to some 2 inches of the tapered aft end of the tubular section.

Segment 3 - portion of tubular section between Segments 1 and 2, which was not recovered.

Segment 1 showed clear indications of compressive buckling failure at its aft end, (*ie* at approximately mid-length of the complete rod). Segment 2, however, revealed clear evidence of tensile failure at the rod fracture. This combination of failures was inconsistent with the results of a single load application and was also difficult to explain even as a sequence of separately applied loadings.

Consideration of the damage to the mechanism, in particular the direction of failure of the outboard bellcrank lug, suggested the following sequence of events:

a. compressive buckling and failure of the two forward rods arising from forceful overtravel of the aft flap beyond the selected position;

b. continued movement of the aft flap beyond the maximum down (flaps 30) position, until the bellcranks were orientated fore and aft.

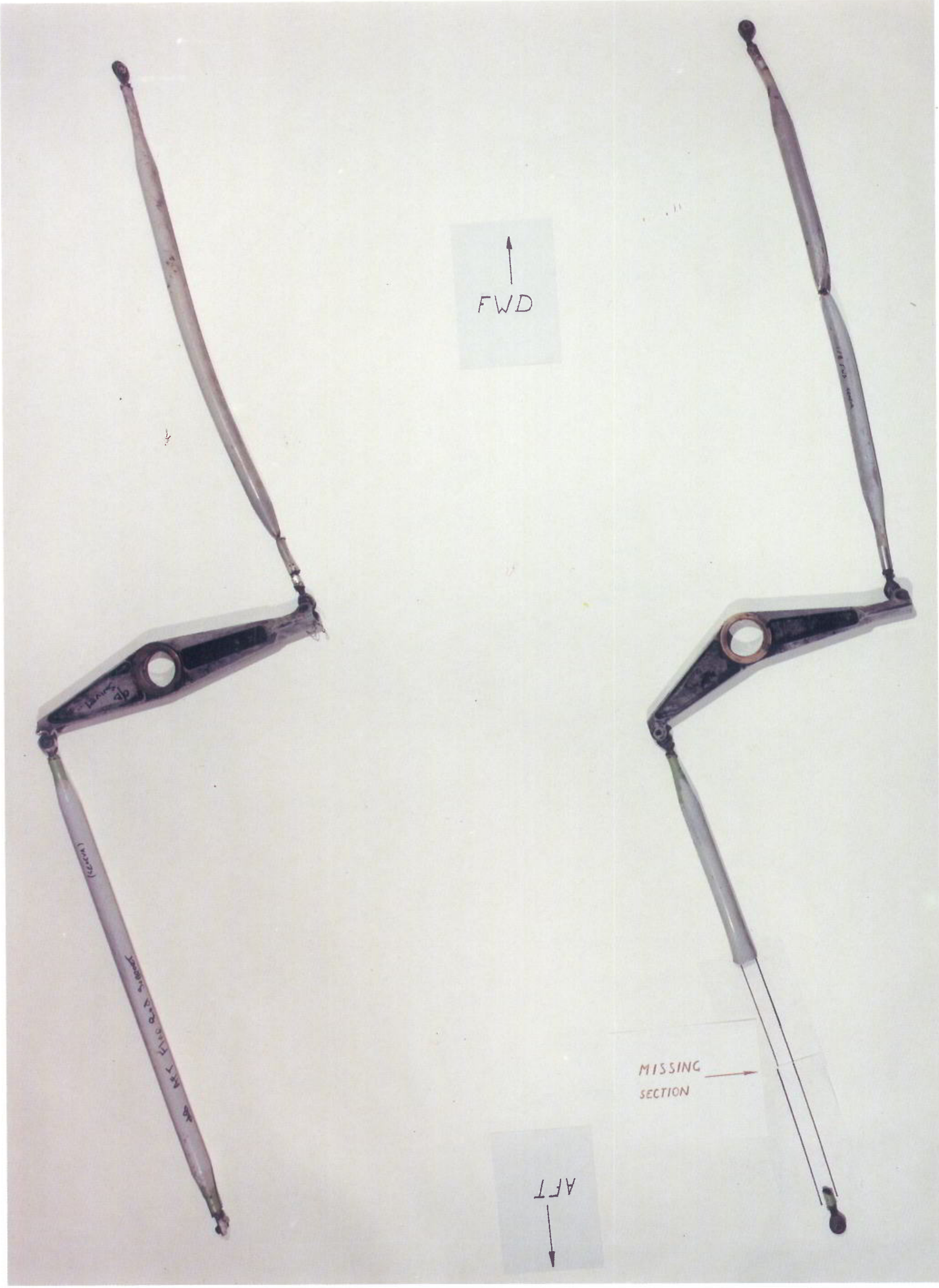
c. sudden high tensile loads then occurring in the aft drive rods as the bellcranks reached the fore and aft position, reacted wholly by the bellcrank pivots, causing failure of the lugs on the outboard bellcrank attachment to the aft outboard rod and corresponding tensile failure of the aft inboard rod.

d. compressive loading applied to the free end of the inboard aft rod during subsequent flap retraction or later during flap extension for examination. Such loading may have occurred as a result of the free end fouling part of the structure or mechanism within the canoe fairing whilst the flaps were in transit. (Note that after failure of the aft-flap drive rods, the mid flap, on which the bellcranks are mounted, continues to respond to control inputs in the usual way and the sequencing of movement of the canoe fairing remains unchanged).

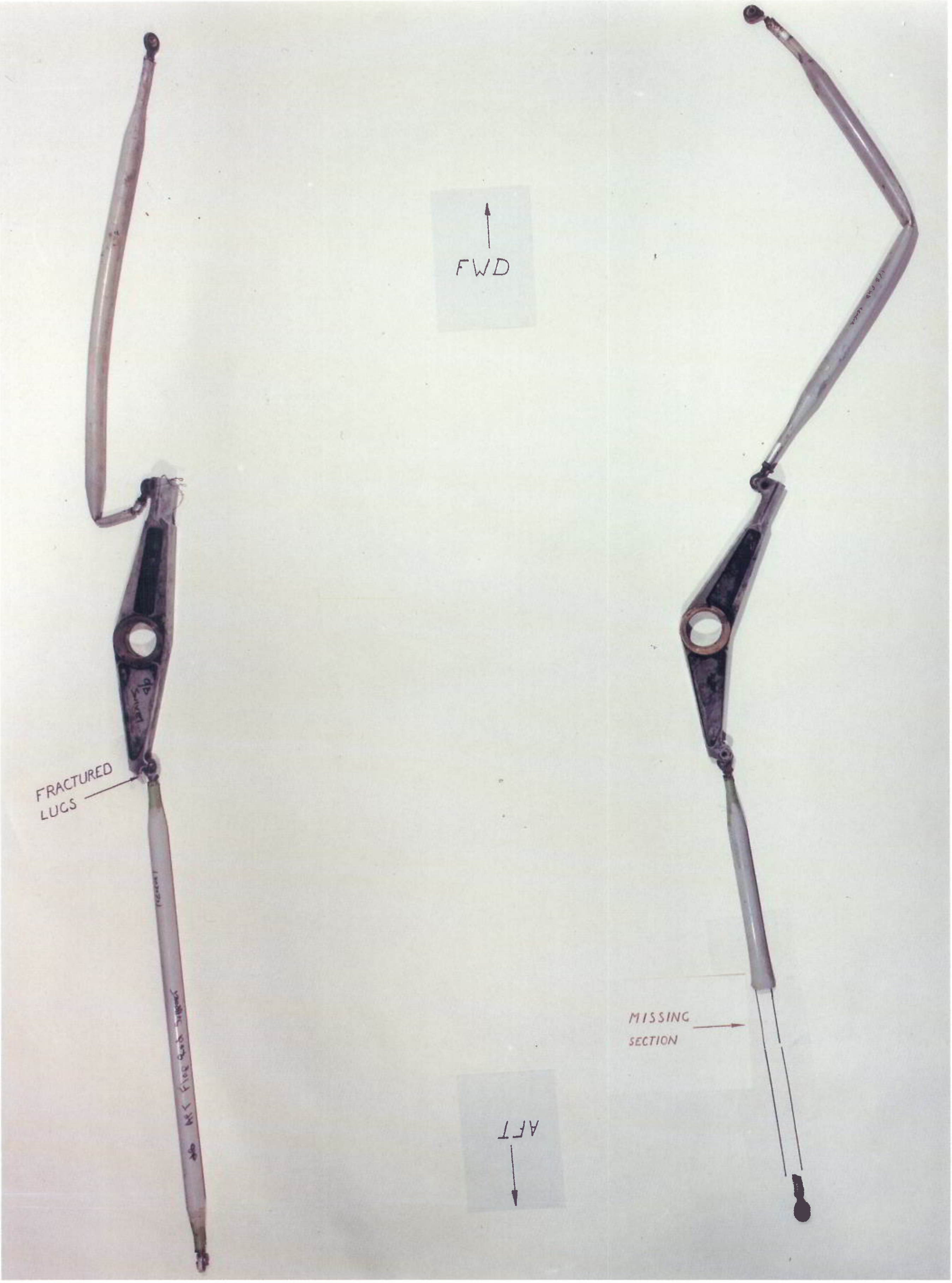
Another 747 operator is known to have experienced at least two instances of failure of aft flap drive rods associated with hard landings. The precise modes of rod failure experienced by the other operator are not known but it is understood that the distribution of rod failures differed from that experienced on G-VIRG.

The Boeing Airplane Company supply modified designs of rod for these applications. These modified rods have greater wall thickness and were incorporated as standard on production Boeing 747 aircraft some time after G-VIRG was built. Owing to the absence of any identification on the failed rods, it has not been possible to establish whether these were of the original or the modified type.

During dismantling of the forward attachments of the No 2 flap at Kennedy Airport, prior to removal of one of the canoe fairings, a lug on the forward mounting bracket assembly was found to have failed. Part of the fracture surface bore evidence of a long-standing crack. It was considered, however, that this cracking and fracture had no relevance to the incident.



VIEW A



VIEW B