AAIU Report No.2001-010
AAIU File No.2000-0062
Published 30 August 2001

Operator:	Futura
Aircraft Type and Registration:	B737-800, EC-HMK
No. and Type of Engines:	Two, CFM 56-7B27
Aircraft Serial Number:	28624
Year of Manufacture:	2000
Date and Time (UTC):	30 November 2000, 1236 hrs
Location:	Shannon Airport, Co. Clare, Ireland
Type of Flight:	Public Transport
Persons on Board:	Crew - 6 Passengers -189 + 13 infants
Injuries:	Crew- One, minor Passengers – Eight, minor
Nature of Damage:	Extensive. Nose landing gear collapsed, deformation of fuselage skin, both engines damaged by FOD. Other collateral damage.
Commanders Licence:	Airline Transport Pilot Licence (Spain)
Commanders Age:	46 years
Commanders Flying Experience:	7680 hours Last 90 days: 206 hours Last 28 days: 52 hours
Information Source:	ATC Watch Manager, Shannon Airport. AAIU Field Investigation

NOTIFICATION

Formal notification of the accident was transmitted to the Spanish Comision de Investigacion de Accidentes, the Irish Aviation Authority (IAA), the USA National Transportation Safety Board (NTSB), Boeing Commercial Airplane Group, ICAO and the aircraft Operator by the Irish Air Accident Investigation Unit (AAIU) on 30th November 2000. Under the provisions of ICAO, Annex 13, (Aircraft Accident and Incident Investigation), State of Occurrence, the Chief Inspector of Accidents, Mr. Kevin Humphreys appointed Mr. Frank Russell, Investigator in Charge, and Mr. John Hughes, Inspectors of Accidents, to carry out an investigation into the circumstances of this accident and to prepare a Report for publication.

Mr. Juan A. Plaza, Chief Investigator, Comision de Investigacion de Accidentes was the Spanish accredited representative in this investigation, assisted by Mr. Jaime Bestard and Captain José Gayo.

SYNOPSIS

The accident, which occurred in daylight hours, followed an uneventful flight of returning holiday-makers, from Lanzarote, Spain, to Shannon Airport, Ireland, with the landing carried out on Runway (Rwy) 24. Weather conditions in the approach and landing area showed rain, strong winds and associated turbulence. On landing, the aircraft's nose wheel assembly collapsed rearwards. The aircraft continued along most of the length of Rwy 24 on its nose, finally coming to a halt beyond taxiway Alpha. Alerted by ATC the Airport Police Fire Services (APFS) were quickly on the scene and monitored and assisted in the evacuation. There was no fire and the passengers and crew evacuated the aircraft using the front and rear right hand exit/entry doors escape slides. Eight passengers were removed to hospital in Limerick City for observation and treatment. None were detained overnight as a result of the accident.

1. FACTUAL INFORMATION

1.1 History of the Flight

The Spanish registered aircraft, flight number FUA 1331, was on a scheduled flight returning holiday-makers from the island of Lanzarote to Shannon Airport. From an operational point of view it was a routine flight. The crew consisted of two pilots, a Captain and First Officer, and four cabin attendants. The First Officer was the handling pilot (PF) that day on the first sector to Shannon. The practice of pilots flying alternate sectors is in accordance with the Operator's policy and is a common practice within the aviation industry. Dublin Airport was the selected alternate aerodrome.

At 1220 hours, Shannon ATC approach radar made contact with FUA 1331 on handover and identified it as being 23 miles South Southeast of Shannon. FUA 1331 was advised by ATC that it was No. 3 (in the landing pattern) with radar vectoring for an ILS approach to Rwy 24. All three aircraft were on the same radio frequency and regular update on the prevailing weather conditions at Shannon was being passed by ATC. Aircraft No. 1 on approach was a Bae 146 and aircraft No. 2 was a B737-400. As aircraft No. 1 made its final approach ATC advised the runway surface winds, which, over six calls, averaged 150°/26 gusting 37 kt. At 1225 hours the No. 1 aircraft carried out a missed approach and diverted to Dublin. As aircraft No. 2 made its final approach ATC advised the runway surface winds, which, over six calls, averaged 150°/27 gusting 39 kt. At 1230 hours the No. 2 aircraft also carried out a missed approach and diverted to Dublin.

FUA 1331 now became No. 1 for landing. In a post-accident interview with the AAIU the Captain, First Officer and cabin crew gave their recollection of events, on the approach, landing and subsequent evacuation of the passengers, as follows:-

The Captain recalled being given radar vectors to Rwy 24, being aware of the runway cross-wind and that it was gusty and turbulent on the approach. The First Officer, who was flying the aircraft, established the aircraft on the glide path and localiser, he was satisfied with the airspeed and flap configuration (30). The Captain felt that the cross-winds were within their limitations, but discussed the missed approach procedure with the First Officer, just in case the occasion arose to use it. However, as the approach was stabilized, this did not arise, he said. As the aircraft made its final approach, ATC advised the runway surface winds, which, over five calls, averaged 150°/29 gusting 42 kt. When they were on the final stage of the approach, maybe 20 ft or 30 ft over the runway, he recalled, the aircraft suddenly "went down". He thought it was caused by a heavy down-draft or a sudden change in the wind direction. He said that the aircraft impacted the runway and bounced up and then down again on the mainwheel landing gear, followed by the nose wheel landing gear, which collapsed. This was at 1236 hours. With this impact, or shortly thereafter, the forward left and rear left exit/entry doors partially opened but were closed again by the quick reaction of the cabin crew sitting beside these doors and with the assistance of adjacent passengers. A number of overhead bins also opened at this time. As the pilots strove to maintain the aircraft on the runway the Captain cancelled the speed brakes and the aircraft finally came to rest on the runway beyond taxiway Alpha, some 8600 ft from the initial touchdown point. The Captain ordered the cabin crew to carry out the emergency evacuation procedures, using only the exit doors on the right hand side of the aircraft because of the strong winds blowing from their left hand side. He recalled the swift arrival of the Airport Police Fire Services (APFS) and their deployment covering the evacuation. When asked, the Captain said that he did not recall hearing any aural warnings of windshear nor did he see any predictive windshear alert on the weather radar display.

The First Officer recalled manually flying a stabilized approach, and that the winds, while strong, were "within limits", i.e.36 kt. He did not express experiencing any undue difficulty to the Captain and he felt quite confident with his handling of the approach. Just before the actual landing, he too felt what he thought to be a sudden downdraft, which he tried to counteract by an increase in engine power and angle of attack but that this action on his part, did not prevent what subsequently occurred. Earlier, he recalled, he was aware of the two preceding aircraft carrying out missed approaches but he did not know the exact reason why. As he explained, a missed approach can be as a result of various factors, weather conditions being only one such factor. When the aircraft came to a halt he carried out the emergency shutdown procedures, including selecting flaps 40. Both he and the Captain then assisted the cabin crew with the passenger evacuation. He recalled that two passengers in particular were most helpful in this regard.

The cabin crew recalled that some of the overhead luggage bins in the cabin opened on the aircraft's initial impact with the ground. When the aircraft came to rest they supervised the evacuation of the aircraft through the front right and rear right exit doors, using the two deployed escape slides. Because of the nose-down attitude of the aircraft, the front door exit was considerably closer the ground than the rear door exit (***Photo.1***).

The escape slides, which were severely buffeted in the very strong winds, particularly the rear slide, were initially anchored by the first passengers out of the aircraft and thereafter by fire services personnel**.** As there was no fire the two overwing emergency window exits were not used.

The non-use of these exits by the cabin crew was to reduce the risk of injury to passengers sliding off the aircraft's wings via the extended flaps onto the concrete runway, it was recalled. In the circumstances the Captain thought that this was a very good decision by the cabin crew manager. Numerous passengers subsequently praised the cabin crew for their professional efforts.

Consequent to the accident, Shannon Airport was closed to commercial traffic until 0600 hours on the following day, 1st December 2000, as special moving equipment had to be dispatched by road from Dublin Airport to move the aircraft from the runway to a nearby aircraft maintenance facility on the airfield.

The accident was witnessed by the Captain of a Boeing 737 which was parked at the holding point of Rwy 24, preparatory to carrying out a post maintenance test flight. He had been some time at the holding point awaiting the wind to abate and had seen the two earlier missed approaches. His best recollection of events is as follows:

- *From our viewpoint at the hold of Rwy 24, the aircraft (FUA 1331) was visible from about 2 miles out on the approach. Given the weather conditions the aircraft appeared to be very stable and was flying the approach profile with minimum adjustment.*

- *As the aircraft approached the touchdown area of the runway for landing, the configuration aspect and flare looked very good for a successful landing – in other words it all looked perfect for a good landing.*

- *The aircraft seemed to start the landing flare at approximately 3 metres over the runway and from here on in is where it all seemed to go wrong.*

- *From the flare height the aircraft flew onto the runway with a high rate of sink. The aircraft landed heavily on all three legs of the undercarriage, bounced back into the air, then flew back onto the runway again with a high sink rate, this time landing on the nosewheel first.*

- *At this point I could see the No. 2 nosewheel (right hand) break off and roll towards the grass on the right hand side of the runway adjacent to the (Shannon) Aerospace hangar.*

- *Almost immediately afterwards, the No.1 nosewheel appeared to break off and then the nose gear collapsed. This resulted in the forward section of the fuselage resting on the runway while the two main landing gear legs remained intact.*

- *The aircraft then veered to the left hand side of the runway for a brief moment before it was straightened up and went sliding down the runway. It continued down the runway for a considerable distance and came to a stop beyond the intersection with taxiway "A".*

- *As the aircraft was not in contact with tower frequency* (121.4 mHz, Shannon Approach, was the allocated frequency) *I advised the tower that the Futura aircraft had a problem and they in turn advised the emergency services*

With the runway now obviously closed this witness then taxied his aircraft back to the apron via the taxi-way.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	None	None	None
Serious	None	None	None
Minor	One	Eight	

Eight passengers were treated in hospital in Limerick city for their injuries. None were detained overnight. Some twenty other passengers received treatment locally from the Airport Doctor and Paramedics. The Captain received minor head injuries during the landing.

1.3 Damage to Aircraft

The nose undercarriage struck the runway surface on landing resulting in the severance of both nose wheels. The consequential horizontal drag force acting on the nose strut caused the fracture of the lower drag strut. The gear then rotated rearwards and the undercarriage doors disintegrated on impact with the ground. The door pieces impinged on the airframe and wing surfaces and were also ingested into the two engines.

The following is a synopsis of the extensive damage to this aircraft:

Fuselage

1. L.H. horizontal stabilizer leading edge skin and rib punctured.
2. Skin pillowing above R.H. aircraft service door.
3. Numerous wrinkles on R.H. skin panels between Station 727 and Station 887. Skin dented in this area also.

Numerous skin panel punctures and dents in area Section 43(rear of cockpit). Major damage rework was necessary at Section 41(cockpit area) to skin panels and nose wheel well side walls, due to collapse of nose undercarriage and consequent grinding down of fuselage surrounding areas. Many panels destroyed in this area.

Skin panel located in cockpit area between Station 259.5 and 360 buckled. Nose wheel well doors, hinges, seals, seal retainers, upper and lower fuselage assemblies and bell cranks destroyed**. (*Photo. 2*)**

All associated nose wheel equipment such as steering cables, hydraulic pipelines destroyed. Nose landing gear destroyed including wheels, tyres and actuator. Lower drag strut fractured at lower bolt end. Half of the bolt plus one nut in place recovered from debris.

Electrical bundles inside nose wheel well destroyed. ATC, VHF and TCAS antennae including coaxial cables destroyed. Damage to airstair assembly and track support. Stringers between Station 259 and Station 360 damaged.

Wings

L.H. inboard flap outboard track fairing damaged. Numerous punctures to L.H. and R.H. inboard aircraft trailing edge flaps. Dents to outboard L.H. trailing edge flap and R.H. slat. Abrasions to L.H. fixed leading edge.

Engines

Both engines suffered major FOD (Foreign Object Damage) damage necessitating repairs at the engine manufacturers facility. The L.H. engine fan blades and stator vanes were gouged. L.H. engine nose inlet cowl acoustic panels punctured in numerous locations and ground off on bottom. L.H. engine inboard fan cowl ground off. R.H. engine fan blades gouged. R.H. nose inlet cowl acoustic panels and rubber strip had several punctures and gouges. R.H. engine inboard and outboard fan cowls ground off.

1.4 Other damage

The initial damage to Runway 24 was at a point 600 metres (m) from the start of this runway. This consisted of a 3 cm deep groove, cut into the runway surface 2 m right of centreline for a length of approx 5m.

Score marks continued for another 200m up to Taxiway G where the aircraft damaged three centreline light fittings.

The aircraft then skidded to the left of centre reaching a maximum of 14 m from the runway centreline at a distance of 200 m from Taxiway G. The skid mark continued up the runway 4 m from the centreline as far as Taxiway A, where three further centreline light fittings were damaged.

The skid mark then diverted left for a further 800 m beyond Taxiway A, ending where the aircraft came to a stop at 320 m before the end of the runway

1.5 Personnel information

The Captain and First Officer each held a valid Airline Transport Pilot Licence – Aeroplane and Commercial Pilot Licence – Aeroplane respectively, issued by the Kingdom of Spain. Both licences are certified for B-737/300-400-800 CAT II, without limitations.

Captain	ATPL (Spain), No. 2314
Total Time:	7680 hours, including 6780 on Boeing 737 aircraft
Date last medical :	23 November 2000
Date last Sim Check :	17 July 2000

First Officer	CPL (Spain), No. 9669
Total Time:	1287 hours, including 1081 on Boeing 737 aircraft
Date last medical :	15 March 2000
Date last Sim Check:	16 August 2000

Each pilot completed a Crew Resource Management Course (CRM), in Spain, a number of years ago.

1.6 Aircraft Information

The aircraft had a valid Certificate of Airworthiness and had been maintained in accordance with an approved schedule.

The aircraft was delivered new to the operator in June 2000. There were no outstanding servicing items at the time of the accident. An aircraft loadsheet was made out prior to departure from Lanzarote as follows :

Zero Fuel Weight	58,359 kg
Take Off Fuel	12,800 kg
Total Take-Off Weight	1,159 kg (78,244 kg Max. Take-Of Weight Allowed)
Trip Fuel Burn	9,050 kg
Landing Weight at Shannon	62,109 kg (65,317 kg Max Landing Weight Allowed)

Estimated Fuel Remaining
On Board 3,750 kg Fuel Removed At Shannon Airport 3,775 kg

1.7 Meteorological Information

The following information was supplied by the Aviation Services Division of Met Eireann, the Irish Meteorological Service.

General Meteorological information:

A very strong Southeasterly airflow existed over Shannon associated with an active frontal depression which was rapidly approaching from the Southwest. The depression of 968 hPa was centred approximately 180 nautical miles Southwest/West of Valentia meteorological reporting station. An associated occluding frontal system located over the area was moving Northeastwards at a speed of approximately 30 kt.

Meteorological Report for Shannon Airport for 1240 UTC.

Wind:	140º/28 kt max 42 kt
Visibility:	10 km
Weather:	Light Rain
Cloud:	SCT 1900 ft
	BKN 2700 ft
	OVC 4300 ft
Temperature:	11º C
Dewpoint:	9º C
QNH:	982 hPa
Freezing Level:	6500 ft
Wind at 1000 ft:	150/55 kt
Wind at 2000 ft:	150/65 kt
Wind at 5000 ft:	150/75 kt

Shannon Terminal Aerodrome Forecast (TAF) issued 300900 UTC - valid 301919:

140/20 G 35kt	8000-RA	SCT008		BK015
Tempo 1117	140/26 G 45 kt	3000 RA		BKN008
Becmg 1719	210/15 G 26 kt	9999	SCT 010	BKN020

The following SIGMET was in operation:

EISN SIGMET 02 –valid 301200/301600 EINN
Shannon FIR SEV TURB forecast LAN below FL060 NC

There was a local WARNING in operation until 1232 UTC:

EINN 301032/301232

WINDSHEAR WARNING issued at 301030:

ACFT OBS WS TDZ Rwy 24 from 40 kt to 15 kt

1.8 Aids to Navigation

The Instrument Landing System (ILS) on Runway 24 was serviceable.

1.9 Communications

Normal communications existed between FUA 1331 and Shannon ATC

1.10 Aerodrome Information
A plan view of the touchdown zone of Runway 24 is shown at Annex B. A maintenance facility is located north west of the runway and 380 Metres from the centreline of that runway. The touchdown zone is diagonally 520 Metres (1700 ft) from this facility. (*Annex B*)

Runway 24/06, Accelerate Stop Distance available: 10,500 ft

1.11 Flight Recorders

Allied Signal Cockpit Voice Recorder (CVR), serial no. 2394 and Digital Flight Data Recorder (DFDR), serial no. 5422 were installed on this aircraft. Also a Proximity Switch Electronics Unit (PSEU) was installed. The PSEU is a component of the aircraft's air/ground sensing system. As an aid to maintenance crews, the PSEU can detect and record faults in various aircraft systems sensors. The PSEU does not record the specific time that faults occur but does record whether the aircraft was in the air at the time of the fault. The procedure used to extract the data also tests the PSEU for internal failures.

The CVR and DFDR were downloaded at the UK Air Accident Investigation Branch (AAIB) facility in Farnborough. The PSEU was downloaded by Boeing.

1.11.1 FDR Data--Approach and Landing
The following is with reference to flight parameters as recorded during the approach and landing and reproduced at *Annex A.*

At about *6 miles* from touchdown and 2 minutes 15 seconds to run, the final flap selection was made, changing from 25 to 30. The FDR readout of barometric height was 2740 ft (altitude based on 1013 hPa), radio altitude (RADALT) was 1883 ft, computed air speed (CAS) was 168kt and the heading read 217° magnetic. During this initial coupled approach the aircraft was positioned on the glideslope. There is evidence of variations in load factor (+/- 0.35 G), and pitch attitude (+1.5 to –2.5°)

At *3.5 miles* from touchdown and 1 minute 17 seconds to run, the autopilot was disengaged. The barometric height was 1966 ft, RADALT was 1110 ft, CAS was 162 kt and the heading read 219°magnetic. Manual control was initiated but the autothrottle remained engaged and in speed mode. Ceilings were reported as 1800 ft AGL with good visibility, and the approach was continued visually. From this point to touchdown, the aircraft was below the glideslope, ranging from 0.32ddm (3.6 dots) to twice that amount 2.5 seconds before touchdown

At 1000 ft AGL, the speed selected was at 155 kt or (V ref+12), and remained at that value until touchdown. The actual approach was flown at an average speed of about 163 kt, but excursions of 150 kt to 173 kt were recorded due to gusts and turbulence. Strong headwinds were indicated on the initial approach and decent, but by the time the aircraft was at 700 ft radio altitude, the headwind component had largely vanished. The gusts, turbulence, and variable crosswinds contributed to continuous oscillations in all parameters, particularly pitch attitude.

At *0.6 miles* and 14.4 seconds to go to touchdown the "*glideslope*" warning sounded. The barometric height was now 1016 ft and the RADALT was 186 ft. The CAS registered 160kt with an aircraft heading of 233° magnetic. The "*glideslope"* warning was again repeated as the aircraft was still below the glideslope.

At *0.25 miles* and 5.4 seconds from touchdown, the "*sink rate*" warning sounded and lasted for 2 seconds. The maximum vertical speed recorded was minus 1128 ft/min. The RADALT now read 50 ft, CAS 165 kt, at a heading of 234° magnetic.

As the aircraft approached the touchdown zone with the autothrottle engaged and the aircraft under manual control, the pitch attitude became oscillatory with excursions from –3.3º to + 3.5º with a frequency of 1 cycle in 3 seconds (see Annex C). The angle of attack (AOA) changed in synchronisation with the pitch attitude.

At 4 seconds from touchdown, as the aircraft reached a maximum nose up attitude, the control column was positioned forward 5° (elevator 8° down) in order to push the nose of the aircraft down. The Radalt recorded at this point was between 48ft and 26 ft, the computed airspeed was 170 kt and the aircraft's heading was 233º magnetic. As the nose was going down the control column was eased back. However, the aircraft reached a maximum nose down angle of 2.8°. The control column was brought back further to a maximum of 12° (elevator 10° up)

The aircraft had now entered the automatic flare phase with the engine power being automatically reduced. The airspeed remained at an average of 165 kt.

The aircraft was now horizontally 380 ft and 1.3 seconds from the touchdown point at a height of approx 15 ft. The vertical speed at this point was in the region of minus 752 ft/min, the computed airspeed 169 kt and the heading 236º magnetic. The above stick forces registered a maximum "aft" force to bring the nose up again. The aircraft was now less than one second from touchdown. As the nose was coming up at the rate of 6º/sec the main wheels touched the runway and as the aircraft bounced in the air a vertical force of 2.14G was recorded. The aircraft's longitudinal acceleration reached 0.1G during the bounce such that the aircraft's high airspeed was maintained at the second main gear touchdown, which occurred 0.25 seconds later. The aircraft rolled on the main wheels for a distance of approximately 300 ft. The speed brakes, being already armed, deployed on touchdown.

During this bounce, a height of 7 ft was recorded with a following vertical speed of +72 ft/min. The computed airspeed recorded was 168 kt at that time. During the bounce the control column was moved 8° forward (elevator 12° down) and then eased back again. The aircraft responded to this command and the nose of the aircraft started to come down. In the wake of the bounce, the aircraft became almost weightless (-0.03G recorded) as a 3.7° nose down angle was reached. The aircraft became airborne for an instant. The Radalt recorded 1ft. The aircraft also rolled 2° left wing down. The left main undercarriage strut compressed as its wheel touched the runway. Both the right main wheel and nose wheel were off the runway at this stage. As the aircraft rolled to the right 2°, the left wheel came off the runway as the nose continued to drop. In an attempt to pull the nose up, the control column was moved 9°aft (elevator 6° up) but the nose wheel struck the runway as the nose down angle registered 4.2°. At this time, the nose gear impacted the ground with a longitudinal deceleration of 0.4G. The throttle then moved forward, the N1 engine speed started to increase, the flap handle went from 30 to 25. The aircraft's forward speed was maintained and 0.25 seconds later the main wheels impacted the runway, as a maximum vertical force of +3.86G was recorded. The speed brake system then disarmed.

Forward momentary pressure was exerted on the control column and the nose down attitude continued. The nose was being commanded down as all three undercarriage gear recorded "weight on wheels" (WOW). The aircraft continued along the runway for a further 140 ft until the nose gear no longer recorded WOW indicating that the nose strut was no longer in compression.

The aircraft took 62.5 seconds from the first touchdown point to come to rest along the runway. The deceleration was an average 4.4ft /sec/sec and the length of the rollout was 8606 ft or 2648 metres. The aircraft accelerated slightly during the first bounce and decelerated rapidly after at the second.

During the second bounce of the aircraft the flap handle was moved from 30 to 25. At the same instant both engine N1 speeds were increased from 45% to around 90% and immediately reduced again to eventually fall away to 20%. This caused a momentary increase in aircraft longitudinal acceleration 5.4 seconds and 1485 ft or 457 metres after the first touchdown.

Reverse thrust was used on both engines from an airspeed of 109 kt (26.3 seconds after touchdown) to about 20 kt (46.3 seconds after touchdown)

Max brake pressure was recorded (3000psi) from 6 seconds after landing until <40 kt groundspeed.

The aircraft's final heading was 245° at rest on the runway.

Note: The vertical speed recorded on the FDR is provided by the aircraft's inertial navigation system. It is calculated by integrating the sensed accelerations. The nature of the calculation and recording system introduces a time lag that resulted in a positive vertical speed being recorded at the moment of touchdown.

1.11.2 Glideslope DDM

The FDR measures divergence from the glide path in DDM's. ICAO Annex 10 states DDM is the difference in depth of signal modulation and defines it as follows:

The percentage modulation depth of the larger signal minus the percentage modulation depth of the smaller signal, divided by 100.
0.0875 DDM's is equivalent to one "dot" up or down (+ or -) on the pilot's glideslope indicator. Negative represents a command to fly up.

20 seconds from touchdown the FDR recorded	-0.198	(2 dots)
15 seconds from touchdown the FDR recorded	-0.321	(3.6 dots)
4 seconds from touchdown the FDR recorded	-0.484	(5.6 dots)
2.5 seconds from touchdown the FDR recorded	-0.64	(7.3 dots)

1.11.3 CVR Data

A review of the CVR transcript showed cockpit conversations in Spanish and communications with ATC in English over the last thirty minutes of the flight. At the beginning of the descent from cruising level the Captain spoke with the cabin manager and advised him to make sure that everything (cabin service equipment) was secured as soon as possible as they could expect severe turbulence up to and during the landing. Thereafter normal cockpit routine and ATC monitoring continued, with ATC giving continuous information on the weather conditions. The two aircraft ahead of FUA 1331 could be heard carrying out their missed approaches and receiving their diversion instructions from ATC. This was commented on very briefly by both pilots in FUA 1331. Shortly thereafter the First Officer called for the landing checklist, which was completed. Further cockpit discussion centred on the approach speed, 160 kt was agreed. The First Officer confirmed to the Captain that he was manually flying the aircraft. Shortly after receiving 'cleared to land' from ATC a computerised voice called out *'glide slope', glide slope'*, followed by *'sink rate, sink rate'*. This was subsequently followed by impact sounds, alarms and voices.

1.11.4 PSEU Data

The PSEU recorded a fault with one of the sensors on the nose gear that was consistent with the observed damage to the nose landing gear. There are two sensors on each of the three landing gears. The PSEU transitions to "On Ground" when any two of the six sensors indicate target. The fact that the PSEU recorded the fault "In Air" suggests that neither main gear was on the ground when the damage to the nose gear sensor or wiring occurred. There was no damage or internal failures to the PSEU although it is mounted in the forward avionic bay, which suffered severe damage from the rearwards and upwards collapse of the nose wheel strut.

1.12 Wreckage Information

Most of the wreckage, as detailed below, was confined to an area to the right of runway 24 and covered a distance along the runway of 250 m from the touchdown point.

On the day of the accident the LH nose tyre was found on the grass approximately 16 metres from the runway edge. The wall of the tyre had suffered severe damage on impact. Part of the wheel rim had been retained inside the tyre. The axle and bearing cages of this wheel remained on the nose strut. Parts of the fibre-glass nose undercarriage door and door mechanism including the lamp fitting were also found in this general area between the RVR transmitter access road and Taxiway G.

Several days after the accident the complete RH wheel and tyre plus the axle were discovered in the long grass further in from the runway edge.

Also found was part of the main bolt and nut which holds the lower drag strut to the main undercarriage shock strut. Part of this bolt and nut assembly had been worn away by ground impact when the drag strut fractured following impulse loading on nose touch down.

1.12.1 Examination of Nose Undercarriage Damage

The initial force on the nose caused the right axle complete with right wheel and tyre to snap off. The weight on the remaining wheel caused it to disintegrate leaving the bearing cages on the left axle. The axle then impinged on the ground until the forces on the drag brace caused the pin to shear and the nose strut to rotate 90° rearwards. The nose gear broke within 1 second of the second touchdown. The aircraft pitch attitude then decayed to 4° nose down for the remainder of the "rollout".

1.13 Medical and pathological information

Not applicable

1.14 Fire

Not applicable

1.15 Survival aspects

Both left hand side entry/exit doors opened momentarily on ground impact. Swift reaction by the CCM's seated alongside these doors, aided by some adjacent passengers, succeeded in closing the doors again. They kept them closed by maintaining pressure on the opening handles until the aircraft came to a halt.

Because of the very strong winds from the left hand side of the aircraft the escape slides of the right hand doors only were deployed. This action provided a measure of protection from the wind. The rear right hand escape slide was severely buffeted in the strong winds and had to be anchored initially by evacuating passengers until the arrival of the Airport Police Fire Service.

1.16 Test and Research

Not applicable

1.17 Organisation and Management information

Not applicable

1.18 Additional information

The Airplane Flight Manual (AFM) limitations and recommended operating limitations, as utilised by the Operator, are contained in the Boeing 737 Operations Manual.

In Chapter L, Limitations, Section 10, the following information is contained

"Non-AFM Operational Information

***Note**: The following items are not AFM limitations, but are provided for flight crew information.*

On revenue flights, the escape slide retention bar must be installed during taxi, take-off and landing.

The maximum demonstrated takeoff and landing crosswind is 36 knots."

1.19 Additional Investigation

The manufacturers state that pitch attitude at nose gear and main gear ground contact with oleo's fully extended would be –0.94º. The right nose wheel axle was sent to a State laboratory for fracture analysis.
Their report states:

"The detached axle had a distinct bend in it adjacent to the fracture.

The fracture surface was fresh and bright, apart from superficial corrosion, which had occurred subsequent to fracture. The fracture features were indicative of a single event, overload failure. Secondary cracks were observed to be associated with the fracture. The orientation of these was consistent with the direction of bending. There was no indication of any pre-existing defect associated with the fracture".

2 ANALYSIS

2.1 FDR

The flight proceeded uneventfully until the approach and landing at Shannon Airport. The FDR data showed that the crosswind component on short final, with a small tailwind component, was approximately, 40 kt,. Boeing notes that the FDR winds are not accurate during crab and sideslip, as would occur in the wing low, crosswind landing technique that was being used in this approach (the Shannon reported winds were pure crosswind).

At the early stages of the approach the speed was maintained at approximately Vref + 20, 163 kt, with pitch attitude maintained near 0º. The autothrottle remained engaged during the approach and touchdown after manual control was initiated at 3.5 miles from touchdown. The aircraft manufacturer, Boeing, recommends that the autothrottle be disconnected during manual flight in turbulent conditions.

It is clear that the thrust changes resulting from the selection of the autothrottle in the prevailing conditions also affected the pitch trim of the aircraft. Consequently, pitch attitude was not stabilised during the final approach and touchdown.

The gusts and turbulence contributed to over control of the pitch attitude during the flare resulting in a hard touchdown. The aircraft pitched down. This caused the aircraft to contact the ground nose gear first, with a longitudinal deceleration of 0.4 G. Shortly thereafter, the main gear contacted the ground coincident with a vertical load factor of 3.8 G.

Three seconds before touchdown the aircraft entered the flare phase and engine speed N1 started to reduce automatically. However, the aircraft had been in autothrottle mode and this contributed to the consistency of a high airspeed of 165 kt and preventing the aircraft from slowing down in the flare and causing thrust induced pitching moment effects. This can be seen in the oscillation of aircraft pitch during this phase (*Annex C*). The high vertical descent rate was not arrested in the flare and this contributed to the bounce of the aircraft prior to the final touchdown. Whilst maintaining the same airspeed the aircraft was commanded to a nose-up attitude and both main wheels made contact with the runway.

The speed brakes then automatically deployed (as the system had been armed in the correct manner). The elevator was then moved to push the nose down rapidly. As the nose came down the aircraft lifted momentarily off the runway with a nose-down attitude. However, the airspeed only reduced to 161kt.

The elevator was then rapidly moved to bring the nose up. Before the aircraft had time to respond to this command the nose wheel struck the ground. The attitude of the aircraft at this time was 4.2º nose down. The configuration of the aircraft shows that at this angle the main wheels were off the ground. This is confirmed by the FDR recording for WOW and the PSEU. The airspeed remained constant at 164 kt. Excessive control column movement was made following a bounced landing.

With the lack of pitch stabilization, a glide slope warning, and a sink rate warning, there were many indications that this approach was unstabilized. The Flight Safety Foundation Approach and Landing Accident Reduction task force recommended elements of a stabilized approach include: "Only small changes in heading/pitch are required to maintain the correct flight path". Another element is "sink rate no more than 1,000 feet per minute below 500 feet". A further element is that instrument landing system (ILS) approaches must be flown within one dot of the glide path or localizer. If the airplane becomes unstabilized, it "requires an immediate go-around" (Flight Safety Foundation, Flight Safety Digest, Aug-Nov 2000).

It would appear from the FDR data that a go-around on the ground had been initiated in the cockpit and then abandoned, as it is shown, when the nose gear went to ground, the throttles moved to a high thrust setting or N1 speed of 90%, the speed brakes retracted and the flaps handle was moved from 30 to 25. The autothrottle then disengaged. N1 speed then fell off rapidly to 20%.

Based on the 135,350 lbs landing weight, -0.4G corresponds to an unbalanced drag load of 54,000 lbs. The ultimate design load for the nose gear is 38,000 lbs in the aft direction.
Therefore, it appears likely that the nose gear first contact caused the right nose wheel axle to snap off which subsequently led to the failure of the nose gear in the aft direction.

2.2 Limitations

Vref for the 135,350 lb gross weight, flaps 30 configuration is 143 kt. At 1000 AGL the selected speed was set at 155 kt. or Vref + 12, and remained at that value until touchdown. This is the expected target speed if the autothrottle is disengaged. With the autothrottle engaged, the expected target speed should be Vref +5. The actual approach was flown with an average speed of about 163 kt, (Vref + 20) but excursions of 150 kt to 175 kt were recorded due to the gusts and turbulence. In turbulent conditions with the autothrottle engaged, the average speed can exceed the target speed because the autothrottle acceleration rate is higher than the deceleration rate. Strong headwinds were indicated on the initial approach and descent when comparing airspeed to groundspeed. By 700 feet radalt the headwind component had largely vanished and the remainder of the flight was subject to pure crosswinds, with a minor tailwind recorded on landing.

The Boeing 737 Operations Manual states that "the maximum demonstrated takeoff and landing crosswind is 36 knots". As an aircraft certification requirement, the AFM provides the maximum crosswind demonstrated during flight test. This is the figure used by Futura. Boeing further states that "discretion in evaluating and determining acceptable gust values is left to individual operators". As part of the investigation the A.A.I.U. queried the Irish Operators of Boeing 400 to 800 series aircraft, as to their crosswind limits. The airlines stated that their maximum crosswind limitations for take-off and landings were 25 knots and 30 knots for wet and dry runways, respectively. The airlines also pointed out that even with their published maximum cross-wind limitations, aircraft commanders can use their discretion, on the day, as to whether these maximum conditions are acceptable in their operating circumstances.

2.3 CRM

CRM Courses are nowadays an integral part of flight crew training and airlines run such courses, suitably tailoring them to their own operational needs and requirements. CRM means the retrieval and use of all resources available (hardware, software, liveware) that combine to maximise flight safety. Technical competence is assumed in CRM training, which focuses instead on the links that bind human or personal performance to technical competence. CRM is team driven. Major descriptors of team performance include: challenge and response, leadership and followership, advocacy and inquiry.

Thoughtful analysis of the CVR transcript shows little meaningful discussion on the prevailing weather conditions at Shannon. Both pilots recalled that the winds were "within limits", and, when asked about these limits, one pilot recalled 40 kt and the other 36 kt. Similarly, the continued engagement of the autothrottle could reasonably have been expected to initiate an inquiry from either pilot. This did not occur. Neither were there any calls made on final approach. Towards the end of the approach there were three courses of action open.

The first was to divert, given the weather considerations, the second was to carry out a go around due to the unstable final approach, and the third was to land. The third option was chosen.

2.4 Weather

2.4.1 Further elaboration from Met Eireann, the Irish Meteorological Service, on the weather conditions at the time of the accident is as follows:

Radar analysis and surface reports suggest that the more intense precipitation had moved north and northeast of Shannon by the time the accident took place. Thus cumulonimbus (Cb) downdraft was unlikely to be a factor in the accident.

The anemometer traces show that the wind speed and direction at the anemometer site were fairly steady, the 10 minute mean direction varying between 136º (true) and 138º (true), with the speed remaining steady at 28 knots. The reports to ATC showed that the 2 minute averages for wind speed and direction confirmed the 10 minute averages, with gusts varying between 40 and 42 knots. Thus there is no evidence to indicate significant windshear at the time of the accident.

There was a SIGMET valid for the area at the time, warning of severe turbulence at low levels (below FL060). The gradient wind measured 65 knots at 150º (true).

There is no evidence that the maintenance facility hangar (Shannon Aerospace) had any effect on the wind profile at the Runway 24 threshold or touchdown zone at the time of the accident. In particular, there is no evidence, nor is Met Eireann aware of any theory, that could account for wind "reflection" from the hangar that would impact on the Runway 24 threshold or touchdown zone in these circumstances.

2.4.2 The aircraft observed comment (ACFT OBS) on windshear was given by the Captain of an A330 aircraft landing on Rwy 24 at 1029 hrs.

2.4.3 The Predictive Windshear System (PWS) on the B737-800 uses wind velocity data gathered by a Doppler weather radar system to identify the existence of a windshear. Radar energy is emitted through the airplane's radome in order to gather atmospheric information such as wind speed and direction. The weather radar receiver/transmitter then uses this information, in addition to air data and inertial data, to determine the presence of a windshear. The weather radar processor identifies wind velocity characteristics that indicate a rapid change in wind velocity or direction over a relatively small area. When the magnitude of the detected windshear reaches a predetermined intensity level, the system alerts the flight crew.

The Doppler weather radar system can only detect horizontal headwind/tailwind velocities and make assumptions about crosswind and vertical wind speeds. The software in the weather radar receiver/transmitter assumes that all detected horizontal shears also have a proportional vertical component (similar to typical microburst characteristics). It adds the detected horizontal winds to the assumed vertical winds to determine a total magnitude for the windshear. A variable crosswind would not be detected by the PWS. However, it must be stressed that the PWS cannot detect vertical winds or vertical air movements.

3. CONCLUSIONS

3.1 Findings

3.1.1 The crew were properly qualified and licensed, in accordance with Spanish Ministerio de Fomento Regulations, to undertake this flight.

3.1.2 The aircraft had a valid Certificate of Airworthiness and had been maintained in accordance with an approved schedule.

3.1.3 No evidence was found of any technical problem on the aircraft or its systems.

3.1.4 The First Officer was the handling pilot (PF) on the sector Lanzarote to Shannon Airport.

3.1.5 Crosswinds at Shannon gusting up to 39 kt caused two preceding jets, a BAe 146 and a B737-400, to divert to Dublin, at 1225 hours and 1230 hours, respectively.

3.1.6 While aware of these diversions, the aircraft crew considered the existing winds to be within their limits and the landing was proceeded with.

3.1.7 An ILS approach was flown to Rwy 24. DFDR data show that pitch attitude averaged near 0º during the initial coupled approach, which was appropriate for the airspeed, gross weight and flap setting. The glide slope and localizer were tracked to within tolerances until the final approach segment. At 3.5 miles from touchdown the autopilot was disengaged. Pitch excursions from –3.3º to 3.5º were present throughout the final approach. A crosswind heading correction of approximately 5ºnose left was maintained at touchdown.

3.1.8 The autothrottle remained engaged after manual control was initiated on the approach, and remained engaged until after the touchdown, when it disconnected.

3.1.9 The 737 Flight Crew Training Manual (FCTM), Reference C, page 2.8, states: *"when in manual flight, manual thrust control is recommended"*. The approach was flown using autothrottle while in manual flight, contrary to the FCTM recommendation

3.1.10 The gusts, turbulence and autothrottle engagement contributed to an unstabilized final approach under manual control. At 0.6 miles and 14.4 seconds to go to touchdown the "*glideslope*" warning sounded. Overcontrol of the pitch attitude started after a high rate of descent occurred at 100 ft at 0.25 miles and 5.4 seconds from touchdown, causing a "*sink rate*" warning. Overcontrol continued throughout the flare.

3.1.11 This led to a hard first ground contact and rebound, followed by a large forward pilot control input to a negative pitch angle of – 3.5º. A go-around was apparently attempted but this was quickly discontinued.

3.1.12 With the collapse of the nose wheel structure, there was an almost simultaneous partial opening of the front left and rear left entry doors. Overhead luggage bins in the cabin opened also.

3.1.13 Quick reaction by the cabin crew members seated beside these doors, aided by some passengers, succeeded in closing the doors again, with the door opening handle being tightly gripped by the crew members, until the aircraft stopped.

3.1.14 The aircraft continued on its nose for over 8000 ft of Rwy 24 before it came to rest on the runway beyond taxiway Alpha.

3.1.15 There was no fire. Alerted by the witness pilot at the threshold of Rwy 24 and ATC, the Shannon Airport Police Fire Service were quickly on the scene and assisted in the evacuation of the passengers and crew via the right hand side doors escape slides.

3.1.16 Many passengers subsequently praised the cabin crew both orally and in writing to the AAIU, for their professional conduct during the evacuation.

3.1.17 Eight passengers were treated in hospital in Limerick city for their injuries. None were detained overnight. Some twenty other passengers received treatment locally from the Airport Doctor and Paramedics. The decision to use only the right hand doors escape slides was most likely a major factor in the relatively small number of personal injuries sustained.

3.1.18 The airport was closed for operations until approximately 0600 hours on the following day.

3.1.19 The Operator uses the Boeing maximum demonstrated cross wind of 36 knots for their operations. This is a steady state wind component only. It does not take wind gusts into account.

3.1.20 Other operators of similar Boeing aircraft use crosswind limitations which are considerably lower than the aircraft certification figures. These lower cross wind limitations aid the crews decision making process in marginal weather conditions, in the interests of flight safety.

3.1.21 The use of the Boeing demonstrated cross wind component of 36 kt by the Operator is an operational decision. However, in the light of this accident, it would seem prudent for the Operator to review their crosswind limitations as a priority, in the interests of flight safety.

3.22 Both pilots recalled that the aircraft suddenly went down, caused by either a heavy downdraft or a sudden change in the wind direction. This event occurred in the last seconds of the flight. There was no aural warning of windshear nor did either pilot recall seeing a predictive windshear alert on the weather radar display.

3.1.23 The aircraft suffered major structural damage. None of the 208 persons on board sustained serious injuries in the initial ground impact or the subsequent evacuation of the aircraft. Given the extent the damage to both the engines and airframe, a more serious accident was only narrowly avoided.

3.2 Causal Factors

The accident was due to an excessive control column forward input, causing negative pitch attitude which led to a very high impact loading on the nose undercarriage, leading to the severing of the two nose wheels and the collapse of the nose gear strut assembly rearwards. This followed a chain of events, which contributed to the accident including the wind gusts, turbulence, the use of the autothrottle and the decision to land from an unstabilized final approach

4. SAFETY RECOMMENDATIONS

It is recommended that:

4.1 The Operator publish specific maximum crosswind limitations with airfield conditions for their B737.800 aircraft. ***(SR No. 18 of 2001*)**

This Safety Recommendation was made to Futura on 2nd February 2001, as an *interim* Safety Recommendation, (reference SR No. 6 of 2001), pending the completion of the Report. The Operator accepted this Safety Recommendation.

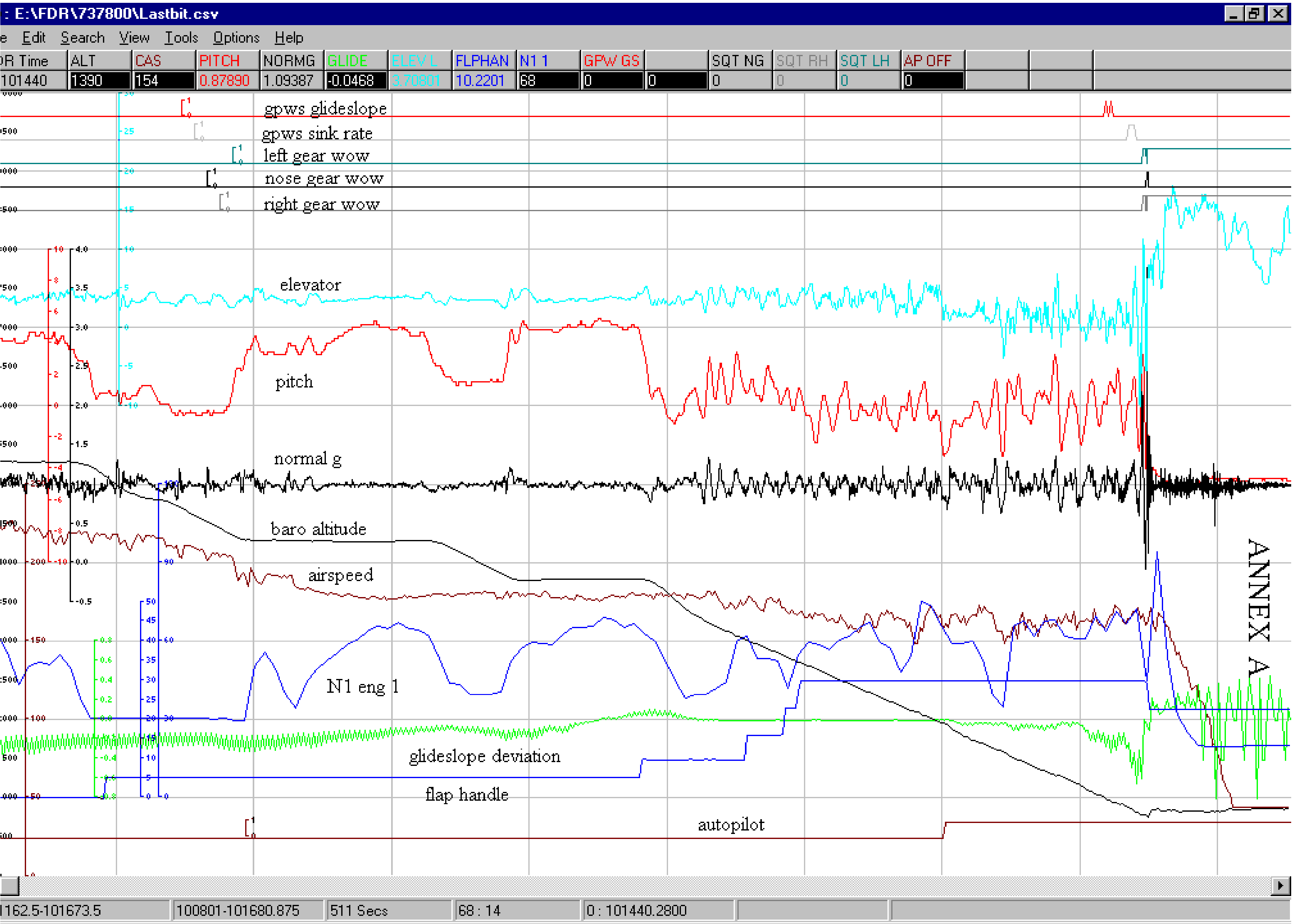
4.2 The Operator reviews its flight training programme to re-emphasize the following points:

a) The stabilized approach concept, definition and requirements
b) The importance of executing a missed approach if the approach becomes destabilised.
c) The inclusion of a Line Operations Safety Audit (LOSA) in addition to CRM training for aircrew ***(SR No. 19 of 2001)***

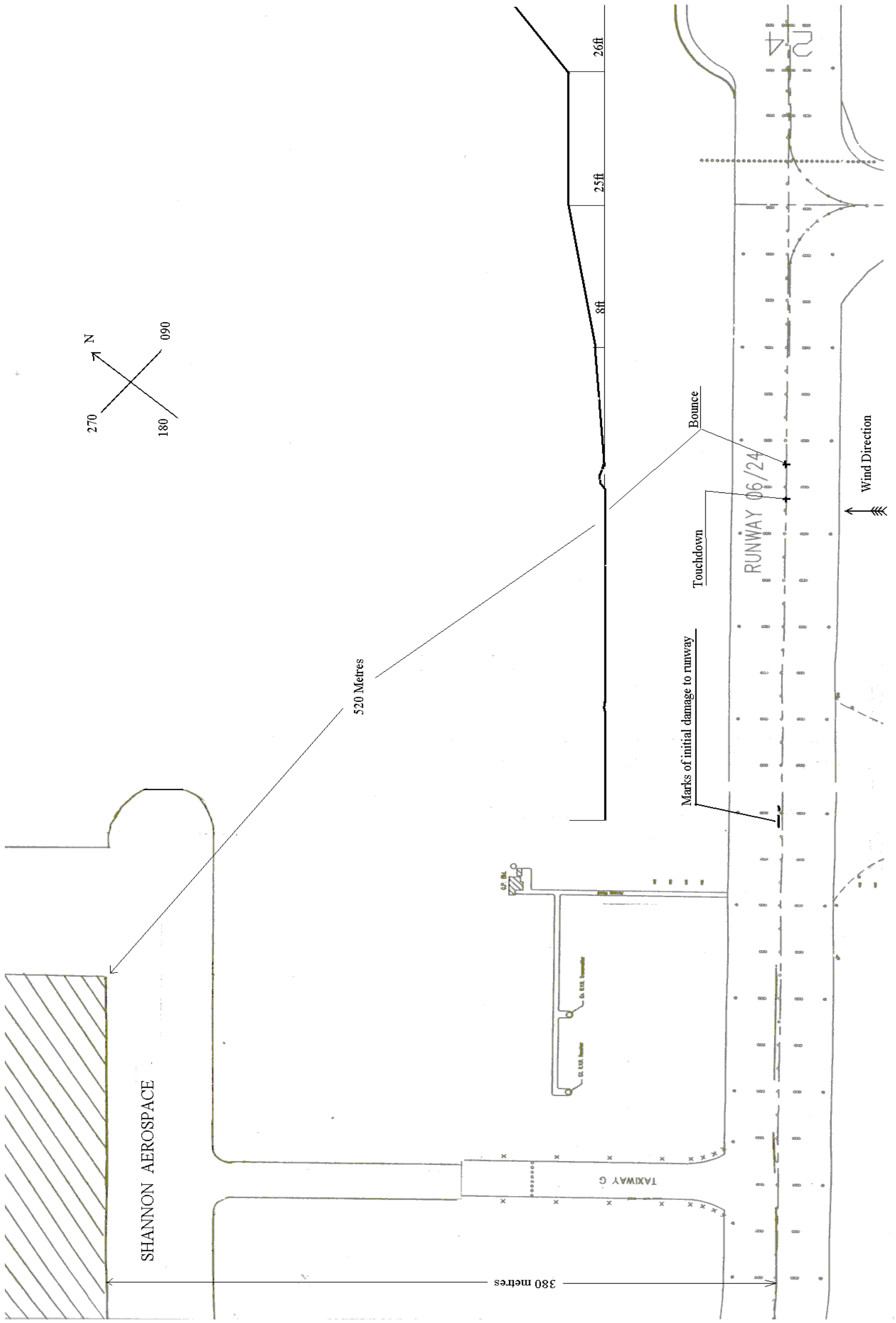
The Operator accepted this Safety Recommendation.

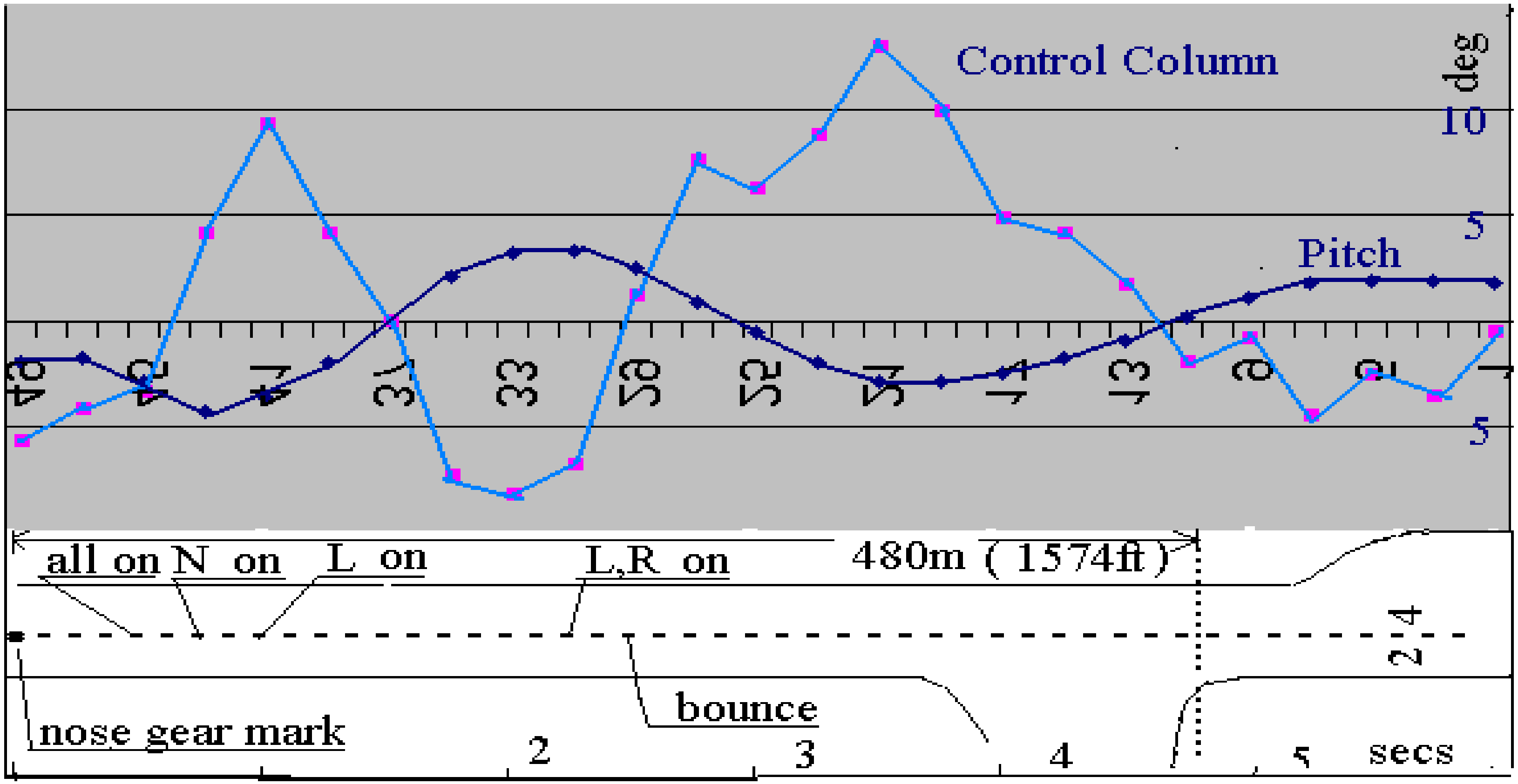
Photo 1. Showing the escape slides deployed on the right hand side of the aircraft

Photo 2. Damage to the drag strut, shock strut and axle of the nose undercarriage assembly and to the nose cone skin of the aircraft. This photo was taken following the removal of the aircraft to the hangar. The damaged nose strut is shown in the normal down position, without its wheels, having been rotated forward from the belly of the aircraft by engineers. Also shown (insert) is the right hand axle, ruptured from the strut, and found in the grass alongside the runway following the accident.


: E:\FDR\737800\Lastbit.csv
e Edit Search View Tools Options Help
R Time | ALT | CAS | PITCH | NORMG | GLIDE | ELEV L | FLPHAN | N1 1 | GPW GS | SQT NG | SQT RH | SQT LH | AP OFF
101440 | 1390 | 154 | 0.87890 | 1.09387 | -0.0468 | 3.70801 | 10.2201 | 68 | 0 | 0 | 0 | 0 | 0 | 0
gpws glideslope
gpws sink rate
left gear wow
nose gear wow
right gear wow
elevator
pitch
normal g
baro altitude
airspeed
N1 eng 1
glideslope deviation
flap handle
autopilot
ANNEX A
1162.5-101673.5
100801-101680.875
511 Secs
68 : 14
0 : 101440.2800

ANNEX B


N
090
270
180
26ft
25ft
8ft
Bounce
Touchdown
RUNWAY 06/24
Wind Direction
Marks of initial damage to runway
520 Metres
SHANNON AEROSPACE
TAXIWAY G
380 metres



Graph of fwd/aft position of First Officer's control column with pitch of the aircraft superimposed during flare and landing of EC-HMK.
+ is control column aft and + is aircraft nose up.
N = Nose gear, L = Left main gear, R = Right main gear.