HELLENIC REPUBLIC
MINISTRY OF INFRASTRUCTURE & TRANSPORT

AIR ACCIDENT INVESTIGATION
AND AVIATION SAFETY BOARD
(AAIASB)

ACCIDENT INVESTIGATION REPORT OF THE AIRCRAFT SX-DIA AT THE AIRPORT OF RHODES 'DIAGORAS' ON 2 FEBRUARY 2015

03 / 2018

ACCIDENT INVESTIGATION REPORT

03/2018

Aircraft SX-DIA (Jetstream 41)

at the Airport of Rhodes 'Diagoras' on 02.02.2015

The accident investigation was carried out by the Air Accident Investigation and Aviation Safety Board in accordance with:

- **Annex 13 to the Chicago Convention;**
- **Regulation (EU) No 996/2010;**
- **Hellenic Republic Law No 2912/2001.**

'In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and Law No 2912/2001, the purpose of investigations into aviation accidents and incidents is not to assign blame or liability. The sole purpose of the investigation and its findings is the prevention of accidents and incidents. As a result, use of the findings for any purpose other than the prevention of future accidents could result in erroneous conclusions.'

LIST OF CONTENTS

OPERATOR	: SKY EXPRESS S.A
OWNER	: SKY EXPRESS S.A.
MANUFACTURER	: BRITISH AEROSPACE
TYPE	: JETSTREAM 41
REGISTRATION	: SX-DIA
NATIONALITY	: Greek
AIRCRAFT TYPE	: Airplane
SERIAL NUMBER	: 41075
COUNTRY OF MANUFACTURE	: United Kingdom
PLACE OF OCCURRENCE	: Airport of Rhodes 'Diagoras'
DATE & TIME	: 02/02/2015 & 05:36 UTC
Note	: (local time = UTC + 2h)

SYNOPSIS[1]

On 2 February 2015, the Jetstream 41 operated by "SKY EXPRESS", Registration SX-DIA, was on the scheduled flight 'SEH 100' from the Airport of Heraklion 'N. Kazantzakis' (LGIR) to the Airport of Rhodes 'Diagoras' (LGRP). Upon landing in runway 07 of the aerodrome, at 07:36 hrs. local time, while the aircraft was decelerating following touchdown, the left main landing gear collapsed and folded rearward. As a result, the aircraft dragged the runway on its left side and came to rest at the runway left edge and without leaving the runway, about halfway of the runway's length and facing eastward. There was no fire or injuries, and the passengers were disembarked without any problem.

The Air Accident Investigation and Aviation Safety Board was notified of the accident by means of document Sky Express/3271/02.02.2015 and an Investigation Team was appointed by virtue of document AAIASB/205/02.02.2015.

The competent International and National Authorities were notified under document AAIASB/209/02.02.2015. The state of manufacturer appointed accredited representative (non-travel).

[1] This report has been translated into English and published by the Hellenic Air Accident Investigation and Aviation Safety Board. As accurate as the translation may be, the original text in Greek should be considered as the work of reference.

1 FACTUAL INFORMATION

1.1 History of the Flight

The Jetstream 41 aircraft, with registration number SX-DIA, operated by "SKY EXPRESS", took off on 2nd February 2015 at 07:00 hrs. local time from the Airport of Heraklion 'N. Kazantzakis', performing the scheduled flight No. 'SEH100', the first in the day, destined for the Airport of Rhodes 'Diagoras'.

Pre-flight checks were completed with no findings and in this flight the Captain was designated as the Pilot Flying. A 3-member crew and 16 passengers were onboard. The flight crew reported for duty one hour prior to the time of flight and proceeded with all actions as laid down in the Company manual. The flight crew was also briefed that in the area of the Airport of Rhodes the winds were S-SE at 17 kt with Wind Gust 36 kt.

At 07:23:54 hrs., approximately 12 min prior to landing, in the first contact of the flight crew with the Control Tower of the Airport of Rhodes, the flight crew was briefed by the Air Traffic Controller (ATC) with respect to the weather conditions at the area of the airport, variable winds prevailing with a direction from 20º to 160º, average wind direction from 110º, wind velocity 20 kt gusting 38 kt.

As laid down in the airport procedures, ATC, given the weather conditions, alerted the fire service vehicles to be stationed in readiness at their designated positions on the taxiways.

At 07:24:43 hrs. Rhodes ATC contacted the flight crew wishing to remind that as a result of the strong wind shear and turbulence, landing at the airport is not recommended under the circumstances.

At 07:29:34 hrs. Rhodes ATC contacted again the flight crew informing that the wind is shifting from 40º to 260º, average wind direction from 120º, mean wind velocity 20 kt and wind gust 32 kt.

At 07:32:36 hrs., at about 8nm to the airport, the ATC contacting again the flight crew informed that wind in the last ten minutes is shifting in all directions, with mean wind velocity 16 kt and wind gust 37 kt; ATC also reminded that under these conditions landing is not recommended.

At 07:34:04 hrs., at about 4 nm to the airport, Rhodes ATC contacted again the flight crew informing that wind is shifting from 60^{o} to 200^{o}, mean wind velocity 15 kt, wind gust 32 kt and that runway 07 is free for landing.

At 07:35:08 hrs. ATC again reports wind direction from 110^{o}, 17kt.

Communication between ATC and the flight crew was smooth without any problem, with the flight crew each time acknowledging the information provided by ATC.

Given the prevailing winds, landing with 9^{o} flaps and an airspeed of about 129 kt was selected. With the flight crew having performed all pre-landing checks prescribed in the manual and with the indicator lights for the 'Down and Lock' landing system being illuminated green, at about 07:36 hrs. the aircraft landed, with the right main landing gear touching down first.

During deceleration immediately after touchdown, with the flight crew having performed all checks specified in the a/c manual and after ATC directed the aircraft to vacate the runway via taxiway 'C', the aircraft veered to the left and came to rest at the left edge of the runway without exiting the runway, with an eastward direction.

With the fire service vehicle approaching the aircraft, the flight crew contacted the Control Tower of the airport stating that everything is ok, and then reporting inability to taxi when asked whether the aircraft is able to taxi; when asked whether a tire was burst, the flight crew confirmed that this is the case.

At 07:37:49 hrs. the Fire Service advises the Control Tower of the airport that the fire truck sprays foam due to fuel leakage.

At 07:41:08 hrs. the Control Tower, when so asked by the 'follow me' vehicle, inquired of the flight crew whether passengers could be disembarked and the answer was that getting off from the passenger door (forward left) would not be feasible given the presence of the fire-fighting foam on the runway, and that the rear right door (Emergency Exit) would be used instead.

Fig. 1

As reported by the Air Traffic Controller passengers were disembarked 15 minutes after the incident, and the process lasted approximately 10 minutes.

Upon a first visual inspection at the accident site and before the left wing of the aircraft was raised on jacks, it appeared that the left main landing gear folded back resulting in the aircraft's left side dragging the runway (the left main landing gear and its housing into contact with the runway) and stopping at the left edge of the runway facing to the east.

Fig. 2

Fig. 3

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	---	---	---
Serious	---	---	---
Minor/none	-- / 03	-- / 16	---

1.3 Damage to aircraft

The left main landing gear's folding rearward resulted in the blade tips of the left propeller of the aircraft coming into contact with the runway while the propeller was turning, which led to the blade tips sustaining serious structural damage (Fig. 4).

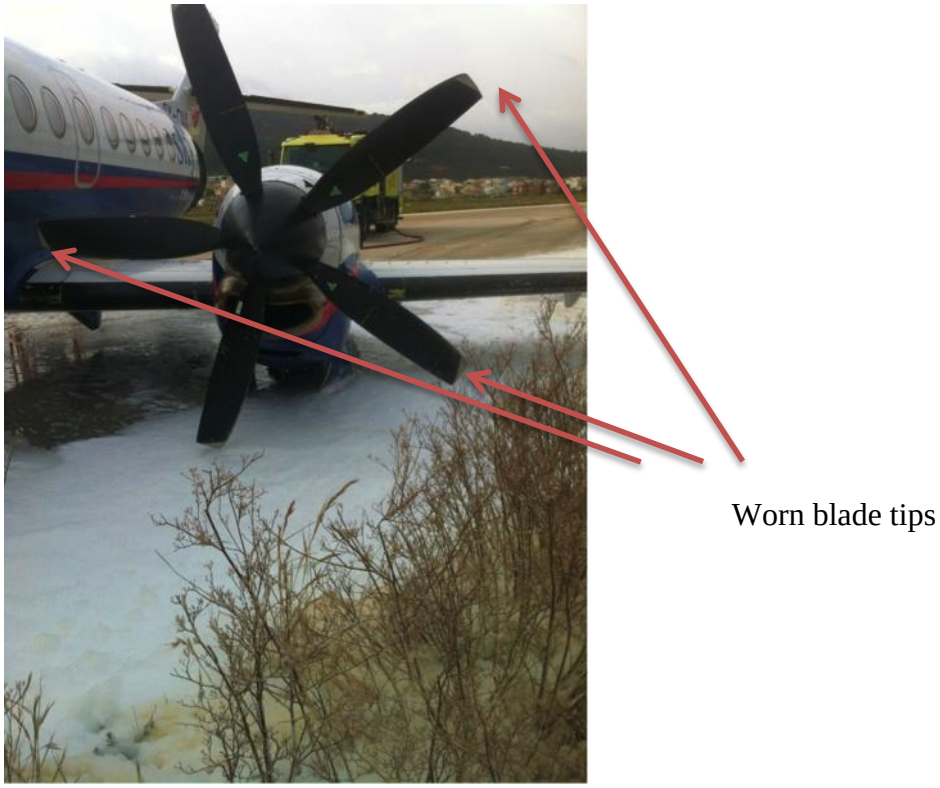


Fig. 4. Left Propeller

When the a/c left wing was raised on jacks, upon visual inspection of the left main landing gear the following was observed:

- The hydraulic lines at the back of the shock strut were deformed, consequent to impact, possibly due to the gear collapsing and folding.
- Ribs 7 and 8 where the two trunnion pins of the Drag Brace as well as the two respective pins of the Shock Strut are housed were found to be broken (figures 12-13). Rib 7 (inboard structural element relative to the undercarriage) had broken at its rear segment, directly above the well of the inboard pin of the shock strut, whereas Rib 8 (outboard structural element relative to the undercarriage) had broken at its forward segment directly above the well of the outboard trunnion pin of the drag brace.
- The Drag Brace Lug at the lower segment of the inboard pin well, where it is attached to the Retract Actuator, part of which was within the lug, presented wear due to friction (Fig. 5).

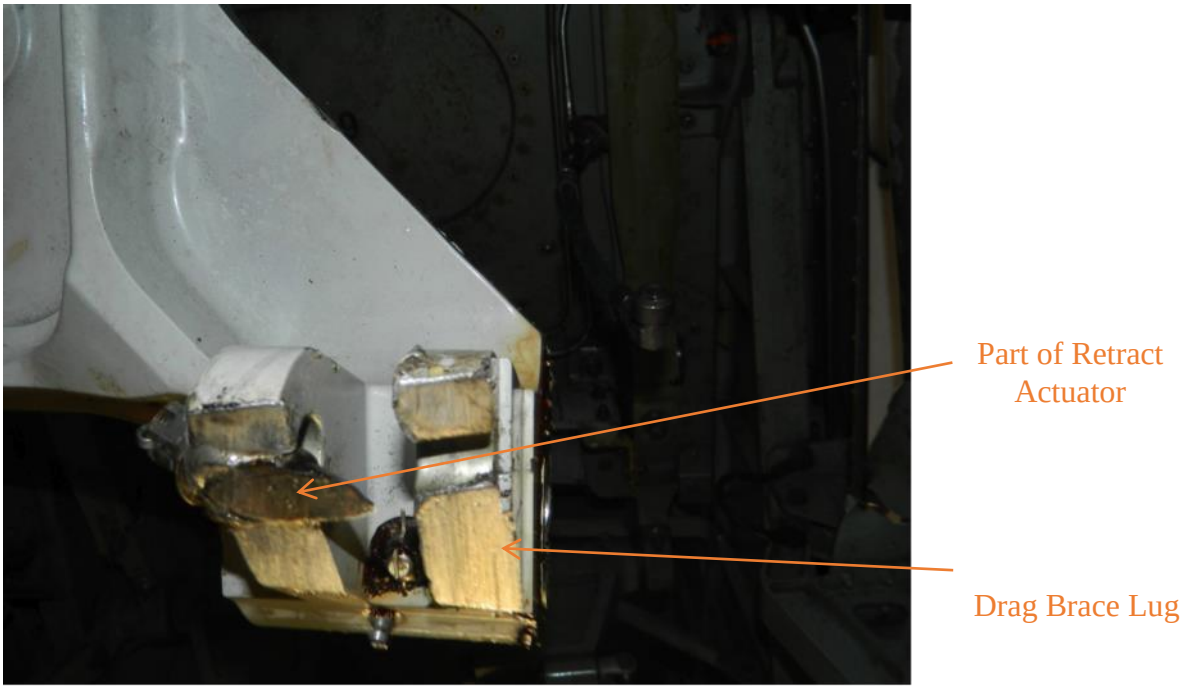


Fig. 5 - Drag Brace

- The edge of the Retract Actuator (Fig. 6), where it is attached to the Drag Brace, presented wear due to friction in the same manner as seen in the Drag Brace Lug.
- The inboard trunnion pin of the Drag Brace attaching it to Rib 7 had fractured (Fig. 8-9-10).
- Damage was found to the landing gear bay, due to its having been dragged on the runway.

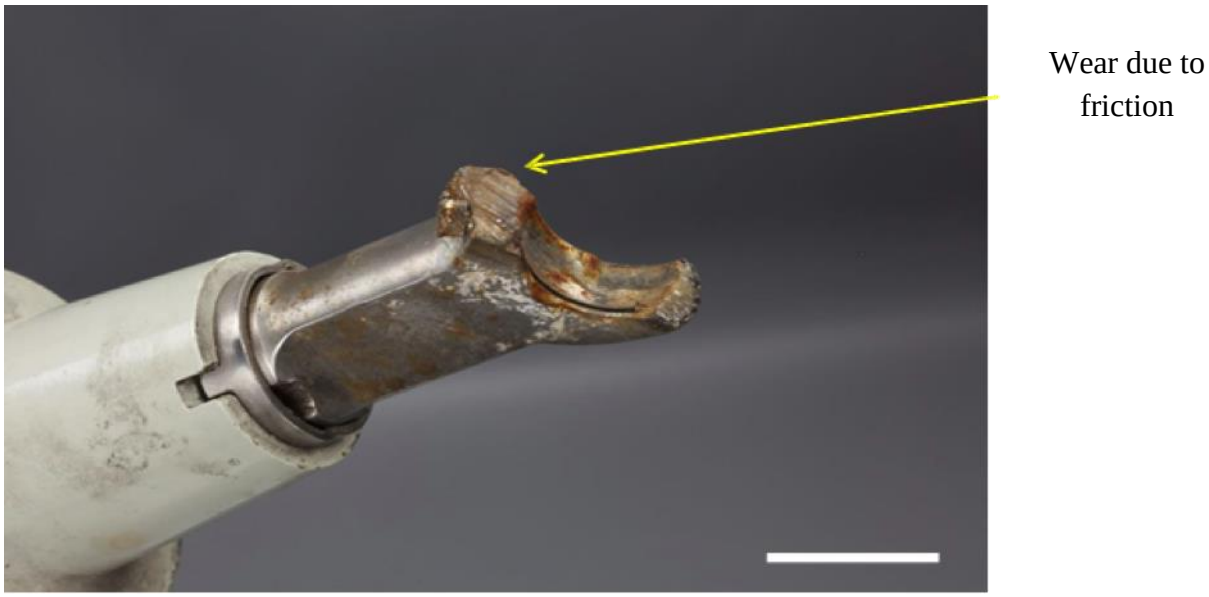


Fig. 6. Retract Actuator

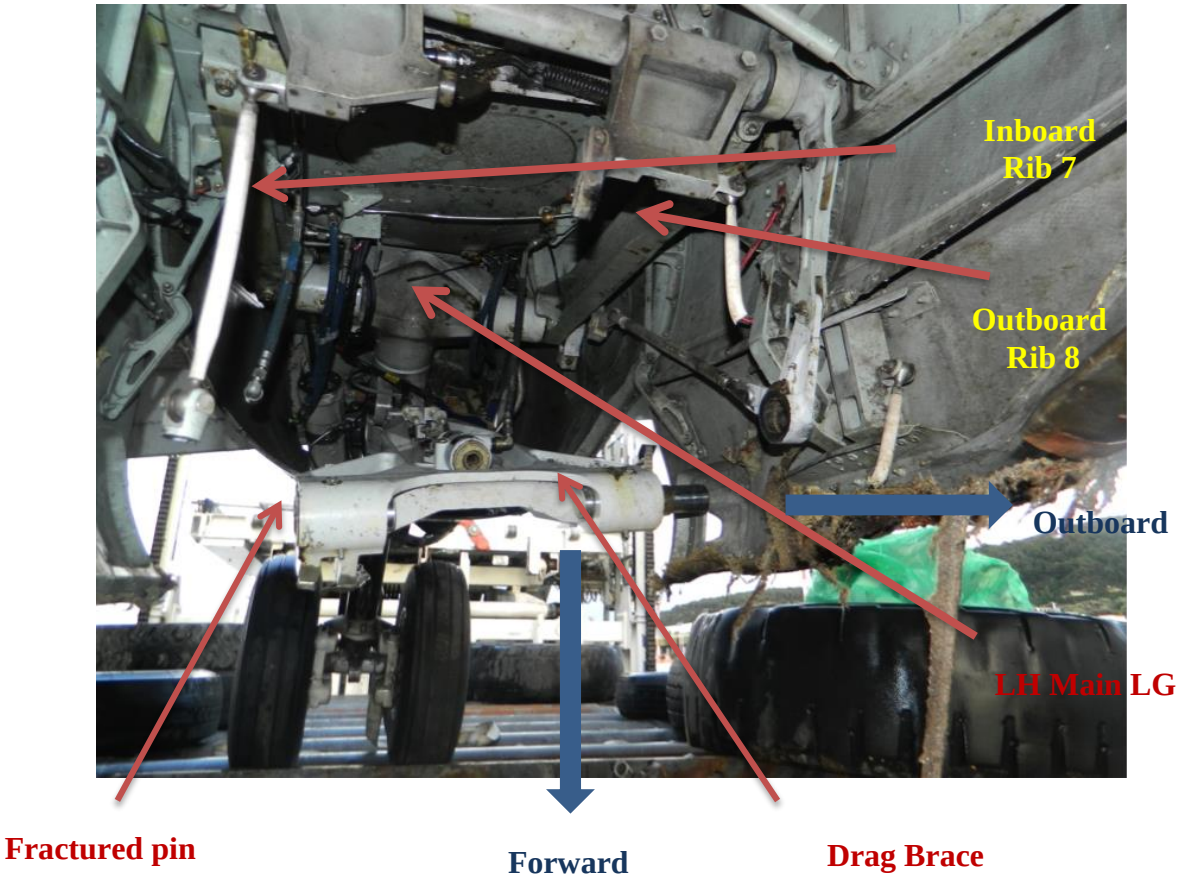


Fig. 7. LH MLG Well

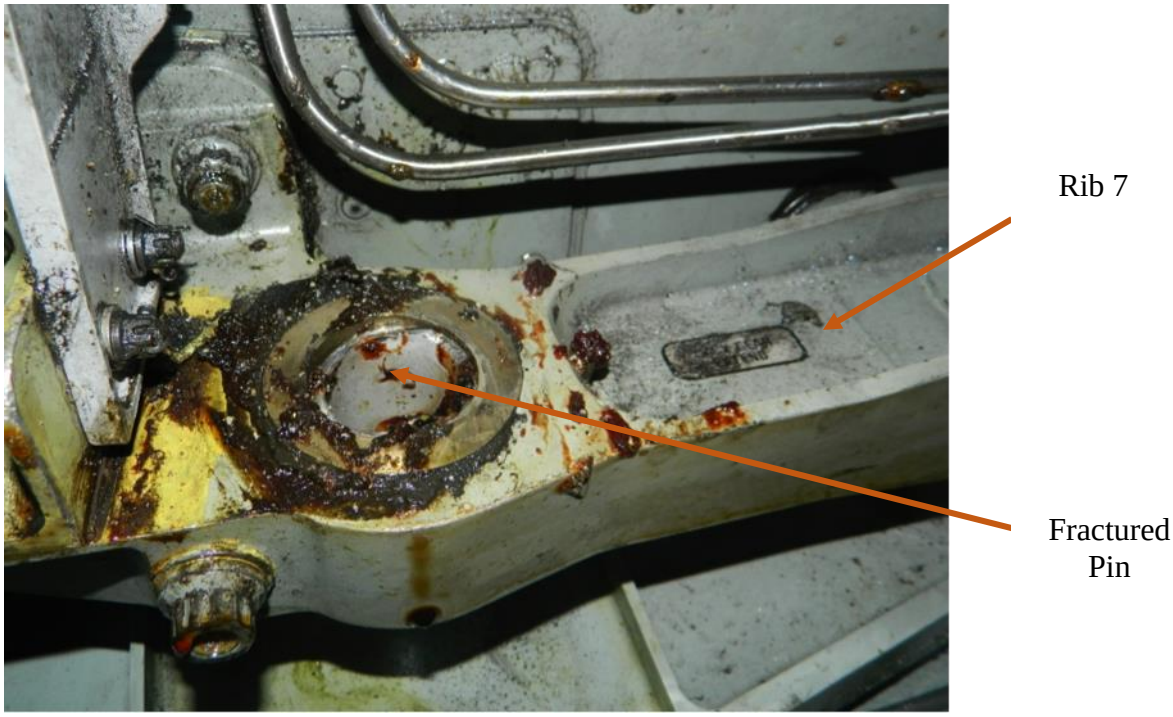


Fig. 8 Rib 7

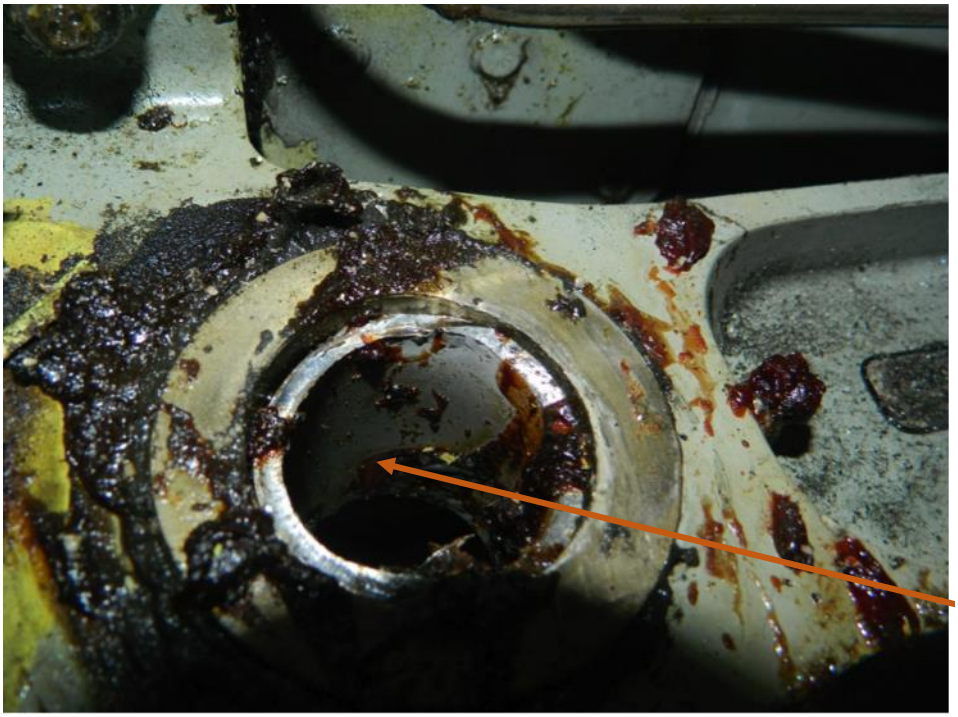


Fig. 9　Rib 7

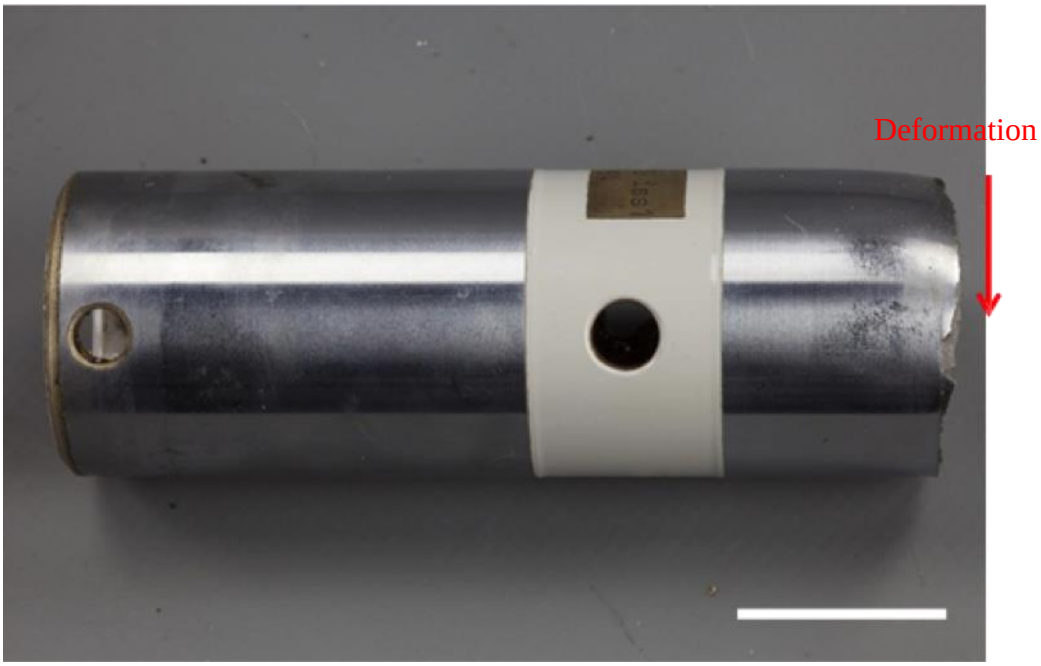


Fig. 10　Fractured Pin

1.4　Other Damages

Apart from scrape marks on the runway surface caused by strikes of the propeller blades, no other damage was noted.

1.5 Personnel Information

1.5.1 Captain

The Captain was a 47-year old male who was hired by SKY EXPRESS on 29.06.2006, and has been the Flight Operations Manager of the company since 17/05/2013; he was an instructor and examiner in this particular type of aircraft.

He holds an ATPL(A) license under No. GR-001740 issued by the Hellenic Civil Aviation Authority on 26.03.2003 and expiring on 25/06/2019; his Medical Certificate Class 1 was issued on 24/09/2014 and was valid until 24/09/2015.

Flying experience:

- a total of 11,117 flying hours.
- 3574 flying hours on type (JS 41)

Service time:

- 32 hours in the last 7 days, with a prescribed maximum of 60 hours
- 67:02 hours in the last 14 days, with a prescribed maximum of 95 hours
- 142:46 hours in the last 28 days, with a prescribed maximum of 190 hours.

1.5.2 First Officer

The First Officer was a 49-year old male who was hired by SKY EXPRESS on 17.11.2010.

He holds a CPL(A) license under No. GR-003184 issued by the Hellenic Civil Aviation Authority on 02/09/2002 and expiring on 21/11/2017; his Medical Certificate Class 1 was issued on 17/10/2014 and was valid until 30/10/2015.

Flying experience:

- a total of 3834 flying hours.
- 1334 flying hours on type (JS 41)

Service time:

- 35 hours in the last 7 days, with a prescribed maximum of 60 hours
- 57:35 hours in the last 14 days, with a prescribed maximum of 95 hours

- 100:10 hours in the last 28 days, with a prescribed maximum of 190 hours.

1.6 Aircraft Information

1.6.1 General

Manufacturer	: British Aerospace
Type	: Jetstream 41
Manufacturer's serial No.	: 41075
Year of manufacture	: 1995
Registration Number	: SX-DIA
Country of manufacture	: United Kingdom
Passengers accommodated	: 30
Airworthiness Certificate	: Issued on 18/06/2008
Airworthiness Review Certificate	: In effect, expiring on 03/06/2015
Aircraft Radio Station License	: In effect, expiring on 25/06/2017

Aircraft Total Flight Hours:

- since new : 28327:47
- since the last 3000 h and 6000 h check (07.01.14) : 1945
- since the last 300 h check (06.01.15) : 128:07

Aircraft Landings since new : 32961

The aircraft is fitted with two Garrett turboprop engines TPE331-14GR (left) / TPE331-14HR (right) of a power output of 1650 SHP and two McCauley variable pitch propellers B5JFR36C1103-E (left) /C5JFR36C1104-E (right).

1.6.2 Drag Brace maintenance information

As per the a/c maintenance records, on 18/11/12, with the a/c having accumulated 27941 cycles, the Drag Brace at the left main landing gear was replaced by an overhauled Drag Brace under serial No. APB960243, part No. AIR84352/5, having 26924 cycles (The overhaul was conducted at "APPH Aviation Services Ltd", an

EASA Part 145 approved maintenance organization by the UK Civil Aviation Authority under No. UK.145.00354). At the time of overhaul of the Drag Brace, the inboard pin under part No. AIR135158 was replaced with a new one which, on the day of the incident had 5020 cycles with a life limit of 66500 cycles. The manufacturer of the undercarriage is 'APPH' (Heroux Devtek).

1.6.3 Undercarriage

The aircraft is fitted with a tricycle-type retractable landing gear; the nose leg retracts into the fuselage and the two main legs retract into the wheel wells of the engine nacelles.

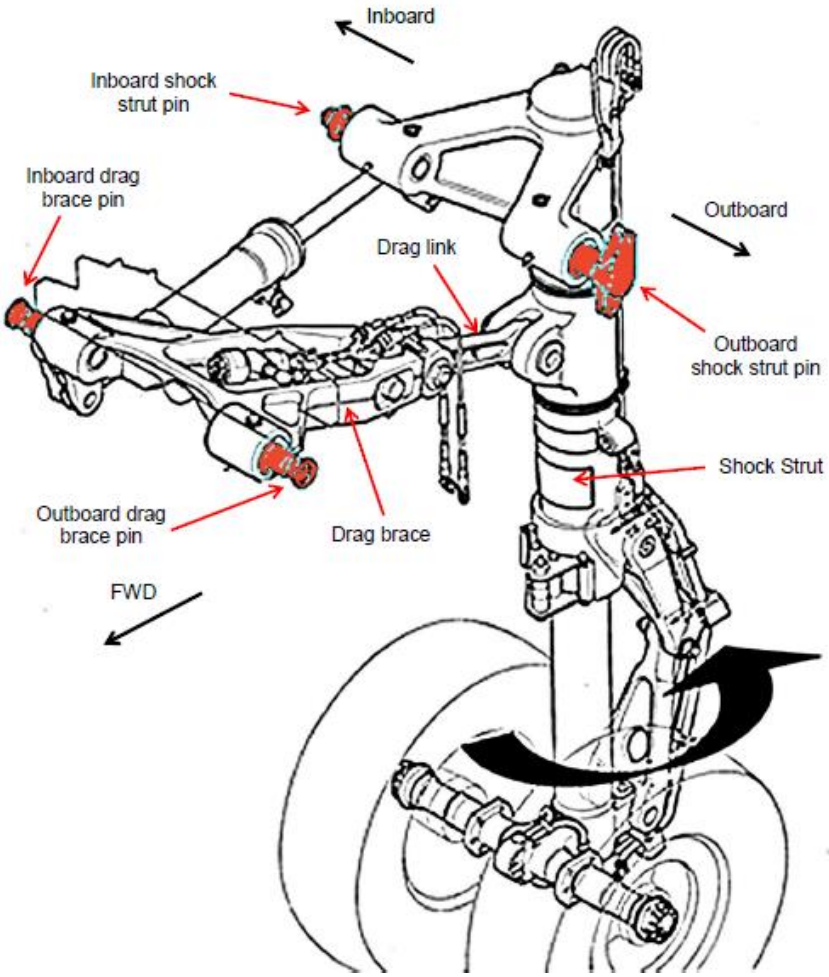


Fig. 11 – Left main landing gear

In order for the landing gear to become attached to the aircraft, the inboard pin of the shock strut and the corresponding pin of the drag brace are housed in Rib 7, whereas the outboard pin of the shock strut and the corresponding pin of the drag brace are housed in Rib 8.

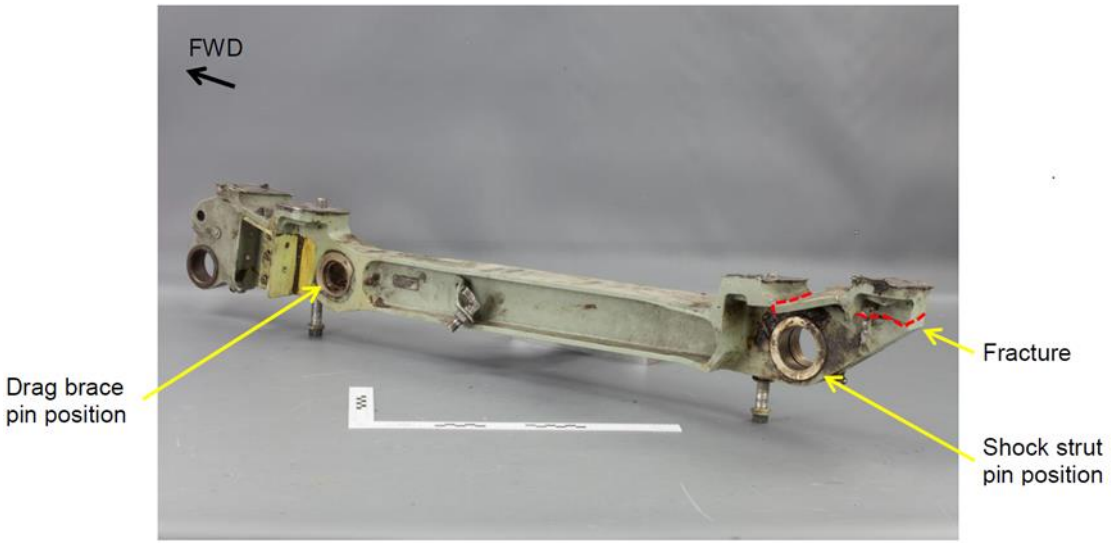


Fig. 12. Rib 7

Fig. 13. Rib 8

1.6.4 Aircraft weights

The aircraft departed from the airport in Heraklion having:

1. A ramp (taxi) weight of 23124 lb, with the maximum ramp weight being 24110 lb.
2. Taxi fuel 100 lb.
3. A takeoff weight of 23024 lb., with the maximum takeoff weight being 24000 lb.
4. Total fuel in the reservoirs 5016 lb.
5. A zero fuel weight of 18108 lb., with the maximum zero fuel weight being 21400 lb.

6. Fuel for the specific flight sector 800 lb.

7. A landing weight of 22224 lb., with the maximum landing weight being 23300 lb.

The centre of gravity of the aircraft having a takeoff weight of 23024 lb, a landing weight of 22224 lb. and a zero fuel weight of 18108 lb. is at 25.2%, 25% and 22.3% respectively of the mean aerodynamic chord, i.e. within the manufacturer's defined limits.

The weight of the aircraft was 14058 lb. when last weighed on 10.08.2012. The dry operating weight of the aircraft without cabin crew was 14463 lb. with the respective dry operating weight index being 41.5.

1.7 Meteorological Information

As per information supplied by the Meteorological Station of Rhodes, strong S-SE winds changing both in terms of speed and direction prevailed prior to, during and after the landing.

LGRP 020420Z 13017G36KT 040V210 9999 FEW010 SCT018 17/13 Q1007 WS R07 WS R25

LGRP 020450Z 13014G34KT 060V190 9999 FEW010 SCT018 17/13 Q1007 WS R07 WS R25

LGRP 020520Z 12016G34KT 060V180 9999 FEW010 SCT018 17/13 Q1007 WS R07 WS R25

LGRP 020550Z VRB17G47KT 9999 FEW010 SCT018 17/13 Q1007 WS ALL RWY.

1.8 Aerodrome Information

The Airport of Rhodes 'Diagoras' (LGRP) is located on the northwestern part of the island at an altitude of 6 ft. above sea level (ASL) and has one runway (07-25) 3305 m long.

As concerns aids to navigation, the airport is equipped with VOR, ILS (RWY 25) and NDB, as well as PAPI visual aids.

Fig. 14. 'Diagoras' Airport of Rhodes

As per AIP GREECE, at the airport of Rhodes (*Rodos*) given the terrain elevations at the runway S-SE side, landing or takeoff is not recommended when S-SE winds of more than 15 knots prevail due the wind shear at the final approach or takeoff. More specifically, the following is stated:

"LGRP AD 2.22 FLIGHT PROCEDURES

2.22.1 General

…

2.22.1.3 Pilots landing or taking off at RODOS / DIAGORAS Airport should exercise extreme caution when South or South-East (S-SE) winds of more than 15 kt prevail, as moderate or severe turbulence and wind shear may be encountered on the final approach and/or initial climb out areas (mainly of RWY 07). More specifically the following phenomena affecting seriously the flight safety are observed:

- *The wind direction and speed at a given time vary along the runway (horizontal wind shear).*
- *The wind direction and speed, at a given point of the runway, are continuously changing (turbulent wind shear).*
- *Severe turbulence on the final approach, take-off and initial climb out areas.*

- *When the South or South-East wind speed increases over 15 Kt, landing and/or take-off not recommended, since a severe horizontal and turbulent wind shear may prevail at some intermediate point on final approach and/or take-off and initial climb out areas.*
- *Because unexpected changes in wind direction and speed can be hazardous to aircraft operations at low altitude on approach to and departing from RODOS/DIAGORAS Airport, pilots are urged to volunteer reports of wind shear to DIAGORAS TWR or RODOS APP, as soon as possible, so that the pilots of following aircraft can be warned. It is suggested that pilots experiencing a wind shear in flight should report it in the following format:*
  a) A simple warning of the presence of wind shear, even if no further information can be given.
  b) The altitude or altitude band, where the wind shear was encountered.
  c) Details of the effects of the wind shear on the aircraft, i.e. airspeed gain or loss, vertical speed tendency, etc. …"

1.9 Flight Recorders

1.9.1 Flight Data Recorder (FDR)

The aircraft is fitted with a Fairchild flight data recorder (FDR). FDR readouts were performed at the premises of the UK Air Accidents Investigation Branch (UK AAIB). The recordings (Annex A) showed the following:

- About 20 seconds before Touch Down, the speed was approx. 188 kt and during approach there was extensive operating of the flight control surfaces in order to keep the flight path lined up with the runway centerline.
- The trailing edge flaps were set at 9^{o}.
- The aircraft touched the runway at a vertical acceleration of approx. 1.8 g, lateral acceleration of approx. 0.2 g and longitudinal acceleration of approx. -0.4 g.
- The aircraft first touched down with the right main landing gear, with an indicated airspeed (IAS) of 170 kt. There is no evidence of contact of the left main landing gear with

the runway.

- The left main landing gear collapsed about 1s to 2s after touchdown, as shown by the aircraft's 7.7^{o} roll attitude to the left. The aircraft came to rest about 42 seconds after touchdown.

The FDR, in addition to the sector in question, had also recorded the data of another 57 sectors. In such flights all landings were flap 25 degrees landings with a speed between 100 kt and 120 kt, except for one landing at 140 kt.

With regard to vertical acceleration, the following was recorded:

- landing 34 prior to the accident had a vertical acceleration of 1.529 g.
- landing 31 prior to the accident had a vertical acceleration of 1.47 g.
- landing 5 prior to the accident had a vertical acceleration of 1.46 g, and a lateral acceleration at Touchdown in the order of +/-0.2 g.

Given that under the applicable legislation there is no requirement for flight data monitoring (FDM) for this particular type of aircraft, the initial inspection for a heavy landing is performed pursuant to the aircraft maintenance manual when a heavy landing is reported by the flight crew, and two days after the incident a second inspection is carried out when the analysis of the flight data recorder has shown that at Touchdown vertical acceleration is equal to or greater than 1.5g.

1.9.2 Cockpit Voice Recorder (CVR)

The aircraft is fitted with a Universal Avionics cockpit voice recorder, with a 30-minute recording capacity. The extracted data provided no information relating to the accident as the recorder had not been disabled and remained operational, despite the events that led to the accident and even after the pilots left the aircraft.

1.10 Wreckage and Impact Information

There was no wreckage from the rearward collapse of the left main landing gear.

1.11 Medical Information

None of the persons on board, crew or passengers, was injured.

There is no information as to whether an Alcohol Test and Drug Test was performed on the crew.

1.12 Fire

Given a small leakage of fuel from the left wing of the aircraft, foam was sprayed by a fire truck on the left engine and the left wing, and the captain had initiated fire-fighting action on both engines.

1.13 Survival Aspects

Passengers were disembarked from the right rear exit (Emergency Exit) given that there was foam on the runway and the left front passenger door could not be used. As per the captain's testimony, in addition to the cabin attendant the first officer also participated in the aircraft evacuation process.

As reported by the Air Traffic Controller, disembarkation started approximately 15 min after the incident and lasted about 10 min.

1.14 Tests and Research

The left main landing gear was removed from the aircraft and, in cooperation with the AAIB, BAE SYSTEMS and HEROUX DEVTEK, was dispatched to QinetiQ, Cody technology Park, for examination in order to determine the cause of fracture of the inboard pin of the Drag Brace connecting it to the inboard Rib 7, as well as the cause for the breaking of Rib 7 and Rib 8 where the two Drag Brace retaining pins and the two corresponding Shock Strut pins are located.

The Shock Strut was then sent to HEROUX DEVTEK where it was disassembled for further inspection.

The examination of the left main landing gear involved the following:

1.14.1 Mapping of cracks

- Upon examination, the surface of the crack in Rib 7 was matt and fibrous, typical of the failure of an aluminum alloy as a result of overload. Also, there was no evidence of progressive cracking, such as fatigue or corrosion cracks.
- Upon examination, the surface of the crack in Rib 8 was identical to that in Rib 7, matt and fibrous, typical of the failure of an aluminum alloy as a result of overload. Also, there was no evidence of progressive cracking, such as fatigue or corrosion cracks.
- Upon examination, the surface of the crack in the inboard pin removed from the drag brace was shown to have sustained major damage, possibly as a result of its contact with the bushing in Rib 7 (presenting similar damage) as the drag brace and the inboard pin segment within moved away from Rib 7 following the fracture of the inboard pin.
- Upon examination, the surface of the crack of the inboard pin of the drag brace removed from Rib 7 had lesser damage than that of the segment removed from the drag brace. Half of the surface was smooth and perpendicular on the pin axis, whereas the other half of the surface was rougher and not perpendicular on the pin axis, and more deformed in general. The findings are characteristic of fracture due to overload.

The smooth surface of the crack was examined using electron microscopy and was found to present shear dimples with the surface being characteristic of shear overload and also presenting mechanical wear (spots). Shear angle was between 25^{o} and 50^{o} to the horizontal.

The rough surface of the crack was also examined using electron microscopy, and was found to present ductile dimples in random directions with the surface being characteristic of fracture due to tensile overload without evidence of shear.

On the surface of the crack of the inboard pin there was no evidence of progressive cracking, such as fatigue or corrosion cracks.

1.14.2 Dimensional inspection

The material of the pins of both the drag brace and the shock strut is designated as UTS (Ultimate Tensile Strength) 220-240 ksi . Given that the dimensional inspection revealed that all four pins were deformed, their internal and external diameters were measured and found to be within the specified limits.

1.14.3 Direction of deformation

Deformation of the two pins of the shock strut was at 45^{o} to the pin lock axis. The deformation of the outboard lug of the shock strut indicates that the main landing gear moved forward and upwards. Deformation of the outboard pin of the drag brace was almost perpendicular to the pin lock axis. The direction of deformation of the outboard pin of the drag brace indicates that the drag brace moved backwards relative to the structure.

The inboard pin section that remained on Rib 7 was deformed in a horizontal direction relative to the structure. The direction of deformation of the inboard pin section that remained on Rib 7 indicates that the drag brace moved backwards relative to the structure, whereas the deformation of its other half indicates was perpendicular to the pin lock axis.

The deformation of the pins of the drag brace and the shock strut is a known problem occurring following a heavy landing, and for this reason pins are inspected upon overhaul and replaced when found deformed.

1.14.4 Metallographic examination

The molecular structure of all four pins was examined and found to conform to AMS 6411 (AISI 4330M). Chrome-plating thereof was also measured.

The general molecular structure of Ribs 7 and 8 was consistent with aluminum alloy 2014 T651.

No defect in the molecular structure was observed in all specimens.

1.14.5 Composition of materials

X-ray examination determined that the composition of the four pins was consistent with AMS 6411 (AISI 4330M) and the composition of Ribs 7 and 8 was consistent with aluminum alloy 2014 T651.

1.14.6 Hardness of materials

Measurement of the hardness of the pins and approximate conversion to the UTS equivalent established that the drag brace pins were within the specified limits of 220-240 ksi, whereas the outboard pin of the shock strut was at the maximum value (240 ksi) and the inboard pin was slightly above the upper limit (241 ksi).

Furthermore, hardness measurement for Ribs 7 and 8 established that the strength thereof was within the specified values for aluminum alloy 2014 T651.

1.14.7 Conductivity

The conductivity of Ribs 7 and 8 was measured and found to be consistent with the typical conductivity of aluminum alloy 2014 T651, thus it is considered that the material was in the specified thermal processing state.

1.14.8 Material cause for the collapse of the left landing gear

The load on the inboard pin of the drag brace appears to be greater than the designed maximum, resulting in the pin's fracture. The pin originally fractured as a result of shear and, with the progressing fracture there was tensile overload.

After the inboard pin failed, the load was taken up by the outboard pin of the drag brace resulting in the drag brace link bending inwards, as indicated in the evidence, which in turn resulted in the fracture of the Rib 8 section directly above and facing the seating of the drag brace's outboard pin. Deformation of Rib 8 was observed at the site of the fracture, suggesting that the rear of Rib 8 containing the outboard pin had moved inwards resulting in the outboard pin leaving its seating, thus, without action by the drag brace, the shock strut folded

to the back.

As the shock strut folded to the back, the lug located at its rearward section forced Rib 7 upwards (the findings show that the fractured rear segment of the Rib has a dent, matching in size with the mark on the lug), resulting in the rupture of the Rib.

The edge of the retract actuator, where it attaches to the drag brace, showed signs of friction wear, in a manner matching the wear observed in the drag brace lug. This indicates that the retract actuator was attached to the drag brace even after it was disengaged from the main landing gear.

1.14.9 Flutter Plate

When the shock strut was disassembled at Heroux - Devtek it was found that the flutter plate had been mounted incorrectly. The purpose of the flutter plate is to regulate the flow of hydraulic fluid within the shock strut. The restriction of the flow of the hydraulic fluid results in the creation of larger than anticipated vertical loads on the wheels upon compression; however, the load analysis undertaken revealed that the loads generated as a result of the high rate of descent (12 fps) alone were close to the Ultimate Load.

1.15 Organizational and Management Information

1.15.1 The Air Carrier

1.15.1.1 General

The Air Carrier SKY EXPRESS is a Commercial Airline holding Air Operator Certificate No. GR-021, EASA Part M Continuing Airworthiness Management Organization Approval No. EL.MG.002 and EASA Part 145 Maintenance Organization Approval No. EL.145.041 issued by the Hellenic Civil Aviation Authority.

Its fleet is comprised of 3 Jetstream 41 and 1 ATR 42 aircraft.

1.15.1.2 Operations Manual

The Operations Manual, edition 3 revision 0 dated 28.10.14, in Section 8 of Part A "Standard Operating Procedures", para. 8.9.11 on Stabilized Approach stipulates as follows:

'All approaches should be stabilized by 1000 feet ARTE[2] and must be stabilized by 500 feet ARTE.

An unusual approach procedure or abnormal condition requiring a deviation from the elements of a stabilized approach below requires a special briefing:

An approach is considered stabilized if:

- ✓ *The Aircraft is on the correct track.*
- ✓ *The Aircraft is in the appropriate landing configuration.*
- ✓ *After glide path intercept, or after the FAF, the Pilot Flying requires no more than normal corrections to maintain the correct track and desired profile to landing within the touchdown zone. Level-off below 1,000 feet HAT is not recommended.*
- ✓ *The Aircraft speed is between VREF and VREF+20 kts.*
- ✓ *The rate of descent is no greater than 1,000 fpm. If an expected rate of descent greater than 1,000 fpm is planned, a special approach briefing should be performed. If an unexpected, sustained rate of descent greater than 1,000 fpm is encountered during the approach, a missed approach should be performed. A second approach may be attempted after a special approach briefing, if conditions permit, and*
- ✓ *Thrust setting is appropriate for the landing configuration.'*

In Section 2 "Normal procedures" of Part B of the operations manual (edition 4 revision 0 dated 28.10.14) with regard to operational issues of the Jetstream 41 aircraft, in para. 2.12.2 relevant to the Stabilized Approach Criteria, the following is stipulated:

'Approaches must at all times be stabilized, unhurried and flown configured as described in these SOPs. Aircraft must be stabilized latest at 1000' AGL in IMC conditions and latest at 500' AGL in VMC conditions. Circling approach – turn final at latest 400' AGL and wings

[2] ARTE: **A**bove **R**eference **T**hreshold **E**levation

level on final at latest 300' AGL Visual approach – turn final at latest 500' AGL and wings level on final at latest 300' AGL

Stabilized Approach Conditions

- *The aircraft is on the correct flight path.*
- *The aircraft is in the correct landing configuration.*
- *Only small changes in heading, pitch and speed are required to maintain the correct flight path.*
- *The vertical speed (also called rate of descent or sink rate) is not greater than 1000 fpm.*
- *The Power setting is appropriate for the aircraft configuration.*
- *All briefings and checklists have been completed. …'*

And in para. 2.13, 'VFR Approach' of the said section, it is stated:

2.13.1 Non-Precision Approach (Two Engines)

Outbound, reduce sped to 160 kt and select 9º flap. Not later than 2nm from the final approach fix/final descent point (FAF/FDP) inbound, select gear down, 15º flap and continue reducing speed to below 140 kts calling for the landing checklist. As soon as speed is less than 140 kts request flap 25. With flap 25 in level flight with about 1 mile to the FAF/FDP the PF selects 'VS' ensuring VS '000' is indicated on the Hess. At about 0.2 DME before the descent point initiate descent to DA (MDA+30ft) (or MDA for circling) in VS setting the required ROD and reducing speed to the green bugged speed. When descending from the FAF/FDP the PF selects the missed approach altitude. …'

The Flight Manual of the Jetstream 41 aircraft, in part 1 'General', with regard to the position of the Flaps, stipulates:

- ✓ *0º : final take-off climb, fifth segment climb (NTOFP), en-route climb.*
- ✓ *9º : take-off, first segment climb (LOG GEAR ON), second segment climb (LOG GEAR UP), fourth segment climb (NTOFP), one-engine-inoperative discontinued approach.*
- ✓ *15º : take-off, first segment climb (LOG GEAR ON), second segment climb (LOG GEAR UP), all engine approach and landing, balked landing.*
- ✓ *25º : all engine landing, balked landing.*

In part 8 'Landing procedures and speeds', it is stated:

'Airspeeds

Approach Speed

For the applicable flap, this is V_{REF25} or V_{REF15} (Ref. Figure 6-8-1), the speed at which the pilot should aim to cross the runway threshold.

Example

Aircraft weight of 21,000 lb (9,525 kg):

25º flap: V_{REF25} = 110 kt and 15º flap: V_{REF15} = 116 kt

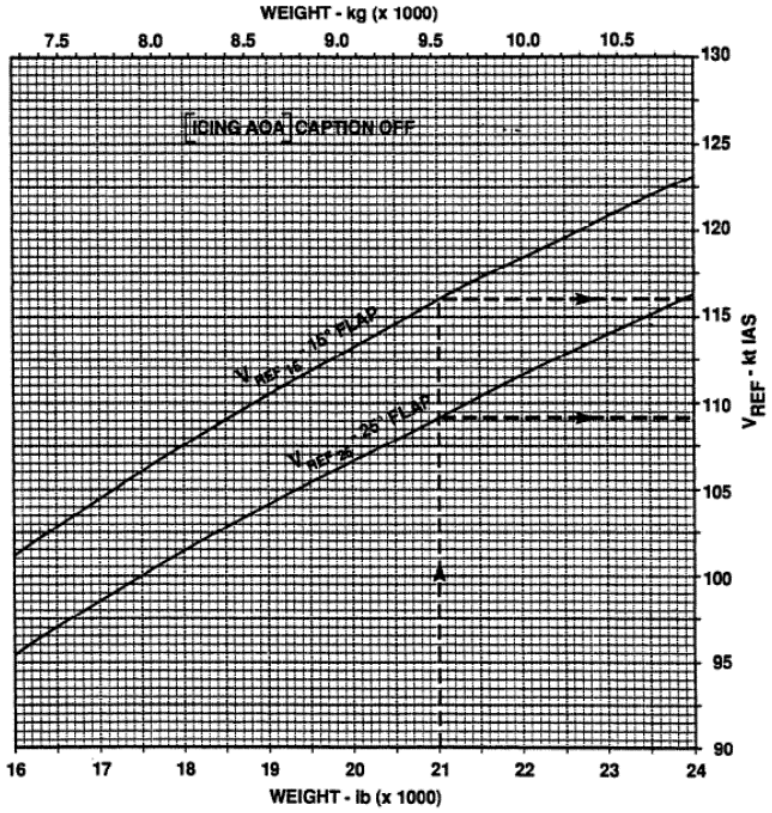


Figure 6-8-1

In Annex C 'Airfields Briefings' of Part C of the Operations Manual (edition 2 revision 0 dated 28/10/14) regarding Route and Aerodrome Instructions and Information, the following is stated with respect to the aerodrome of Rhodes, LGRP:

*'**General***

- *Aerodrome is considered Category B due to Circling Minima higher than 1.000ft AGL, unusual local weather and due to operational restrictions according to surface winds.*
- *The aerodrome is situated on the NW coast of the island 8nm SW of the city of Rhodes.*

Highest peak is nearly 4.000ft AMSL 17nm SW of the aerodrome. There are hills to over 1.500ft AMSL within 5nm to the S and SW. The approaches to both RWYs are along the coast. At 1.5nm finals RWY25 and 1nm S of the centre line is a hill to nearly 900ft AMSL. 1.000m S of the RWY is an outcrop of high ground to just over 900ft AMSL which causes difficult local wind effects. …

Caution

…

Exercise extreme caution as moderate or severe turbulence and wind shear may be encountered in the final approach and/or initial climb out areas (mainly RWY07). More specifically when S or SE-ly winds of more than 10-15 kts prevail, the wind direction and speed vary along the RWY (horizontal wind shear), continuously changes (turbulent wind shear), and severe turbulence prevails in the final approach, T/O and initial climb out areas

…

Operational Restrictions

When surface wind direction is between 110º and 180º and speed exceeds 20 kts, T/O and LDG is prohibited due to associated severe horizontal and turbulent wind shear.'

The Operations Manual (edition 3 revision 0 dated 28.10.14), in Section 1 'Limitations' of Part B, para. 1.8 'Wind Limits', states that:

'Maximum demonstrated crosswind component is 30 knots.'

and also contains the 'Wind Component' chart given in Annex B hereto.

With regard to the flight recorders (FDR & CVR) the Operations Manual (edition 3 revision 0 dated 28.10.14), in Section 1 'Organization and Responsibilities' of Part A, para. 1.4.2 'Commander's Duties and Responsibilities' states that:

'The Commander shall:

…

- *Not permit:*
  - *A flight data recorder to be disabled, switched off or erased during flight nor permit recorded data to be erased after flight in the event of an accident or an incident*

subject to mandatory reporting

- *A cockpit voice recorder to be disabled or switch off during flight unless he/she believes that the recorded data, which otherwise would be erased automatically, should be preserved for incident or accident investigation nor permit recorded data to be manually erased during or after flight in the event of an accident or an incident subject to mandatory reporting … ."*

2 ANALYSIS

2.1 Weather conditions

Prior to departing from Heraklion airport, the flight crew were briefed about the weather prevailing at the area of the Rhode's airport (S-SE winds of mean speed 15 kt and Gust Wind 37 kt).

As inferred from the Captain's report, he deemed that the wind was within the limits specified in the Operations Manual of the company for the aerodrome of Rhodes, i.e. wind direction between 110^{o} and 180^{o} and speed up to 20 kt, without giving consideration to the Gust Wind 37 kt. The company manual does not provide clarification as to whether it is the mean wind speed, which was at the limit, or the gust wind which was much higher, that is to be taken into account.

Moreover, pursuant to the Wind Component chart in Annex B hereto, it is noted that with a wind on the 37 kt isotach the wind from 110^{o} and 180^{o} has a crosswind component greater than 30 knots over almost the entire arc. Pursuant to the Wind Limits, the maximum demonstrated crosswind component is 30 knots.

Pursuant to the recorded communications extract the Air Traffic Controller at the Control Tower of the airport of Rhodes reported emphatically on four occasions to the aircraft that the wind was outside the limits set for landing, given that as per AIP Greece for the aerodrome of Rhodes when the speed of a Southerly or Southeasterly wind exceeds 15 kt, landing and/or takeoff is not recommended because severe horizontal and turbulent wind shear may be encountered at some intermediate point in the final approach or takeoff and in the initial

climb out area.

Finally, at the moment of landing the Air Traffic Controller reported wind from 110º, 17 kt (something intelligible can be heard).

The answers given by the flight crew to the Air Traffic Controller, following the weather briefings, indicate that the captain was determined to proceed with landing despite the provisions of the Operations Manual, the recommendations of AIP Greece and even though one of the reasons that corporate procedures designate the said aerodrome as a Category B aerodrome is the unusual local weather and the operational restrictions according to surface winds.

2.2 Cockpit Voice Recordings

Cockpit voice recordings for the last 30 minutes of the flight in question were not available for the analysis of the circumstances of the accident due to the fact that the cockpit crew and more specifically the Captain failed to disable the CVR immediately after the accident even though corporate procedures in para. 1.4.2 stipulate that the cockpit voice recorder (CVR) is to be disabled or switched off.

2.3 Flight information

The flight crew decided to make a Flap 9º configured landing at a speed of 129 knots having regard to the prevailing winds, rather than the procedure envisaged in the aircraft's flight manual and the corporate procedures specifying Flap 25º or 15º.

During the approach and with the aircraft being approx. 20 sec to Touchdown, the speed of the aircraft reached 188 kt indicating that this was a non-stabilized approach, under the Operations Manual, para. 8.9.11 of Part A and para. 2.12.2 of Part B thereof.

Furthermore, speed at Touchdown was approx. 170 kt, more than 50 kt higher than in the envisaged configurations (with 15º or 25º Flaps) and vertical acceleration 1.8g (the limit for a heavy landing is 1.5g), with horizontal and lateral acceleration as well.

The high speed at Touchdown resulted in the high drag on the wheels due to the prolonged

acceleration of the wheels to reach the speed of the aircraft. The fact that the wheels did not blast shows that the loads exercised were not excessive.

The First Officer failed to point out to the Captain that they were not performing a stabilized approach, that the speed was in excess of the calculated speed for the approach and failed to urge the Captain to perform a go-around.

Also, given the absence of cockpit voice recordings, it was not possible to establish whether the flight crew, at the time of the briefing prior to initiating the descent for approach and landing and based on the latest data on the winds prevailing, contemplated the possibility of performing a go-around.

Finally the flight crew composed of the Captain, who was also the company's Flight Operations Manager, and a new First Officer, does not appear to have adhered to the Crew Resource Management (CRM) principles given that the First Officer, being the Pilot Monitoring, at no time during the approach did he question the decisions of the Captain who was the Pilot Flying.

2.4 Laboratory and Maintenance Details

The analysis conducted at the laboratory of QinetiQ, Cody technology Park, where the left main landing gear was dispatched for examination, established that the fracture of the Drag Brace trunnion pin is due to overload.

After the inboard pin failed, the load was taken on by the outboard pin of the drag brace, resulting in the breaking of Rib 8 directly above and forward of the housing of the outboard pin of the drag brace. After the fracture, the rear segment of Rib 8, containing the outboard pin, moved inwards which resulted in the outboard pin being pulled out of its housing and thus, without the Drag Brace's action the Shock Strut folded rearward.

As the Shock Strut folded rearward, it pushed Rib 7 upwards resulting in the Rib's breaking in overload.

The examination conducted established that the inboard pin of the Drag Brace as well as Ribs 7 and 8 were sound and manufactured in accordance with the manufacturer's drawings.

Furthermore, the inboard pin of the Drag Brace and Ribs 7 and 8 showed no indication of progressive cracking, such as fatigue or corrosion cracks.

The inboard pin of the Drag Brace, Part No. AIR135158, that had been replaced with a new one on 18/11/12 during the overhaul of the Drag Brace, on the day of the incident had 5020 cycles with a life limit of 66500 cycles, whereas the Drag Brace, under Part No. AIR84352 and Production series No. APB960243, had 5020 cycles and 27 months since last overhauled (the limit for an overhaul is 15000 cycles or seven years).

Upon inspection of ADs it has been established that none exists having a bearing on the inboard pin of the Drag Brace in terms of inspection or life limit.

The analysis of data recorded by the FDR which contained data of 57 sectors (flights) shows that all landings prior to the incident except one, which was a little over the limit of 1.5g for its designation as a heavy landing (1.53g), were Flap 25 landings within the limits set out in the flight manual.

The landing weight of 22,224 lb (maximum landing weight: 23,300 lb) as well as the respective centre of gravity were within the manufacturer specified limits.

3 CONCLUSIONS

3.1 Findings

3.1.1 The operating flight crew members were correctly licensed and qualified to conduct the flight.

3.1.2 The aircraft was airworthy and all its requisite certificates and documents were in effect.

3.1.3 The weights of the aircraft were within the specified limits.

3.1.4 The Drag Brace was within the specified operational service limit.

3.1.4 The inboard trunnion pin of the Drag Brace:

- satisfied the manufacturer's requirements
- had accumulated much fewer cycles than is its life limit
- shows no indication of progressive cracking, such as fatigue or corrosion cracks
- has no AD outstanding
- failed on overload due to the high rate of descent.

3.1.5 Ribs 7 and 8:

- satisfied the manufacturer's requirements
- show no indication of progressive cracking, such as fatigue or corrosion cracks
- failed on overload.

3.1.6 Under the examination of the data of all 57 sectors contained in the FDR, it was established that only one of those exceeded the limit value of 1.5 g in order for it to be characterized as a heavy landing (1.53 g).

3.1.7 The speed at Touch Down was 170 kt, i.e. about 50 knots higher than the values specified at Flaps 15^{o} or 25^{o} configurations and a landing weight of 22224 lb. The 1.8g vertical acceleration generated loads very near the Maximum Permitted Loads (the limit for a heavy landing is 1.5g) as well as horizontal and lateral acceleration.

3.1.8 The landing was performed with Flap 9^{o}, a configuration not envisaged in the flight manual of this type of aircraft or in the corporate procedures.

3.1.9 The incorrect mounting of the Flutter Plate played a secondary role in the pin's

fracture.

3.1.10 At the time of the landing phase strong variable S-SE winds prevailed (mean wind speed 16 knots, maximum value of approx. 35 knots and Wind Shear) much stronger than the limit specified in the company's Operations Manual and in AIP GREECE for the aerodrome of Rhodes.

3.1.11 At the phase of final approach for landing the aircraft did not meet the stabilized approach criteria.

3.1.12 At the approach – landing phase the exhibited CRM level was found to be poor.

3.1.13 The Cockpit Voice Recorder had not been disabled after the accident even though this is an action specified in the standard operating procedures.

3.2 Probable Causes

The decision to perform a landing following a non-stabilized approach.

Landing with a strong and variable wind, the speed and the crosswind component of which were in excess of the values specified by the standard operating procedures, the aircraft manufacturer and the recommendations for the said aerodrome in AIP GREECE.

The failure to adhere to CRM principles.

4 SAFETY RECOMMENDATIONS[3]

4.1 To Air Carrier 'SKY EXPRESS'

2018-09 In its Operations Manual the Company must review wind limits having regard to the provisions of AIP GREECE.

[3] **Note:** Under Article 17.3 of European Regulation (EU) 996/2010, the safety recommendation shall in no case create a presumption of blame or liability for an accident, serious incident or incident. The addressee of a safety recommendation shall inform the Safety Investigation Authority which issued the recommendation of the actions undertaken or under consideration in accordance with the conditions laid down in Article 18 of that Regulation.

2018-10 The failure to adhere to CRM principles exhibited during approach–landing must be addressed by the company and in particular for the case in which a member of the flight crew is also charged with top management functions.

Hellinikon, 13 April 2018

THE CHAIRMAN

Athanasios Binis

THE MEMBERS

P. Vasilopoulos

A. Tsolakis

N. Goutzouris

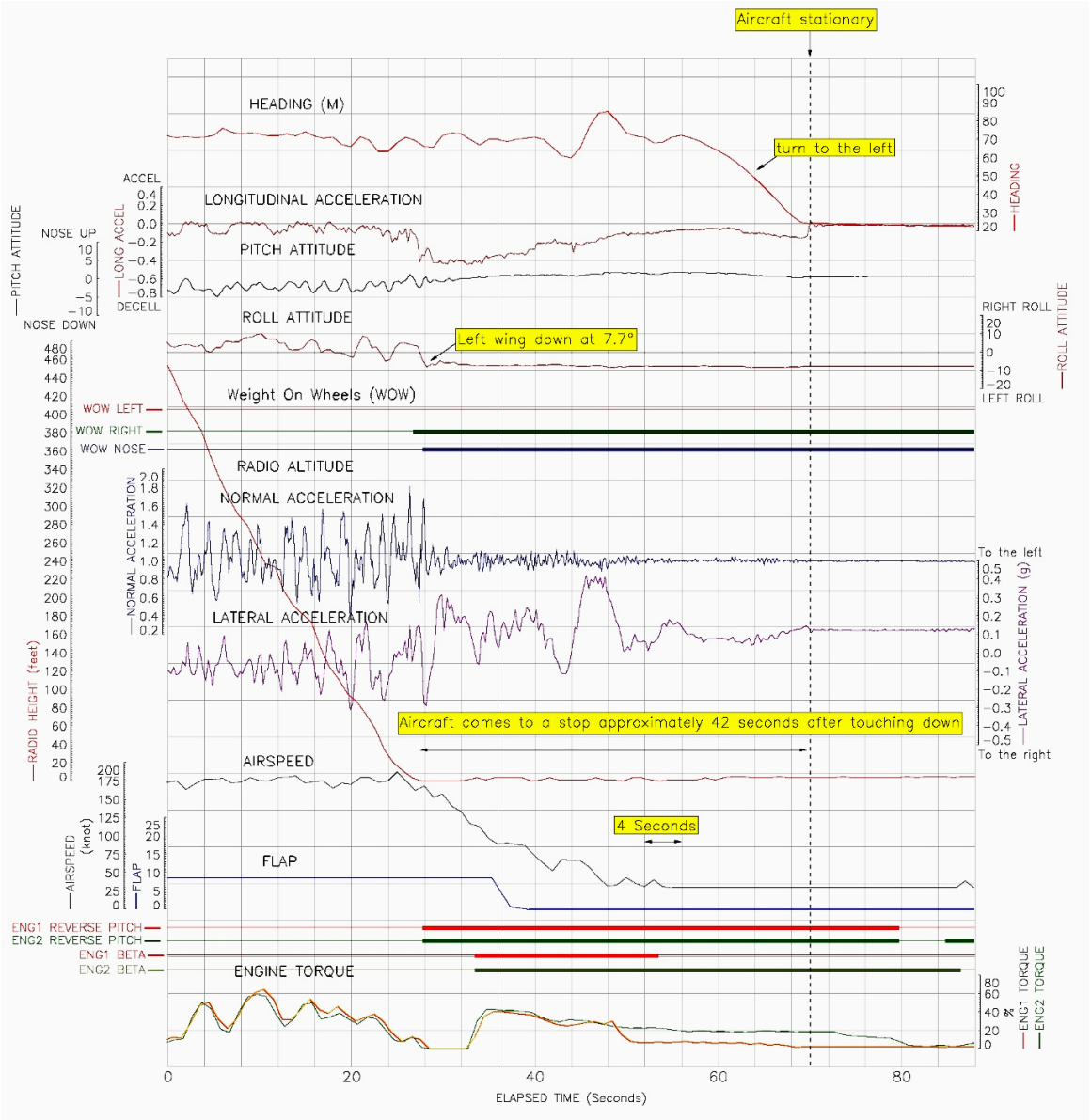
Ch. Tzonos - Komilis

Exact Copy
The Secretary

N. S. Pouliezos

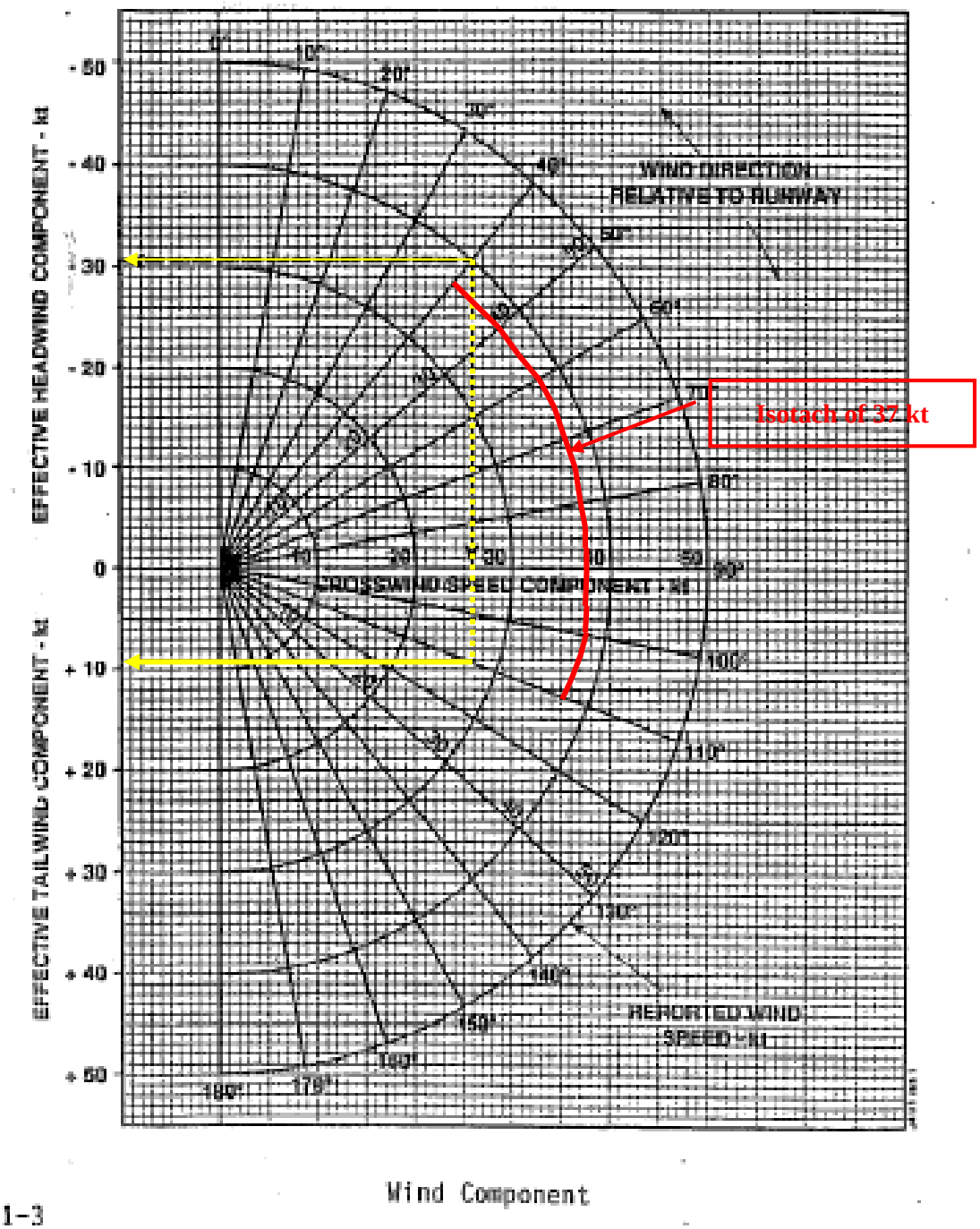
ANNEX A

Plots of FDR Data



ANNEX B

Wind Component Chart



Red Line: Isotach of 37 kt Wind from 110º – 180º for RWY 07.

Dotted Line: It gives the speeds of wind from 110º – 180º for RWY 07 where maximum crosswind is 30 kt.