AAIU Report No. 2001-005
AAIU File No. 19990080
Published:19/04/2001

Name of Operator:	Royal Jordanian Airlines
Manufacturer:	Airbus
Model:	A310-300
Nationality:	Jordanian
Registration:	JY-AGK
Place of Accident:	Shannon Airport, Ireland
Year of Manufacturer:	1991
Date/Time :	16.09 hrs UTC; 27 December 1999

SYNOPSIS

While landing in Shannon, the aircraft bounced and landed heavily on the nose wheel, causing extensive damage to the forward fuselage frames in the nose wheel area.

The Jordanian CAA appointed an Accredited Representative, Mr Shukri Absi, who assisted the AAIU in this investigation.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft, operating as flight number Royal Jordanian RJ 263 was on a regular scheduled public transport flight from Amman-Jordan, to Shannon-Ireland, thereafter routing onwards to Chicago. The F/O was the designated handling pilot (PF) for the Amman-Shannon sector. The aircraft conducted a right hand approach to Runway 06 at Shannon. During the descent to 3,000 ft, ATC gave the aircraft a right turn onto 030°, to intercept the localiser for Runway 06. This instruction was accepted by the Pilot-In-Command (PIC). At 3000 ft., the leading edge slats were set to 15° and flaps were at 0°. Engine power setting was 62% N1. ATC then informed the aircraft that they were 10 miles from touch-down. The F/O pointed out "*very red WX radar Active CB activity to the left*" (of their flight path).

The PIC then informed ATC that he wanted to go on a right heading of 040°. ATC informed the aircraft "I won't be able to intercept you from that heading. Let me know when you can take a vector for the approach". PIC answered "No problem we just take a break to the left and intercept, just give me thirty seconds ". ATC replied "OK". At this point the PIC took the controls and manually flew the aircraft to intercept the ILS.

Engine power was then reduced to approx 30% and a right turn was made onto a heading of 055°, and the ILS was captured. At 2,600 ft., the leading edge slats and flaps were extended to 20°. During the descent from 3,000 ft to 2,100 ft the vertical load factor fluctuated between 0.8 and 1.15 g, and lateral loads fluctuated between 0.035 and 0.02 g. These fluctuations were consistent with air turbulence. The glide slope was not correctly maintained during this period.

At 2,300 ft the undercarriage was lowered, power increased briefly to 47% and pitch attitude was increased. The power was then reduced to 30%.

At 1,900 ft, the slats were extended to 25° and flaps to 40°. Fluctuations of vertical G increased from 0.75G to 1.25G while lateral loads were 0.055G to 0.085G. There were significant aileron and rudder inputs. At about 300 ft power was increased to 64%, and was then varied between 72% and 56% for the remainder of the approach. The speed increased, reaching 156 kts (Vref +20 kts) when the aircraft was at 60 ft. Between 350 ft and 60 ft, the rate of descent was approximately 965 ft/minute. The vertical accelerations reduced slightly during this phase to a range of 0.75G to 1.1G and the lateral accelerations ranged from -0.05G to 0.05G. The aircraft pitch oscillated between 0.5° and 4°, finally stabilising between 2° and 2.5°. The heading of 055° was maintained, and the aircraft systems recorded a wind of 320° at 10 kts.

In the later stages of the approach, at a radio altimeter indication just above 300 ft, approximately 30 seconds before the initial touch-on, the auto call alert called "Glide Slope" three times.

Between 60 ft and the ground the rate of descent was approximately 500 ft/minute. Engine power was increased from 56 % to 62% N1. The flare was initiated at an altitude of about 18 ft. as indicated by a change in elevator deflection. During the flare the pitch increased from 2.5° to 5.5°. Just before touch down, the aircraft rolled 5° left. This was countered by a right aileron input, which resulted in a 3° right wing down attitude. 4° of left rudder were also applied at about the point of touchdown. The aircraft touched on at 4.5° pitch, at 146 kts (Vref +10) initially on the right main leg with 3° right roll and 58% N1. A vertical load factor of 1.9 G and lateral load factor of 0.32 (sideslip to the right) was recorded during the touch down.

The aircraft then bounced on both main wheels. The ground spoilers, which had opened on the initial touchdown, retracted. While airborne during this bounce the throttles were briefly advanced and an elevator input of 9° nose down was made. The aircraft pitch angle decreased from 5.5° at a rate of 6°/sec. The aircraft then landed on the nose wheel, with a nose pitch-down rate still of 6°/sec., and an aircraft pitch angle of 3° to 4° nose-down. A vertical load of 1.65 G and lateral load of 0.195 G was recorded at this point. The main gear then came into ground contact and a vertical acceleration of 1.36 G was recorded.

At this point the ground spoilers deployed, the pitch attitude increased to 2.5°, an elevator nose down input of 11° was made and the aircraft bounced again. During in this second bounce, it is probable that the main undercarriage reached full extension of the shock absorbers and that the aircraft did not become airborne again. However due to the pitch attitude of 2.5°, the nose wheel was airborne. The aircraft then "landed" again and a vertical load of 1.5 G was recorded. An elevator nose down input of 14° was made during this bounce and the nose wheel made ground contact again, recording 1.2G.

With all three undercarriage legs on the ground, thrust reversers were selected and the aircraft stopped normally. During the rollout the crew reported to ATC that they experienced wind shear at touchdown.

The aircraft then cleared the runway. As the aircraft approached the stand, the crew had a further discussion with ATC and stated that they experienced a variable head wind of 47 kts at touchdown.

At 19.50 hrs, the staff of the company that was responsible for handling the aircraft at Shannon reported to Shannon ATC that the aircraft would be overnighting due to a damaged nose wheel. This was the only communication concerning possible damage on heavy landing, received by ATC. Shannon ATC then informed the AAIU that the aircraft was overnighting due to a damaged nose wheel.

When ATC reported the event to the AAIU, it was initially regarded as a minor incident, as it was understood that only a nose wheel (tyre) required to be changed.

In the course of another unrelated investigation in Shannon on 5 January, the AAIU looked at the A310, and noted considerable external damage to the nose area of the aircraft. Because of the extent of the damage observed an investigation was then launched.

1.2 Injuries to Persons

There were a total of 198 crew and passengers on the flight. No injuries were reported.

1.3 Damage to the aircraft

The aircraft suffered considerable distortion of the main fuselage frames immediately aft of the nose leg, in the lower half of the fuselage. These frames are numbered 17 and 18. Distortion of the frame inner flanges was of the order of a few centimetres. Bending was also noted on Frames 13 to 16A. The frame damage was between stringers 44 and 30. There was also damage to the stringers and aircraft skin in this area.

Temporary repairs, including fitting of reinforcing straps to the fuselage, were completed by Airbus specialists at Shannon over the subsequent weeks. The aircraft was then flown, gear-down, to the Airbus facility at Toulouse for extensive repairs.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 Aircraft Commander (PIC)

Male aged 46 years

Licence	Airline Transport Pilot
A/C Types	B707, A310
First Issued	4 December 1995
Valid Until	31 May 2000
Current rating	A310
Instrument Rating	Renewed 02 December 1999
Medical Certificate	Class 1, issued 10 November 1999
Last Base Check	02 December 1999
Last Line Check	18 July 1999
Flying Experience	Total All Types 7,087 hours
On type P1	2,727 "
Total on type	2,734 "
Total last 90 days	120 "
Last 28 days	31 "

1.5.2 First officer (F/O)

Male, aged 29 years	
Licence	CPL
A/C Types	A310
First Issued	03 October 1990
Renewed	28 October 1999
Current rating	A310
Instrument rating	22 July 1999
Medical Certificate	Class 1 issued 06 September 1999
Last Base Check	20 November 1999
Flying Experience	Total all types 2,553 hours
On Type	2,343 "
Last 120 days	168 "
Last 28 days	60 "

1.5.3 Crew Duty Time

Crew duty time of event	9 hours
Rest period prior to duty time	more than 24 hours

1.6 Aircraft Information

1.6.1 Leading Particulars

Type	Airbus A 310-300
Constructors Number	573
Date of Manufacturer	1991
Register Owner	GATX/CL AIR
Operator	Royal Jordanian Airlines
Certificate of Airworthiness	Last renewed 6 September 1999
Total Aircraft Hours	27114
Total Aircraft Cycles	10661
Previous Inspection	A2 on 27 November 1999
Next Inspection Due	A3
Total Airframe Hours	27114.
Total Airframe Cycles	10661
Time Since Last Check	270
Cycles Since Last Check	85
Carried Forward defects (at time of Occurrence)	Nil
Max take Off Weight	150,000 kg
Actual Take Off Weight	139,000 kg
C of G at Take-Off	23.38
Landing Weight	117,882 kg
C of G at landing	29.2

1.6.2 The aircraft was taken onto the Jordanian register on 6 September 1999. It had been previously registered in the Republic of Seychelles and later in the United Arab Emirates. While on the register of the United Arab Emirates, the aircraft experienced a wing strike on landing. Following this event the aircraft was repaired and returned to normal service.

1.6.3 Slats and Flaps Position

The Operations Manual of the A310 gives a slat/flap position of 30/40 (30° slats and 40° flap). However the actual position of the surfaces at this selection is 25.4° slat angle and 41° flap angle. In the FDR section below, the surfaces' position (25/40) is used.

1.6.4 The A310 is equipped with ground spoilers, which, when opened on landing, increase aerodynamic drag and decreased lift, thereby reducing the landing roll. The ground spoilers have the capability to be armed before landing. In this configuration the spoilers deploy automatically when main wheel spin-up is detected on landing. If the throttles are subsequently advanced beyond flight idle, the ground spoilers automatically retract.

1.6.5 Aircraft equipment

The aircraft's navigation display shows wind speed and direction. This information is produced by vector subtraction of the aircraft ground speed and track, as computed by the Inertial Reference System (IRS), from the aircraft's airspeed and heading information.

1.6.6 The aircraft was equipped with wind shear detection equipment. This equipment did not indicate the presence of wind shear during this event, either to the crew or to the DFDR.

1.7 Meteorological Information

1.7.1 As the aircraft descended through 3000 ft, Shannon ATC passed the following weather to the aircraft:

SCT	3,500 ft
BKN	20,000 ft
Temp	03°C
Dew Point	02°C
QNH	992 hPA

NO SIG. *(No significant weather)*

1.7.2 No weather warnings had been issued by Met Eireann, the Irish Meteorological Service, for the time of the event.

1.7.3 As the aircraft descended through 2000 ft, Shannon ATC cleared the aircraft to land on Runway 06 and gave the surface wind as 280° at 3 kt.

1.7.4 An after-cast obtained from Met Eireann gave the following information:

General Situation. A fresh northwest airflow was established over Shannon behind a rapidly deepening depression centred off the coast of northwestern France at 1200 UTC.

Wind: At surface: 24002 kt at 1600 UTC
29005 kt at 1615 UTC
At 2000 ft: 33030 kt

Weather: No significant weather was reported in the METAR reports for 1600 UTC and 1630 UTC. Radar analysis suggested that there were showers in the vicinity of Shannon Airport at the time of the incident, but of light or moderate intensity.

Visibility: 10+ kilometres

Cloud: The 1600 UTC METAR reported the following cloud: FEW at 1000 feet, FEW Cb at 1800 feet, SCT 3500 feet and BKN at 20000 feet.

Temperature/Dew- Point: 03/02 Celsius QNH

Pressure: 992 hPa

1.7.5 The Shannon 16:00 METAR gave:

2761600 Z	26002 kt	9999	Few 010
FEW 018CB	SCT 035	BKN 200	03/02
NO SIG			

1.7.6 The Shannon 16:30 METAR gave:

2716302	32006 kt	9999	SCT 008
BKN018 CB	03/02	00992	NO SIG

1.7.7 The following meteorological was provided by Met Eireann in Shannon to the Operator's Captain who was scheduled to fly the next leg of the flight of JK-AGH. (He had previously positioned at Shannon):-

Time of Report	1600 UTC	
Surface Wind	260° T 02 Kts	
Visibility	10 Km	
Present weather:		
Cloud Group	Few 1,000 ft	Few 1,800 ft CB
	SCT 3,500 ft	BKN 2,000 ft
Temperature	03°C	Dewpoint 02°C
QNH 992 hPa	QFE 990 hPa	ThQFE RWY 29 991 hPa

Recent Wx	---------- *(Blank)*
Trend	NO SIG
Remarks	---------- *(Blank)*

1.7.8 Met Eireann also provided recorded readings from Anemometer Mast B in Shannon Airport, which was the anemometer in use at the time of the event on 27 Dec 1999. This anemometer is located 230 metres south of the centre-line of Runway 06 approx 900 metres before the end of the Runway. The anemometer is located 10 metres above ground level. The anemometer recordings are shown in Annex A.

These recordings show that the wind speed did not exceed 5 kts between 15.30 and 16.15 and did not exceed 10 kts between 16.15 and 16.30. At 16.09 it was 270° at 3 kts.

The recorded wind direction at 15.45 was 290°. It gradually backed to 260° by 16.00 and then veered to 315° by 16.30. At 16.09 it was 285°.

1.7.9 Met Eireann also provided copies of the weather radar pictures recorded at 16.00 (Annex B attached) and at 16.16 (Annex C attached).

1.7.10 Shortly after landing, the aircraft reported to ATC that it had encountered wind shear at touchdown. However while taxiing, the crew, in further discussion with ATC, reported that they had encountered a variable headwind of 47 kts.

1.7.11 Three other aircraft landed at Shannon in the hour before JY-AGK. The closest aircraft to JY-AGK landed 15 minutes before JY-AGK. None of these aircraft, or any subsequent aircraft, reported wind-shear or any other problems.

1.7.12 Met Eireann subsequently provided the following data relating to wind direction and speed, at various altitudes as follows :

At 1000 ft Cannot be estimated with any accuracy.
At 2000 ft 33030 kt (true bearings)
At 3000 ft 33025 kt.
At 4000 ft 33028 kt.
At 5000 ft 33030-35 kt.

1.7.13 In response to AAIU queries in relation to wind shear, low-level turbulence and Cb downdraughts, Met Eireann provided the following:

*"**Wind Shear**:*
The wind at the surface was 2 to 5 knots and at 2000 feet was 30 knots. This could be expected to generate wind shear, but not of an intensity sufficient to justify the issue of an aerodrome warning.

Low-Level Turbulence:
A gradient of 30kt would generate low-level turbulence, but of light to moderate intensity at most. Thus this pressure gradient was not sufficient to justify the issue of a SIGMET for severe low-level turbulence.

Cb Downdraughts:
There was Cb activity in the vicinity of the aerodrome at the time of the incident, as indicated by radar analysis and the METAR report for 1600 UTC. However, the shower activity from these Cb's was registered by radar at a maximum of 3.7 mm/hour, a rate sufficient to produce light to moderate showers. Such showers would not be expected to produce severe downdraughts. This contention is supported by the fact that no gusts were reported in the METARs around the time of the incident."

1.8 Aids to Navigation

Shannon Airport is a fully equipped international airport. Runway 06 is equipped with a Category I ILS.

1.9 Communications

1.9.1 A copy of the relevant transmissions on Shannon Approach and Tower frequencies was obtained and a transcript was produced.

1.10 Aerodrome Information

1.10.1 Shannon Airport is a Category 9 Airfield. Runway 06 is 3,199 meters long and 45 meters wide, with an available landing distance of 3,099 metres. The runway threshold is 47 ft AMSL.

1.10.2 Shannon Airport is equipped with weather radar. The recorded pictures for the time of the event are shown in Annex B and C. These copies are taken from the archived radar recordings, which are stored at low resolution. The high resolution copies are not available, as a request to store them in this format was not made immediately after the event, due to the non-notification of the details of the event to the AAIU.

1.10.3 There have been reports from aircraft that turbulence and/or wind shear, due to local effects, has been experience on approach to Runway 24 when the wind direction lies in the sector from 260° to 320° with wind speeds greater than 15 kts. This has been identified by the IAA in December 1996 and issued as a write-in amendment to the Aeronautical Information Publication (AIP) Ireland in 1997. It was incorporated into the revised Instrument Approach chart in March 2001, with the following note:
"Caution: Turbulence and/or wind shear may be experienced on approach to RWY 24 when wind direction lies in the sector from 260° - 320°T (clockwise) with wind speeds > 15 kts".

It is widely believed that the source of this turbulence and/or wind shear is a large structure built 400 metres to the north of Runway 24 about 1991. This structure is located 2,300 metres after the threshold of Runway 06.

1.10.4 Shannon Airport is not equipped with wind shear detection radar or other wind shear detection equipment.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

1.11.1.1 The aircraft was fitted with a Fairchild A100 CVR.

1.11.1.2 Following the taking of controls by the PIC, a number of calls which would normally be made by the Pilot-Not-Flying (PNF), the role now being filled by the F/O, were not made.

1.11.1.3 The CVR transcript shows that during the roll-out the F/O reported to the Tower, on the instructions of the PIC, that they had encountered wind shear on the approach. The PIC then instructed the F/O to correct this to wind shear on touch down. During subsequent discussion between the Tower and aircraft, the aircraft reported that it had encountered a variable headwind of 47 kts. When further queried by the Tower, the PIC instructed the F/O to report that the variable headwind was encountered at touchdown.

1.11.1.4 The CVR transcript also shows that the PIC instructed the F/O to report a heavy landing. The F/O noted this in the aircraft technical log. However a heavy landing was not reported to ATC at this time.

1.11.1.5 The CVR did not record any wind shear audio warning during the approach and landing.

1.11.2 Flight Data Recorder

1.11.2.1 The aircraft was fitted with a Honeywell DFDR, part number 980-4100-AXUS, which recorded 140 flight parameters.

1.11.2.2 The FDR shows an average wind speed, as recorded by the aircraft's on-board systems, of 20 kts down to an altitude of 1,000 ft. The maximum wind speed recorded during this phase was 25 kts and the minimum was 15 kts. The wind direction was approximately 320°, gradually veering as the aircraft descended.

1.11.2.3 Below 1,000 ft the average calculated wind speed reduced to 10 kts and was still recording this figure at touch down. The maximum wind speed recorded during this phase was 13 kts and the minimum was 8 kts. The wind direction remained at approximately 320°.

1.11.2.4 The FDR samples wind speed and direction data at the rate of once per 4 seconds. Therefore gusts of very short duration may not register on the recording.

1.11.2.5 During the approach the aircraft held a heading of 060° (magnetic), which is exactly the same as the Runway direction. About 4 seconds before landing, the heading reduced, reaching 055° at the first touchdown.

1.11.2.6 At touch down the wind speed, as recorded by the aircraft, was still 10 kts but the system recorded a sudden change of wind direction of 055° from 320° to 015°. The DFDR recorded this change of wind direction only once, in one 4-second frame. This frame spans from 6 to 2 seconds before the initial touchdown. The system did not indicate any significant change of wind speed about the time of this directional change. There were significant amounts of aileron and rudder applied during this frame.

1.11.2.7 Approximately 20 seconds after the initial touchdown, during the de-acceleration phase, the recorded wind speed started to increase reaching a peak of 47 kts at 30 seconds after the initial touchdown. As the recorded wind speed reached 47 kts, a major change of wind direction was again recorded. The recorded wind speed then reduced to 40 kts before climbing to peak of 70 kts was the aircraft slowed to a standstill.

1.11.2.8 The DFDR shows that the aircraft did not maintain stabilised glide-slope on the approach, between 3,000 and 300 ft. At 2,300 ft the aircraft was in excess of 2.5 dots above the glideslope. At 300 ft the aircraft was almost 2 dots below the glideslope.

1.11.2.9 The DFDR shows that during the final phases of the approach the airspeed reduced from 168 kts at 2000 ft to 144 kts at 350 ft, before increasing to 156 kts prior to the initial touchdown.

1.11.2.10 The DFDR showed that the Ground Spoilers, which are used to dump lift on landing, only deployed for 2 seconds at the initial touchdown. It also showed that the throttles were at 46% Throttle Resolver Angle (TRA) and an engine power setting of 58% at the initial touchdown.

1.11.2.11 The DFDR did not record any wind shear warning during this approach and landing.

1.11.3 Handling of Recorders

1.11.3.1 Both the CVR and DFDR were removed from JY-AGK and taken to Jordan by Royal Jordanian Airline personnel on the evening of the event, without consultation with, or the agreement of, the Irish Authorities.

1.11.3.2 A C60 cassette copy of the CVR was subsequently, on request, provided by the Jordanian CAA to the Irish AAIU.

A transcript, with all crew conversations translated into English, was also provided. However when the draft report was circulated to the crew, it was found that the transcript was incomplete. A certified copy of the transcript was provided on 20 March 2001. In this transcript it was noted that due to noise and poor quality of the recording, some communication could not be understood.

1.11.3.3 The FDR was forwarded from Jordan to Airbus Industries, in France, where it was decoded. Airbus provided the investigation with print outs of the FDR parameters.

1.12 Wreckage and Impact Information

Not applicable.

1.13 Medical and Pathological Information

Not applicable

1.14 Fire

There was no fire.

1.15 Survival Aspects

Not applicable

1.16 Tests and Research

Nil

1.17 Organisational and Management

Not Applicable

1.18 Additional Information

1.18.1 PIC's Report

1.18.1.1 The PIC completed a standard AAIU Report, which was returned to the AAIU by the Jordanian Authorities. In this he stated that he believed that he was hit by lateral wind shear after touchdown. He also stated that the aircraft drifted to the left following the initial touchdown.

1.18.1.2 In another report to the Jordanian Civil Aviation Department the PIC stated: " *at the time when the a/c lifted off after the* (initial*) touch down I spotted the ND* (Navigation Display) *showing wind speed of 47 kts. That was the time I believed that I was hit by wind shear at the touch down*".

1.18.1.3 The PIC also stated that he had received simulator wind shear training, but he had not seen what happened in the Shannon landing before.

1.18.1.4 In a response to the draft report the PIC stated that having taken control of the aircraft, he was not under pressure to complete the approach.

1.18.2 Inertial Reference System (IRS)

1.18.2.1 The IRS units are used to provide aircraft ground speed and track. Their output is used in the calculation of wind speed and direction.

1.18.2.2 During the final repair of the aircraft at Toulouse, after the accident, the Inertial Reference Units (P/N HG1050BD02 S/N 447, P/N HG1050BD02 S/N 448 and P/N HG1050BD05 S/N 94080827 were found to be defective. Examination of the aircraft technical records and the reliability printout did not show any indications of IRS defects prior to the heavy landing at Shannon.

1.18.3 Flight Crew Operating Manual (FCOM)

1.18.3.3 The FCOM lays down the action to be taken in the event of a bounce on landing. If a high bounce is encountered, the required action is to abandon the landing and initiate a go-round. If the bounce is not sufficiently high to require the initiation of a go-round, the aircraft pitch attitude should be maintained until the aircraft settles back onto the runway.

1.19 Useful on Effective Investigation Techniques

Nil

2 ANALYSIS

2.1 The Approach

2.1.1 The weather radar recordings and the pilots' observations show that the aircraft passed close to areas of CB activity during the approach. This resulted in moderate turbulence in the approach, in particular above 1000 ft.

2.1.2 The turbulence continued to near ground level, but at a reduced intensity.

2.1.3 The PIC took control in order to avoid the CB cell to the left of the aircraft. As a result, he had to manoeuvre the aircraft in a more demanding manner than required by a standard approach in order to subsequently capture the ILS. This would have contributed to an initial destabilisation of the approach.

2.1.4 The turbulence and light wind shear conditions encountered during the approach made the task of stabilising the approach more difficult.

2.1.5 The aircraft was not stabilised on the glideslope at several stages of the approach.

2.1.6 Below 1000 ft, the aircraft was considerably above the glide slope. When at 300 ft., the aircraft was significantly below the glideslope. The recovery from the high position resulted in a high rate of descent in the later phase of the approach, followed by a late flare with increased engine power and a fast touch-down at 20 kts above Vref.

2.2 The landing

2.2.1 As a consequence of the unstable approach, the initial touchdown was a hard landing followed by a bounce.

2.2.2 The large input of nose down elevator input during the bounce resulted in a heavy landing in a nose down attitude on the second touchdown. The initial impact of this second touchdown was therefore absorbed by the nose wheel, with consequent damage to the aircraft structure in the area of the nose wheel.

2.2.3 The action of the PIC in applying nose down elevator during the bounce was contrary to the procedures laid down in the aircraft's FCOM.

2.2.4 The ground spoilers closed automatically during the bounce because the throttles were advanced above flight idle.

2.2.5 A high lateral G of 0.32 was recorded at point touchdown. This was probably caused by combination of right wing down 3° and 4° left rudder, and a heading 4° left of the runway heading at touchdown.

2.2.6 The drift to the left following the initial touchdown, as subsequently reported by the PIC, was probably caused by the combination of left heading and left rudder at the initial touchdown. The evidence from the aircraft's system and the anemometer shows that the wind throughout the landing was from the left and therefore could not have caused the aircraft to drift to the left.

2.2.7 The 47 kts head wind recorded by the avionic systems on JY-AGK occurred about 30 seconds after the initial touchdown, when the airspeed was less than 90 kts. The Shannon Anemometer did not record a wind speed greater than 5 kts during the entire event.

2.2.8 It was subsequently found that the IRS units had been damaged during the course of this event, as a result of high G loading. A defect in these units, such as increased lag, would have the effect of displaying false wind speed and direction information to the crew, especially during a phase of rapid change, such as aircraft braking.

2.3 Human Factors

2.3.1 The transfer of control from the F/0 to the PIC during the approach was done without briefing either before or after the event. The absence of a briefing following the change of control may have resulted in a lack of clarity in the F/O's understanding of his role. There was a notable absence of some of the calls that would normally be made by the PNF, now the F/O, after the change of control.

2.3.2 The subsequent exchanges, or lack of them, between the crew would indicate that a good Cockpit Resource Management (CRM) environment was not active in the cockpit during the approach.

2.3.3 Having taken control abruptly during the approach, there is a possibility that the PIC would have been under personal pressure to successfully complete the landing, rather than initiating a go-round when he was unable to stabilise the approach. However, the PIC subsequently stated that this was not the case.

2.3.4 As a result of the un-stabilised approach, the PIC found himself too high on the glideslope at 1000 ft and initiated a high rate of descent, to avoid overshooting. This caused an increase in speed, and resulted in him being below the glide slope at 300 ft. In trying to land from this situation he flared late, applied power, landed hard and bounced. During the bounce, there was an input of nose down elevator, which was not the appropriate action. This lead to a second, heavy, touchdown on the nose wheel, which caused the damage to the aircraft's nose structure.

2.4 Weather

2.4.1 The recordings of the anemometer, located close to the runway in use, gave no indications of winds exceeding 5 kts for at least 6 minutes before or after the event. The wind for 1 hour either side of the event did not exceed 10 kts. Furthermore, there are no indications of sudden changes of wind directions. Preceding and subsequent aircraft did not pass any comments on weather conditions to Shannon ATC.

2.4.2 The Shannon weather radar indicated the presence of a CB was located about 6 km north of Runway 06 at 16.09. The indicated shower activity was 3.7mm/hr, which is classified as light to moderate shower. This shower could have generated light downdraughts and turbulence.

2.4.3 During the approach, the wind speed and direction recorded by the systems on JY-AGK correspond well to the readings on the Shannon Anemometer, with the wind speed gradually reducing with altitude and the absence of any indication of gusts or abrupt or major changes in wind direction. Throughout the entire event the Shannon Anemometer did not record any significant changes of windspeed or direction.

2.4.4 The recording of a single incidence of a 055° change of wind direction from 320° to 015° immediately prior to the initial touchdown was recorded by the aircraft system in a period of rapidly changing parameters and control inputs, and may well be erroneous. In this regard, it is significant that no change of wind speed was recorded by the aircraft system

2.4.5 The Shannon Anemometer did not show any such change of wind direction corresponding to that recorded by the aircraft system.

2.4.6 The possibility exists that such a brief change of wind direction may have occurred as a result of the proximity of the nearby CB cell. But it should be noted that the recorded change of direction, if it is correct, would have moved the light wind from a cross-wind to a more head-on wind, thereby easing, rather than aggravating, any handling difficulties.

2.4.7 Given that at the time of approach, the surface wind recorded by the anemometer was 270° at 3 kts and at 2000 ft it was 330° at 30 kts the resultant direction and velocity gradient was 60°/27 kts. This is classified as ***light wind shear***. No material evidence indicating the presence of stronger wind shear was found during the course of the investigation.

2.4.8 According to the data of the Shannon anemometer, there was a cross wind of about 3 kts. A cross wind of this magnitude should not cause any difficulties.

2.4.9 While the wind direction during this event was within the sector noted in the airfield caution for turbulence and/or wind shear for Runway 24, this aircraft landing on 06 would not have entered the area for potential turbulence and /or wind shear until the end of its ground roll. Moreover the surface wind recorded by the anemometer throughout the period of this event was well below the caution wind speed of 15 kts. It is therefore improbable that the phenomenon that gave rise to this caution was a factor in this event.

3. Conclusions

3.1 Findings

3.1.1 The aircraft had been properly maintained and its documentation was in order. The weight and centre of gravity were within authorised limits.

3.1.2 The crew were properly licensed, medically fit and rested to conduct the flight.

3.1.3 The aircraft encountered turbulence and crosswind on the approach, particularly in the earlier phases of the approach. Light downdrafts may also have been present.

3.1.4 The aircraft failed to establish itself correctly on the approach with respect to glideslope. There were also significant speed fluctuations during the approach. Engine power was varied by large amounts during the approach. The approach was not stabilised.

3.1.5 The initial hard touchdown was caused by landing from an approach which had not been stabilised, in particular with regard to an excessively high rate of descent, combined with a late flare with increased engine power, and high speed in the later stages.

3.1.6 The ground spoilers did not fully deploy during the first touchdown due to the manual movement of the throttles above the flight idle position in the final stages of the approach.

3.1.7 The initial hard landing resulted in a bounce. The bounce was aggravated by the non-deployment of the ground spoilers. A nose-down input of 9° during the bounce caused the aircraft to enter a nose down attitude, with the effect that the subsequent touchdown was on the nose wheel, with a nose pitch down angle of 3° to 4°. This second touchdown, on the nose wheel, caused the damage sustained by the aircraft.

3.1.8 The application of nose down elevator during the bounce was inappropriate, and contrary to the aircraft's FCOM procedures.

3.1.9 There are no indications that dangerous wind shear was present at the time of the approach or landing. In particular, the aircraft's systems did not detect wind shear, thereby indicating that significant wind shear was not encountered.

3.1.10 There may have been a change of wind direction immediately prior to touchdown. However the wind was light, and no indications of sudden variations of wind speed were found at that time.

3.1.11 While conditions of turbulence and light wind shear were present during the approach, and there may have been light downdrafts during the approach and a possible change of wind direction immediately prior to touch-down, the weather conditions should have presented no difficulties in the course of a normally conducted stabilised approach and landing. However, when such conditions were added to an unstable approach, the handling pilot was faced with a difficult situation.

3.1.12 The cockpit indications of a sudden increase of wind speed to 47 kts during the landing roll were erroneous, and were as a result of damage to the IRS units, sustained in the high G landing.

3.1.13 There are indications of a breakdown of good CRM practises during the approach.

3.1.14 The weather conditions were not primary factors in this accident.

3.2 Causes

3.2.1 The aircraft experienced a hard landing following an un-stabilised approach, combined with a late flare, increased engine power prior to touchdown and high speed at touchdown.

3.2.2 The aircraft bounced as a result of the hard landing. The bounce was aggravated by the closing of the ground spoilers, which was in turn due to the selected throttle position.

3.2.3 During the bounce there was an inappropriate control input. This resulted in the aircraft landing again heavily on its nose-wheel thereby damaging the nose structure of the aircraft.

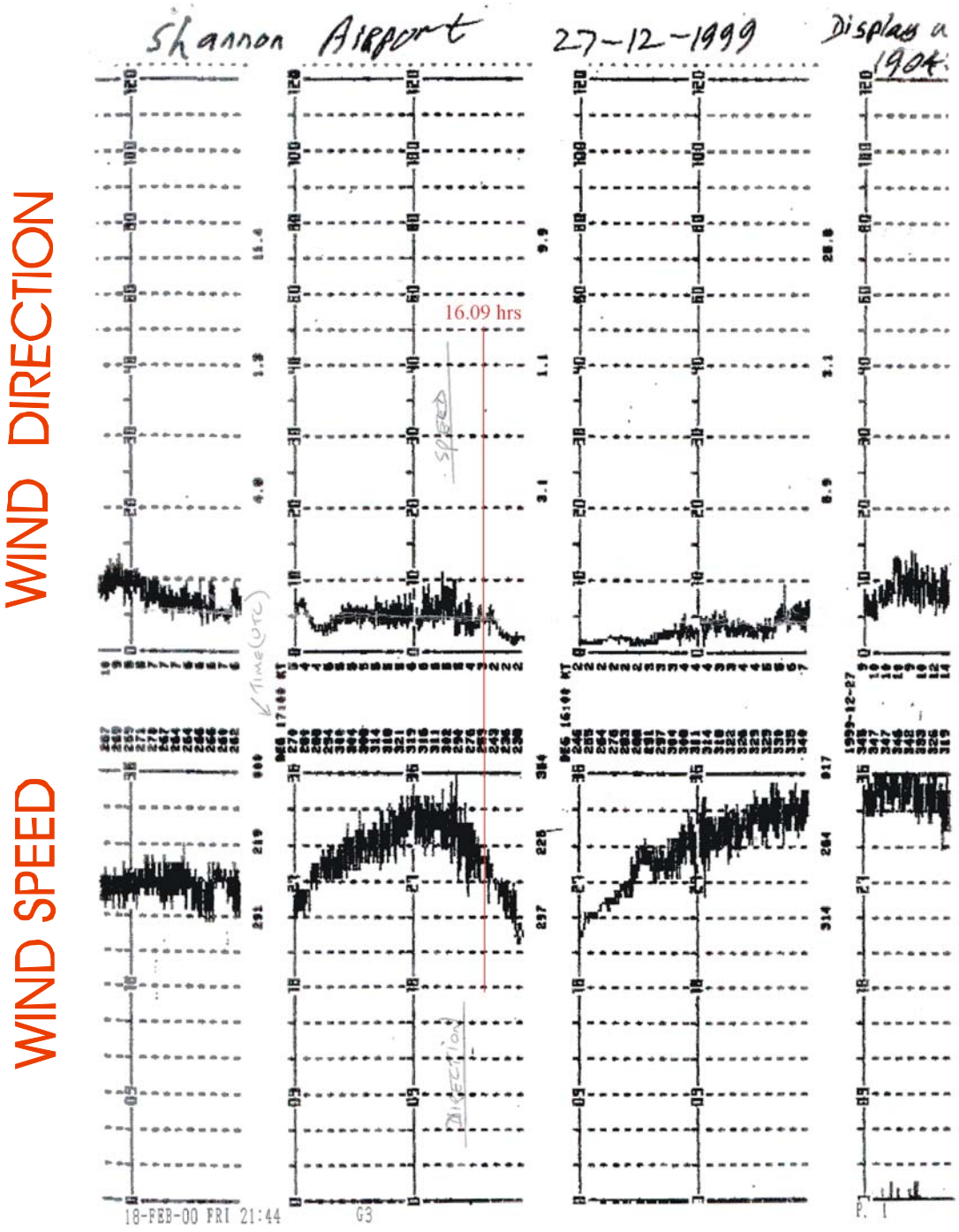
3.2.4 The decision of the PF to continue the approach and landing from an unstable approach, aggravated by moderate turbulence and light wind shear, and possible downdrafts.

4. Safety Recommendations

4.1 The operator should review the effectiveness of its CRM programme with special emphasis on ensuring that standard procedures for both PF and PNF are followed, subsequent to a role change from PF to PNF during an approach. (**SR 12 of 2001**)

ANNEX A

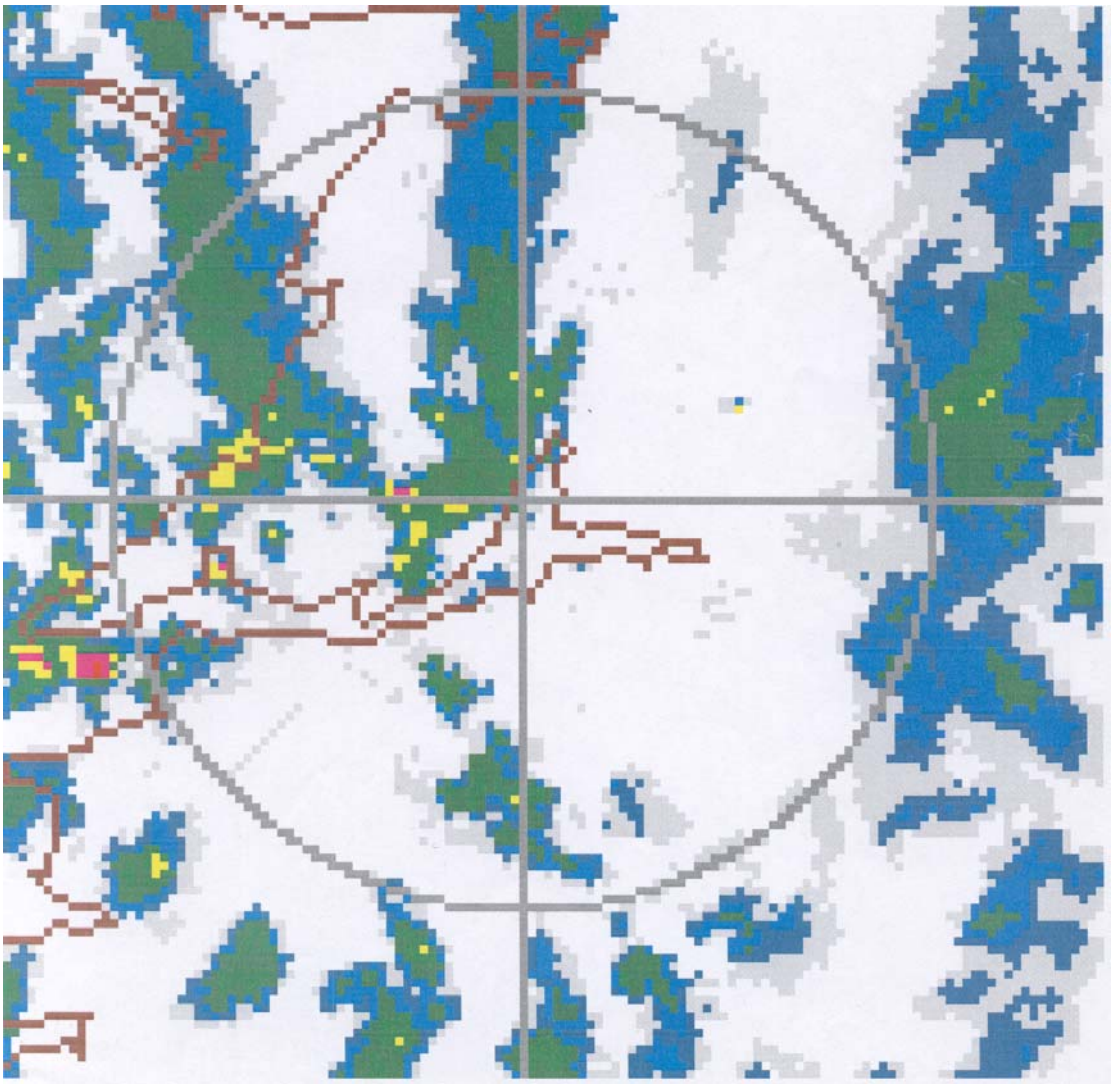
Shannon Anemometer B wind speed and direction data as recorded on 27 December 1999 from 15.00 to 17.00 hrs UTC



ANNEX B

Shannon weather radar as recorded at 16.01 hrs UTC on 27 December 1999

Circle represents 50 km radius
Pixels are 1 km x 1 km



ANNEX C

Shannon weather radar as recorded at 16.16 hrs UTC on 27 December 1999

Circle represents 50 km radius
Pixels are 1 km x 1 km