Accident involving turbulence and Aer Arann ATR-42-300 on descent to Donegal International Airport, Ireland, on December 2, 2001.

Micro-summary: **On descent, this ATR-42 encountered turbulence, injuring several people.**

Event Date: **2001-12-02 at 1300 UTC**

Investigative Body: **Air Accident Investigation Unit (AAIU), Ireland**

Investigative Body's Web Site: **http://www.aaiu.ie/**

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3. Reports may or may not represent reality. Many many non-scientific factors go into an investigation, including the magnitude of the event, the experience of the investigator, the political climate, relationship with the regulatory authority, technological and recovery capabilities, etc. It is recommended that the reader review all reports analytically. Even a "bad" report can be a very useful launching point for learning.

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FINAL REPORT

AAIU Report No.:2002/007
AAIU File No.: 2001/0072
Published: 12 July 2002

Operator:	Aer Arann
Manufacturer:	ATR
Model:	ATR 42-300
Nationality	Irish
Registration	EI-CPT
Location	Mt Errigal, Co. Donegal
Date/Time (UTC)	2 Dec 2001 at 1300 hrs

SYNOPSIS.

The aircraft departed from Dublin Airport (EIDW) for Donegal International Airport (EIDL) at Carrickfin, Co. Donegal at 12.23 hrs. At 2700 ft Above Sea Level (ASL), during the descent to land, the aircraft experienced severe turbulence. One of the crew and two passengers were reported injured during this event. The aircraft landed, as intended, on Runway (RWY) 21. The passengers and crew disembarked and a medical doctor attended the injured.

NOTIFICATION

The Operator informed an inspector of the Air Accident Investigation Unit directly, following this serious incident. The Chief Inspector of Accidents nominated Mr. John Hughes, an Inspector of Accidents, to investigate the event and to compile a report. The inspector arrived in Donegal at 17.00 hrs the same day and commenced the investigation. The inspector was later informed that one of the passengers on the aircraft had been hospitalised for more than 48 hours. The serious incident thus became an accident under the Regulations set out in Statutory Instrument S.I. No.205 of 1997.

1. FACTUAL INFORMATION

1.1 History of the Flight.

Flight REA 201 took off from EIDW at 12.15 with a crew of three and 32 passengers. Prior to descent, the flight to was uneventful. It was a bright clear day with visibility greater than 10 kilometres.

The aircraft passed over the Glendowan Mountain range and at approx 5000 ft commenced an extended left hand downwind approach to RWY 21. At about 10 nm SE of the threshold and approximately 7 minutes to run, the aircraft experienced severe turbulence. The turbulence lasted for about 10 seconds. The cabin attendant and two passengers were injured. On arrival at EIDL all three were examined by a doctor at the airport. One of the passengers was hospitalised and the other released. A technical examination of the aircraft was completed at the airport and the aircraft was later ferried back, without passengers, to EIDW.

1.1.1 Captain's Report

In his report, the Captain stated:

"We were in VMC conditions throughout the entire flight **(See Chart Appendix A)**. *EIDL Airfield was visible from 30 miles out. I started the descent by positioning the aircraft for a visual left base to Runway 21. The actual weather conditions obtained from EIDL confirmed my visual observations, steady without wind (no gusts), no cloud, unlimited visibility and good temperature spread (+7/+3), (benign conditions). On descent and on clearing the high ground we experienced severe turbulence. During this encounter the First Officer's hand had inadvertently hit switches on the overhead panel causing all cockpit lights to illuminate. After the accident the subsequent approach and landing was normal."*

His assessment of the cause of the accident was:

"With hindsight, clear air turbulence in the lee of high ground. The free wind, i.e. the forecast conditions, 200/30 @ 1000ft and 200/35 @ 5000ft would not indicate the possibility of such conditions. Also clear sky, no orographic cloud and no cloud with vertical displacement."

The Captain, who was the handling pilot on the flight, in an interview with the investigator said that it was a bright clear day. He could see Belfast, which was 53 miles away. He said the aircraft was at 2000 ft, having just passed over the mountains, when the aircraft experienced severe turbulence for about 10 seconds. Following the accident the Captain called out to the cabin attendant, who was at the time in the forward baggage area, to go and check the passengers. On hearing that one of them was injured he decided to radio ahead to have a doctor present on arrival. The Captain said that he was carrying out a visual approach on a left turn onto the runway heading. In doing so he said that he would have maintained a constant distance from the runway threshold whilst at the same time turning the aircraft on to the runway heading. This procedure would have taken him over the Derryveagh mountain range. His was the first aircraft into EIDL that day and as the day was very clear, he was not expecting turbulence. There was absolutely no warning. He remembered hitting his head off the cockpit ceiling.

Following the issue of the Draft Report, the Captain made some representations, which included the following:

"I refer to the fact that during this incident the first officer's hand inadvertently hit switches on the overhead panel causing all the cockpit lights to illuminate. This indicated a catastrophic failure. This was not the case but such an indication could have led to actions, which could have had very serious consequences.

Consideration should be given to informing crew of the possibility of inadvertent activation of the annunciator switch and the possible misleading indications."

1.1.2 Co-Pilots Report

The Co-Pilot was also interviewed and he concurred with what the Captain had said. He said that the seat belt sign had been put on as part of the descent checks. He said that the duration of the turbulence felt more like 3 seconds than 10 seconds. He was pushed upwards in his seat and struck his head. His hand struck the overhead panel. As he did so his hand caught the annunciator lights test switch and all the panel overhead lights came on. Afterwards he noticed that his seat belt had opened.

The Co-pilot said that he had attended a one-day Cockpit Resource Management (CRM) course at Toulouse and a 4-day Multi-Crew Coordination (MCC) course at Heathrow on a Kingair 200 aircraft.

1.1.3 Cabin Attendant's Report

The Cabin Attendant said that she had just finished the refreshment service and had locked the cart in the storage area. She went to the cockpit at the Captain's request. She was about to reverse from the cockpit area with glasses in her hand when suddenly she was thrown backwards and her feet went forward and upwards. She was in the small baggage area between the cockpit and the cabin. The door to the cockpit was open but the door to the passenger cabin was closed. The Captain called out to her to look after the passengers, not realising that she had fallen. The first thing she noticed was that all the overhead annunciator lights were on, which was not normal. She said that during the turbulence, she struck the top of the cockpit doorframe with her legs and then fell to the floor. She used the baggage netting to haul herself up from the floor. She then opened the door between the baggage area and the cabin and went through to look after the passengers. The Captain called her on her cabin interphone system and she reported that one of the passengers would require medical attention. In conjunction with one of the passengers, who was medically trained, she rendered assistance to the injured passenger and helped to refasten his seat belt.

1.1.4. Passenger Witness Reports

(a) A passenger who sustained arm, shoulder and back injuries with a suspected fracture of the humerus said that, following the turbulence, he was rendered unconscious for a short duration.

En-route to Donegal whilst the aircraft was over the Cavan area he felt it bank to starboard. He checked his seat belt to make sure it was fastened. He had been worried about the seat belt as it did not seem to tighten very well. He said that later the aircraft was quite low and he was looking out at Dunlewy Lough, which is situated at the south base of Mt. Errigal.

He thought that there was a whisper of cloud resting on the top of the mountain. The aircraft suddenly dipped to port and then banked to starboard. There was a terrible noise coming from up front and he then lost consciousness. When he regained consciousness his left leg hurt. He saw that his seat belt was not now fastened and

requested the passenger next to him to fasten it for him as he (the injured) was lying to one side of his seat.

(b) This passenger said that when flying she always kept her seat belt fastened. She said that the aircraft "went along the side of Errigal Mountain". Then the aircraft encountered turbulence. There was a terrible *"cracking"* noise. She thought it was the propeller hitting something.

She sustained a swollen knee and received injuries around her hip. Afterwards she discovered that her wedding ring had snapped in two. She assumed that this happened as a consequence of her ring catching the armrest during turbulence.

(c) This passenger said that the visibility was very good. She said she had never come in on that approach before. As the aircraft took a nose dive she felt that the aircraft had hit something. Her head hit off the overhead locker and a glass she was holding flew out of her hand. A gold chain she was wearing broke and she received friction burns to her legs.

(d) Another passenger, who was medically trained, came to the assistance of the most injured passenger who was sitting across the aisle from her. She said that she herself sustained minor injuries.

(e) Another passenger who regularly travelled the route said that she was never so near to Errigal Mountain on any previous flight. She said that the seat belt warning light was out at the time of the turbulence but that she had her seat belt fastened. Even so, she suffered bruises to her legs and said that she hit her head off the overhead locker.

She remembered that she was a little dissatisfied with the reception at the airport on arrival and felt that the passengers should have been ushered into a separate area for comforting and some hot drinks prior to their departure from the airport.

(f) One of the passengers said that whilst passing Errigal Mountain the aircraft seemed to be below the top of the mountain.

1.2 **<u>Injuries To Persons</u>**

There were 3 crew and 32 passengers on board the aircraft. The Airport Authority reported that, on arrival, all the passengers were traumatised. It was stated by the Operator that only two passengers were injured. It is probable that there were other injuries, which may not have been evident immediately following the incident. One of the passengers complained of pains in her arms and hips but was released by the doctor on site. The other passenger had more serious head and arm injuries and the doctor decided to hospitalise him. The Airport Authority said that there were no other complaints of injuries immediately following the incident. The Cabin Attendant reported to the Investigation, in an interview, that her right knee had been injured.

A breakdown of reported injuries is as follows:

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	1*	0
Minor	1	1	0
None	2	30	

* This passenger sustained arm, shoulder and back injuries with a suspected fracture of the humerus.

1.3 Damage to Aircraft

Following the accident the aircraft was subjected to a general visual inspection in order to detect any damage resulting from the in-flight turbulence. The inspection was in accordance with the manufacturers maintenance manual and took almost three hours to complete. No anomalies were found in the inspection to the aircraft exterior. The PSU unit overhead Seat C Row 7, complete with its securing frame, was found pushed in and damaged. The lamp holder had broken away from its mounting. The top of the cockpit doorframe was badly dented.

The FDR and the CVR were removed and the aircraft was then put back into service. Both the FDR and CVR were brought by a member of the AAIU to the United Kingdom AAIB facilities in Farnborough for downloading. On the 5th December the AAIU were informed that the aircraft had experienced almost +4G to –2G during turbulence. The aircraft was withdrawn from service and ferried to a maintenance contractor in France on 7 December 2001. They carried out a full inspection and replacement procedure in accordance with the manufacturers schedule. No defect was found.

The following minor repair work was carried out:

- Call push button passenger seat 7A/C replaced.
- Standard exchange of accelerometer.
- Top lining of forward cockpit entrance door replaced.
- Seat belts inspection and functional test performed. No defect found.
- There was no other damage found.

Considered unconnected with the incident, the following work was also carried out at the time:

- Attachment of passenger seat 5B/D replaced.
- Two bearings on outboard hinge of RH elevator replaced.
- Standard exchange of pitch uncoupling mechanism and torque tube assembly replaced.
- Gap between horizontal stabiliser and vertical stabiliser out of limits, necessitating standard exchange of RH middle and RH aft axles and bushings.
- Fuel leak lower skin rib 13 RH wing repaired.
- Rear engine shock-mounts replaced.

The aircraft was released on 18 December 2001 and was ferried back to Dublin. However, the aircraft returned to France on 19 December 2001 where the manufacturers performed "a further complimentary inspection". The aircraft was finally released for service the following day. The manufacturers intended to carry out a full investigation of the event along with a study of the DFDR analysis and would state if there were any further long-term maintenance schedules to be performed on this aircraft.

The manufacturers issued a report to the IAA dated 28 February 2002. This report included an analysis of the FDR and aircraft loads experienced during the turbulence. The analysis highlights, that wing loading exceeded the certification limit loads both for positive and negative bending. The report concludes:

"*A detailed inspection on the aircraft according to JIC 05-51-11 DVI – Inspection after flight in turbulence - has been requested and carried out. No damage or anomaly has been found that can be linked to the overload suffered by ARANN MSN 191. Therefore, based on the analysis and the inspection results the aircraft can be released into service".*

1.4 Other Damage

There was no other damage to property.

1.5 Personnel Information:

1.5.1 PF (Commander)

Personal Details:	
Licence	ATPL AT/250106 O/A
Last Periodic Check	12 June 2001
Medical Certificate	28 Sept.2001, Class 1
Date of Birth	23 June 1940

Flying Experience:

Total all types	20,000	hours
Total on type	500	hours
Last 90 days	88.76	hours
Last 28 days	41.33	hours
Last 24 hours	4.73	hours
Duty Time up to incident	3	hours
Rest period prior to duty	12	hours

1.5.2 PNF

Personal Details:	
Licence	CPL CP/257431 O/A
Last Periodic Check	23 Sept. 2001
Medical Certificate	11 May 2001, Class 1

Flying Experience:

Total all types	700	hours
Total on type	300	hours
Last 90 days	131.28	hours
Last 28 days	56.86	hours
Last 24 hours	4.73	hours
Duty Time up to incident	3	hours
Rest period prior to duty	12	hours

1.6 Aircraft Information

1.6.1

Aircraft type	ATR 42-300
Manufacturer	ATR
Constructor's number	191
Year of manufacturer	May 1990
Certificate of registration	11 August 1999
Certificate of airworthiness	Valid to 26 April 2002
Total airframe hours	17307 hours
Total cycles	20718 cycles
Engines	Pratt & Whitney PW 120
Maximum authorised take-off weight	16,700 kgs
Actual Take off weight	15,500 kgs
Centre of Gravity	27%

1.6.2 General Information

Type 1A and 2A checks were carried out on this aircraft on 25 November 2001. There were no defects carried at the time of the accident. The GPS system required the December 01 update.

1.7 Meteorological Information

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

General Situation: A complex low-pressure system in mid-Atlantic maintained a stable south-southwest airflow over the area. An active cold front just off the west coast of Ireland was moving easterly at about thirty-five knots.

Wind: At surface: 160/15 gust 26kt
At 2000 ft: 210/40 kt

Weather: Nil

Visibility: 10+ kilometres

Cloud: FEW 2000ft BKN 3000ft OVC 12000ft

Temp/Dew Point: 08º/03º Celsius

MSL Pressure: 1015 hPa

The wind profile at the time suggests that any atmospheric turbulence in the area would be moderate at worst. The forecast does not cover localised/lee turbulence.

1.7.2 The crew obtained the following forecast conditions from Dublin Met prior to the flight, at 04:00 hrs, (valid 020600 to 021500):

Wind:	190/18kt Gusting 30-35kt
Visibility:	10 kilometres +
Significant Weather:	Nil
Cloud:	Various

The actual conditions as recorded by the Captain were:

Wind:	170/19kt
Visibility:	10 kilometres +
Significant Weather:	Nil
Cloud:	Few 6000 ft
Temp/Dew Point:	+7º/+3º Celsius

The "wind check" given by Donegal Control on approach to EIDL was 180/24kt and the QNH was 1014 hpa

1.7.3 Lee Wave Air Flow

In the lee of a mountain ridge, the air usually dips sharply down, before undulating up and down in a streamline for some considerable distance downstream. The wavelength of the lee waves is determined entirely by wind and temperature conditions in the upstream flow while the lee wave amplitude depends on both airstream conditions and the size, shape, and surface nature of the ridge. Vertical currents in the wave flow depend on the amplitude, the wavelength and the wind speed. Strong up and downdraughts are favoured by:

1 Large amplitudes – the larger the amplitude the farther the air moves up and down;
2 Short wavelengths – shorter the wavelength the steeper the ascents and descents in the undulating airflow;
3 Strong winds – the stronger the wind the faster the air moves through the wave pattern.

Lee wave conditions can produce some of the most violent turbulence likely to be encountered in the troposphere. This type of turbulence in wave flow is usually the

combined effect of wind shear and a vertical variation in lee wave amplitude. It should not be assumed either that the lowest streamline follows the shape of the ridge or peak. Experience shows that this is not true with rugged or sharp edged ridges such as Mt. Errigal. There the airflow often breaks away leaving an eddy filling the gap left on the lee side. A detailed explanation of lee wave airflow is covered in **Appendix B.** The IAA publish cautionary notices on possible turbulence in their Aeronautical Information Publication (AIP). The turbulence information relating to Sligo Airport is issued as a caution "Low Level Turbulence in winds from 150º to 230º" and for Kerry Airport all the Instrument Approach Charts carry the caution "Turbulence may be experienced due terrain". The information on Donegal Airport does not include a turbulence caution.

1.8 Navigation and Minimum Heights

Navigation aids at EIDL include an NDB and a Localiser/DME. The published data states that the DME reads zero at the threshold of RWY 03/21. The instrument approach chart for an approach to RWY 21 brings the aircraft in an 8 NM DME arc from east of the airport. This arc brings the aircraft over the Derryveagh Mountains at a minimum sector altitude (MSA) of 3600 ft. Having cleared the mountain range the aircraft is then allowed to descend to 2100 ft. The Instrument Approach Chart states that the DME reads zero at the threshold of RWY 21. This flight, however, was conducted in VMC conditions.

1.8.1. Radar Track

The Shannon radar track from Dooncarton, Co. Mayo, gave bearing and distance of the aircraft from EIDL. The stated distance accuracy of the Dooncarton radar at the distances involved is +/- 0.5 nm. The plot of these **(See Appendix C)** indicates that the aircraft made a DME arc of 6 to 7 nm in order to position for a landing on RWY 21. Prior to that, the aircraft flew over the Derryveagh Mountain Range, which has several peaks between 2139 ft to 2460 ft.

With a touchdown time of 12.58 hrs recorded by Donegal ATC after the landing on RWY 21, the plot of bearing and distance recorded at Shannon indicates that turbulence could have occurred to the North of Mt. Errigal between 12.51:15 hrs and 12.51:30 hrs.

1.9 Communications

The EIDL air/ground communications frequency is 129.8.

At 12.33 hrs, Dublin Air Traffic control handed over control to Scottish Control, when the aircraft was at FL 100. At 12.37 hrs the crew were requested to contact Donegal Control to request permission to descend.

1.10 Aerodrome Information

EIDL is situated, 2nm south west of Bunbeg. It is 30 feet above mean sea level (AMSL). The tarmac runway is RWY 21/03 and is 1500 metres in length and 30 metres in width. The Donegal Control Zone (CTR) has a radius of 10 nm.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The aircraft was equipped with a Fairchild Cockpit Voice Recorder (CVR). The landing time at EIDL transmitted to the crew by Donegal Tower, and recorded on the CVR was 12.58 hrs. The time duration from the recording of initial turbulence to the time of landing (taken as time at which the propellers were set to Low Pitch) was 6 min 10 seconds. This would put the time of occurrence at 12.51:50 hrs. Just prior to this time the Co-pilot did express, what under the circumstances could be considered as some concern about the flight path. However, this failed to register as such, and the Captain continued to maintain that path.

1.11.2 Flight Data Recorder

The aircraft was equipped with a Checstroke Flight Data Recorder (FDR). The aircraft roll parameter was not being recorded satisfactorily at the time of the accident.

The aircraft was airborne from RWY 28 at EIDW at 12.21 hrs, corresponding to an FDR frame time of 3767 (elevator going to negative) and turned on to a magnetic heading (M) of 320° M. After 11min 34 seconds, the aircraft reached Flight Level (FL) 100. At 12.33 hrs Dublin ATC handed the aircraft over to Scottish Control. At 12.37 hrs the crew were requested to contact Donegal Control to obtain permission to descend.

The aircraft was now at FL100 and on a heading of 322° M. At 12.40 hrs the aircraft commenced its descent, maintaining the same heading. At 12.44 hrs the aircraft was at a pressure altitude of 7900 ft.

At 12.45 the heading had decreased to 263° M and the pressure altitude was now 7400 ft. At a pressure altitude of 6400 ft. the heading had returned to 350° M. At 12.49 the aircraft had descended to 4700 ft. on a heading of 347° M. The aircraft was now approaching the Glendowan Mountains where the Radio Altimeter (RA) reading recorded 3660 ft.

At 12.50 hrs, the aircraft was at a pressure altitude of 3200 ft on a heading of 342° M and the RA recorded 2160 ft. The heading then decreased to 328° M as the aircraft approached Mt. Errigal and increased again slightly to 330° M as it passed east of the mountain. The pressure altitude remained more or less constant at 2770 ft. but just 4 secs prior to the onset of major turbulence the RA height had decreased to 1135 ft as the aircraft flew over high ground.

After the aircraft passed the high ground, the RA height increased to 1600 ft. The FDR frame number 18095, corresponding to an elapsed time of 29 min 51 sec since take off (at frame number 3767), recorded maximum normal G force due to turbulence, of +3.9 G to -2G as the RA recorded 1630 ft. The estimated time was then 12.50:51 hrs. Turbulence occurred just 6 seconds after passing Mt. Errigal (**See Appendix D)** and

less than 1km NNW of that peak. The pressure altitude recorded at that time was 2756 ft and the radar altitude 1637 ft, giving the terrain a height of 1119 ft (341m) above sea level at that point.

During the turbulence the aircraft pitched up almost 5º in 8 seconds and from there, down violently again to -4º in less than 1 second. The airspeed went from 220 kt to 260 kt in 1 second and back to 225 kt again in a further 2 seconds. Similar oscillations were experienced in the lateral, longitudinal and normal accelerations. These oscillations lasted for about 10 seconds.

1.12 Wreckage and Impact Information

Not applicable

1.13 Medical Information

Not applicable

1.14 Fire

Not Applicable

1.15 Survival Aspects

The seat belt attached to Seat 7C, the seat on which the injured passenger was sitting at the time of turbulence, was tested by the aircraft contractor in France following the accident and was deemed to be serviceable.

1.16 Tests and Research

Not applicable.

1.17 Organizational and Management Information

Section 8 (Operating Procedures, issue No. 2 dated 31 Oct. 2001) of the Operator's Manual, contains a 6 page document on the dangers of flying in or near mountain waves.

Para. 8.3.8.9.3 Flying in Mountain Wave Conditions states:

It must be appreciated that the relative speed of an accidental entry into the rotor zone will be greater than in up-wind flight, because the rotor zone is stationery with regard to the ground. Thus the structural loads, which may be imposed on the airframe when gusts are encountered, are likely to be greater and there will probably be less warning of possible handling difficulties.

On 4 December 2001, the Operators Flight Operations Manager, based on information received from the Captain immediately following the accident, also issued the following Flight Crew Instruction:

"Following a recent incident where severe clear air turbulence was experienced by an ATR42 making an approach to Donegal Airport the following procedures are to be applied.

1. *Regardless of inbound track, it is prohibited to carry out the DME arc procedure to position for the approach onto runway 21.*

2. *All approaches to Donegal Airport shall commence from overhead the CFN beacon at a minimum altitude of 3,600 ft QNH.*

3. *Descent profiles should be planned to reach 3,600 ft QNH no further the 5nm from the CFN beacon."*

1.18 Additional Information

1.18.1 Terrain

The subtraction of the RA readings from the Pressure Altitude readings recorded by the FDR can give a useful indication of the type of terrain over which the aircraft passed **(See Appendix E)**. This was done for a period of 100 seconds prior to the location at which turbulence was experienced. At approximately 60 seconds prior to passing Mt. Errigal the aircraft flew over a mountain peak. With the aircraft at a height of 4000 ft, the height of the terrain at that point was recorded as 1726 ft (526m). The only peak of that height in the vicinity is Moylenanav, which has a height of 1768 ft (539m). This fixes a point over which the aircraft flew, a little over one minute before turbulence. The heading of the aircraft at this time was 345º M and the aircraft's track as recorded by ground radar was 350º M. One minute later, as the aircraft passed alongside Mt. Errigal, the heading had decreased to 328º M and the track to 335º M. The aircraft passed within a lateral distance of 600m from the peak.

The Captain's report on a standard aeronautical chart (**See Appendix A**) indicates that the aircraft's track was east of another peak called Crockskallabagh, which has a height of 1621 ft (494 m), a further 1km east of Moylenanav. The small scale of the chart on which the track was recorded would account for this error in position. Whilst most peaks in the area are recorded and marked on the aeronautical chart, the peak of Moylenanav is not identified although it is higher than Crockskallabagh.

1.18.2 Annunciator Light Switch

The Investigation contacted the manufacturers with reference to the Captain's representations on the above subject and the possibility of mounting a guard over the switch. The manufacturers said that to enable the switch to be put in the TEST position the button had to be first pulled and then shifted rearward. They said that the

switch has enough protection from unintentional selection and no other means of protection against inadvertent selection was necessary.

2. ANALYSIS

By correlating information on the CVR, FDR and ground radar track, it is estimated that the time of occurrence of the turbulence was in the region of 12.51:05 hours.

Approximately one minute prior to this, the aircraft was at an altitude of 4083 ft above sea level and about to enter the Donegal Control Zone. The aircraft was at a safe height above all the mountain peaks in the area. However, at about 12 nm from EIDL, instead of continuing its slow descent (670 ft/min) to the airport, the aircraft increased its rate of descent to 1500 ft/min. The heading also decreased from 345º M to 328º M during this time. When the aircraft reached 600 metres east abeam the peak of Mt. Errigal, it levelled out at 2756 ft. With Mt. Errigal at 2464 ft, the passing height of the aircraft was 292 ft above the peak. Six seconds after passing the east abeam the peak, the aircraft suffered severe turbulence. During this turbulent event, the aircraft descended to a minimum height of 2286 ft Pressure Altitude (RA 1700 ft). The aircraft then was recorded climbing back to 2482 ft, followed by a constant rate of descent (670 ft/min) to EIDL. The time from first up-set, to minimum height reached, to climbing back to 2482 ft was 98 seconds.

If the aircraft had maintained the original rate of descent of 670 ft/min, it would have passed over Mt. Errigal at an approximate height of 3700 ft (approximately + 1200 ft). The meteorological aftercast indicates that any turbulence encountered would have been very moderate at worst. If this were the case, any turbulence encountered would be much less than that experienced at 2700 ft. If flight had been conducted in IMC conditions the Minimum Sector Altitude would have been 3600 ft. As it was, the aircraft was flown at such a height and proximity to the mountain peak, to allow it to be affected by the strong vertical streamlines and/or eddies/rotors, which had developed in its lee as a result of the prevailing wind conditions.
Aircrew should be aware that eddies/rotors exist in the lee of mountain peaks when wind conditions are prevailing. The severity of these eddies/rotors invariably increases with the intensity of the wind, the topography and the altitude. It is not good aviation practice to fly any aircraft in the vicinity of high ground, such as Mt. Errigal, with wind conditions prevailing at that altitude.

It is noted that the Captain had 20,000 hours flying experience whereas the Co-pilot had 700 hours experience. Such a steep cross-cockpit experience gradient might have militated against full and frank communication between the crew in the lead-up to this event.

3. CONCLUSIONS

3.1 Findings

3.1.1 The aircraft and crew were properly certificated for the flight.

3.1.2 The aircraft had been correctly maintained in accordance with the appropriate schedules.

3.1.3 For the first 27 minutes following take-off from EIDW, the aircraft maintained a satisfactory flight profile.

3.1.4 At approximately 12 nm from EIDL, the aircraft diverted from its descent path and flew 600 metres East of and approximately 300 ft above the peak of Mt. Errigal.

3.1.5 The aircraft encountered severe turbulence, in the form of eddies/rotors, approximately 6 seconds after passing the peak.

3.1.6 As a result of this severe turbulence encounter, one passenger suffered serious injuries, while the cabin attendant and another passenger suffered minor injuries.

3.1.7 The cabin attendant displayed a high level of professionalism in immediately attending to the passengers, despite being injured herself.

3.2 Causes

3.2.1 The aircraft was flown through an area in the lee of Mt. Errigal where the transverse wind of 40kt across the peak generated a condition of severe turbulence. The resultant severe turbulence caused the aircraft to experience a G-load range of between + 4G to -2G for a period of 6 seconds. The upset experienced by the aircraft was sufficient to cause injury to two passengers and one crewmember.

3.2.2 The flight crew failed to appreciate the possible effect of a transverse wind when flying in the lee area of a significant conical shaped mountain.

3.2.3 The aircraft's proximity to the mountain did not allow for the possibility of turbulence in the lee of the peak.

4. SAFETY RECOMMENDATIONS

It is recommended that:

4.1 The IAA should review the procedure detailed in the Instrument Approach Chart, which takes an aircraft over Mt. Errigal and the adjacent mountain range. **(SR 12 of 2002)**

4.2 The IAA should consider a turbulence warning for EIDL in their Aeronautical Information Publication (AIP) Section AD under "Additional Information". **(SR 13 of 2002)**

4.3. The Operator should review procedures for the approach and landing at EIDL in both VMC and IMC conditions. **(SR 14 of 2002)**

4.4. The Operator should make it a matter of policy that all their pilots carry out a CRM programme, tailored to their specific flight operation. **(SR 15 of 2002)**

4.5 The IAA should review the current Aeronautical Chart (ICAO 1: 500000) in order to confirm that the highest peaks in the area of Derryveagh Mountains are identified. **(SR 16 of 2002)**

Note1: Following this accident the Operator reviewed the procedures for the approach and landing at EIDL Airport.

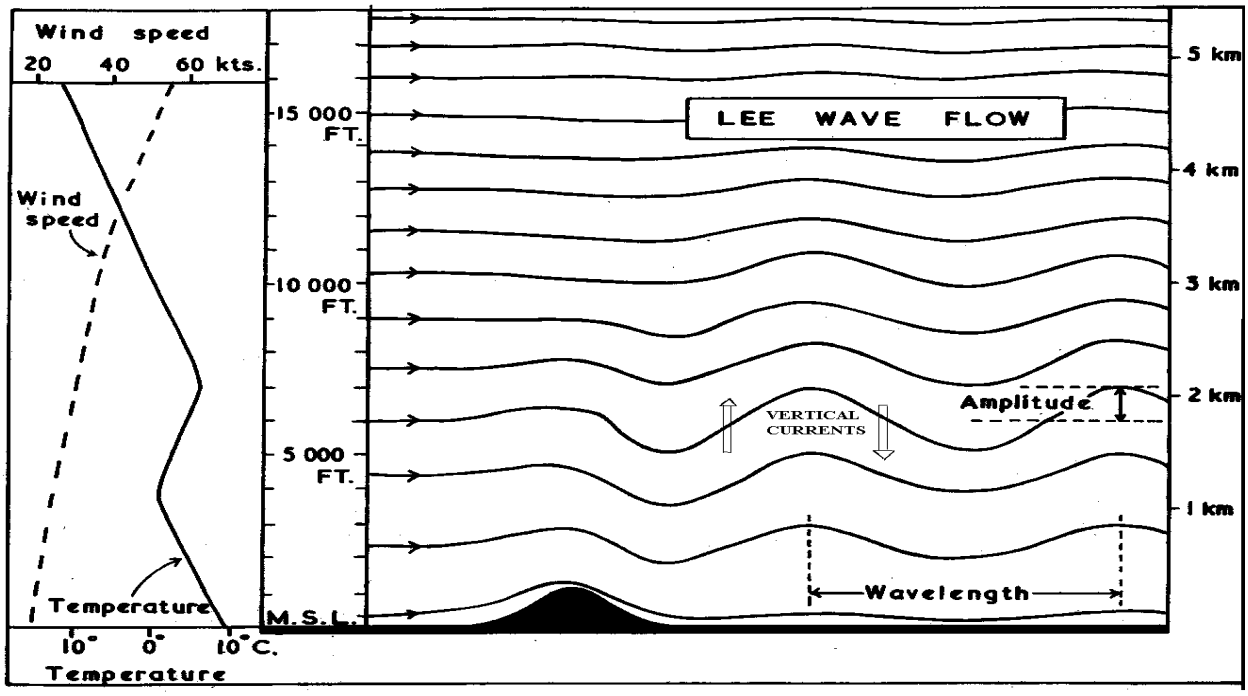
Note2: The Operator has devised and will put in place, a CRM course, which will address the specific requirements of their crews.

APPENDIX A

Aircraft track and DME arc approach to RWY 21 at EIDL reproduced from Captain's report.

APPENDIX B

Lee Wave Flow

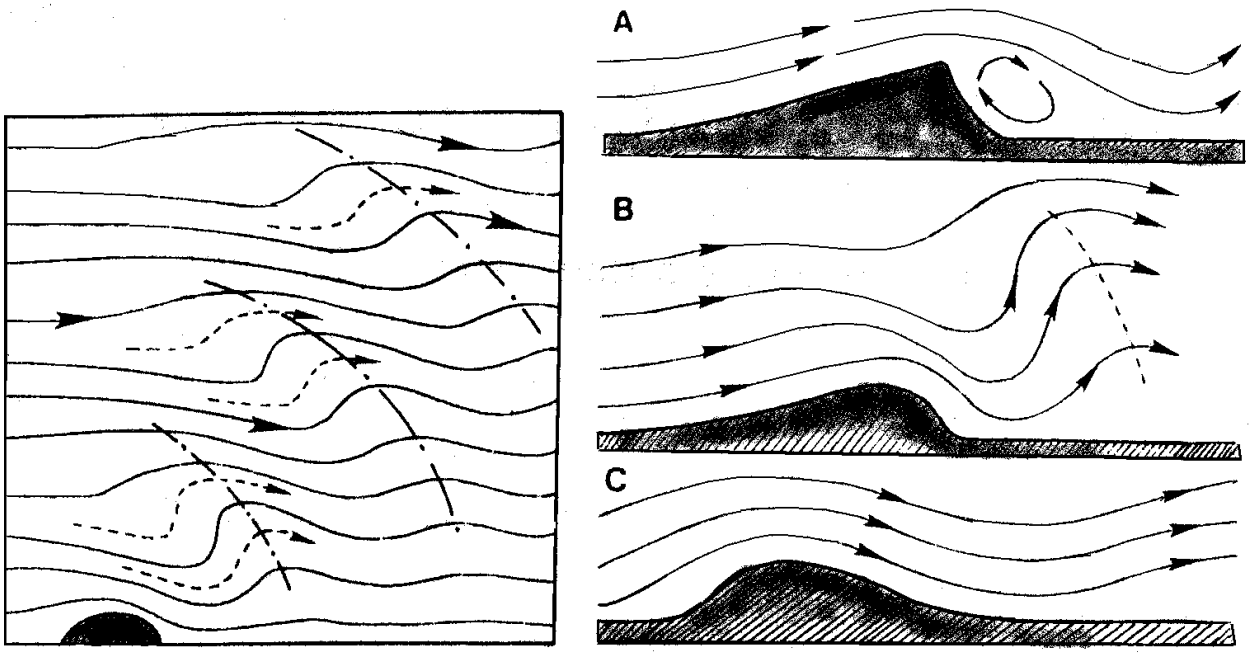


Lee waves are often associated with a stable layer sandwiched between air of lesser stability together with an increase with height of wind components across the ridge. In practice a ridge or peak produces waves where amplitude decreases rapidly downwind and it should not be assumed that all lee waves are as simple as those depicted.

Wave cloud is another phenomenon linked closely with lee wave amplitude. Air rising in the updraught of a wave cools adiabatically, and if this cooling is sufficient to cause condensation then cloud will form. Subsequent warming in the downdraught causes the condensed water to evaporate and so by a continuous process of condensation at its leading edge and evaporation at the trailing edge the cloud as a whole appears to be stationary in the sky. Wave cloud owes its existence to two principal factors:

The wave amplitude and the humidity of the air before it enters the wave flow. Because condensation of water vapour in the atmosphere is a very rapid process the formation of wave cloud does not depend upon the speed of the vertical currents. Therefore the only certain fact implied by the presence of a wave cloud is that near the level of the cloud the wave amplitude is big enough to lift the air to its condensation level. This in turn indicates anything from small amplitude undulations in humid air to large amplitude waves with low humidity, and remembering that the vertical currents are dependent not only on the amplitude but also on the wavelength and wind speed it becomes apparent that a wave cloud is not an absolutely sure sign of strong updraughts. Conversely, the absence of cloud does not indicate the absence of lee waves.

Turbulence in the lee of a ridge is often slight. It may amount to no more than shallow patches of ruffled air sandwiched between layers of smooth wave flow. But in the strong wind shears even weak waves can trigger off high-level turbulence rough enough to surprise and shake the unwary pilot, and at lower levels, where the wave amplitude often varies considerably with height, turbulence due to wind shear and waves can sometimes be really violent.



The above diagram shows a more realistic wave flow pattern. It can be seen that the waves are not symmetrical but tilt forward at a marked angle to the vertical. This can produce large sudden lift forces where the lines joining the trough to crest are almost vertical.

Diagram A, B and C show how the shape of the streamlines can be modified by the shape of the ridge:

A) Here the ridge drops away too sharply; separation of flow occurs leaving a lee eddy to fill the break in the flow

B) This shows a ridge where the upslope is gentle but the downslope is steep. This produces very steep streamlines with a forward tilted wave front.

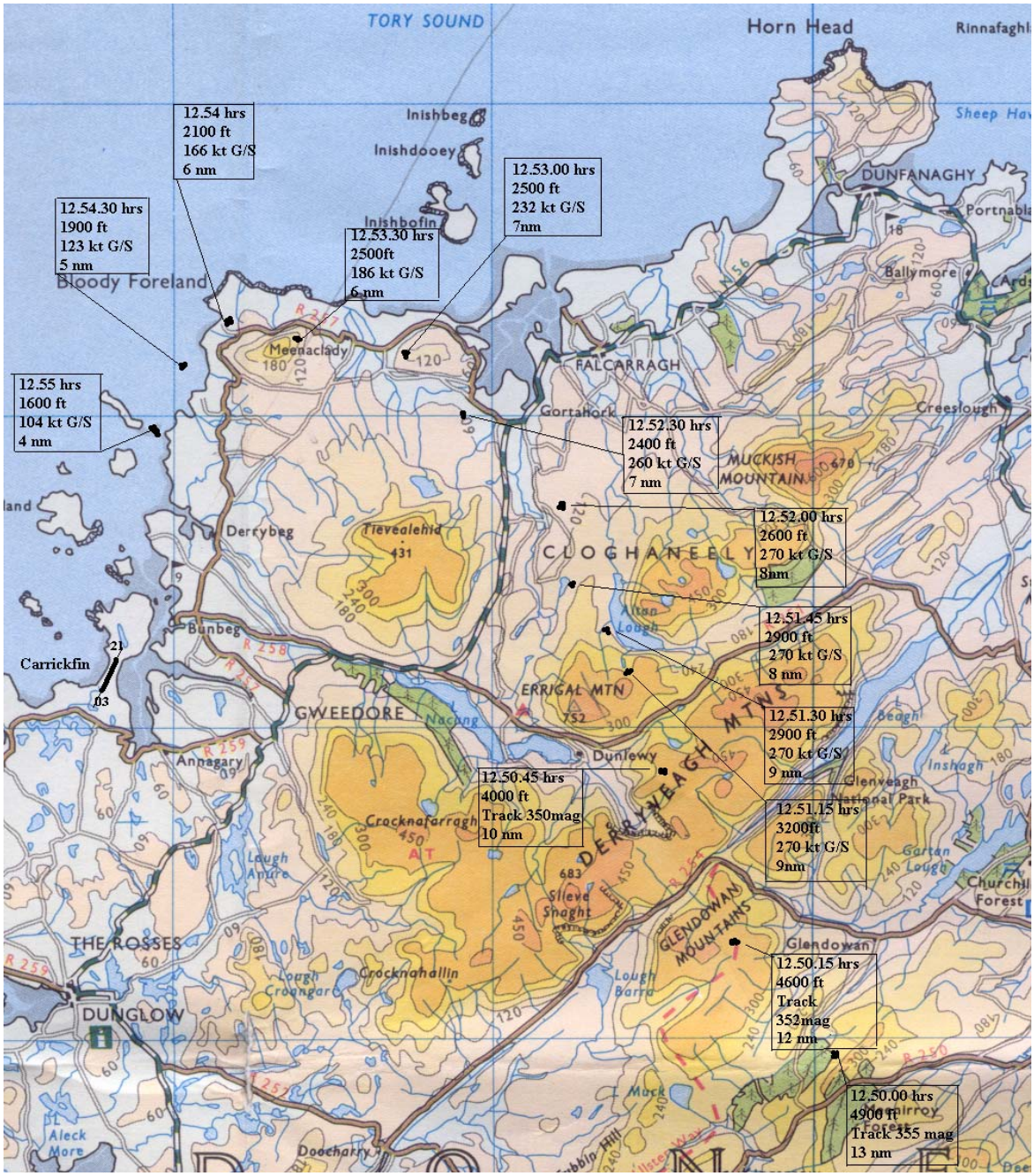
C) This shows the opposite situation to case B. The ascent is steep but the descent from the ridge but the descent from the ridge crest is gradual. The result is a much flatter wave.

Whenever large amplitude waves occur then rotor turbulence can be expected (with or without cloud) under at least the first wave crest. Rotor turbulence is a continuous circular movement of air and can also occur to the lee of large ridges.

The loss of many small aircraft per annum in the western USA is probably due to mountain wave effects. Loss of height can be so rapid (vertical currents of up to 5,000 fpm have been observed) that the pilot would often not have time to transmit a distress message before colliding with the high ground and it may subsequently appear that he was flying with terrain clearance below the recommended value.

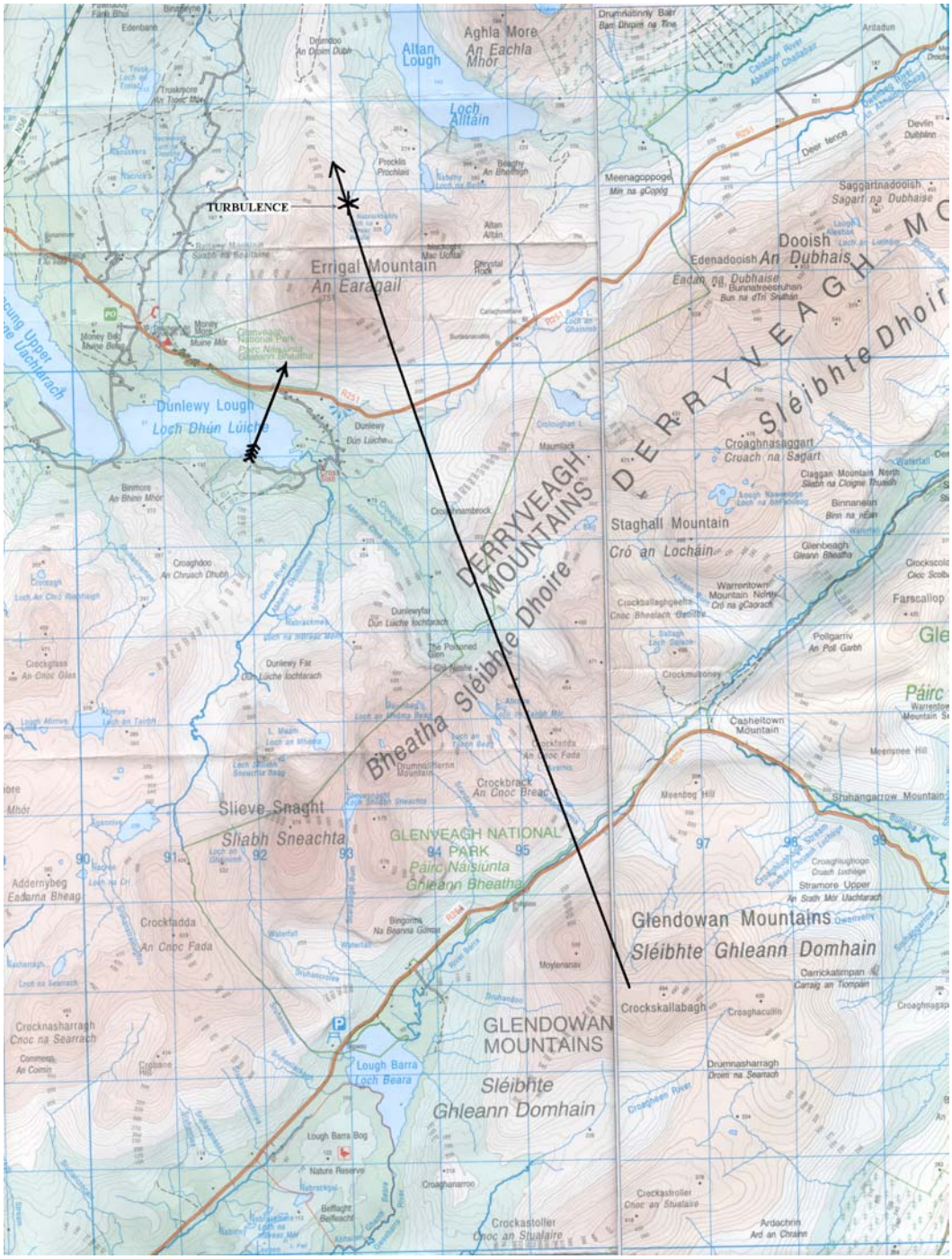
References: (1) "Meteorology for Glider Pilots" by C.E. Wallington
(2)"Airflow in the lee of mountains" by T. Sheridan
(3)"Theory and observation of waves" by T.A.M. Bradbury

APPENDIX C



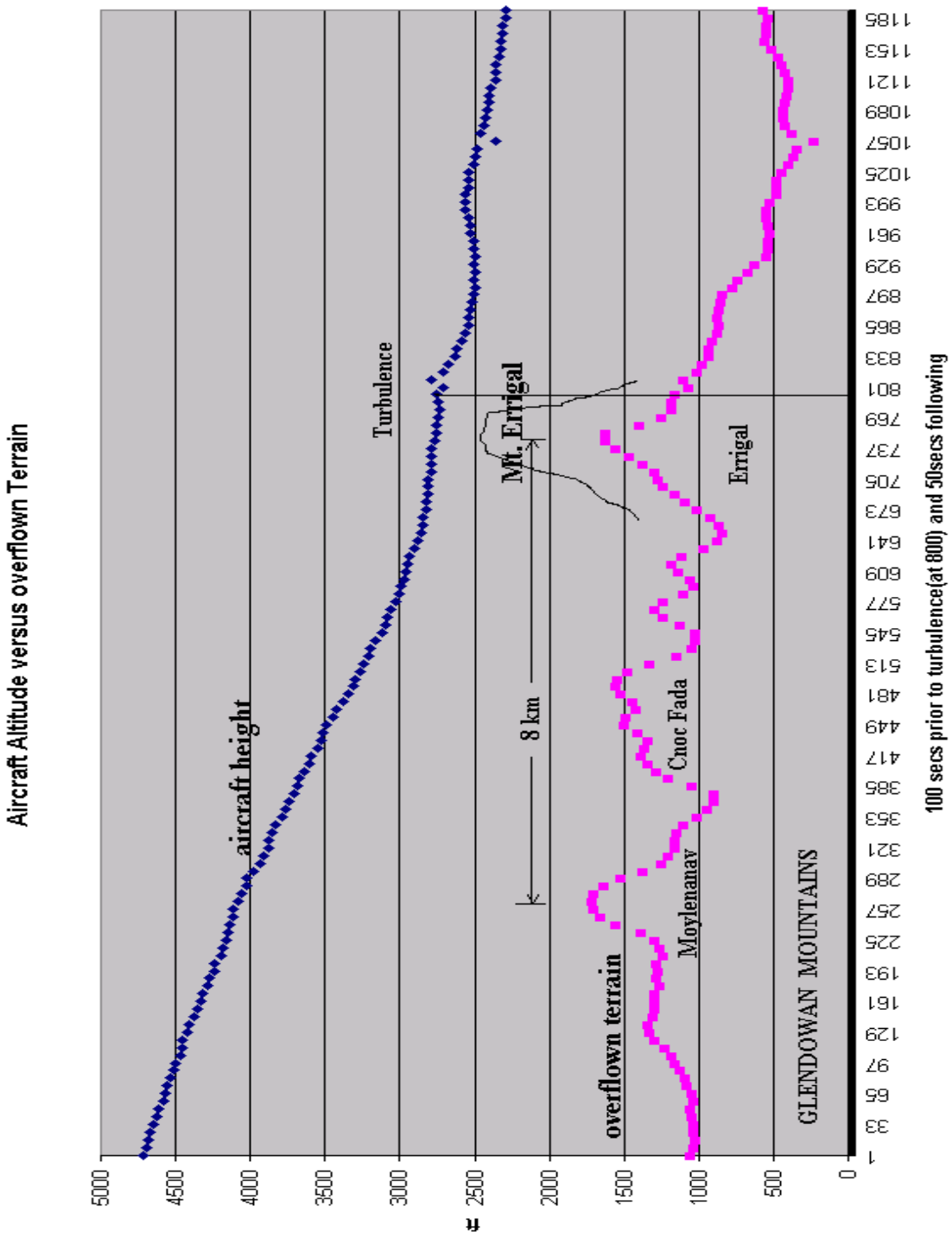
Radar Track of EI-CPT from 12.50 hrs until touchdown on RWY 21, EIDL, at 12.58 hrs. (Stated accuracy +/- 0.5 nm)

APPENDIX D



Approximate track of EI-CPT derived from its FDR and showing the location at which turbulence took place. The wind as shown is that for a height of 2000ft given by the Met Eireann aftercast for the area.

APPENDIX E


Aircraft Altitude versus overflown Terrain
aircraft height
Turbulence
Mt. Errigal
8 km
overflown terrain
Moylenanav
Cnoc Fada
Errigal
GLENDOWAN MOUNTAINS
ft
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1
33
65
97
129
161
193
225
257
289
321
353
385
417
449
481
513
545
577
609
641
673
705
737
769
801
833
865
897
929
961
993
1025
1057
1089
1121
1153
1185
100 secs prior to turbulence(at 800) and 50secs following