INVESTIGATION REPORT
9704041

British Aerospace 146-300
VH-NJL
11 December 1997

Department of Transport and Regional Services

Bureau of Air Safety Investigation

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1.0 FACTUAL INFORMATION

1.1 History of the flight

VH-NJL, a British Aerospace 146-300 (BAe 146), was on a scheduled passenger flight from Cairns to Ayers Rock. Take-off weight was 42,200 kg and there were 68 passengers and five crew on board. The duty runway was runway 33, and the crew planned to commence the take-off roll abeam the taxiway Bravo 5 intersection, using 18˚ of flap and a reduced thrust setting appropriate to the prevailing conditions. The start and taxi were normal, and the aircraft was cleared for takeoff. The departure instruction included an assigned heading of 360˚ M.

Relevant speeds and power settings for the takeoff were as follows:

V_1	132 kts	The highest speed at which a takeoff can be rejected and the aircraft brought to a stop in the runway distance remaining.
V_2	142 kts	The take-off and initial climb speed required to provide an appropriate margin above the stall speed under the prevailing aircraft configuration and conditions.
V_{fto}	188 kts	The speed above which the flaps can be selected from 18˚ to 0˚ (retracted).
$N1_{ref}$	94%	The engine speed for rated (design) thrust under the prevailing conditions.
$N1_{flex}$	89%	The desired engine speed for a takeoff using reduced (flexible) thrust under the prevailing conditions.

The Cairns aerodrome controller observed the aircraft take off and climb, apparently normally, until it was about 1 km beyond the departure end of runway 33. He then saw the altitude of the aircraft begin to decrease, and noted that the landing gear was still extended. He became concerned about the progress of the flight activated the crash alarm and then sought confirmation from the crew that operations were normal. The crew replied that operations were normal. The controller saw the landing gear retract and the aircraft altitude begin to increase. The flight then proceeded normally.

Neither pilot reported the incident to the operating company or to BASI. However, it was later established that the flaps had been retracted from the take-off setting of 18˚ to 0˚ shortly after takeoff. The retraction occurred at the time at which the landing gear normally would have been retracted.

1.2 Personnel information

1.2.1 Pilot in command

The pilot in command was appropriately licensed and qualified to conduct the flight. His total flying experience was 13,964 hours, including 2,682 hours in command on BAe 146 aircraft. Most of his BAe 146 experience was on Series 100 and 200 models of the aircraft. He flew the Series 300 model infrequently.

The pilot in command did not hold a check and/or training position within the company. However, he considered that his duties as pilot in command included advising co-pilots of

errors and omissions in procedures and checks. The investigation revealed that while the pilot in command was enthusiastic in this role, some co-pilots viewed his manner as abrasive. This resulted in a number of co-pilots asking not to be rostered to fly with the pilot in command. However, the co-pilot involved in the incident was not among this group.

The pilot in command was given a period of additional training following the incident. During that training there were instances reported where he lacked situational awareness within the cockpit and did not adequately monitor the other pilot.

1.2.3 Co-pilot

The co-pilot was appropriately qualified and licensed for the flight, and had accrued 13,674 hours flying experience, including 535 hours as co-pilot on the BAe 146 aircraft. He had initially been recruited as a DHC-8 aircraft pilot in command and had filled this role for some years before progressing to the BAe 146. In early 1996, he had gained an approval as a DHC-8 training captain. He filled this role until being transferred to fly BAe 146 aircraft in April 1997.

1.3 Relevant aircraft information

There were no faults or defects in the aircraft that were likely to have contributed to the incident.

The BAe 146-300 Series aircraft involved in the incident differed from earlier model 100 and 200 Series aircraft in two respects, which had relevance to the incident:

1. The normal N1 RPM setting for rated engine thrust on the 100 and 200 Series aircraft was 91—92 %. This compared with about 94% on the incident aircraft.
2. The flap system on the 300 Series aircraft included an elevator trim system that automatically compensated for trim changes during flap extension or retraction between the 0˚ and 18˚ positions. The 100 and 200 Series aircraft were not equipped with that system. The result was that the pitch trim change due to flap movement was masked on the 300 Series aircraft compared to that evident in the earlier models.

1.3.1 Flaps

The aircraft was equipped with single-piece, tabbed, Fowler type flaps on each wing. The flaps could be selected to any of five gated positions — 0˚, 18˚, 24˚, 30˚, and 33˚. A selector positioned on the centre pedestal, immediately right of the thrust levers, controlled flap movement. This meant that operation of the selector was more readily accessed by the right cockpit seat occupant than the left cockpit seat occupant.

The flap selector was spring-loaded into each position and could be moved only after it had been lifted out of the gate for that position. If movement of the selector from one gated position to another took longer than 5 seconds, flap movement stopped and the FLAP FAULT caution illuminated. If the selector position was reversed after flap movement had begun and before flap travel was complete, the direction of movement was immediately changed to the newly selected position. The rate of movement of the flaps was 1˚ per second.

1.3.2 Thrust modulation system (TMS)

The aircraft was equipped with a thrust modulation system (TMS) which controlled engine thrust by adjusting, within a limited range, the engine power settings selected by the flight crew. It consisted of a control display unit (CDU) on the instrument panel and a computer controlled actuator on each engine. The TMS operated in a number of modes selected via the CDU. There were four modes of operation of the TMS, including the take-off (TO), and go-around (GA) modes.

As the engines accelerated on advancement of the thrust levers in TO mode, blue arrows (also known as 'chevrons') illuminated within each engine identifier frame on the CDU. The computer controlled actuators trimmed fully up initially so that, as each engine reached N1, the actuators trimmed against the advancing thrust levers to control engine speed to the target N1. As each engine reached target N1, its associated blue chevron disappeared. If a thrust lever was advanced to a position beyond the limit of the actuator, a white chevron within the engine identifier illuminated, advising the flight crew to retard the relevant thrust lever.

With the thrust levers positioned correctly, the TMS set the engine N1 RPM to achieve the required take-off performance. At 75 kts, the position of the actuators was frozen and the CDU indicator lights extinguished. Above 75 kts, the thrust levers directly controlled engine N1.

1.3.3 Stall warning and stall identification system

The aircraft was equipped with a stall warning and identification system that provided warning of an impending stall through the operation of stick shakers connected to each control column. If the system identified a stall condition, a 'stick push' force was applied to each control column to produce a 'nose down' change in aircraft attitude.

The stall warning and identification systems each had dual control channels. Below 180 kts, input was also received concerning flap position, aircraft speed, and rate of change of angle of attack. Either channel operated the stick shaker, but activation of the stick pusher required both channels to confirm stall identification. In this context, the simultaneous illumination of two red annunciators (STALL VALVE A OPEN and STALL VALVE B OPEN) on each pilot's instrument panel indicated operation of the stick pusher.

1.3.4 Ground proximity warning system

The aircraft was equipped with a ground proximity warning system (GPWS) which operated in a number of modes, depending on the aircraft's flightpath and configuration, as well as its distance from, and rate of closure with, terrain. Mode 3 of the system alerted pilots to an altitude loss if the aircraft was below 700 ft above ground level (AGL) after takeoff. The warnings presented were an audible 'Don't Sink, Don't Sink' and a flashing red 'Pull Up' light on the instrument panel. The flaps had to be in the 24˚, 18˚, or 0˚ position for the warning to operate. Up to 700 ft AGL, the system computed the barometric altitude rate of change to determine the height loss. The lower the altitude of the aircraft above ground level, the less altitude loss was allowed before the warning activated.

1.3.5 Co-pilot's aircraft systems knowledge

During the investigation, it became apparent that the co-pilot did not fully understand the operation of the TMS or the flap system. He thought that, with the TMS in TO mode and aircraft speed greater than 75 kts, only about 1% change in N1was was possible, regardless of thrust lever movement. With regard to the flap system, he thought that if a flap selection

was made but reversed before flap movement was complete, then the flaps would travel fully to the first selected position before moving to the newly selected position.

1.4 Flight recorders

The aircraft was fitted with a digital flight data recorder (DFDR) and a cockpit voice recorder (CVR). The duration of the flight meant that the recording of cockpit activity during the takeoff was overwritten before the aircraft reached its destination.

A graphical presentation of the DFDR data is at Attachment A. The table at Attachment B summarises the principal events in the sequence.

The recorded data indicated that the stick shaker and the stick pusher activated at the same time. The aircraft angle of attack (AoA) was recorded at intervals of 0.5 seconds. The recorded angle of attack values (in degrees) from 1 second before to 1 second after the stick shaker/stick pusher event were:

Angle of attack (AoA)	
13.4	
14.8	
16.9	} *Recorded stick shaker and stick pusher activation*
16.2	
14.7	
10.7	

According to the aircraft flight manual, the stick shaker should activate at 16˚ AoA, and the stick pusher at 22.5˚ AoA.

At the take-off weight of the aircraft, the stalling speed with flaps up was 148 kts.

1.5 Aircraft operating procedures

Chapter 2 of the company operating handbook for the aircraft detailed the standard take-off calls by the operating crew as follows:

Pilot Flying	*Pilot Not Flying*
'Power set'	'Checked'
	'80 Knots power normal'
	'V1'
	'Rotate'
'Gear Up' (positive rate of climb)	'Selected'
	'Gear up'
At 600 ft AGL or nominated SDP acceleration altitude, and V_{FTO}	
'Flap up'	'Selected'
	'Flap up'
'Set climb power'	'Climb power set'

In the event of stall warning and/or stall identification operating, the initial actions to be taken by the pilot flying were:

Aircraft pitch attitude	Ease nose down to reduce angle of attack
Aircraft configuration	Check
Airspeed	Ensure adequate for conditions
Thrust	Increase, if appropriate

Other information concerning take-off procedures was included in various company documents. The following extracts, considered to be relevant to the incident, have been taken from a variety of these documents.

> Up to 75 kts, adjust thrust levers as required to achieve target N1. Monitor engine performance. Up to 80 knots, abandon the take-off if N1 falls more than 1 percent below the target N1, or engine limitations are exceeded. If such a condition occurs between 80 knots and V_1, the take-off may be continued unless actual engine failure is suspected.
>
> When the Captain is PF he/she will set take-off power and call 'Check Power'. The First Officer (PNF) will make any necessary fine adjustments to thrust and call 'Power Set'.
>
> The PNF shall throughout the take-off and initial climb continuously monitor engine instruments and make any adjustments to thrust. (See Note 1)
>
> The support pilot should keep calls to the minimum consistent with actual requirements, but must immediately query a missed verbal or aircraft handling response. Depending on the phase of flight and the urgency of corrective action required, the failure of the PF to respond to a second challenge may provide justification for the support pilot to assume incapacitation, and immediately take control of the aircraft to ensure safe flight.
>
> When the aircraft is rotated at the rotate speed on takeoff, the desired climb attitude is to be achieved in four seconds, to obtain an airspeed of V2 + 10 kts. When a positive rate of climb is achieved the landing gear is selected up. For scheduled performance, the landing gear is retracted three seconds after lift-off.
>
> If flexible thrust is being used for takeoff and an engine fails, it is recommended that the thrust levers be advanced as soon as practicable, to achieve the reference N1, as displayed on the N1 bugs.
>
> In the event of an abnormal or emergency situation after V_1, no call of the abnormal or emergency situation shall be made until after the PF calls for 'Gear Up'.

Normal practice in a two-pilot aircraft would be for the pilot not flying to follow movement of the thrust levers with his/her hand at the base of the levers. Engine power adjustment could then be made by pushing or retarding the relevant thrust lever, while the flying pilot maintained a hand grip on the thrust lever knobs.

1.6 Initial information from the crew

As a result of a BASI request to the crew for a report detailing the circumstances of the occurrence, each flight-crew member submitted a report within a few days. At that time, the recorded flight data concerning the takeoff was not available. A synopsis of the event as recalled by each pilot at that time follows.

1.6.1 Pilot in command

The pilot in command had been the flying pilot for the sector. He said that he had advanced the thrust levers at the commencement of the take-off roll and made the normal call for the co-pilot to check the engine power. A few seconds later, he had noticed that the TMS indicator was displaying a signal to reduce thrust on the number 3 engine. He had moved the number 3 engine thrust lever rearwards slightly, and the light went out. He recalled that the co-pilot had then asked if he had reduced the engine thrust. The pilot in command replied that he had. The pilot in command had then maintained a loose grip on the power levers until V_1 when he moved his right hand from the thrust levers and grasped the control column.

The pilot in command said that he remembered calling 'gear up' after the aircraft became airborne. The co-pilot had then said something to the effect of 'do you want it up?'. The pilot in command thought that the co-pilot had been referring to the number 3 engine N1 indication, which was slightly low, so he answered 'yes'. The co-pilot had his left hand on the thrust levers at that time. The pilot in command had felt the aircraft sinking. As he continued to control the aircraft by reference to the instruments, the pilot in command noticed that the flap indicator was showing that the flaps were up.

By that time, the cockpit instruments indicated that the aircraft speed had been increasing and that a positive rate of climb existed. The pilot in command had heard an airframe noise that prompted him to look at the landing gear lever and gear indicating lights. These were indicating that the landing gear was still down. At about this time, there was a radio call from air traffic control asking if operations were normal. The pilot in command reported that, by that stage, he had realised that the flaps had been retracted prematurely and that he had consequently understood the unusual behaviour of the aircraft. As the situation had stabilised, he instructed the co-pilot to advise ATC that operations were normal. He did not think to call for either maximum thrust or for flap 18.

1.6.2 Co-pilot

The co-pilot said that at the commencement of the take off roll, all engine parameters were normal. He had responded with 'power set' to the pilot in command's challenge to check power. A few seconds later, at 110 kts, the co-pilot had noticed that the thrust indications were 88% for engines 1, 2 and 4 and 86%, for number 3 engine. The co-pilot had called 'power' and then transferred his attention to the airspeed indicator and continued with the normal take-off calls.

When the aircraft was airborne, the co-pilot had again checked the engine instruments and noted that the thrust settings had not changed. He asked the pilot in command if he could adjust the thrust levers and then moved the levers forward to obtain the take-off thrust indication.

When the aircraft had climbed to about 500 ft, the co-pilot asked the pilot in command if he wanted the landing gear selected up and simultaneously moved the selector to the up position. The pilot in command then said that the flaps were UP. The co-pilot thought that the stick shaker had activated at that stage, but he was occupied making the departure radio call. He remembered that the tower controller had asked if operations were normal. By that time, however, the aircraft was established in a climb. The remainder of the flight was uneventful.

The co-pilot said that, apart from the preceding recollections, he could not recall any verbal comments between taking off and retracting the landing gear. He had not been aware of any shortfall in the aircraft's climb performance and there was no indication from the pilot in command of any aircraft abnormality. The co-pilot had no recollection of when, how, or why the flaps had been selected up.

1.6.3 Additional information from the pilot in command

The pilot in command indicated that when the co-pilot was unable to obtain the AVFAX weather forecast data at the crew's hotel, he had arranged for it to be at the company's briefing office at the airport. His normal practice had been to complete the flight plan at the airport rather than the hotel.

The pilot in command indicated that the aircraft had been carrying full fuel for the flight, and his recollection was that the appropriate fuel checks had been completed. He said that he heard the cabin crew completing their preparations for takeoff and had asked the co-pilot to request line-up clearance in anticipation of the signal that cabin checks had been completed. In the event, the signal had sounded as the aircraft entered the runway.

The pilot in command said that, in accordance with his usual practice, he maintained a loose grip on the thrust levers until V_1 so that the co-pilot could make any fine adjustments to the thrust settings. He had then transferred his right hand to the control column. He was confident that he had called 'gear up', although he could not positively recall this action; nor could he recall hearing a response from the co-pilot.

The pilot in command said that, after the aircraft was airborne, the co-pilot had put his hand on the thrust levers and called words to the effect of 'do you want it up'. The pilot in command had been focusing on maintaining the correct heading at a speed of between V_2 + 10 kts and V_2 + 20 kts. He said that the initial period after takeoff had been normal, but that he had to apply back-pressure on the control column for a few seconds to maintain V_2 + 20 kts. He had felt and heard the stick shaker activate. He had checked that the airspeed was correct for an 18° flap configuration, and could not understand why the stick shaker had operated. However, in response to the stick shaker, he had applied forward pressure on the control column to lower the nose attitude of the aircraft and checked the engine N1 indications. At that time, he noticed that the flap indicator showed that the flaps were fully retracted.

In response to the lower nose attitude, the aircraft speed had begun to increase. The pilot in command then felt airframe buffeting and heard a noise. As he again checked the engine instruments, he saw that the three red landing gear 'in transit' lights were illuminated.

1.6.4 Additional information from the co-pilot

In January and March 1998, after both crew members had access to the recorded flight data, the co-pilot provided the following additional information concerning his recollection of the incident.

The co-pilot said that he had been conscious of his responsibility to adjust the thrust lever position to achieve the target engine settings by 75 kts. He had called 'power' when he saw the thrust indications for the engines fall to 88%. However, there had been no noticeable response to that call. The pilot in command had appeared tense and had a firm grip on the thrust levers. At a speed of about 110 kts, the N1 indications for engines 1, 2, and 4 had stabilised at 88%, and engine No 3 at 86%. The pilot in command still had a firm grip on the thrust levers. Because of his understanding of the operation of the TMS above 75 kts,

the co-pilot had thought that movement of the thrust levers without selecting the GA mode would have no significant effect on engine performance. He had considered moving the thrust levers by placing his hand on the pilot in command's hand, or selecting GA mode. However, he believed that either action would have caused a distraction at a critical stage of the flight.

At V_2 + 20 kts (162 kts), the pilot in command's right hand had still been on the thrust levers. The engine power settings had not changed, and there had been no 'gear up' call by the pilot in command, who still appeared tense. When the aircraft was climbing through 150—200 ft, the co-pilot had placed his left hand against the rear of the thrust levers and loudly asked if the pilot in command wanted the power increased. The pilot in command had not responded to that call verbally, but had lifted his right hand above the thrust levers and placed it on the control column. The co-pilot had then placed his hand on the thrust levers and moved them forward to adjust the thrust settings. By that time, because the pilot in command had been slow to respond to his calls, the co-pilot had formed the view that the pilot in command may have become incapacitated. He said that he had made the call concerning the power increase with the express intention of gaining a response from the pilot in command. He had also been waiting for a call to retract the landing gear. However, the pilot in command had continued staring straight ahead. The co-pilot said that he had then asked the pilot in command if he wanted the landing gear retracted but, at the same time, had selected the landing gear up without waiting for a response. The stick shaker had sounded as the landing gear retracted. The co-pilot had reached for the power levers but pulled back when he saw the pilot in command also reaching for the levers. The pilot in command had then remarked that the flaps were up. It was about that time that the tower controller asked if operations were normal.

The co-pilot indicated that some of the pre-flight preparations and checks had not been conducted in the normal manner. They involved having to conduct the flight planning at the airport rather than at the hotel, the method of obtaining the weather forecast for flight planning, the fuel quantity check, and requesting line-up clearance before all appropriate checklist items had been completed. The co-pilot said that he had been surprised by these inconsistencies and considered that they had established the background against which he judged the pilot's actions during the takeoff.

1.7 Medical information

During the investigation, the Civil Aviation Safety Authority's Office of Aviation Medicine advised that both pilots had valid medical certificates at the time of the incident and that there was no history to suggest that the pilot in command could have been subjected to any form of incapacitation. Further, after reviewing the circumstances of the incident, and the reported behaviour and actions of the pilot in command, the Office of Aviation Medicine advised that there was insufficient evidence to suggest that he had been incapacitated.

1.8 Crew training

The operator included crew resource management (CRM) training both in aircraft type conversion training and recurrent training programs. The type conversion syllabus included a 1-day CRM theory course. The practical application of CRM was covered during simulator exercises that included line-oriented flight training (LOFT).

The pilot in command indicated that he had not received any CRM training during his time with the operator. The co-pilot had undergone CRM training and considered that the training had been beneficial to him.

2.0 ANALYSIS

The information concerning the incident provided by the pilot in command and the co-pilot conflicted in a number of areas. There were also aspects central to a complete understanding of the incident that neither pilot could recall. Against this background and in the absence of recorded cockpit voice information, analysis of the incident was limited predominantly to the recorded flight data.

The flight data information allowed a number of conclusions to be drawn concerning the incident:

1. At the commencement of the take-off roll, the N1 values had peaked between 91% and 93%. They had then reduced to between 89% and 90%, probably as a result of TMS operation (N1 flex was 89%). This information supported the recollections of both pilots concerning the power check.

2. As the aircraft accelerated through 70 kts, the number 3 engine's N1 had increased slightly to 90.1%. This may have activated the CDU white chevron for that engine. At 72 kts aircraft speed, the number 3 engine's speed had reduced rapidly to about 86%. This was probably the result of the pilot in command retarding the power lever in response to the white chevron. Over the same period, as the aircraft reached 75 kts, the TMS would have ceased controlling N1 speeds in the TO mode and extinguished the chevron. Thus, the white chevron may have extinguished either because of movement of the thrust lever by the pilot in command or because of the operation of TMS.

3. At 80 kts, the numbers 1, 2 and 4 engine speeds were 88%—89%, while the No. 3 engine speed was about 86%. From 80 kts to V_1, the speeds for engines 1 and 2 engines reduced slightly, while the speeds engines 3 and 4 were substantially constant. Minor thrust lever movement by the pilot in command had probably caused these changes.

4. Although reduction of the number 3 engine's N1 resulted in it being more than 1% below the target N1, the aircraft speed had been almost 80 kts when the adjustment was made. On this basis, along with the fact that there was no indication of engine failure, the crew acted appropriately in continuing the takeoff.

5. It was the responsibility of the co-pilot to adjust the low number 3 engine's N1. However, there was no indication from the recorded data that the number 3 engine's N1 was adjusted until the aircraft had climbed above 300 ft after takeoff (see also (7) below). One explanation for this, as claimed by the co-pilot, is that the pilot in command did not remove his hand from the thrust levers at V_1 and that this prevented the co-pilot from moving the thrust lever. Another explanation is that the co-pilot did not attempt to make a power adjustment because of his incorrect understanding of the functioning of the TMS. In the absence of any further evidence in this regard, no conclusion can be drawn concerning the late adjustment of the number 3 engine's N1.

6. After V_1, all engine speeds had increased slowly as the aircraft accelerated. This was normal engine behaviour and indicated that no further power lever adjustment was made until after the flaps had been selected up (see (8) below). This supports, at least in part, the pilot in command's recollection that he withdrew his hand from the levers at V_1.

7. Just before the aircraft reached 100 ft AGL after takeoff, the flaps had begun to retract. This was the position after takeoff when the call to retract the landing gear would have

normally been made. Again, because of the conflicting recollections of the pilots, no positive conclusion could be drawn concerning a 'gear up' call and the actions of either pilot. On balance, however, given that the pilot in command was the pilot flying the aircraft, and that neither gear retraction nor flap retraction is performed by the flying pilot during normal operations, the likelihood rests that the co-pilot inadvertently selected the flaps up instead of the landing gear. His reported concern regarding the number 3 engine's N1 and the behaviour of the pilot in command may have contributed to such an error by disrupting his normal activity pattern.

8. When the aircraft was above 300 ft AGL and 17 seconds after the flaps had been selected up, the number 3 engine speed increased to just below 89%. This supports the co-pilot's recollection that he had adjusted the engine speed after the aircraft was airborne.

9. A few seconds after the stick shaker and stick pusher had activated, the engine speeds increased from about 89% to between 91% and 92%. From the recollections of both pilots, this adjustment appears to have been made by the pilot in command in response to the stall warning. A correct response under the circumstances would have been to increase the engine speed to at least 94.4% (the rated thrust for the 300 Series aircraft). It indicated that the pilot in command had set the rated thrust for the aircraft model he was more familiar with.

10. The data indicated that the stick shake and stick push actions took place simultaneously and that they were recorded for 1 second only, immediately after the flaps had fully retracted. At the same time, the aircraft angle of attack peaked at 16˚. This value exceeded the parameter for stick shaker activation. The report from the pilot in command that both stall valve lights illuminated indicated that the stick pusher activation had occurred, even though the angle of attack did not reach 22.5˚. The high rate of increase in angle of attack was probably sufficient to activate the system. However, the almost immediate reversal in the trend and value of the angle of attack would have de-activated the stick pusher. The high angle of attack and the rapid reversal were probably due to atmospheric factors, as distinct from any pilot action, which would have been later. The reported brief illumination of the stall valve lights, and the pilot in command's recollection that he did not feel the stick pusher operate (this was possible, given the short period of activation), support such a conclusion.

11. After the stick shaker activation had ceased, the aircraft altitude decreased by 80 ft. This triggered the ground proximity warning system (GPWS) 'Don't Sink' warning reported by the crew and indicated that the GPWS system had been functioning normally.

12. The co-pilot had selected the landing gear up 2 seconds after the ground proximity warning ceased.

13. The recorded data showed that the pilot in command had commenced rotation to takeoff at the correct airspeed and at a reasonable rate for the aircraft to become airborne. From that stage until flap retraction was complete, there were no unusual divergences in the recorded heading, speed, or aircraft attitude. There was evidence that the pilot in command had responded promptly, although not entirely correctly, to the stick shaker activation. There was, therefore, no factual information to support the co-pilot's interpretation that the pilot in command had been incapacitated.

The effect of the early flap retraction had been to reduce the margin of safety of the aircraft during a critical stage of the flight. While the recorded airspeed of the aircraft when the

flaps became fully retracted was 15 kts greater than the stalling speed in the 'flaps-up' configuration, the operation of the stick shaker, and the brief stick push activation, indicated that the aircraft had been rapidly approaching a stalled condition.

In addition to the events that the recorded data highlighted, the recollections of both pilots revealed other deficiencies concerning the operation of the crew, both individually and as a unit. These included:

1. Although their recollections differed, rectification of the low number 3 engine's N1 was not achieved until 17 seconds after the flaps were selected up.
2. Neither pilot was aware that the flaps had been selected up and that the landing gear had remained extended. This implied a breakdown in the standard procedures regarding landing gear retraction. Assuming that he made a 'gear up' call, it also implies that the pilot in command did not check that the co-pilot had carried out the appropriate action.
3. The pilot in command did not adequately communicate his concern to the co-pilot when he was unable to understand the reason for the stick shaker activation.
4. The co-pilot selected the landing gear up after the GPWS warning without previously communicating his intention to do so with the pilot in command.
5. The co-pilot did not initiate any action, either during or after the flight, concerning his view that the pilot in command may have been incapacitated.

The deficiencies in the co-pilot's knowledge of the aircraft flaps and thrust management systems reflected on the company's check-and-training system. Such deficiencies implied inadequacies in the manner in which knowledge was imparted and/or tested.

3.0 SIGNIFICANT FACTORS

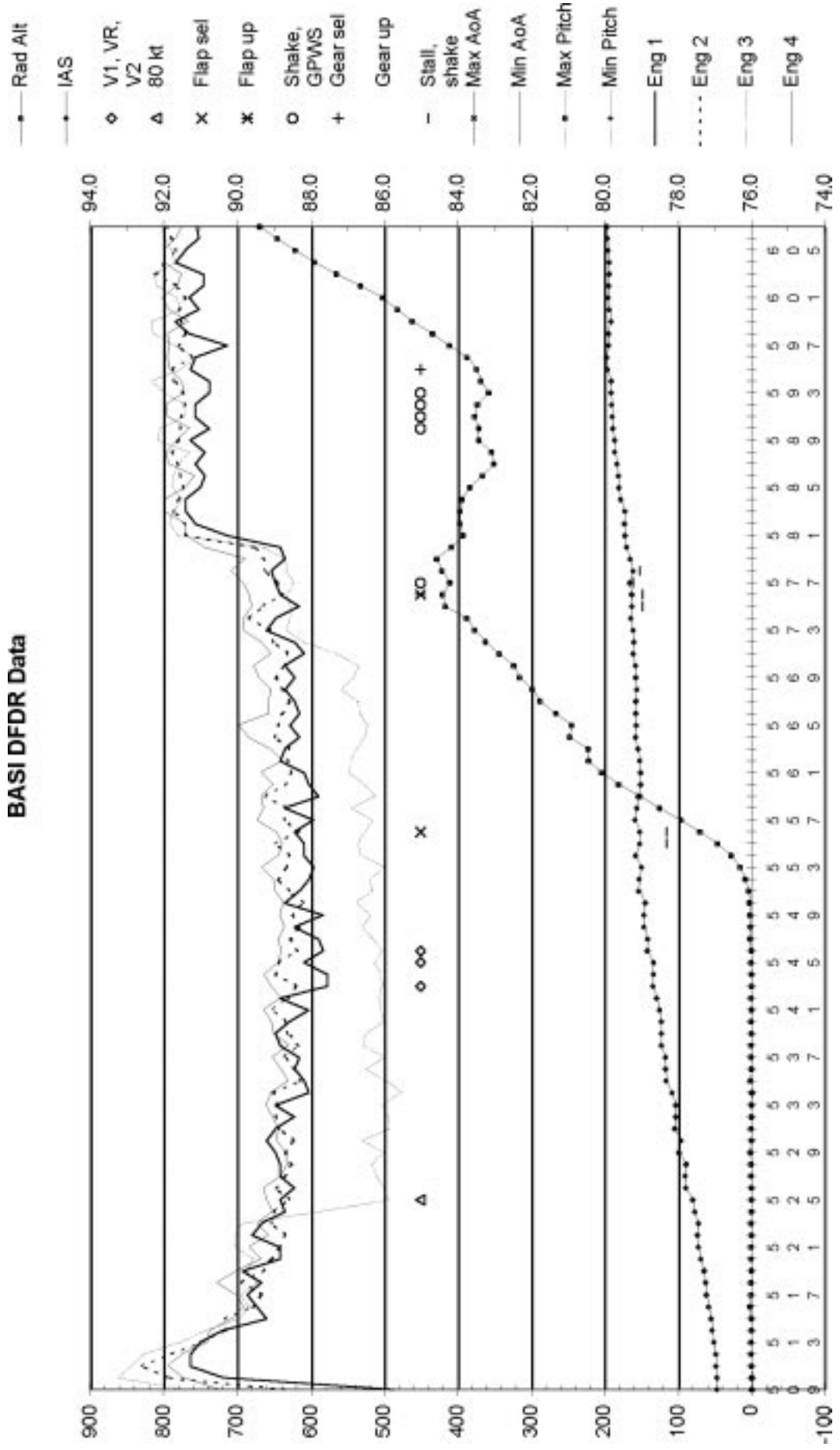
1. The co-pilot did not understand the operation of the thrust modulation system in takeoff mode.
2. The co-pilot was probably distracted by the number 3 engine's low N1.
3. Neither pilot detected that the flaps had been selected up.
4. The monitoring of cockpit activities by the pilot in command was inadequate.

4.0 SAFETY ACTION

Following the occurrence, the operator introduced the following changes to company procedures:

1. Conducted a review of the check and training system, including syllabuses and assessment procedures, to ensure pilots receive adequate training in aircraft systems and operation, and situational awareness fundamental to safety.
2. Amended the standard take-off procedure to include the following additional calls:
   a. In response to ‘gear up’, the pilot not flying is to call ‘selected, three reds’.
   b. In response to ‘flap zero’, the pilot not flying is to call ‘zero selected’.

APPENDIX 1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IAS
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Flap sel
Flap up
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Gear sel
Gear up
Stall, shake
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Min AoA
Max Pitch
Min Pitch
Eng 1
Eng 2
Eng 3
Eng 4
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92.0
90.0
88.0
86.0
84.0
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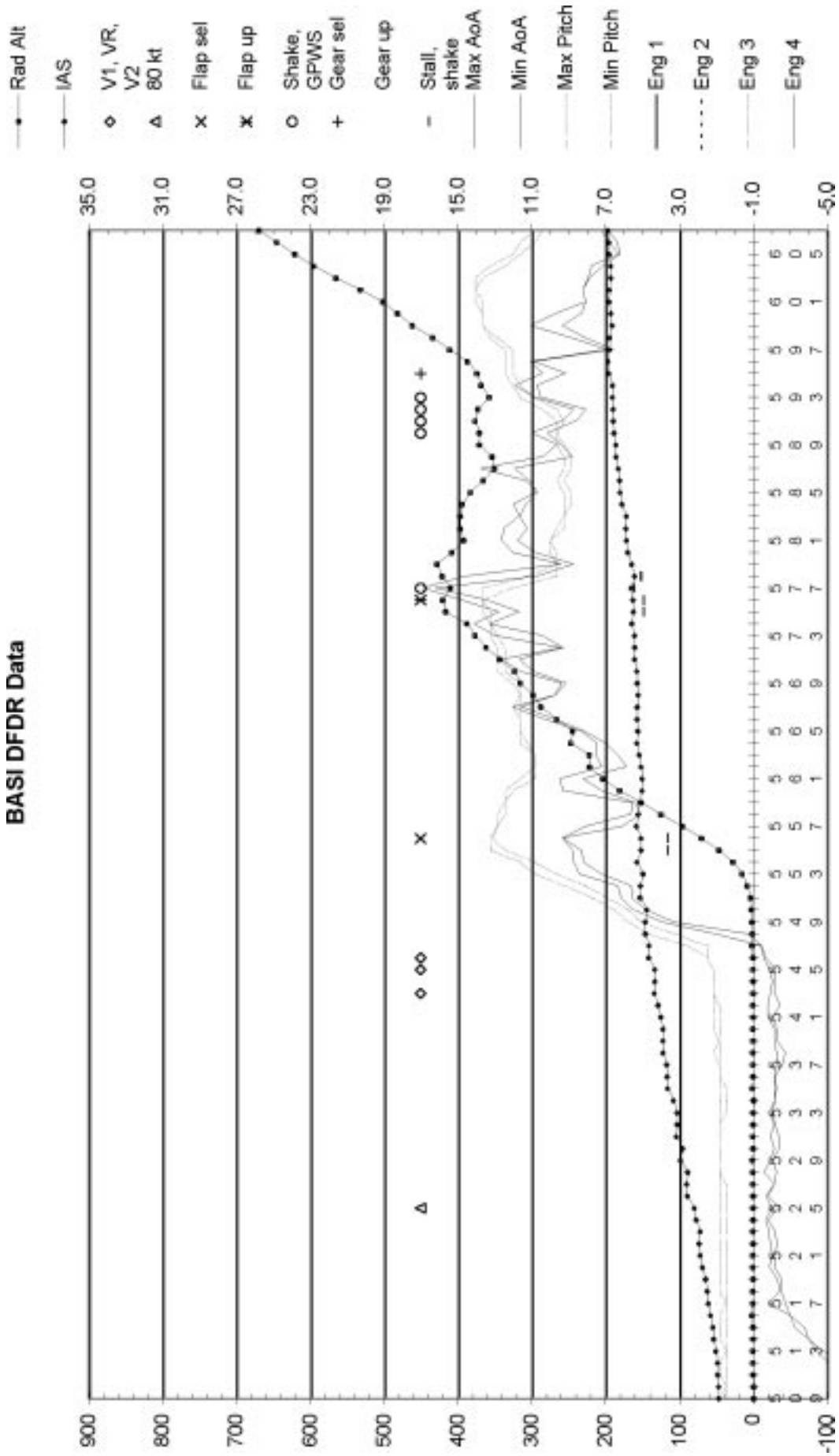
100
0
-100

(Seconds)		*(feet)*	*(kts)*	*(degrees)*	*(degrees)*	*(degrees)*	*N1(percent)*	*N1(percent)*	*N1(percent)*	*N1(percent)*
0	Start of data	1		-7.1	0.5	18.4	25.0	26.4	25.9	27.8
10	Takeoff roll	0	47	-7.0	0.5	18.4	90.4	91.9	93.2	91.5
20		0	69	-1.8	0.8	18.4	88.8	89.1	89.6	89.3
22		0	73	-1.9	0.8	18.4	89.6	88.7	90.1	89.2
25	80 kts	0	80	-2.0	0.8	18.4	88.8	88.6	85.9	89.2
43	V1 speed	0	134	-1.9	1.2	18.4	87.5	88.4	86.0	89.1
46	V2 speed	0	142	-1.6	1.5	18.4	87.7	88.4	86.0	88.8
49	Airborne	2	146	3.9	5.8	18.4	87.7	88.5	86.4	88.8
56	Flaps selected up	70	152	9.3	13.3	17.5	88.4	88.3	86.5	88.9
71	Power increase	343	161	12.6	12.9	9.8	88.2	88.6	87.3	89.1
76	Flaps fully retracted	421	163	14.8	13.7	0.7	88.8	88.8	88.7	89.7
77	Stick shaker	410	165	16.9	13.7	0.7	88.9	88.9	88.5	89.8
87	Minimum altitude	351	183	13.8	9.2	0.7	91.1	91.6	91.6	91.9
90-93	GPWS Mode 3	373	190	8.8	10.4	0.7	91.1	91.4	91.4	91.9
95	Landing gear sel UP	374	196	10.4	12.4	0.7	91.3	91.8	91.5	91.8
105	Landing gear up	621	195	6.3	12.0	0.7	91.4	91.7	91.8	92.0


BASI DFDR Data
Rad Alt
IAS
V1, VR, V2
80 kt
Flap sel
Flap up
Shake, GPWS
Gear sel
Gear up
Stall, shake
Max AoA
Min AoA
Max Pitch
Min Pitch
Eng 1
Eng 2
Eng 3
Eng 4
35.0
31.0
27.0
23.0
19.0
15.0
11.0
7.0
3.0
-1.0
-5.0
900
800
700
600
500
400
300
200
100
0
-100