



# **Air Accident Investigation Unit Ireland**

**FORMAL REPORT**

**ACCIDENT**

**Avions de Transport Regional 72-212,**

**EI-SLM**

**Shannon Airport**

**17 July 2011**



**An Roinn Iompair  
Turasóireachta agus Spóirt**

Department of Transport,  
Tourism and Sport

## FINAL REPORT

AAIU Report No: 2013-008

State File No: IRL00911067

Report Format: Formal Report

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010 and the provisions of S.I. 460 of 2009, the Chief Inspector of Air Accidents, on 17 July 2011, appointed Mr Graham Liddy as the Investigator-in-Charge to carry out an investigation into this Accident and prepare a Report. After Mr Liddy retired, Mr Paddy Judge was appointed Investigator-in-Charge. The French Bureau d'Enquetes et d'Analyses (BEA), as State of Manufacture appointed a non-travelling Accredited Representative to assist the Investigation.

The sole purpose of this Investigation is the prevention of aviation Accidents and Incidents. It is not the purpose of the Investigation to apportion blame or liability.

Operator:	Aer Arann
Manufacturer:	ATR (Avions de Transport Regional)
Model:	ATR 72-212
Nationality:	Ireland
Registration:	EI-SLM
Type of Operation:	Commercial Air Transport, Passenger
Location:	Shannon Airport (EINN), Ireland
Date / Time (UTC) <sup>1</sup>	17 July 2011 @ 09.21 hrs

<sup>1</sup> UTC: Universal Time Co-ordinated. All timings in this report are quoted in UTC; to obtain the local time add one hour.



## SYNOPSIS

The scheduled passenger flight from Manchester (EGCC) to EINN made two approaches to Runway 24 (RWY 24) in blustery weather conditions that featured a strong and turbulent crosswind. The first approach resulted in a bounced landing following which a go-around was performed. The aircraft then conducted a second approach. Following a number of bounces the aircraft impacted the runway in a nose down attitude and the nose gear collapsed. The aircraft skidded along the runway before coming to a stop. There were no injuries but the aircraft was deemed to be damaged beyond economical repair.

A Preliminary Accident Report was published on the 23 August 2011. This Report contained Safety Recommendation IRLD2011010 which recommended that the Operator review the maximum crosswind limitations for approaches onto RWY 24 at EINN. The Safety Recommendation was accepted by the Operator and new reduced limits were published.

This Final Report issues four further Safety Recommendations.

## NOTIFICATION

The Duty Operations Manager at EINN informed the AAIU of the accident following which an AAIU team was dispatched to EINN.

## 1. FACTUAL INFORMATION

### 1.1 History of the Flight

The aircraft and crew commenced operations in EINN that morning, departing at 05.52 hrs and arriving at EGCC at 07.13 hrs. During the turnaround, fuel was uplifted and 21 passengers boarded. Using the flight number and call sign EI-3601 the scheduled passenger service departed EGCC at 07.47 hrs for EINN with an estimated flight time of one hour and nine minutes. En-route operations were normal and, in consultation with ATC, the aircraft descended and was cleared to self-position to DERAG<sup>2</sup> for an Instrument Landing System (ILS) approach to RWY 24.

At 09.08 hrs the aircraft commenced an approach to RWY 24 in strong and gusty crosswind conditions. Following a turbulent approach difficulty was experienced in landing the aircraft, which contacted the runway in a nose-down attitude and bounced. A go-around was performed and the aircraft was vectored for a second approach. During this second approach landing turbulence was again experienced. Following bounces the aircraft pitched nose down and contacted the runway heavily in a nose down attitude. The nose gear collapsed and the aircraft nose descended onto the runway. The aircraft sustained damage with directional control being lost. The aircraft came to rest at the junction of the runway and a taxiway.

Following engine shutdown the forward Cabin Crew Member (CCM) advised the cockpit that there was no smoke and that the doors could be opened following which, an evacuation was commenced. Airport fire crews arrived on scene promptly and assisted passengers disembarking the aircraft. There were no injuries.

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<sup>2</sup> DERAG: A waypoint 15 nautical miles (nm) on the extended approach to RWY 24.

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**1.1.1. Interviews and Reports**

Both pilots were interviewed and reports were supplied to the Investigation from a number of sources.

**1.1.1.1. Pilot Interview**

The Commander, who was the handling pilot or Pilot Flying (PF) said that she had briefed to touch-down at the end of the RWY 24 Touch-down Zone (TDZ). This was to avoid possible turbulence from a hangar abeam the TDZ of RWY 24 during the final stages of the approach/landing. The PF stated that both pilots were aware of the cautionary warning regarding turbulence given on the approach plate for RWY 24.

Although the touchdown was just beyond the TDZ, the PF considered, given the 10,000 ft length of RWY 24 and the landing performance of the ATR 72, that the remaining runway length available was more than sufficient to achieve a safe landing. The PF stated that the approach was flown using  $V_{app}^3 + 15$ , the maximum allowed. During the flare the speed was fluctuating and the *"gusts were nasty"*. The aircraft touched down but a gust caught the right wing.

The aircraft lifted but touched down more heavily a second time, so a go-around was initiated as they were further down the runway than desirable. The PF did not feel that the nose gear had contacted the runway the first time. During the go-around the undercarriage was retracted and normal cockpit indications were observed by the Flight Crew with no warning tones sounding during the landing or go-around.

The PF stated that they were visual for the second approach with the ILS tuned for reference. The aircraft was configured for landing with gear down and flaps 30 by 4 nm. She recalled that it became rougher below 1,000 ft and that the autopilot was disconnected at about 830 ft. This time their aiming point was the normal landing position on the TDZ of RWY 24. The PF said that they were on the visual glideslope on short finals when turbulence from the hangar was experienced. Again the right wing lifted and the aircraft rose after it touched down. Power was applied to stabilise the aircraft but again it bounced.

The PF became increasingly concerned about the remaining length of runway available and decided to land the aircraft. A positive forward input was made on the control column to reduce the effect of the bounce so that a normal flare could be made. Although go-around was called, the PF felt that the aircraft did not respond normally and simultaneously heard a loud scraping noise. The landing aural warning activated<sup>4</sup> so she closed the power levers and used full right rudder to try to keep directional control on the runway.

The PF said that there was no directional control of the aircraft after the initial runway impact as the rudder had jammed. Reverse and brakes were used as they approached Taxiway A. When the aircraft stopped the PF was unable to shut down the engines by retarding the condition levers, as the levers would not retard to the aft position and the propellers would not feather. The engines were therefore stopped by pulling the fire handles.

<sup>3</sup> **Vapp:** See Section 1.6.2.

<sup>4</sup> A warning horn advising that the landing gear is not in a safe condition.



The PF stated that the forward CCM called the cockpit, confirmed that there was no smoke and was told to open the passenger door. She then decided not to perform an emergency evacuation as they had not detected any evidence of fire or smoke.

#### **1.1.1.2. Co-Pilot Interview**

The First Officer (FO), who was the pilot not flying (PNF) or pilot monitoring (PM), confirmed that the first touchdown was intentionally long to avoid the known turbulence from the hangar abeam the TDZ. They felt a kick from this turbulence during the first landing. During the go-around, after pitch up, the PNF put the go-around speed into the ADU<sup>5</sup>. Following this, a second approach was conducted with plenty of time being taken to fly a reasonably wide downwind leg.

The PNF felt that after the flare the aircraft landed on both main gears, then the right wing came up and the aircraft lifted. She thought the aircraft then came down quite flat, as though there was no flare, and was not aware of the nose gear impacting the runway or that the nose gear had collapsed. The PNF stated that there was a difference in techniques between landing the ATR 72-500 and the -200 series, the -200 requiring power on in order to cushion the landing.

#### **1.1.1.3. Cabin Crew Report**

The Cabin Crew Report submitted after the flight stated that the fibreglass shroud of the aft toilet became separated from its enclosure during the first landing.

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#### **1.1.1.4. ATC Report**

The EINN Tower Staff reported that they observed the aircraft experiencing difficulties in landing during its first attempt. It conducted a go-around and was transferred to the Approach Controller who vectored the aircraft for another approach to RWY 24. The Tower advised EINN Fire Service of the aircraft's difficulties and that it would commence another approach shortly.

ATC stated that during the subsequent landing the front wheel assembly was observed to collapse with ensuing sparks. The aircraft was seen to skid along the surface and eventually come to a halt at the Taxiway A intersection with its nose pointing towards Taxiway A. The crash siren was immediately activated and the Fire Service was notified by a call on the direct line to the Watch Room. No fire was observed and the passengers later disembarked normally.

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<sup>5</sup> ADU: Advisory Display Unit.

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**1.2 Injuries to Persons**

No injuries were reported to the investigation

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor /None	4	21	
TOTAL	4	21	0

**1.3 Damage to Aircraft**

The aircraft came to rest fully down on its nose. The nose undercarriage leg, which normally retracts forwards, had folded rearwards into the fuselage behind the undercarriage bay (this failure is further addressed in **Section 1.12**).

This resulted in significant structural damage to the under-surface of the nose of the aircraft which suffered abrasion damage, in addition to the damage caused by the rearwards retraction of the nose leg, contrary to normal operation.

Part of the right rear nose undercarriage door was found embedded in the right hand composite wing root fairing. Other debris impact damage was noted on the right side of the fuselage. One blade of the No. 1 propeller was damaged, consistent with contacting debris while under power.

Subsequently, the aircraft was deemed to be beyond economical repair.

**1.4 Other Damage**

A runway taxiway sign and a runway edge light were destroyed.

**1.5 Personnel Information****1.5.1. (Commander):**

Personal Details:	Female, aged 29 years
Licence:	JAA IRL ATPL - Valid
Last Periodic Check:	14 March 2011
Medical Certificate:	14 July 2011



#### Flying Experience:

<b>Total all types:</b>	2,882	hours
<b>Total on type:</b>	2,444	hours
<b>Total on type P1:</b>	212	hours
<b>Last 90 days:</b>	261	hours
<b>Last 28 days:</b>	76	hours
<b>Last 24 hours:</b>	3	hours

#### Duty Time:

<b>Duty Time up to incident:</b>	4 hours 20 mins
<b>Rest period prior to duty:</b>	40 hours 00 mins

The Commander, who had been recently promoted, commenced command training on the 11 April 2011. Base Training was completed on the 19 April 2011. Command training took place over 40 sectors (44.55 hours) with 5 different captains, all of whom recorded satisfactory progress. The Final Command Line Check was on 3 May 2011. During the next 2 ½ months before the accident she flew a total of 212 hours over 152 sectors.

#### **1.5.2. (First Officer)**

<b>Personal Details:</b>	Female, aged 37 years
<b>Licence:</b>	JAA UK CPL(A) - Valid
<b>Last Periodic Check:</b>	8 July 2011
<b>Medical Certificate:</b>	10 December 2010

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#### Flying Experience:

<b>Total all types:</b>	1,678	hours
<b>Total on type:</b>	1,351	hours
<b>Total on type PI:</b>	0	hours
<b>Last 90 days:</b>	220	hours
<b>Last 28 days:</b>	131	hours
<b>Last 24 hours:</b>	6	hours

#### Duty Time:

<b>Duty Time up to incident:</b>	4 hours 20 mins
<b>Rest period prior to duty:</b>	16 hours 00 mins

The First Officer stated that she commenced employment with the Operator in June 2008 and was made redundant 5 months later. She was re-employed in April 2010, the accident happening 1 year and 3 months later.

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### 1.6 Aircraft Information

The ATR 72-212 is a high wing monoplane powered by two Pratt and Whitney PW127 engines which drive Hamilton Standard 247F four bladed propellers. It has two hydraulic systems, green and blue; the green system powers the retractable landing gear and brakes while the blue system powers the nose gear steering system. The entry door is an outward opening, non plug type door which incorporates a stairs. A folding handrail attached to the door automatically erects when the door is opened.

The Operator's Form AAE76, which notified flight crew of defects that might affect the operation, contained a notice that the aircraft had been downgraded to CAT I approach standard on 18 July 2011 until a simulated CAT II approach was carried out.

#### 1.6.1. Leading Particulars

<b>Aircraft type:</b>	ATR 72-212
<b>Manufacturer:</b>	Avions de Transport Regional
<b>Constructor's number:</b>	413
<b>Year of manufacture:</b>	1994
<b>Certificate of registration:</b>	15 March 2011
<b>Certificate of airworthiness:</b>	28 May 2010
<b>Airworthiness Review Certificate:</b>	27 May 2011
<b>Total airframe hours:</b>	32,617
<b>Total cycles:</b>	37,149
<b>Engines:</b>	2 x Pratt & Whitney – PW127
<b>Maximum authorised take-off weight:</b>	22,000 kg
<b>Actual Take off weight:</b>	18,307 kg
<b>Maximum Landing Weight:</b>	21,350 kg
<b>Estimated weight at time of accident:</b>	17,284 kg
<b>Centre of Gravity index limits (at accident weight):</b>	7.3 – 12.9
<b>Centre of gravity at time of accident:</b>	10.7

#### 1.6.2. Aircraft Operational Information

The ATR 72 FCOM<sup>6</sup>, Section 3.08.02, states that the airspeed required for the final approach is  $V_{app}$ , with  $V_{app} = V_{mHB}^7 + \text{wind factor}$  or  $VMCL^8$ , whichever is higher.

Wind factor is defined as the highest of 1/3 of the headwind velocity or the gust in full<sup>9</sup>, the maximum wind factor being 15 kts.

<sup>6</sup> **FCOM:** Flight Crew Operations Manual

<sup>7</sup> **VmHB:** Minimum speed used for approach. It also provides the best two engines rate of climb.

<sup>8</sup> **VMCL:** The minimum control speed for flight with the critical engine inoperative and the other set at go-around power while using 5° bank towards the live engine.





The estimated weight at time of accident was 17,284 kg. In accordance with procedure, this weight would have been rounded up, according to the Operator's procedure, to 18,000 kg thus giving a VmHB Flap 30 of 99 kts.

## 1.7 Meteorological Information

### 1.7.1. Automatic Terminal Information Service (ATIS)

The EINN ATIS "Golf", received by the Flight Crew, stated that RWY 24 was damp, the wind velocity was 300°/20 kts, visibility 10 km, few clouds at 1,000 ft, broken cloud at 1,300 ft, temperature 14°C, dew point 12°C with moderate turbulence for RWY 24. The subsequent ATIS "Hotel" was identical except for the wind, which was given as 310°/23 kts, gusting 32 kts.

During both approaches ATC passed wind information to the aircraft four times and cautioned, on commencement of both approaches, that *"occasional moderate turbulence observed and forecast in touch-down zone RWY 24"*. The four wind reports were very similar and the strongest winds given were on the third report: *"310°/24 kts gusting maximum 32 minimum 14"*.

### 1.7.2. Previous Evening Turbulence Report

The previous evening, the same aircraft, but with a different flight crew, reported difficult conditions during approach to RWY 24 on two separate flights. In both cases the wind strength, gusts and direction were similar to those prevailing at the time of the accident. The flight crew in question reported this to ATC immediately after landing and a notification of this report was put on EINN ATIS.

### 1.7.3. Meteorological Aftercast

Met Éireann, the Irish Meteorological Service, provided the following information after the incident.

**Meteorological Situation:** A low pressure system over Scotland maintained a moderate to strong, unstable northwest to north airflow over the area.

<b>Surface Wind:</b>	300/25 kts gusting 32-36 kts
<b>Wind at 2000ft:</b>	320-330/50 kts
<b>Visibility:</b>	10+ km
<b>Weather:</b>	Isolated light rain showers
<b>Cloud:</b>	FEW/SCT 1,000-1,500 ft SCT Cb 1,800 ft BKN Cu 1,800 ft
<b>Surface Temp/Dew Point:</b>	14/11°C
<b>MSL Pressure:</b>	998 hPa
<b>Freezing Level:</b>	7,000 ft

<sup>9</sup> According to the Manufacturer, "gust in full" is the difference between the maximum gust velocity reported by ATC and the steady state wind. This difference is commonly called the "gust factor".

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### 1.7.4. Met Éireann Comments

Met Éireann commented that:

*In general the atmosphere can generate wind shear<sup>10</sup> and turbulence whether stable or unstable. An unstable atmosphere with a strong gradient can generate wind shear through a combination of convective and mechanical turbulence. A stable, moist airflow across an obstruction such as mountains and hills can produce lee waves and rotors.*

*At the time of the incident the atmosphere was generally unstable – absolute instability at low level with conditional instability aloft and a shallow inversion at about 6000 to 7000ft.*

*The gradient wind speed was 50 kt with the hangar upwind of TDZ RWY24. Such a gradient speed would normally be expected to generate moderate low-level turbulence or wind shear. As turbulence and wind shear at low levels can be generated or accentuated by the degree of surface “roughness”, it is reasonable to hypothesise that the .... hangar would have accentuated the “natural” turbulence of the airflow in the circumstances pertaining at the time of the incident. However, without detailed mathematical modelling, it is not possible to quantify this effect with any certainty.*

Met Éireann stated that the following turbulence warning message is appended to the Local Routine and Special Meteorological Reports for the TDZ RWY 24 at Shannon Airport when the wind direction is between 270° and 010° and the mean wind speed is in excess of 15 kt and gusts in excess of 25 kt:

*“MOD OCNL SEV TURB FCST<sup>11</sup> TDZ RWY 24 or OCNL MOD TURB FCST TDZ RWY 24 or (when turbulence observed) MOD TURB OBS AND FCST TDZ RWY 24”*

Met Éireann further stated that this instruction was first issued in 1992 because of an increase in the number of wind shear/turbulence reports following construction of the Hangar. This instruction quoted 3 examples of downdrafts experienced at 100 ft and 50 ft. Since 1992 there have been many examples of turbulence/wind shear reports on the TDZ of RWY 24.

### 1.8 Aids to Navigation

Neither the ILS, which the aircraft used to conduct an approach, nor the other navigational aids in use at the time recorded evidence of any malfunction.

### 1.9 Communications

ATC VHF and radar recordings were provided to the Investigation. Radar recordings showed the aircraft position. At 08.56:30 hrs the aircraft was transferred to Shannon Approach which cleared it for an approach informing the aircraft that the ATIS was “Hotel” and subsequently cleared the aircraft to 3,000 ft when 30 nm from EINN. At 09.00 hrs the aircraft was 25 nm from EINN. At 09.02:30 hrs, at 15 nm, the aircraft was transferred to Shannon Tower and reported established on the ILS.

<sup>10</sup> Both “wind shear” and “windshear” are used in this Report depending on source documentation.

<sup>11</sup> Moderate Occasional Severe Turbulence Forecast



The aircraft was cleared to land and advised that the wind was 310°/17 kts gusting to 29 kts and was cautioned regarding possible turbulence at the touchdown point of RWY 24.

This was acknowledged and the aircraft crossed waypoint ROSRO at 09.03:50 hrs descending through 3,500 ft. Approaching the outer marker the Tower advised that the wind was “310/21 gusting 29 Minimum 11”. At 09.08 hrs radar showed the aircraft as having landed and shortly afterwards climbing again. It was then transferred back to Approach Control and stated that it wished to conduct another approach to RWY 24. It was then given vectors for a right hand downwind, a right hand base to join finals and a turn inbound to intercept the ILS.

When established on the ILS it was transferred to Shannon Tower which advised that the wind was “310/23 knots gusting maximum 32 minimum 13, cleared to land” and “... occasional moderate turbulence observed and forecast touchdown zone RWY 24”, which the PNF acknowledged. At 09.16 hrs a further wind report of “300/24 knots gusting maximum 32 Minimum 13” was given. At 09.21:30 hrs the recording showed the aircraft on the ground.

#### 1.10 Aerodrome Information

The main runway at EINN is RWY 06/24. RWY 24 is 3,199 metres (m) long and 45 m wide. Its threshold elevation is 15 ft. The runway is equipped with an ILS, PAPI, runway centre line and edge lights and an approach lighting system that supports CAT I and II operations. Taxiway A is located approximately two thirds of the way along the runway and leads east to the apron. It is 23 m wide.

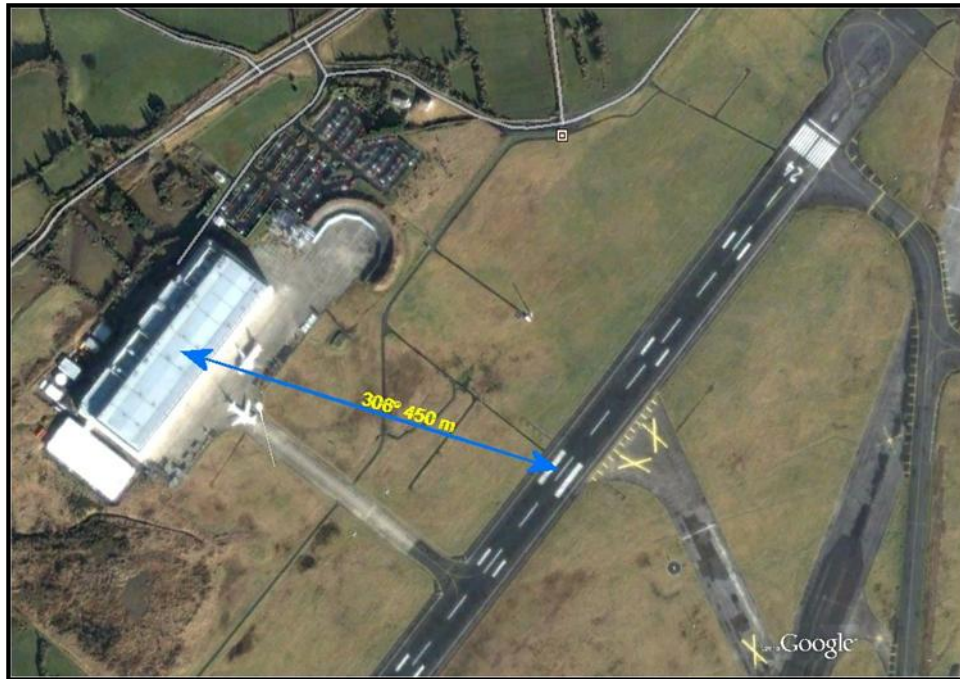
A secondary runway (RWY 13/31), originally constructed in 1945/46, was withdrawn from service, due to its surface condition not being in conformity with ICAO recommendations regarding longitudinal slope changes and smoothness of surface. The Investigation was informed by the airport operator that a maximum weight restriction of 25 tonnes for landing or take-off movements had been imposed and the runway was last used in 2001 for landing and take-off. RWY 13/31 was declassified as a runway on the 26 July 2012; it is currently used as a taxiway. A single isolated Hangar (**Photo & Graphic No. 1**) is located 450 m to the northwest of the TDZ aiming point on RWY 24. The Hangar is 240 m long, 92 m wide and 24.6 m high.

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**Photo No. 1: Hangar from opposite the TDZ aiming point**

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**Graphic No. 1: Hangar relative to the TDZ RWY 24**

### 1.11 Flight Recorders

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The flight recorders were both recovered on the day of the accident. Data from these devices was downloaded the following day under the supervision of the Investigation at the Air Accident Investigation Branch (AAIB) facility in Farnborough, UK.

#### 1.11.1. Cockpit Voice Recorder (CVR)

The four channel CVR recording was of good quality and covered 31 minutes. It commenced during the descent of the aircraft towards EINN and ended 2 minutes and 12 seconds after the aircraft stopped.

In general, it recorded normal cockpit procedures with checklists and Standard Operating Procedures (SOPs) being adhered to, with the exception of speed deviation call outs during both approaches.

During both approaches the Flight Crew made references to likely turbulence from the Hangar and attempting to avoid it. During the first approach the PNF was recorded saying that the full 15 knots gust factor would be used and that the “fly speed” ( $V_{app}$ ) would be approximately 114 kts.

Following the go-around the CVR recording indicated that the PF had higher levels of stress and following an ATC query a second approach was immediately requested. During a subsequent crew discussion, where the turbulence experienced was attributed to the Hangar, a decision was made to land in the normal TDZ.





On the base leg the PNF commented that it was her first go-around in the past year and the PF responded that it was her first go-around in command and her third ever during line operations<sup>12</sup>. Following a radar vector to final the aircraft became established on the localiser at 6.5 nm.

During the landing, following an initial momentary rumble, a grating noise commenced followed immediately by a gear unsafe warning. This grating sound continued for 42 seconds. Some confusion arose when the PF found that the propellers would not feather and the engines would not shut down.

She requested the PNF, who had already transmitted a “Mayday” call to ATC, to pull the fire handles. The forward CCM was called immediately after the fire handles were pulled, contacted the cockpit 6 seconds later (34 seconds after stopping) and was advised that the Rescue Services were en-route. The CCM advised that they were OK in the cabin, that the doors could be opened and was told that the engines were stopped. After 74 seconds a checklist was commenced by the PNF but sound became muffled for a short period. After 2 minutes and 12 seconds the CCM was recorded reporting that the passengers were off the aircraft, following which the CVR stopped.

#### 1.11.2. Digital Flight Data Recorder (DFDR)

The DFDR recorded, inter alia, pitch and roll angles and both vertical and longitudinal accelerations. The DFDR data showed that both approaches were flown in turbulent conditions with indicated airspeed (IAS) fluctuations of 10 kts and roll variations of up to 10°. The left drift angle recorded during both approaches was approximately 15° at 1,000 ft Radio Altimeter (RADALT), decreasing to 11-12° at 20 ft.

The indicated airspeed (IAS) recorded during the end of the first approach (Graphic No. 2) before the flare averaged 125 kts with torques averaging 25-27% at -3.25° average pitch. At 100 ft, an IAS variation of -15 kts in one second was recorded. Engine torque increased, reaching a maximum of 52% torque at 6 ft and then progressively reduced.

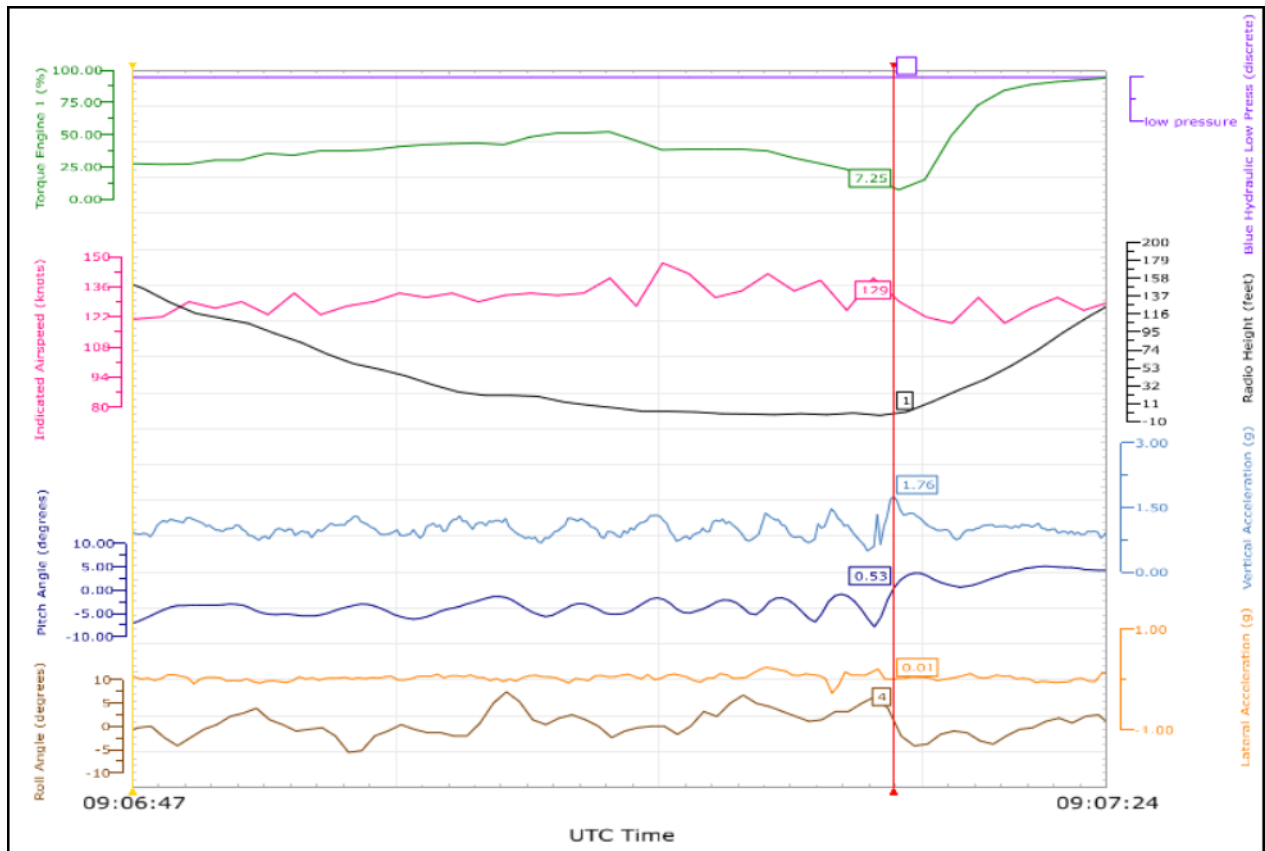
The flare pitch-up commenced at 20 ft followed by an extended 8 second float during which the IAS averaged 136 kts, varying from 125 to 142 kts. Maximum IAS variations from +20 to -14 kts in one second were recorded during this flare. At this same time the aircraft was rolling through 10° with its pitch oscillating between -3° to -1.5°.

The DFDR recorded that, at a height of -3 ft following two bounces at 2 second intervals, an elevator input of -5.4° caused a nose-down pitch angle of -7.9° resulting in a 1.34 g-spike in vertical acceleration. The pitch of the aircraft then rose immediately to +0.5° in 0.7 of a second, at which point, a second g-spike of 1.76 g occurred. The DFDR Weight on Wheels (WOW) discrete, which samples once per second did not record main gear ground contact.

Following this the aircraft continued to pitch up, power was applied and the aircraft climbed to circuit height.

<sup>12</sup> Pilots perform several go-around manoeuvres during regulatory simulator training every six months.

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Graphic No. 2: DFDR Recording of First Approach

The DFDR recorded similar turbulent conditions during the second approach. The recording showed that the approach was commenced with the autopilot engaged and that 30° of flap was selected at 1,330 ft at an IAS of 140 kts. The autopilot was disconnected at 660 ft and, from that height to 100 ft, the IAS was generally 126 to 130 kts with engine torque at 27%. At 100 ft the IAS increased from 117 kts to 140 kts (**Graphic No. 3**). Shortly afterwards, at 8 ft, the IAS was recorded as having decreased to 123 kts and torque increased slightly to 30%. Pitch then increased to -1.5° as the aircraft flared and, at -2.8 ft, the pitch oscillated through three cycles by 3° to 4° with engine torque increasing to 48%.

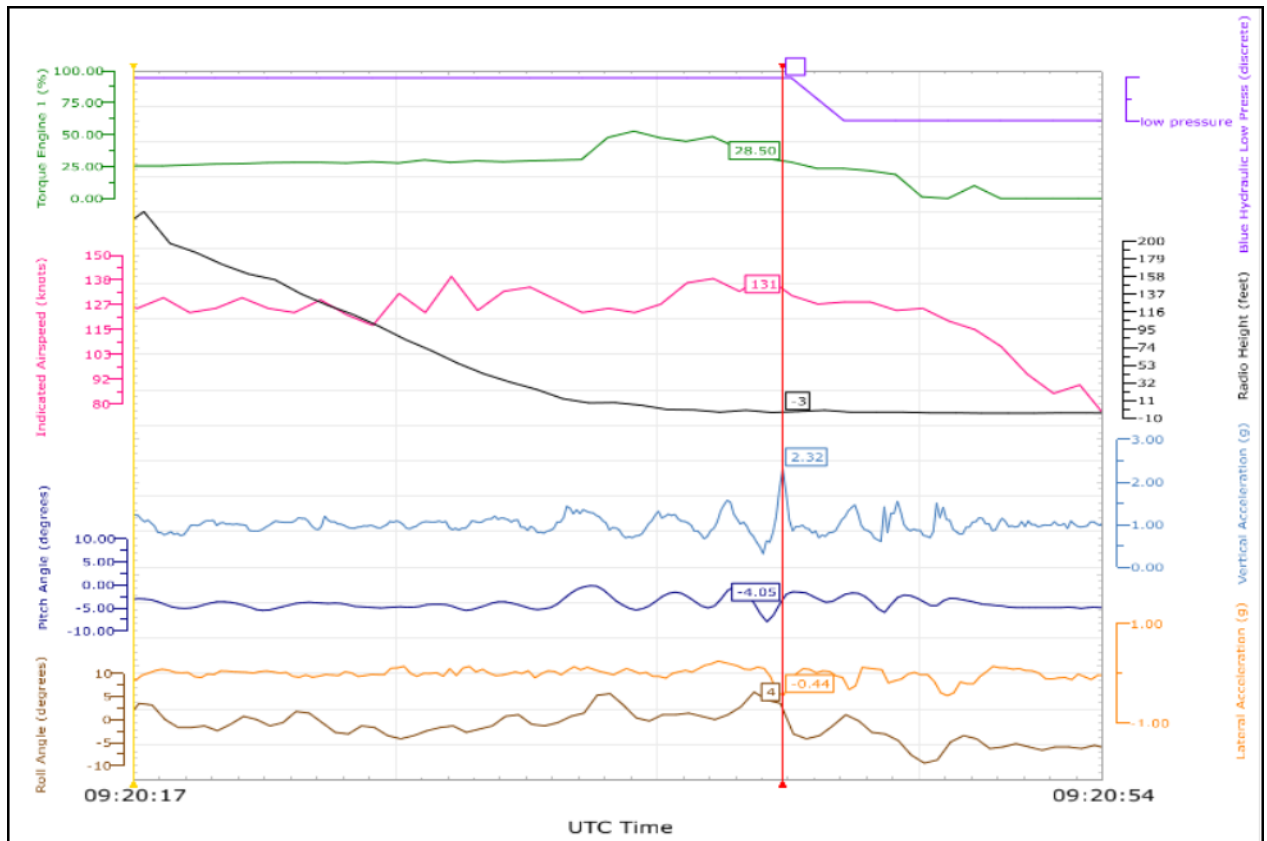
During this period the IAS increased from 123 to 139 kts and torque progressively reduced. IAS variations from +10 kts to -6 kts in one second were recorded during this 3 second flare during which one bounce occurred.

The DFDR then recorded that, at a height of -3 ft, an elevator application of -10.4° caused a nose-down pitch angle of -8.0°, the airspeed at the time being 131 kts. A 2.32 g-spike in vertical acceleration followed immediately. Blue system hydraulic failure was recorded almost immediately. The DFDR subsequently recorded 3 further positive g peaks before the main gear WOW discrete indicated that main wheels of the aircraft were on the ground.

Analysis of other FDR parameters showed that during both approaches, at approximately 20 ft, a pitch nose up input was recorded on the left control column followed by a second nose up input a few seconds afterwards.

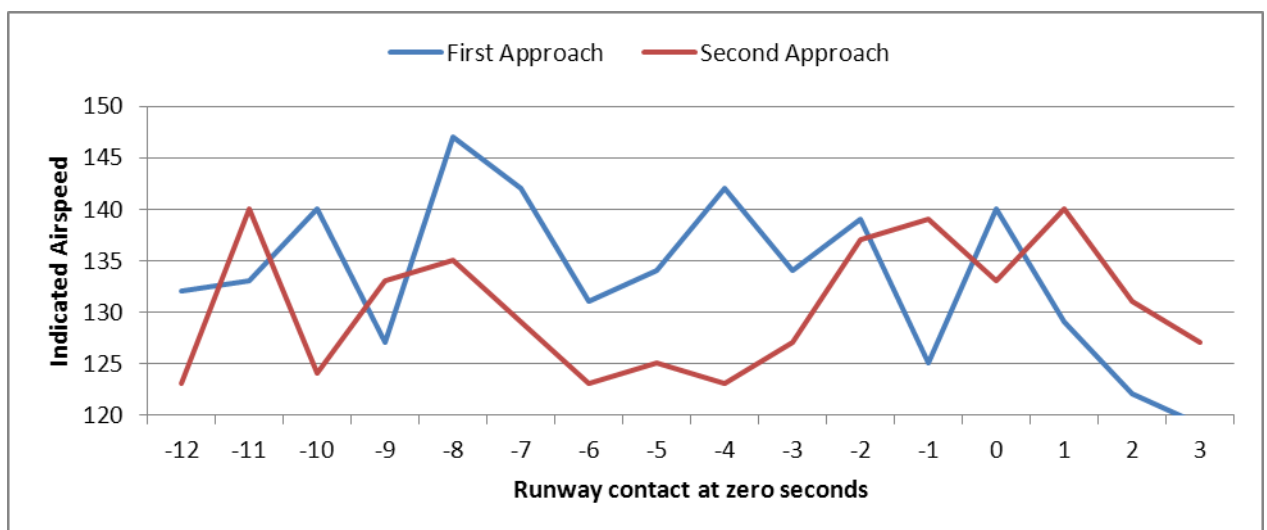


Then, nose down inputs were recorded on the right control column during both approaches. This led to an excessive nose down pitch attitude with a subsequent impact on the nose landing gear. Neither pilot recalled such inputs subsequently.



**Graphic No. 3: DFDR Recording of Second Approach**

**Graphic No. 4** compares the indicated airspeeds during the final seconds of both approaches.



**Graphic No. 4: Indicated airspeeds**

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### 1.12 Wreckage and Impact Information

The initial point of impact on RWY 24 was found 740 m from the beginning of the runway, in the TDZ and approximately 80 m before the entrance taxiway to the Hangar. The separated RH nose wheel was found 167 m further along, in the grass to the left of RWY 24 TDZ abeam the hangar. Marks were found on the surface of the runway for 1,197 m, consistent with the nose gear leg and nose of the aircraft being in contact with the runway until the aircraft stopped.

The damage to the nose fuselage area was found to have caused a total restriction of the rudder pedals and engine condition levers movement. This prevented the aircraft being steered on the ground and the engine condition levers from being retarded into the engine shut-down position. Hydraulic pipelines (blue system) attached to the nose gear leg, which powered nose wheel steering and the retraction/lowering system, were found ruptured due to the nose gear leg retracting rearwards.

The axle of the right nose wheel had failed, resulting in the separation of this wheel. Both nose wheel tyres had burst and the rim of the separated wheel hub was flattened at one point on its circumference.

The nose gear drag brace, which controls the position of the nose gear, had separated from the nose leg. The lower web attachment eye of the drag brace, which connected the drag brace to the front of the nose gear leg, had failed and the eye had opened up completely. The appearance of the fracture surfaces on both sides of this failure were consistent with being ground down due to abrasion. The drag brace was sent for further examination (**Section 1.16**).

Following inspection of the aircraft the Investigation was satisfied that continuity of the primary flight controls was established. No pre-existing aircraft flight control or technical problem was identified.

### 1.13 Medical Information

Not applicable.

### 1.14 Fire

There was no fire.

### 1.15 Survival Aspects

There were no injuries and the aircraft was evacuated through the rear entry door.

### 1.16 Tests and Research

The failed RH nose gear stub axle and wheel were submitted to an approved facility for metallurgical examination. The report of this examination stated that the wheel rim had been slightly flattened, having suffered severe impact damage. This was coincident with the damage to the tyre.





The report stated that the fractured surface of the nose gear stub revealed features indicative of tearing/shear over 40-50% of the surface. The remainder of the fractured surface had a chevron type pattern of fibrous fast fracture, indicative of a single event overload. It found no indication of any material or manufacturing defect associated with the fracture or any pre-existing defect such as fatigue cracking. It concluded that failure of the stub axle occurred due to a single event overload in bending.

The nose undercarriage drag brace link was sent to a different approved facility for examination. The facility reported that the fracture faces of the drag brace link were destroyed by abrasion against the runway and so no definite conclusions regarding the nature of the fracture could be drawn.

However, there had clearly been significant plastic deformation of the attachment eye end. In addition, the material hardness, conductivity and ultimate tensile strength of samples taken from the drag brace link were all satisfactory.

#### **1.17 Organizational and Management Information**

The Air Operators Certificate (AOC) was valid until 31 January 2012.

#### **1.18 Additional Information**

##### **1.18.1. Airport Video Recorders**

Both landings were recorded on a number of airport security cameras (CCTV)<sup>13</sup> of different quality and coverage. These were located both on the airport Terminal building and the Hangar near the TDZ of RWY 24. Depending on their position and coverage they recorded parts of the landings though they did not provide complete coverage.

The first touchdown was recorded by a camera of good quality. This showed the aircraft contacting the runway in a significant nose-down attitude well down the runway. The aircraft immediately bounced nose up with the main gear momentarily contacting the runway and a go-around was performed.

The recording of the second landing was of poorer quality but a number of bounces were observed with the final touch-down being outside camera coverage and not recorded, as it occurred at an earlier point along the runway than the Terminal camera covered. However, the subsequent ground roll was clearly recorded by the Terminal camera. This showed the aircraft with the nose wheel collapsed and the nose scraping along the runway. Smoke/steam can be seen emanating from the nose area until the aircraft stopped. The aircraft continued along the runway but gradually veered to the left and exited the runway surface onto the grass to the left of the runway, as it approached Taxiway A.

The left propeller was then seen to strike a runway sign causing debris. The aircraft continued to turn left and came to a stop on the left edge of Taxiway A.

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<sup>13</sup> CCTV: Closed Circuit Television.

## FINAL REPORT

**1.18.2. Manufacturer Information**

Procedures for landing the ATR 72 are published in the Manufacturer's FCOM. These state, inter alia:

FCOM Section 2.01.03:

*The maximum demonstrated crosswind on dry runway is 35 Kts.*

FCOM Section 2.02.12:

**LANDING**

*In order to minimize landing distance variations the following procedure is recommended:*

- *Maintain standard final approach slope (3°) and final VAPP until 20 ft is called on radio altimeter.*
- *At « 20 ft » call by PNF, reduce to FI<sup>14</sup> and flare visually as required.*  
*Note: 20 ft leaves ample time for flare control from a standard 3° final slope.*  
*- During this flare the airspeed will necessary decrease, leading to a touch down speed of 5 to 10 kt lower than the stabilized approach speed.*
- *As soon as main landing gear is on ground.*
- *Control nose wheel impact*
- ....

FCOM Section 2.02.08:

**Adverse weather**

*The recommended landing flap configuration is the same as the standard landing flap setting, even with strong crosswind. Large flaps extension does not impair the controllability in any manner. Moreover it minimizes the flare duration and allows a quicker speed decrease down to the taxi speed.*

**General**

*Precautions or special Instructions may be necessary depending on the force and direction of the wind.*

**Wind shear**

*This phenomenon may be defined as a notable change in wind direction and/or speed over a short distance.*

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<sup>14</sup> FI: Flight idle.



*Winds shear can be encountered in the vicinity of thunderstorms, into rain showers (even without thunderstorms), during a frontal passage or on airports situated near large areas of water (sea breeze fronts).*

*Severe windshear encountered above 1,000 feet, whilst unpleasant, can generally be negotiated safely.*

*However if it is encountered below 500 feet on take-off or approach/landing it is potentially dangerous. As far as possible this phenomenon must be avoided.*

*Procedure during an approach: If windshear is encountered,*

- *Initiate a normal go around procedure with 10° pitch.*
- *When positively climbing at a safe altitude, retract the gear and complete the normal go around procedure.*

*CAUTION; The positive rate of climb must be verified on at least two instruments.*

*COMMENTS : 1. Leaving the gear down until the climb is established will allow to absorb some energy on impact, should the microburst exceed the aircraft capability to climb.*

*2. Ten degrees pitch attitude is the best compromise to ensure a climbing path together with an acceptable maximum ADA.*

Guidance on operation of the aircraft was also provided in the Manufacturer's Pilot Training Manual. FCOM (Procedures and Techniques section – flight characteristics –2.02.12 page 1) indicates: *"the control column is held [...] neutral or deflected TOWARD the wind in case of crosswind component"*. The Investigation did not find any relevant Manufacturer published material regarding the operation of the aircraft in gusty or turbulent crosswinds or a recommendation regarding a crabbed or sideslip final approach technique.

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### **1.18.3. Operator Information**

The Operator informed the Investigation that at the time of the accident, their procedures did not require a damp runway to be considered when calculating crosswind limits. It stated that gusts were only taken into account when the wind was above 45 kts (including gusts) and more than 40° off the runway.

It stated that the Manufacturer did not provide any guidance on factoring gusts and therefore, when calculating crosswind components, gusts may be disregarded.

The Operator uses a mixed fleet of ATR aircraft. These include ATR 42, ATR 72-201, ATR 72 – 212 and ATR 72-212A. These aircraft are fitted with various powerplants that include 4-bladed propellers, 4-bladed propellers with larger blades and 6-bladed propellers. Pilots routinely fly all these variants. The Operator stated that there are no stipulated handling differences between any of the ATR 72 variants but, in practice, landings can vary slightly due to the different propellers. The 212 version tends to decelerate quite rapidly when the power is closed due to the "discing" effect of the larger blade propeller providing greater drag when powered off. The Operator stated that this was most notable between the 200 and the 212 versions with the 500 somewhere in between.

## FINAL REPORT

The Investigation noted that the Operator's procedures did not require that the gust component of crosswinds be considered when calculating landing limits. Consequently, forecast turbulence was not factored into cross-wind limitations for approaches to RWY 24 at EINN. Accordingly, on 23 August 2011 the Investigation issued Safety Recommendation IRLD2011010 recommending that the Operator should review the maximum crosswind limitations for approaches onto RWY 24 at EINN in conditions where the wind direction lies in the sector from 260° - 320° and the wind speed is more than 15 kts, i.e. when turbulence on the landing/approach might be expected.

The Operator addressed this Safety Recommendation and issued new procedures via Flight Crew Instruction FCI No. ATR 11/13 (**Appendix A**). It designated EINN a Category B airport with the following restrictions:

- A self-briefing must be completed before operating into the airport.
- A reduction of 5 kts must be applied to the CAT I crosswind limits and Wet or Contaminated runway Limits.
- The reported gusts must be taken into account when calculating the cross-wind factor and;
- The Captain must land the aircraft.

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With regard to new commanders, the Operator stated that they were placed on restricted flying for the first 100 hours or sectors following their command line check (this line check normally occurs at approximately 50 - 60 hours or 40 sectors).

Promotion to command is in accordance with EU OPS 1.955(a)<sup>15</sup>. A pilot must have a total of 2,000 hours which includes 1,000 hours of commercial airline experience with a minimum of 500 hours on large multi-engine aircraft. Following command assessments of 12 supervised line flying sectors, a command exam and interview, the pilot is reviewed by a Command Review Board. If successful, the candidate then completes command simulator training followed by 30 sectors line training and 10 sectors of command checks.

Upon completion of command training and checks, the results are reviewed and a final decision as to promotion is made by the Command Review Board.

On successful completion of the above process, the candidate will be promoted to Captain, on restricted flying for the initial 100 sectors in command. The new captain may not fly with a RF<sup>16</sup> first officer and has reduced visibility and cloud base minima but the Operator does not stipulate reduced crosswind limits.

<sup>15</sup> Regulation (EC) 859/2008 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane.

<sup>16</sup> RF: Restricted Flying



#### 1.18.4. Obstacle Downwind Turbulence

The area downwind of a building or obstacle is known as its wind shadow or wake area. It is characterised by turbulence whose intensity depends on a number of factors that include wind strength, obstacle size and shape, the general topography of the local area and atmospheric instability. The wake effect can extend downwind for quite a distance and wind tunnel tests have shown that this can be 10-20 times the building height, where the building shape is oblong with slab or flat sides. Whereas outside corners of the building can generate vortices the centre of the wake can have updrafts, in which case the corner vortices can be in opposite direction.

In addition, the wake effect is affected by gusts which can augment or decrease it. In the case of a significant gusty crosswind, when an aircraft encounters wake effect it will result in varying headwind and crosswind components. For an aircraft on a stable flight path the changing headwind component results in speed instability that must be overcome by power change, otherwise the aircraft will increase or decrease its rate of descent. The varying crosswind components results in drift with the aircraft rolling and/or yawing. This makes directional control critical if a large crosswind component change occurs when an aircraft is landing. In extreme cases the aircraft can be displaced laterally across the runway.

##### 1.18.4.1. Previous Study

The Investigation learned that, as a result of wind shear/turbulence reports, referred to in **Section 1.7.3.1**, following the construction of the Hangar, a study was conducted by Civil Engineering in University College Galway entitled “*Wind Speed and Turbulence Measurements in the wake of the ..... Hanger for Wind Directions of 260°, 280° and 300°*” and dated 16 July 1996.

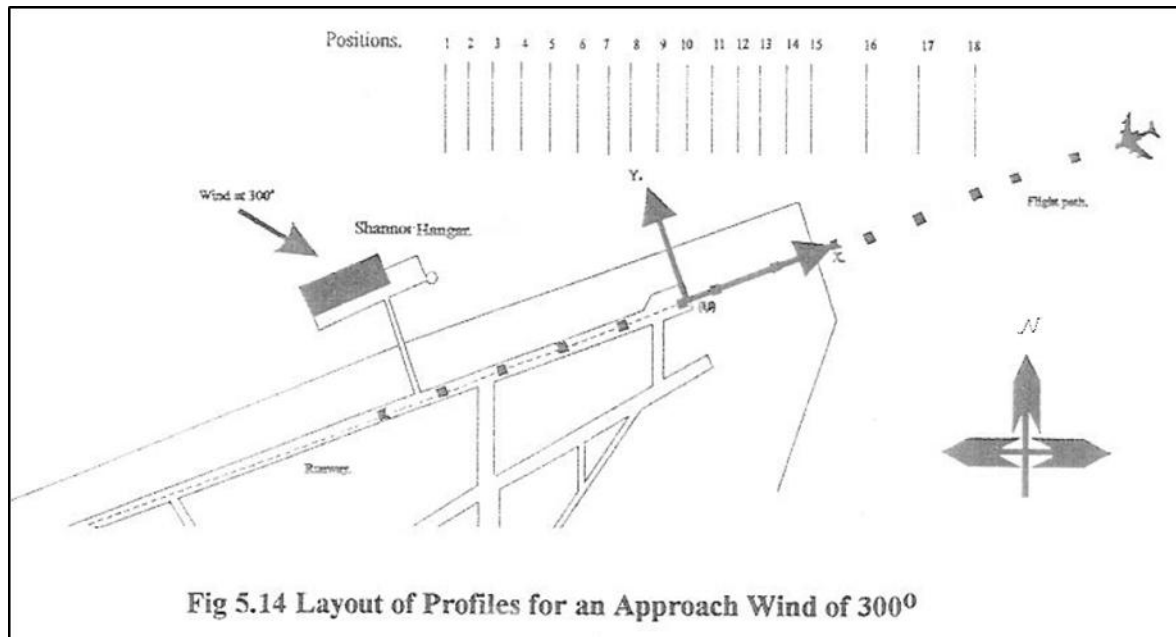
This Study was conducted using wind tunnel testing with models built to a scale of 1:750. Local terrain features were included and wind tunnel measurements taken with and without the presence of a scaled model of the Hangar.

Chapter 5.7 outlined the Study’s conclusions which state:

- *The set of readings taken for an approach wind direction of 260° shows that the ... Hangar has little effect on the wind regime along the flight path leading to the runway and along the runway itself.*
- *The set of readings taken for an approach wind direction of 280° shows that there may be a slight effect at positions 5 to 10 along the runway but the deficits that do appear are very small and may be explained by the statistical nature of the turbulent flow that exists in the boundary layer, irrespective of the hangar and due to small measurement errors.*
- *The set of readings taken for an approach wind direction of 300° shows that the hangar has a slight effect on the wind regime at positions 2 to 5 (fig 5.14) [Graphic No. 5]. The set of readings taken downwind from the hangar show that the wake effect of the hangar has not fully dissipated at positions W10 and W11<sup>17</sup>, which intersect the runway.*

<sup>17</sup> Positions W10 and W11 are where the vertical lines from positions 10 and 11 intersect the extended runway centreline.

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Graphic No. 5: EINN Hanger induced wake turbulence

Chapter 6 contains the Final Conclusions of the wind tunnel testing and states, inter alia, that:

*The results showed that the hanger had little, if any, effect on the wind regime along the flight path.*

*Tests carried out directly downwind from the hanger showed the rate at which the wake effect generated by the hanger dissipates. These measurements agree very closely with results obtained in similar investigation [6.1].*

*In each case it was found that the extent of the wake effect of a single building does not extend beyond 15 to 20 building heights downwind from the building. In this case, this is equivalent to between 370 m to 490 m downwind from the hanger. The service hanger is approximately 340 m from the neighbouring runway. Hence, there are slight wind velocity deficits and turbulence intensity changes along the runway close to the hanger when the approach wind is blowing almost normal to the rear face of the hanger".*

The author of the Report, when contacted by the Investigation, stated that a neutral air mass had been considered and that no allowance was made for atmospheric instability.

#### 1.18.4.2. National Aerospace Laboratory Study

In July 2010, a report was produced by the National Aerospace Laboratory NLR titled "Wind Criteria due to obstacles at and around Airports" (NLR-TP-2010-312). This examined the effect "of wind disturbances on the flight handling and landing performance of aircraft using offline mathematical simulations. Two aircraft types were used in the simulation, a Boeing 747 and a Fokker 100.

The following extracts are considered relevant:





*Wind, wake and turbulence induced by obstacles may affect the flight handling and performance of aircraft during take-off and landing. Therefore wind disturbance criteria are required. Because aircraft are much more vulnerable to disturbed wind velocity profiles during the final stage of the approach than during take-off the focus of the study was aimed on landing aircraft.*

*Firstly, height between 0 ft and 200 ft. In this region flare, de-crab and high speed roll out takes place. Apart from prevailing gust and turbulence due to general surface characteristics, stand alone obstacles may play a dominant role in this part. From a safety point of view this is a critical phase”.*

The results and conclusion of the study state, inter alia, that:

*For the segment that covers the landing phase from 200 ft to touch down and the high speed roll out it was established that wind disturbance criteria are necessary that are more stringent than the “Annex 14” planes. The segment where the wind disturbance plane is restrictive is bounded by a disk-shaped segment with origin in the center of the runway threshold and radii of approximately 1,200 m (perpendicular to runway centerline) and 900 m in front of the runway threshold. In order to cover the high-speed roll out the 1:35 plane is extended up to 1,500 m aft of the runway threshold.*

*The study also revealed a strong relation between surface roughness, reference wind speed and gust/turbulence levels. Surface roughness and reference wind speeds selected for the simulations lead to gust and turbulence levels varying from medium to severe.*

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Further detail from this study in relation to Schipol Airport, Amsterdam, is contained in **Appendix B.**

#### **1.18.5. Wind shear**

The International Civil Aviation Organisation (ICAO) in 1987 published Circular 186-AN1122 85 on Wind Shear which states:

*“The most generalized explanation of wind shear is: “a change in wind speed and/or direction in space, including updrafts and downdrafts”. From this explanation it follows that any atmospheric phenomenon, or indeed any physical obstacle to the prevailing wind flow, which produces a change in wind speed and/or direction is, in effect, causing wind shear.*

#### **3.2 Wind Flow Around Obstacles**

*3.2.1 A combination of strong surface winds and obstacles to the prevailing wind flow situated upwind of the approach or departure path, such as large buildings, low hills or close-planted stands of tall trees can create localized areas of low-level wind shear. In these circumstances the wind shear is usually accompanied by clear – air turbulence. The effect that the obstacles have on the prevailing wind flow depends on a number of factors, the most important of which is the speed of the wind and its orientation relative to the obstacle and the scale of the obstacle in relation to the runway dimensions.*

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3.2.2 The most commonly encountered wind shear of this type, particularly at smaller aerodromes, is that caused by large buildings in the vicinity of a runway. Although the height of buildings is restricted in proportion to their distance from the edge of the runway strip, to ensure that they do not constitute an obstacle to aircraft, their lateral dimensions tend to be rather large and, for many reasons, they tend to be grouped together in the same area. This means that whilst the buildings (hangars and fuel storage tanks, etc.) are comparatively low, they present a wide and solid barrier to the prevailing surface wind flow. The wind flow is diverted around and over the buildings causing the surface wind to vary along the runway. Such horizontal wind shear, which is normally very localized, shallow and turbulent, is of particular concern to light aircraft operating into smaller aerodromes but has also been known to affect larger aircraft.

The Circular further stated that it is extremely difficult to recognize any but the most extreme deviations in airspeed, glide slope holding and descent rate due to wind shear if the aircraft is not flying a stabilized approach.

The Federal Aviation Administration (FAA) of the United States of America in 1996 published TSO-C117a, Airborne Wind shear Warning and Escape Guidance Systems for Transport Airplanes. This defined Severe Wind shear as:

*(ix) Severe Windshear. A windshear of such intensity and duration which would exceed the performance capability of a particular aircraft type, and likely cause inadvertent loss of control or ground contact if the pilot did not have information available from an airborne windshear warning and escape guidance system which meets the criteria of this TSO.*

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#### 1.18.6. Similar Events

The Operator has since experienced two other landing events on their fleet of ATR aircraft. In both cases the aircraft involved was an ATR 72-201 that bounced while landing in gusty crosswinds. Neither occurrence happened at EINN.

Following this the Operator conducted a survey of landing techniques used by its pilots on different ATR 72 aircraft types. This survey was conducted in a period of relatively light winds and the results were obtained from pilot comments rather than data measurement.

The Investigation raised this lack of data measurement with the Operator which confirmed that it did not have Flight Data Monitoring (FDM) equipment installed on the ATR 72-212 that would allow it to monitor the landing techniques used by its pilots. Whilst FDM is not required by EU Regulations<sup>18</sup> on aircraft with a maximum certificated take-off mass (MTOW) that is less than 27,000 kg, the Operator had FDM equipment fitted to 4 aircraft in its fleet.

Nevertheless, the Operator found that there may have been a misconception among some of its pilots; that the 212 series aircraft, because of increased drag from larger propellers, required a short application of power immediately prior to touch-on. This technique was not in accordance with the published landing procedure in the ATR 72 FCOM.

<sup>18</sup> Regulation (EC) 859/2008, OPS 1.037 and Regulation (EU) 965/2012, ORO.AOC.130.





As a result the Operator published Training Notice 04-11 for its crew stating that the correct technique was to fly the approach at Vapp. At 20 ft, power should be reduced to flight idle, simultaneously flaring. The aircraft should then touchdown at Vapp -5 to -10 kts. It stated that:

*“Keeping the power on prevents the speed from bleeding back to the touchdown speed.... So a bounce or balloon is very likely. Now if we have to recover from the bounce or balloon but our speed is still high and we have power on. If we try to force the aircraft onto the ground, we run the very severe risk of the nose wheel contacting the ground before the main gear. The nose wheel cannot take this treatment and severe damage can result”.*

It further stated:

*“Bounce landing may result from either too much speed or too high a slope on final. Never push forward control column”.*

The Operator published a further Training Notice 02-12 in October 2012, entitled “The ATR Landing Technique”. This Notice included additional information regarding approach speed, its computation and relationship to stall speeds. It examined landing pitch attitude trends and emphasised the importance of stabilised approaches. The Operator has also amended procedures in its Operations Manual Part B, dated 1 March 2013, regarding stabilised approaches, approach speeds and providing additional guidance for calculating a wind factor.

#### **1.19 Useful or Effective Investigation Techniques**

Not Applicable.

## **2. ANALYSIS**

### **2.1 General**

Both approaches were made in blustery and turbulent conditions during which the DFDR recorded frequent IAS deviations of 10 kts with the aircraft rolling through 10°. The previous evening in similar weather conditions a different crew flying the same aircraft had reported difficult conditions but landed safely.

### **2.2 Aircraft**

At the time the aircraft was lightly loaded, at 17.3 tonnes or 5 tonnes under maximum landing weight and therefore performance was not an issue. In addition its centre of gravity was within limits and therefore aircraft balance or its longitudinal trim was satisfactory.

Although the aircraft had been downgraded to CAT 1 Approach and the CCM reported that the toilet had come loose in the earlier landing, these issues were not factors in the accident. No technical anomaly or defect attributable to the controllability of the aircraft was found from the examination of the aircraft. In addition the PF did not indicate that there was any issue with flight controls until after the nose gear collapsed, nor was anything heard to suggest otherwise on the CVR.

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Furthermore, the DFDR recorded the aircraft and its engines responding normally to control input throughout the flight and during both approaches. The Investigation therefore concluded that the aircraft was responding normally to flight control input at the time of the accident.

Following examination of the DFDR, airport security videos and from the Flight Crew interviews the Investigation is satisfied that the nose gear was intact when the second landing was attempted. The nose gear then failed at ground impact as evidenced by the CVR recording an unsafe gear warning and the DFDR recording blue hydraulic failure as the nose gear folded to the rear and hydraulic lines fractured. Metallurgical testing of the nose gear stub axle indicated that its failure occurred due to a single event overload, the 2.32 g contact the nose gear made with the runway, as a result of which plastic deformation of the attachment eye and fracture of the drag brace link occurred, thus leading to the nose gear folding rearwards. Therefore, the Investigation has concluded that neither the loading nor technical aspects of the aircraft were causal factors in the accident.

### 2.3 Meteorology

Throughout the time of the accident and the evening before strong gusty north westerly winds existed in an unstable atmospheric air mass. With a strong gradient wind of 50 kts, moderate low-level turbulence and wind shear had been forecast. EINN procedures required that a turbulence warning be issued in these circumstances. ATC transmissions were recorded issuing a caution during each approach that moderate turbulence should be expected in the TDZ RWY 24, in accordance with procedure.

#### 2.3.1 Turbulence

The Investigation notes that the CVR recorded the Flight Crew on each approach discussing turbulence from the Hangar. With winds from a north westerly direction ranging from 20 - 32 kts the decision to land long, where turbulence generated by the Hangar might affect the landing less, was reasonable considering that the aircraft was light and stopping distance was not a concern. In the operational context, turbulence generally manifests itself by a short term gain or loss of airspeed, whereas wind shear is more serious and airspeed change may not be regained.

The Investigation notes from the DFDR readouts that the gains and losses of IAS though significant were of short term duration, typically over one or two seconds, and is satisfied that the longer term average airspeed changes were due to engine power changes and not wind shear.

#### 2.3.2. Hangar Wake Effect

The Hangar had been erected twenty years previously and thereafter frequent reports of turbulence and wind shear reports were made by pilots landing in the TDZ of RWY 24 in moderate to strong north westerly winds. Subsequently, a study of the likely effects of turbulence generated by the Hangar was conducted in 1996 using a scale model in a wind tunnel.



For a wind velocity at the time of the accident the Study stated that the wake effect extends to some 370 to 490 m downwind. This distance includes the TDZ of RWY 24. The study concluded that the Hangar had little effect on the wind regime along the flight path (i.e. on short finals) but that there were slight wind velocity deficits and turbulence intensity changes along the runway close to the hangar.

The Investigation therefore concludes that, depending on the prevailing atmospheric conditions at the time (wind velocity, turbulence, turbidity and instability), the wake effect can locally augment turbulence at the TDZ of RWY 24. The continued reports of turbulence recorded by pilots over the years lend validity to the assumption that the wake effect of the Hangar has a local effect at the TDZ of RWY 24 in strong winds between west and northwest and therefore the turbulence caution is considered warranted.

More recently a study was conducted by the National Aerospace Laboratory, using offline mathematical simulation. The results of this study also confirmed that the TDZ of RWY 24 was in the wake turbulent area of the Hangar. The Investigation examined the DFDR recording of the approach conducted the evening before and both approaches on the day of the accident but was unable to form an opinion regarding the effect of wake turbulence from the Hangar in the prevailing conditions due to factors that included:

- The approaches were at different flight path angles to different parts of the runway.
- The aircraft was not sufficiently stabilised at low height for accurate measurements.
- Instrumentation and recording was inadequate for such an evaluation.
- An insufficient number of approaches was available to establish the validity of data observations.

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The Investigation notes that when the Hangar was originally built, RWY 13/31 was still in use and could be used by aircraft such as the ATR 72 with winds from the northwest or southeast.

This is no longer the case as the runway is now de-classified and therefore approaches are conducted in wind conditions where previously the option was available to land on a TDZ unaffected by the Hangar wake effect. This places additional demands on pilots who attempt to land at their destination airport in difficult crosswind conditions and, due to the non-availability of the crosswind runway, it is inevitable that some flights divert due to crosswinds and turbulence.

## **2.4 Aircraft Operation**

### **2.4.1 General**

When landing, the ATR 72 FCOM recommends maintaining a 3° approach angle at Vapp until 20 ft when the aircraft should be flared and the power reduced to flight idle. This allows the aircraft to touch down at a slightly lower speed.

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During the first approach the DFDR recorded the aircraft approaching with a 15° drift (crab) angle which reduced to 11° during the flare. The PF was then required to align the aircraft with the runway (using left rudder) while keeping the into-wind, right wing down since the into-wind wing tends to rise in strong crosswinds.

While this manoeuvre generates some into-wind sideslip that can assist keeping the aircraft on the runway centreline, in gusty conditions this can be difficult, as high wing aircraft with slab sides, such as the ATR 72, can have a tendency to weathercock into wind during gusts. Some aircraft manufacturers recommend landing with a combination of partial crab and sideslip during strong crosswinds. However, aircraft geometry together with aileron and rudder authority limits dictate the capability of an aircraft to maintain a steady side slip close to the ground and no guidance is provided by the Manufacturer.

### 2.4.2 ATR 72 Crosswind Limits

The ATR 72-212 has a demonstrated maximum crosswind component of 35 kts on a dry runway. At the time of the accident, the Operator was using a cross-wind limit of 30 kts on a dry or damp runway and 25 kts on a wet runway. The Operator's procedures also stated that gusts may be disregarded when calculating crosswind components. As the general wind reported was 310°/24, the crosswind component on RWY 24 was 23 kts. RWY 24 was classified as "damp" at the time of the approach and wind gusts of 32 kts, 70° off the runway heading, were reported by ATC during the approach. The crosswind component of a 32 kts wind gust was 30 kts, the limit for a damp RWY 24, and consequently correct crosswind limits were applied by the Flight Crew during the approach. The Investigation notes that the Operator has since reduced the crosswind component limit at EINN by 5 kts.

### 2.4.3 Aircraft Handling

The VmHB Flap 30 is estimated to be 99 kts at the time of the accident, to which a 15 kts gust factor was added thereby giving a Vapp of 114 kts, the "fly speed" the PNF was recorded stating that they would use. However, the method described in the Manufacturer's FCOM (Section 1.6.2) gave a wind factor of 8 kt, and therefore the Vapp should have been 107 kt.

The term "*gust in full*" in the FCOM may have been misunderstood by the crew leading to this 7 kt error in Vapp computation. Furthermore, the FCOM uses "*1/3 of the headwind velocity*" in this computation rather than a more correct "*1/3 of the headwind component*".

Nonetheless, the typical IAS flown during both approaches was 20 to 25 kts above that. Although both flares correctly commenced at 20 ft RADALT, the IAS recorded on both occasions were excessive at touchdown, momentarily reaching 139 and 140 kts respectively. This was partly due to the PF increasing torque after flaring and partly due to the prevailing gusty conditions.

In such gusty crosswind conditions the key focus of the pilot must remain on handling the aircraft and keeping it aligned on the runway centreline after the flare. In turbulence, such as that which was experienced, the ability of a pilot to monitor airspeed is significantly reduced and assistance should be given by a co-pilot calling airspeed deviation from Vapp.



The Investigation notes in the CVR recording the absence of SOP speed callouts being requested or given during both approaches, which would have assisted the PF in controlling airspeed in such conditions. It therefore recommends that the Operator reviews this issue during its training.

Furthermore, a lightly loaded aeroplane at IAS speeds well above  $V_{app}$  does not tend to touch down after the flare. At such speeds the aeroplane has to be flown onto the runway; then it can tend to bounce due to excessive lift still being generated by the wings. Generally the upwind wing generates the greater amount of lift, which accounts for the observations of both pilots regarding the right wing lifting and the aircraft bouncing.

Bounces were reported by both Flight Crew and DFDR data indicated they occurred after both approaches. The video and DFDR recordings showed that the aircraft was pitched down after it floated following the first approach. It initially landed on its nose gear at 1.3 g while a late pitch up was being commanded by the PF.

It then rocked onto its main gear, recording 1.7 g, and bounced airborne. Weight on wheels was not recorded by the DFDR probably because of the sampling rate of that parameter. As the landing gear subsequently retracted normally the Investigation is of the opinion that no significant damage was caused to the nose gear during the first landing.

The Investigation is of the opinion that, whilst the crew discussed the landing zone for the second approach, an evaluation of the first approach and the prevailing weather conditions should have been then conducted by the Flight Crew. This was not done and no discussion on diverting to another airport took place. Instead a second approach was immediately requested with a different landing position on the runway chosen, this time the standard TDZ since the previous approach had ended too far down the runway. Again, similar conditions prevailed.

Following this flare power was again added, which resulted in increased airspeed, the aircraft bouncing and not descending onto the runway. Ultimately the control column was pushed forward and the aircraft reached a significant nose down attitude, impacting the runway at 2.3g. This caused the nose gear to fracture and the hydraulics to fail.

#### 2.4.4 Operational Guidance

The PNF stated that there was a difference in techniques between landing the ATR 72-500 and the -200 series, with the -200 requiring power on in order to cushion the landing. The DFDR also recorded a substantial increase in torque after flare and prior to touchdown during both landings.

The Investigation notes that the Operator found that there was a misconception amongst some of its pilots that power should be added due to the larger blade propellers providing greater drag when powered off. In this case the power increase resulted in an increased airspeed which compounded landing problems.

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However, no reference to such a technique was found in the Manufacturer's documentation which, on the contrary, recommends the reduction of power to Flight Idle and to flare visually. In addition, the Investigation found no information provided to flight crew at that time concerning landing the various types of ATR 72, nor guidance regarding the use of crabbed or sideslip final approach techniques while operating the aircraft in gusty or turbulent crosswinds.

The published procedures required that severe wind shear below 500 feet on take-off or approach/landing be avoided but severe wind shear was not defined and no further operational guidance was provided. The Investigation therefore considers that the operational information and guidance provided by the Manufacturer is too limited.

The Investigation notes that the Operator subsequently provided its crews with information regarding landing techniques for the different types and guidance for operation in turbulent crosswind conditions. This included reducing the crosswind limits at EINN. Nevertheless, the Investigation is of the opinion that the aircraft Manufacturer should be the primary source for such information and issues a Safety Recommendation accordingly.

### 2.5 Flight Crew

The licences of both the Flight Crew were valid and both were correctly rated on the ATR 72. The Commander had been promoted two months previously and, having successfully completed a month of restricted flying, was now an unrestricted though relatively inexperienced Captain. The First Officer had over a year's experience on type. The Flight Crew rest periods before the flight were 40 hours and 16 hours respectively and both pilots should have been sufficiently rested. As the start time for the series of flights was very early, it is possible that alertness levels were affected by the early start.

The Investigation further examined the processes and procedures conducted by the Operator when upgrading a pilot to command. This included the command selection process, simulator training and line sector command checks.

The Operator's procedures, which were complied with, were considered to be in line with industry norms for this type of aircraft with new captains being appropriately restricted for their first 100 hours in command.

### 2.6 Human Factors

Although this was the first go-around during line operations by the recently promoted Commander, command training and previous experience should have adequately equipped her to recognise and appraise the prevailing conditions relative to her experience. The Investigation believes that the severity of the prevailing conditions was not recognised by either of the Flight Crew, either before or after the go-around.





Whilst the objective was to land at EINN, this was not evaluated against the prevailing weather conditions and their relative experience levels. Although the CVR recorded discussions regarding turbulence from the Hangar and crosswinds, the Flight Crew appeared to not unreasonably consider that the turbulence was due to the Hangar and that this turbulence could be avoided by landing in a different position on the runway. However, the CVR recorded that the stress levels of the PF had increased after the first approach.

The Investigation noted that the CVR recorded the PNF assisting and supporting the PF. As excessive airspeed deviations were not announced this support was uncritical and therefore lacking. Although confusion arose when the PF discovered that the propellers would not feather, or the engines shutdown due to the control run damage, engine shutdown was correctly achieved by pulling the fire handles. Meanwhile the PNF had promptly transmitted a Mayday call to ATC and later correctly initiated a checklist. Although a delay resulted because the engines could not be shut down normally, this was resolved by pulling the fire handles.

Cabin status was established shortly afterwards when the CCM contacted the cockpit to advise that there was no fire and that the doors could be opened. Following this an evacuation was commenced. The Investigation notes that the quick response by the Airport Fire Services was assisted by the advance notice provided by an alert ATC Tower Staff, indicating that there might be a problem.

## 2.7 Similar Occurrences

The Investigation noted that the Operator has since experienced two other landing events on its fleet of ATR 72 aircraft that resulted in nose gear damage. In each case the aircraft bounced while landing in gusty crosswinds. These bounces being the result of unsuccessful crosswind landing attempts, the Investigation is therefore of the opinion that the Operator should review the crosswind landing training it provides to its pilots, particularly in gusty conditions, and issues a Safety Recommendation in this regard.

Although the Operator conducted a survey of landing techniques used by its pilots on its different ATR 72 aircraft types, this relied on the subjective assessment by pilots rather than data measurement. This was because the Operator did not have a Flight Data Management (FDM) system to record data regarding the landing techniques used by the pilots. Nevertheless, the Operator found a misconception about the ATR 72-212 in that it required a short application of power immediately prior to touch-on to smoothen the landing.

This technique is not in accordance with the published landing procedure in the ATR 72 FCOM and, the Investigation believes, contributed substantially to the difficulties experienced by the PF while landing EI-SLM.

As a result of this survey the Operator published two Training Notices for its pilots affirming correct approach and landing techniques. These provide pilots with further information regarding approach speeds, in particular, wind and gust factor computations as discussed in **Section 2.4.3.**

## FINAL REPORT

In addition, the consequences of approaching and landing with an IAS well in excess of the computed Vapp are discussed. Consequently no Safety Recommendation is considered necessary in this regard.

Had the Operator a FDM program in place across its fleet prior to this accident it would have been in a better position to identify and resolve this misconception and therefore the accident could possibly have been avoided. Although EU Regulations<sup>19</sup> do not mandate FDM on ATR aircraft nevertheless, the Investigation is of the opinion that the Operator in the interests of safety should institute an FDM program across its fleet and issues a Safety Recommendation to that effect.

### 3. CONCLUSIONS

#### (a) Findings

1. The aircraft was properly certified.
2. There were no relevant operational or technical problems with the aircraft.
3. Crew were properly licensed with valid medicals.
4. Crosswinds at EINN were strong and blustery in an unstable air mass.
5. Significant turbulence was encountered during the first landing, which was intentionally well down the runway.
6. The aircraft bounced and a go-around was carried out.
7. No significant nose gear damage was sustained during this bounce.
8. No evaluation of the first approach and the prevailing weather conditions was conducted by the Flight Crew prior to commencing a second approach.
9. During the next landing the aircraft was pitched down, in which attitude the nose gear struck the runway at 2.3 g.
10. The nose gear failed in overload and folded aft.
11. Directional control was lost due to control run damage.
12. The aircraft decelerated on the runway, came to rest on the taxiway intersection and the engines were shut down.

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<sup>19</sup> Regulation (EC) 859/2008, OPS 1.037 and Regulation (EU) 965/2012, ORO.AOC.130.





13. The aircraft was substantially damaged.
14. There were no injuries to crew or passengers.
15. The wording in the FCOM led the crew to consider a wind factor of 15 kt instead of 8 kt during computation of the final approach speed.
16. Both approaches were flown in excess of the recommended approach speed by 20 to 25 kts.
17. Incorrect power handling technique caused difficulty in getting the aircraft to touch-down during both landings.
18. A misconception regarding power handling during landing was held by some of the Operator's pilots.
19. The newly promoted Commander was relatively inexperienced in handling the aircraft in limiting conditions.
20. Inadequate guidance was provided by the Manufacturer regarding aircraft handling techniques in blustery crosswind conditions.
21. The Operator did not have a FDM program in place on the ATR 72-212 which could have identified this incorrect power handling techniques.
22. Turbulence in the wake of the Hangar probably affected the TDZ of RWY 24.

**(b) Probable Cause**

1. Excessive approach speed and inadequate control of aircraft pitch during a crosswind landing in very blustery conditions.

**(c) Contributory Factors**

1. Confusing wording in the FCOM that led the crew to compute an excessive wind factor in the determination of  $V_{app}$ .
2. Incorrect power handling technique while landing.
3. Inexperience of the pilot in command.
4. Inadequate information provided to flight crew regarding crosswind landing techniques.

## FINAL REPORT

## 4. SAFETY RECOMMENDATIONS

No.	It is Recommended that:	Recommendation Ref.
1.	Aer Arann should review the training provided to its pilots regarding crosswind landings and standard speed call outs during approach	<a href="#">IRLD2013015</a>
2.	Aer Arann should institute a Flight Data Monitoring (FDM) program across its fleet.	<a href="#">IRLD2013016</a>
3.	Avions de Transport Regional (ATR) should provide improved guidance regarding landing techniques for the different models of ATR 72 during turbulent crosswind conditions.	<a href="#">IRLD2013017</a>
4.	Avions de Transport Regional (ATR) should amend its FCOM to provide a better understanding of “gust in full” and “headwind velocity” in the determination of wind factor computations, thus preventing the computation of an excessive wind factor when determining approach speeds.	<a href="#">IRLD2013018</a>

[View Safety Recommendations](#) for Report 2013-008

## Appendix A

### Operator Flight Crew Instruction

**To** All Flight Crew

**From** Flight Operations Manager

**Date** 9<sup>th</sup> August 2011

**FCI No** ATR 11/13



**Operational**

**Subject:** **Shannon Airport**

#### BACKGROUND:

Following the recent incident in Shannon and a risk assessment on the airfield it has been decided to reclassify the airfield from a Category A to a Category B airfield.

#### INFORMATION:

The approach plates for RWY 24 in Shannon includes the following caution

##### CAUTION

Turbulence and/or windshear may be experienced on approach to runway 24 when wind direction lies in sector from 230° - 320°T (clockwise) with wind speed > 15kts.

The turbulence and wind-shear is largely attributable to the location of the Shannon Aerospace hangar and its proximity to the touch down zone for RWY 24.

#### ACTION:

With immediate effect, Shannon airport will be reclassified to a Category B airport with the following restrictions:

When the wind direction is from 230° - 320° and greater than 15kts...

- A reduction of 5kts must be applied to the Cat I x-wind limits (see OMB 1.8.1) and Wet or Contaminated Limits (OMB 1.11).
- A Captains only landing is required
- Reported gusts must be taken into account when calculating the x-wind factor.

Please note that as a Category B airport, Shannon requires a self briefing to be completed but does not require a dedicated "check flight".

**EFFECTIVE TO DATE: 31<sup>st</sup> Dec 2011**

## Appendix B

### Extract from “Wind Criteria due to obstacles at and around Airports” (NLR-TP-2010-312).

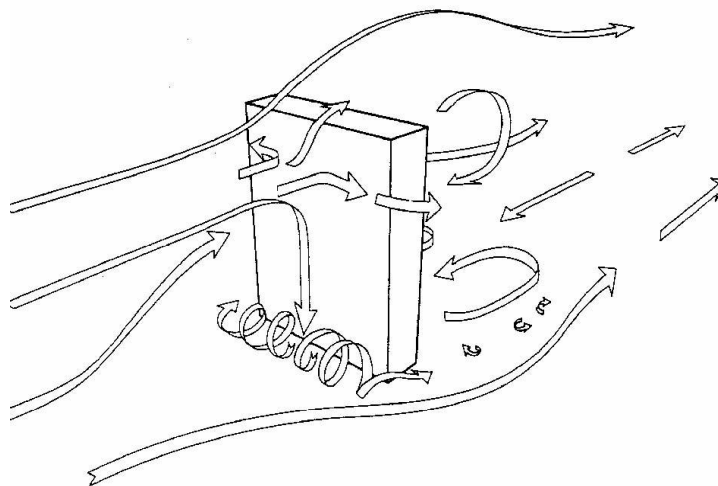
#### 4 Wind climate behind a “stand alone” obstacle

##### 4.1 Introduction

The present study takes a parametric variation of several wind related parameters as a starting point to evaluate where undesired wind conditions start to occur. Moreover, a real time piloted flight simulator test was part of the research, which requires short wind field calculation times. Both requirements made the use of very sophisticated wind field calculation methods or the use of experimental data obtained in a wind tunnel and subsequent interpolation less attractive. Therefore a simple analytic calculation method was developed that fulfilled the requirements. The method was based on widely accepted modelling of wakes behind wind breaks and was further improved by means of wind tunnel data in wakes behind building structures as are typical for Schiphol and also on wind tunnel data on the PDP. The method is described in detail in Appendix B. During the piloted simulator tests, the wind field generated in this way was considered very realistic by the pilots. First a general picture of the wind flow around obstacles will be sketched. Furthermore results will be shown of the boundary layer wind field including a stand alone obstacle with a limited width.

##### 4.2 General description

The airflow around a generic block shaped construction is described in ([26], ([27] and ([28]. It is schematically shown in Figure 4-1.



*Figure 4-1: Schematic airflow around building*

The airflow depends on the characteristics of the approaching wind and on the size and shape of the building itself. Due to the surface roughness the wind speed increases with the height of the building. When the wind reaches the obstacle the wind gradually diverges until at the stagnation point at three-quarter of the building height an upward and downward flow occurs. Below this height air flows downwards and outwards reaching the windward corners. The accelerated air streams pass around the corners of the building where two jets of air are formed in lob-like areas that stretch downwind for a considerable distance. In particular for long slender obstacles high speeds may evolve. The corner streams are usually indicated as the corner effect and are able to create wind shear like phenomena.

As the wind flows around the obstacle it creates pressures above or below local atmospheric conditions. Pressures over most of the “wall towards the wind” are above atmospheric. The maximum occurs at the stagnation point, where the air is brought to rest. The contours follow a well-defined shape around this centre. Close to the corners accelerating flow produces small areas where the pressure is below atmospheric (suction areas).

The sidewalls, roof and “wall on the leeward” all experience suction. At the “wall on the leeward” an upward flow occurs towards the region of high suction on the roof.

Close to the sidewalls and the roof air flows in a reverse direction back towards the front where it separates from the surface of the building. The air motion over the top of the building creates an upward flow that only at a respectable distance behind the building reverts to a downward flow.

The area behind the building is known as the wind shade or wake area. In the wake relative slow wind speeds are present. The area is characterized by its high turbulence levels that can be observed at quite a distance behind the building. This is caused by the transformation of high energy available in the airflow into gust/turbulence when the airflow is slowed down significantly. Changes in wind direction up to 180 degrees may occur in this area. In general the wake behind the building extends to 4 to 5 times the building height. However this does not mean that behind the wake the original undisturbed speed profile immediately is restored. Wind tunnel tests have shown that the disturbances may extend to more than 15-20 times the building height.

The wake and corner streams are two phenomena related to each other. As result of the corner speeds and the wake, whirls will develop starting from the corners of the building. Due to these whirls air is dragged along at the edges of the wake area. The air supply for this comes from larger distances behind the obstacle where speeds gradually decrease and the pressure slowly increases. As result of this a flow will evolve in an opposite direction towards the building. This leads to the formation of two large stationary whirls around a vertical axis in the wake area. The faster moving and smaller whirls are present between the fast airflow outside the wake and the mentioned larger stationary whirls. Due to the wake a site downwind from the obstacle will be shielded from the wind for a considerable distance. In practice this shielding depends on the height of the obstacle and the distance of the site downwind. The shielding effect will vary with height above the site surface and the net result is usually to produce a distorted wind speed profile such as given in Figure 4-2.

Also indicated in Figure 4-2 is the boundary of the internal layer that develops behind the building. In the internal layer wind speeds less than that would occur in the undisturbed flow are present. Above the internal boundary the undisturbed wind speed profile is valid.

It is assumed that the incoming airflow is perpendicular to the front side of the building. This means that a symmetrical air flow can be adopted, which is favorable for the mathematical wind flow modeling behind the building. This is not the case when wind approaches the building from an oblique direction. Then conical whirls are created on the rooftop and sides of the obstacle leading to an asymmetrical flow pattern. The conical eddies are transported with the upward airflow and can be active at a large distance behind the obstacle. The wake area in the case of an oblique airflow is smaller than for perpendicular flow.

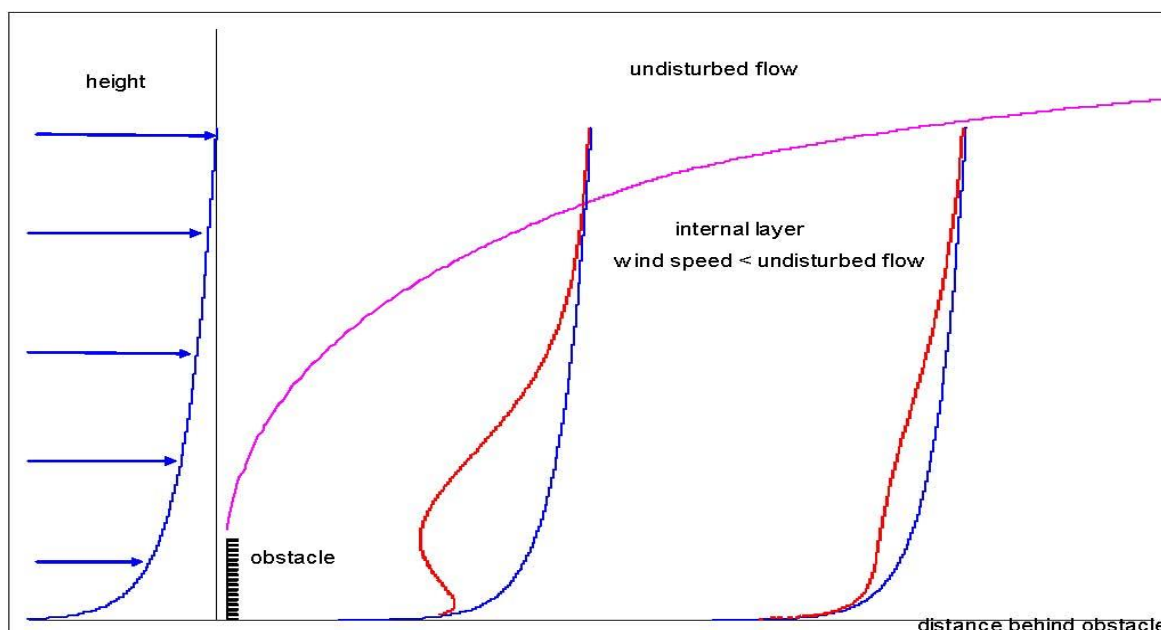


Figure 4-2: Air flow pattern behind obstacle

Consequently parameters that affect the airflow around and behind an obstacle significantly are:

1. Height

When the height of an obstacle is increased the basic airflow patterns around the obstacle don't change very much. However a taller obstacle increases the airflow around the sides of the obstacle significantly. Because of the increased corner streams the height of an obstacle has a significant effect on the wake area. The taller the obstacle the larger the reverse flow area will be.

2. Width

An increase in obstacle width at constant height and depth has a large effect on the magnitude of the wake area. There appears no limit value for this phenomenon. Consequently an increase in obstacle width will automatically lead to a larger wake area.

3. Depth

When the depth of an obstacle is large in relation to the width and height of the obstacle a smaller wake area will develop. This situation arises when the depth is more than two times the building height. Consequently a thin obstacle creates a wake area with larger whirls and more reverse airflow.

4. Airflow direction

When a corner of an obstacle is directed towards the wind direction (oblique flow) this may lead to the creation of strong conical "corkscrew like" whirls that can be transported by the airflow over a large distance behind the obstacle. Very complex and asymmetric flow patterns may result. In general an oblique airflow leads to a smaller wake area.

5. Shape

The shape of an obstacle strongly affects the airflow patterns and the resulting wake characteristics. If an obstacle diverges from the "block shaped" form as is discussed here wake characteristics can deteriorate substantially. An increase in roof inclination enlarges the wake area. Also the roof and roof edge shape define the possibility of the creation of strong conical eddies. Smooth and rounded shapes are favorable in this respect because the lower probability on whirls. An abrupt change in shape creates strong airflows and eddies. As result of the U-shape of the construction this situation occurred at the engine test run facility (PDP) mentioned in section 2.2.2. Characteristics of such an obstacle are defined as "worst case" in the offline and online simulations. Therefore to avoid high-speed airflows the pressure differences must be kept as low as possible. Consequently gradual changes in geometry must be aimed at. If the shape of an obstacle deviates from the rectangular form usually wind tunnel or flow calculations are required.

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

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