FINAL REPORT

ACCIDENT 2018/67

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FINAL REPORT

ACCIDENT

OCCURRENCE NO – 2018/67

AIRCRAFT – Bombardier DHC-8-402, SP-EQG

DATE AND PLACE OF OCCURRENCE –10 January 2018, EPWA

This Report is a document presenting the position of the State Commission on Aircraft Accidents Investigation concerning circumstances of the air occurrence, its causes and safety recommendations. The Report was drawn up on the basis of information available on the date of its completion.

The investigation may be reopened if new information becomes available or new investigation techniques are applied, which may affect the wording related to the causes, circumstances and safety recommendations contained in the Report.

Investigation into air the occurrence was carried out in accordance with the applicable international, European Union and domestic legal provisions for prevention purposes only. The investigation was carried out without application of the legal evidential procedure, applicable for proceedings of other authorities required to take action in connection with an air occurrence.

The Commission does not apportion blame or liability.

In accordance with Article 5 paragraph 6 of the Regulation (EU) No 996/2010 of the European Parliament and of the Council on the investigation and prevention of accidents and incidents in civil aviation […] and Article 134 of the Act – Aviation Law, the wording used in this Report may not be considered as an indication of the guilty or responsible for the occurrence.

For the above reasons, any use of this Report for any purpose other than air accidents and incidents prevention can lead to wrong conclusions and interpretations.

This Report was drawn up in the Polish language. Other language versions may be drawn up for information purposes only.

WARSAW 2021

Table of contents

Abbreviations and Acronyms

A/C	Aircraft
AMM	Aircraft Maintenance Manual
ARC	Airworthiness Review Certificate
ATPL(A)	Airline Transport Pilot License (Airplane)
BEW	Basic Empty Weight
CA	Calendar Day
CG	Center of Gravity
CMM	Component Maintenance Manual
CofA	Certificate of Airworthiness
CofR	Certificate of Registration
CVR	Cockpit Voice Recorder
CY	Cycle
DET	Detailed Inspection
DIS	Discard
DOW	Dry Operating Weight
DSA	Drag Strut Assembly
ED	Engine Display
EH	Engine Hours
ELH	Electrical Harness
EPWA	Warsaw Chopin Airport – ICAO code
FDA	Forward Doors Actuator
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FDS 9	Flight Data Service 9
FH	Flight Hours

FNC	Functional Check
FO	First Officer
GS	Ground Speed
GVI	General Visual Inspection
HEAD	Heading
HMTS	Horn Mute/Test Switch
IIC	Investigator in Charge
IOL	Aerodrome Manual
IPC	Illustrated Parts Catalog
IR	Instrument Rating
L50	Check – intervals 50 flight hours or 12 calendar days
LDS	Lower Drag Strut
LGCP	Landing Gear Control Panel
LGSL	Landing Gear Selector Lever
LGSV	Landing Gear Selector Valve
LLL	Lower Lock Link
LMT	Local Mean Time
LRSL	Lock Release Selector Lever
LSP	Aerodrome Fire Brigade
LUB	Lubrication
LVTO	Low Visibility Take-Off
LW	Landing Weight
MAC	Mean Aerodynamic Chord
MLG	Main Landing Gear
MLW	Maximum Landing Weight
MO	Month

MTWO	Maximum Take-off Weight
N/A	Not applicable
NA	Normal Acceleration
NDA	Nose Door Actuator
NLG	Nose Landing Gear
NLG LR	NLG Inline Restrictor
OPC	Operational Test
P/N	Part Number
PA	Pitch Angle
PDC	Pre-departure Check
PLL LOT S.A.	LOT Polish Airlines S.A.
PS	Proximity Sensor
PSEU	Proximity Sensor Electronic Unit
PSP	State Fire Service
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RA	Roll Angle
RPM	Revolutions per minute
RST	Restoration
RVR	Runway Visual Range
RWY/DS	Runway
SDI	Special Detailed Inspection
SSA	Shock Strut Assembly
SSFDR	Solid state FDR
SSV	Solenoid Sequence Valve
SVC	Servicing

TBO	Time Between Overhaul
TOW	Take-off Weight
TSB	Transportation Safety Board of Canada
UDS	Upper Drag Strut
ULC	Civil Aviation Authority of the Republic of Poland
ULL	Upper Lock Link
VCK	Visual Check
WBR	Weight and Balance Report
WOFW	Weight off Wheels
WOW	Weight on Wheels
WSP	Military Fire Brigade

General information

Occurrence reference number:	**2018/67**			
Type of occurrence :	ACCIDENT			
Date of occurrence:	10 January 2018			
Place of occurrence:	EPWA			
Type and model of aircraft:	Bombardier DHC-8-402			
Registration marks:	SP-EQG			
Aircraft User/Operator:	Polskie Linie Lotnicze LOT S.A.			
Aircraft Commander:	ATPL(A)			
Number of victims/injuries	Fatal	Serious	Minor	None
	0	0	0	63
Domestic and international authorities informed about the occurrence	ULC, TSB			
Investigator-in-Charge:	Andrzej Bartosiewicz			
Investigating Authority:	State Commission on Aircraft Accidents Investigation (PKBWL)			
Accredited Representatives and their advisers:	Accredited Representative – TSB of Canada Advisers: - Transport Canada - Pratt & Whitney - Bombardier's Air Safety Investigation Office			
Document containing results:	Final Repot			
Safety recommendations:	**YES**			
Addressees of the recommendations:	Bombardier Inc., Transport Canada			
Date of completion of the investigation:	24 February 2022			

Synopsis

On 10 January 2018 at 18:07 hrs LMT[1], Bombardier DHC-8-402 aircraft, registration marks SP-EQG, took off for the planned flight EPKK-EPWA (LO 3924). There were 59 passengers on board and 4 crew members.

During climb the nose landing gear (NLG) did not retract after moving the landing gear control lever to the UP position. Amber light N DOOR (nose door open), red light NOSE (nose gear not uplocked or downlocked) and red light on the landing gear control lever (gear in transit) illuminated. The CPT decided to continue the flight to the destination (EPWA).

During the landing approach to EPWA, the crew extended the landing gear with the alternate system. The main landing gear (MLG) was extended and locked, but the NLG did not change its position.

The crew made an emergency landing on EPWA RWY11 with NLG in the transit position, which was folded during the landing roll.

When the plane came to rest on RWY11 (19:19 hrs LMT), the passengers were evacuated. All passengers and crew left the plane uninjured. The plane was damaged to an extent that required repair.

The investigation into the occurrence was conducted by the PKBWL Investigation Team in the following composition:

Andrzej Lewandowski	-	Investigator-in-Charge (until October 2020)
Andrzej Bartosiewicz	-	Investigator-in-Charge (from March 2021)
Jerzy Girgiel	-	Team Member (until October 2020)
Roman Kamiński	-	Team Member
Piotr Richter	-	Team Member (until October 2020)
Bogusław Trela	-	Team Member

During the investigation PKBWL determined the following cause of the accident:

The immediate cause of the accident was excessive free play in the retraction/extension system of the nose landing gear (NLG).

Contributing factors:

1) Lack of procedures to measure and monitor the free play in the nose landing gear retraction/extension system during the Time Between Overhaul (TBO) which was 30000 CY or 14 years.

[1] All times in the Report are in LMT=UTC+1 hr

2) The lack odf analysis of the three-point landings which caused overload of the NLG.
3) The lack of dedicated procedures to verify a possible damage resulting from untypical one-time events, such as the tug hitting the drawbar connected to the aircraft.

After completion of the investigation PKBWL has proposed three safety recommendations.

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1. FACTUAL INFORMATION

1.1. History of the flight

Flight LO 3924 of the Bombardier DHC-8-402 airplane, registration marks SP-EQG, was planned for 10 January 2018 on EPKK-EPWA route. The crew arrived at the departure airport at a planned time and performed routine activities as provided for in the Operator's Operation Instruction.

After boarding 59 passengers, the flight crew started the engines and taxied to a runway and then started the take-off procedure.

After lift-off, in accordance with the applicable procedure, the flight crew set the landing gear control lever in the UP position. The MLG was retracted and locked, while the NLG was unlocked from the downlock, but it was not uplocked. Amber N DOOR light (nose door open), red NOSE light (nose gear not uplocked or downlocked) and amber light on the landing gear control lever/handle (gear in transit) illuminated.The Captain made the decision to continue the flight to the destination airport (EPWA).

EMERGENCY was declared.

The plane performed the flight along the planned route with NLG unlocked. During the flight the crew heard additional noise generated by the airflow around the open NLG door. Except the noise the flight was uneventful.

The cabin crew carried out applicable procedures to prepare the cabin and passengers for emergency landing and evacuation.

During the landing approach to EPWA the crew performed the landing gear extension procedure with the alternate system. After completing this procedure MLG was extended and downlocked (which was confirmed by green lights), while the NLG lights remained unchanged and amber light on the landing gear control lever/handle illuminated.

After the MLG touchdown the crew maintained direction with rudder, while maintaining the highest possible angle of attack, so that the NLG would touch runway as late as possible. When the nose part of the aircraft touched the ground, the flight crew did not feel the characteristic impact of the NLG, but immediately heard and felt that the nose part of the fuselage contacted the runway.

The plane came to rest on RWY 11 at 19:19 hrs LMT.

Immediately after that the crew began to evacuate the passengers. None of the passengers and crew was injured during the evacuation.

Fig. 1. Bombardier DHC-8-402, SP-EQG, on EPWA RWY11 immediately after the occurrence [source: PKBWL][2]

1.2. Injuries to persons

Injuries	Crew	Passengers	Others	
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	4	59	N/A	63

1.3. Damage to aircraft

As a result of the direct contact of the nose part of the fuselage with the runway surface (which resulted from the landing with NLG in the transit position), the plane was damaged to an extent that required repair. Parts of the NLG and the nose-bottom part of the fuselage were damaged.

[2] Unless otherwise indicated the source is PKBWL

To identify and assess the extent of the damage, the operator required manufacturer to carry out the damage survey. It was carried out on 17-18 January 2018 and the findings are contained in the DAMAGESURVEY FOR LOT POLISH AIRLINES SA, DASH 8 - SERIES 400, S / N 4423 report, which was made available to PKBWL by the operator and is attached to the accident records (not published).

1.4. Other damage

During the landing several lights of the RWY centre line were damaged by the nose part of the fuselage.

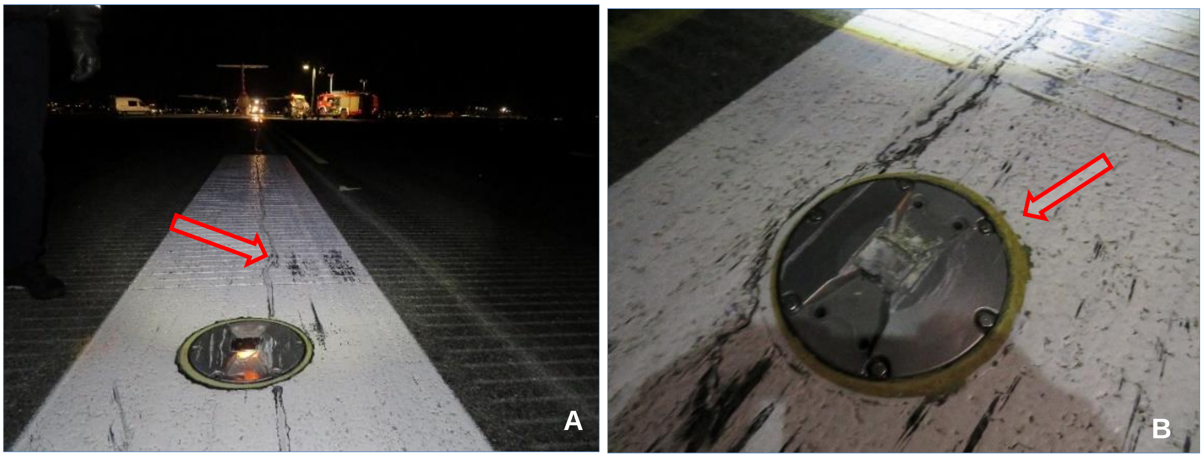

Fig. 2. Marks of the emergency landing on RWY11: A – marks left by the fuselage; B – one of the damaged lights of RWY11 centre line

1.5. Personnel information (crew data)

1.5.1. Aircraft Commander (CPT)

Pilot – male, aged 32.

Holder of ATPL(A) valid for an unlimited period with rating for DHC-8/IR valid until 31 May 2018.

Aero-medical assessment Class 1 without limitations, valid until 2 Feb 2018.

Language proficiency – English, ICAO Level 4, valid until 21 Jun 2018.

Total flight experience – 1985 FH.

Flight experience on DHC-8 – 994 FH including 37 FH as CPT.

Flight experience as PIC – 854 FH.

Line check – 21 Dec 2017.

Flight time on DHC-8 over the last 30 days - 62 FH.

1.5.2. First Officer (FO)

Pilot – male, aged 29.

Holder of CPL(A) valid for an unlimited period with rating for DHC-8/IR valid until 30 Apr 2018.

Aero-medical assessment Class 1 without limitations, valid until 9 Jan 2019.

Language proficiency – English, ICAO Level 4, valid untol 19 Sep 2021.

Total flight experience – 1371 FH.

Flight experience on DHC-8 – 1086 FH as FO.

Flight experience as PIC – 168 FH.

1.6. Aircraft information

1.6.1. General

- class – aeroplane;
- category – large;
- design – high wing cantilever of metal structure;
- role and number of passengers – regional transport, 78 passengers;
- nationality and registration marks – SP-EQG;
- manufacturer – Bombardier Incorporation;
- trade name – DHC-8-402;
- serial number – 4423;
- owner – NAC Aviation 7 Limited, Irlandia;
- user – Polskie Linie Lotnicze LOT S.A., Polska;
- powerplant – turboprop;
- engines – 2 x Pratt & Whitney Canada PW150A;
- propellers – 2 x Dowty Propellers R408/6-123-F/17;
- landing gear – tricycle, retractable, dual wheel with nose gear.

CofR – **valid on the day of occurrence**:

- register No – 4647;
- register date – 7 Sep 2012.

CofA – **valid on the day of occurrence**:

- issued – 7 Sep 2012;
- limitations – none.

ARC – **valid on the day of occurrence**:

- issued – 3 Sep 2015;
- valid until – 31 Aug 2018.

Weight data:

WBR issued 27 Jul 2016 – **valid on the day of occurrence**:

- MTOW – 28 998 kg;
- MLW – 28 009 kg;
- BEW – 17 727 kg;
- DOW – 18177kg;
- CG – 20,32 % MAC;

- TOW – 25 879 kg;
- LW – 25 151 kg;
- CG for take-off – 19,6 % MAC.

1.6.2. Service life data

<u>AIRFRAME – DHC-8-402</u>

Year of manufacture:	2012
Airframe Total Flight Time Since New (TTSN):	11237 h 44 min
Airframe Total Cycles Since New:	12 848
Airframe flight time since the last C1 inspection:	5253 h 12 min
Flight time remaining to the next C1/C2 inspection:	746 h 48 min
Date of the last periodic inspection (C1):	29 Nov 2015
– after TTSN:	5984 h 32 min
– effected by	Flybe Ltd.[3]

<u>ENGINE#1 (LEFT) – PW150A</u>

Year of manufacture:	2012
Serial Number:	PCE-FA0931
Date of the engine installation on the airframe:	2017
Engine Total Time Since New:	10 003 h 10 min
Engine time since the last overhaul:	1670 h 44 min
Cycles to the next overhaul:	3374 CY
Date of the last periodic inspection(L50):	5 Jan 2018
– after operating time:	9966 h 50 min
– effected by:	LS Technics Sp. z o.o.[4]
Time to the next inspection (L50)	13 h 40 min

Note: Last C1 inspection was effected 29 Nov 2015 – at that time the left engine was different.

<u>ENGINE#2 (RIGHT) – PW150A</u>

Year of manufacture:	2012
Serial Number:	PCE-FA0791
Date of the engine installation on the airframe:	2017
Engine Total Time Since New:	11 293 h 42 min
Engine time since the last overhaul:	2 368 h 00 min

[3]Approved maintenance organization (Part 145 - UK.145.00008) in Exeter, UK.
[4]Approved maintenance organization (Part-145 - PL.145.023) in Kraków, Poland.

Cycles to the next overhaul:	3 238 CY
Date of the last periodic inspection (L50):	5 Jan 2018
– after operating time:	11 257 h 22 min
– effected by:	LS Technics Sp. z o.o.
Time to the next inspection (L50)	13 h 40 min

Drag Strut Assembly (DSA) – P/N 47300

Manufacturer: Goodrich Landing Gear Division

Year of manufacture:	2012
Serial Number:	MAL-SP-0447
Date of installation on the airframe:	2012
Total Time since New:	11 237 h 44 min
Cycles to the next repair or overhaul:	17 152 CY
Date of the last periodic inspection (C1):	29 Nov 2015
– after operating time:	5984 h 32 min
– effected by	Flybe Ltd.

Lower Lock Link (LLL) – P/N 47324-1

Manufacturer – Goodrich Landing Gear Division

Year of manufacture	2012
Serial Number	VAC0147
Date of installation on the airframe:	as DSA
Total Time since New:	as DSA
Cycles to the next repair or overhaul:	as DSA
Date of the last periodic inspection (C1):	as DSA
– after operating time:	as DSA
– effected by	as DSA

1.6.3. Landing gear

1.6.3.1. General

Bombardier DHC-8-402 is equipped with a tricycle retractable dual wheel landing gear (general view in Fig. 3).

The landing gear system consists of the following subsystems:

- main landing gear (MLG) and its doors;
- nose landing gear (NLG) and its doors;
- landing gear extension and retraction;
- wheels and brakes;

– steering system;
– position monitoring and warning.

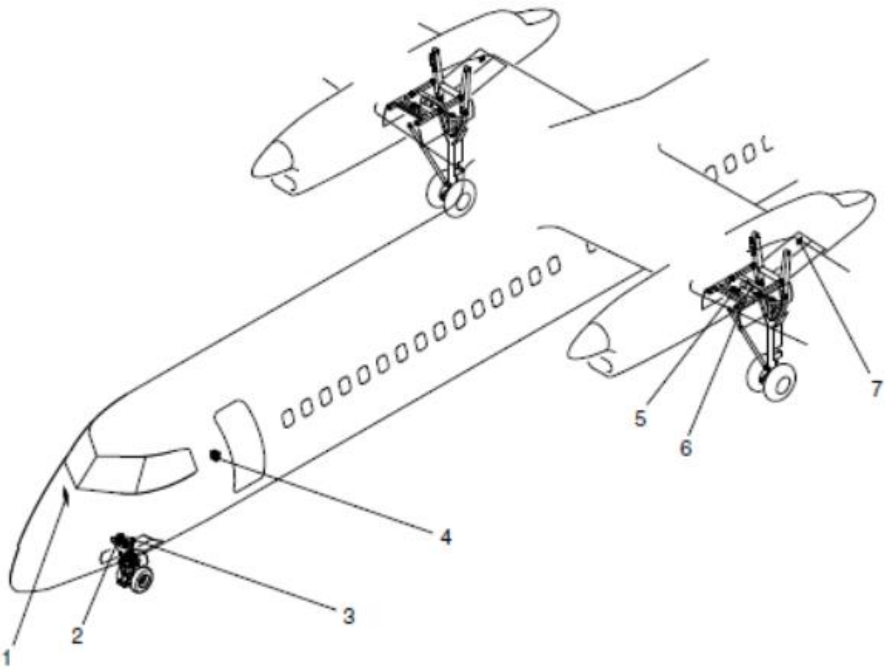

Fig. 3. Landing Gear Primary Extension and Retraction – Component Location [source: AMM 32-31-00]

1. Landing Gear Selector Lever and Control Panel.
2. NLG Retraction Actuator.
3. NLG Lock Actuator.
4. Proximity Sensor Electronic Unit
5. MLG Lock Actuator.
6. MLG Retraction Actuator.
7. Uplock Actuator

NLG) is located in the lower nose part of the fuselage forward of the forward pressure bulkhead. During retraction NLG moves forward into its well located in the fuselage. MLG retracts aft into wells located in the engines nacelles.

The landing gear is electrically controlled, hydraulically operated and mechanically locked.

The landing gear doors completely enclose the landing gear when it is retracted and partially enclose the gear bays when it is extended.

The status of the landing gear and its doors is signaled with lights on the landing gear control panel.

Proximity Sensor Electronic Unit (PSEU) monitors and controls the operation of the landing gear components during its retraction and extension.

If the primary extension system fails, an alternate landing gear extension system can be used to extend the gear.

Since the main landing gear system was functioning correctly in the accident flight, only the information related to the nose landing gear is presented below.

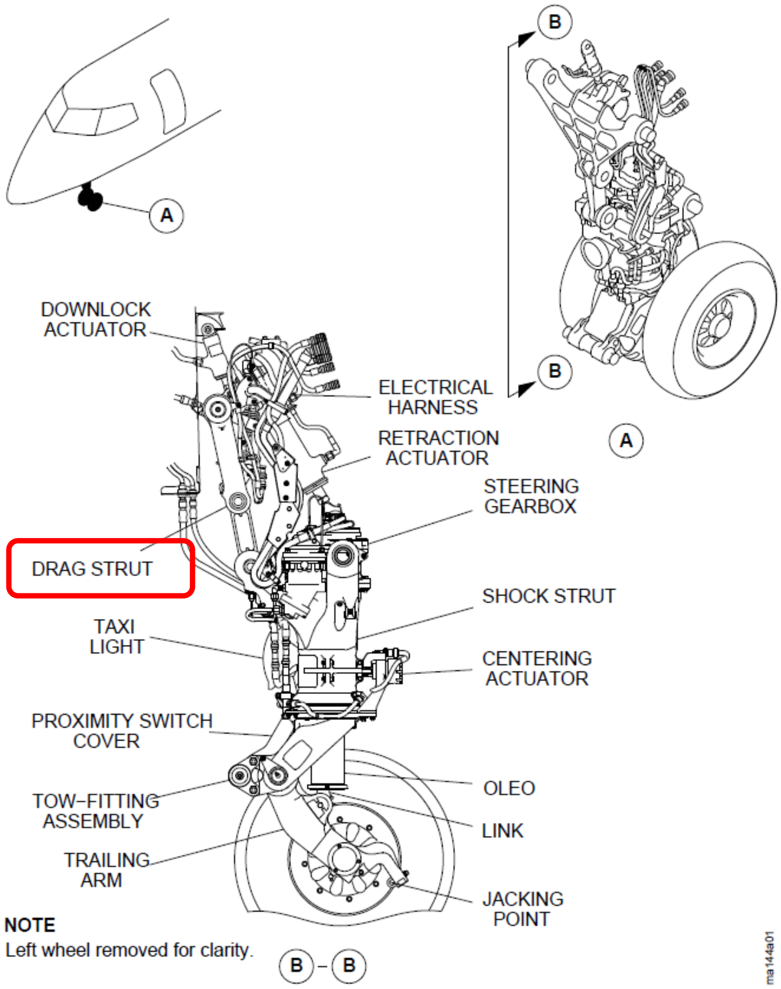

Fig. 4. Main components of the NLG, where: A – location of the NLG, B-B view in the longitudinal plane of the aircraft. Red frame shows the name of the component which was damaged during the accident (details in Chapter 1.3) [source: AMM 32-21-00]

1.6.3.2. Nose landing gear (NLG)

NLG absorbs part of the shock energy during landing (major part of the shock energy is absorbed by the main landing gear (MLG) and gives stability and direction control during aircraft taxi. The NLG assembly is comprised of the following: Shock Strut Assembly, Drag Strut Assembly and Electrical Harness). The main components of the NLG are shown in Fig. 4.

1.6.3.3. Drag Strut Assembly (DSA)

Drag Strut Assembly stabilizes the Shock Strut in either the retracted or the extended position. Main components of othe assembly are shown in Fig. 5.

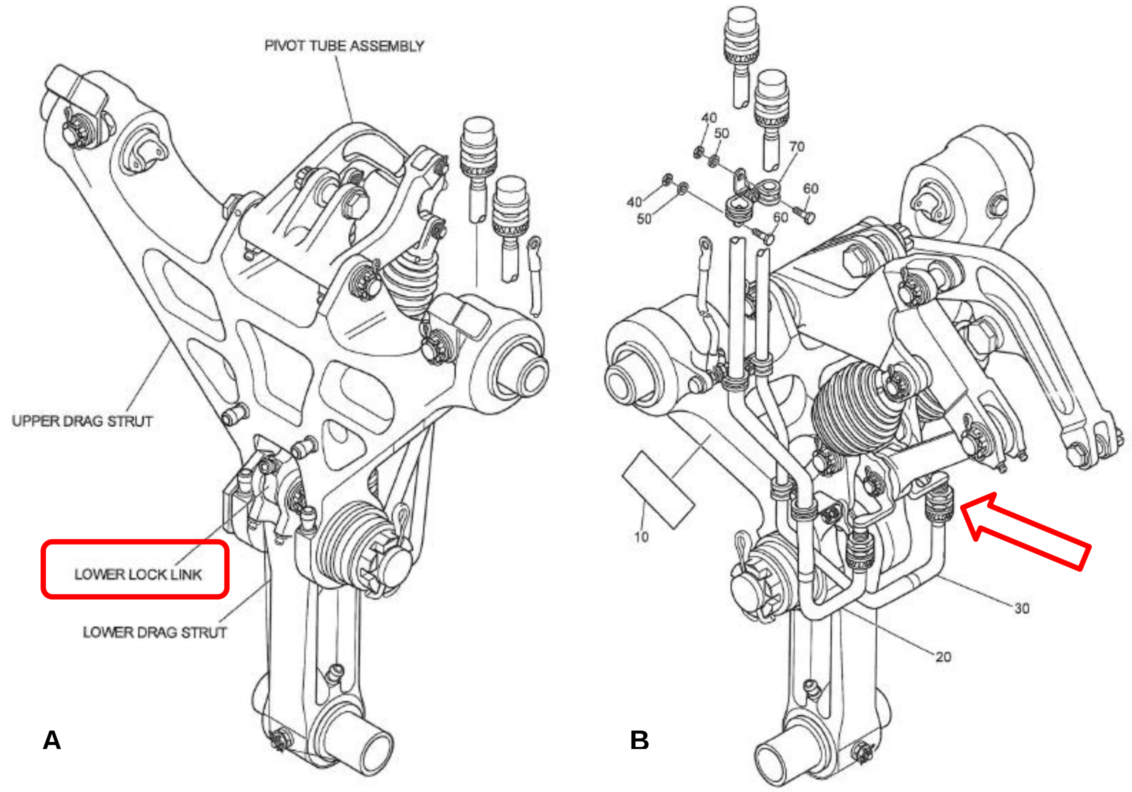

Fig.5. Drag Strut Assembly: A – font view (red frame shows the name of the component which was damaged during the accident); B – rear view(red frame shows the name of the component which was damaged during the accident). [source: CMM 32-21-03]

Note: The above figures show the components whose damage nature indicates the course of the occurrence.

The landing gear is mechanically locked in either the retracted or the extended position.

When the landing gear is either retracted or extended and locked, the axis of the pin connecting Upper Drag Strut (UDS) withLower Drag Strut (LDS) is initially displaced slightly below the plane defined by their axes of rotation, creating "under center", which gives the initial angle of "prefolding" the strut (Fig. 6)

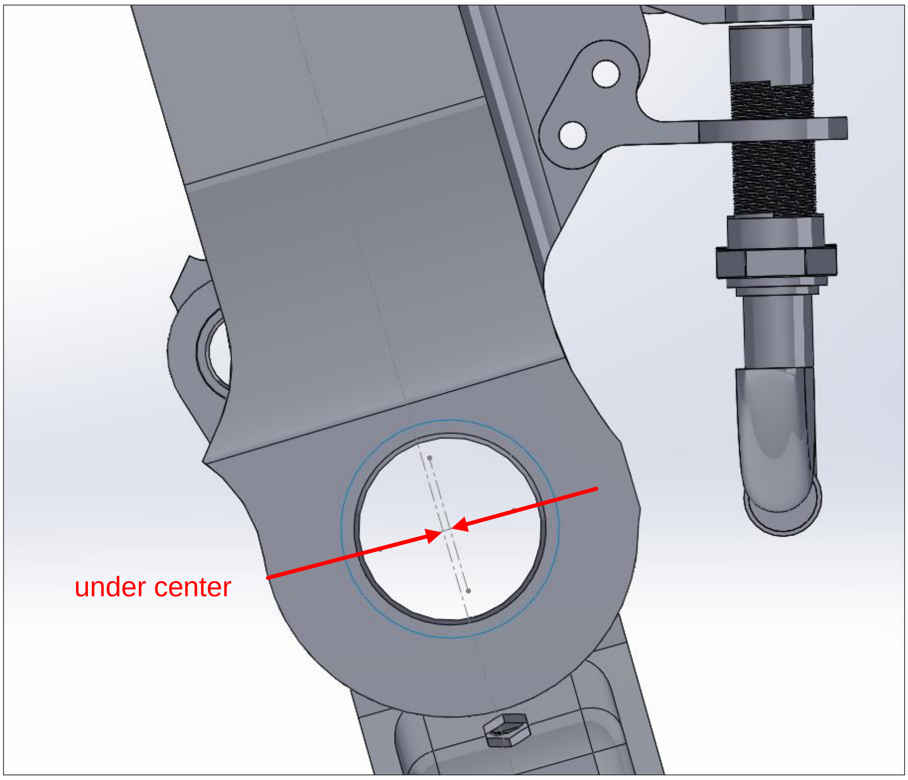

Fig. 6. Swivel connecting UDS and LDS – side view [źródło: ekspertyza ITWL]

The axis of the pin connecting Lower Lock Link (LLL) with Upper Lock Link (ULL) is displaced slightly over the plane defined by the LLL axis of rotation and the axis of the bolt (P/N NAS6206-20D), creating „over center", which causes the strut to lock. The locking mechanism is shown in Fig. 7.

Unlocking consists in "folding" the LLL and ULL assembly in the direction opposite to the initial "prefolding". Then the axis of the connecting pin passes through the "dead point" and the LLL moves away from the stop pin. This process is effected by a Downlock Actuator connected to one of the latch arms of the Pivot Tube Assembly or mechanically through a system of cables and rollers in case of extending the landing gear by an alternate system.

When the locking mechanism passes through the "dead point", the joint connecting the UDS and LDS moves minimally (about 0.4 mm) in the direction of reducing the initial angle of folding the strut, which causes it to straighten and reduces the value of "under center ".

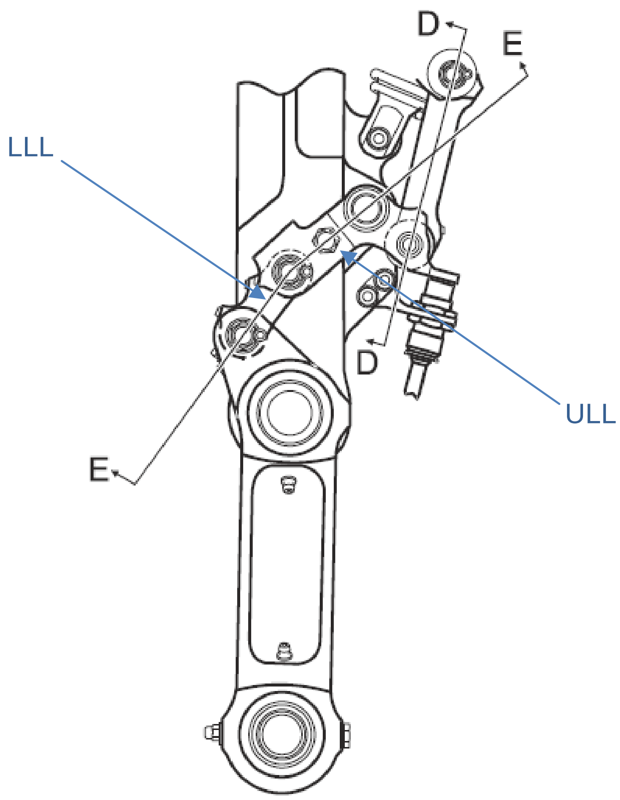

Fig. 7. Drag Strut Assembly – locking mechanizm of the Lower Lock Link and Upper Lock Link (LLL and ULL pins are not in the same plane) [source: CMM P/N 47300]

“Under center” value for UDS and LDS is 0.059” +0.030/-0.027(1,499 mm +0,762/-0,686).

“Over center” value for LLL and ULL is 0.122” +0.008/-0.009(3,099 mm +0,203/-0,229).

The above tolerance values include the tolerances of the elements of all joints affecting the dimensions, position tolerances, joints clearances, their wear and the thermal effect in the temperature range from -67 to + 158° F (from -55 to+ 70ºC).

1.6.3.4. Landing gear control panel

The process of retracting and extending the landing gear with the primary system is controlled and signaled with the Landing Gear Control Panel located in the cockpit on the right side of the Engine Display.

The panel contains the Landing Gear Selector Lever, Lock Release Selector Lever, nine advisory lights to indicate the status og the landing gear and its doors and Horn Mute/Test Switch.

1. "Green" Gear Downlocked
2. "Red" Gear Not Uplocked Or Downlocked
3. "Amber" Door Open
4. Handle "Amber"/"Red") - Gear In−Transit
5. Warning Horn Mute/Test Switch.

Fig. 8. Landing gear control panel [source: AMM 32-31-0]

Fig. 9 below shows the Landing gear control panel of DHC-8-402,SP-EQG during the accident flight.

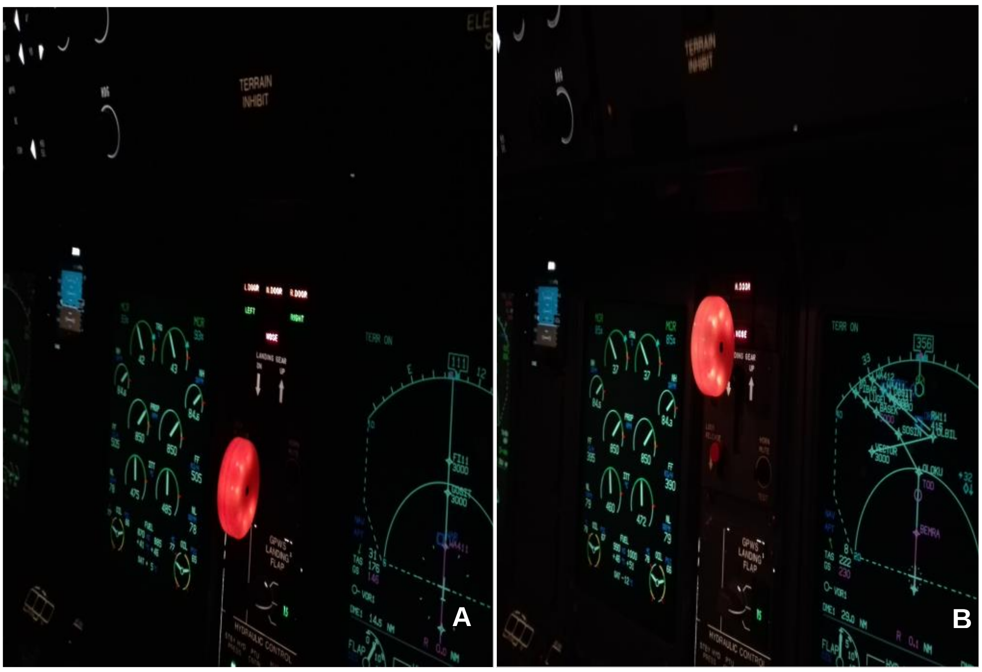

Fig. 9. Landing gear control panel: A – Landing Gear Selector Lever DOWN; B - Landing Gear Selector Lever UP [source: FO]

1.6.3.5. NLG doors

The NLG doors system consists of two forward doors, two aft doors and connecting rods. The two NLG forward doors are hydraulically operated with Nose Door Actuator powered by the No 2 hydraulic system. The doors are closed after the gear is extended or retracted. The aft doors are connected to the NLG shock strut by two connecting rod assemblies and move together with it during retraction or extension. When NLG is extended the aft doors are open.

1.6.3.6. NLG retraction

NLG is mechanically locked in both the lower and upper position.

The process of the primary retraction and extension of the landing gear is effected by NLG Retraction Actuator powered by pressure from hydraulic system No 2. The pressure rating is 3000 psi (20 684 kPa).

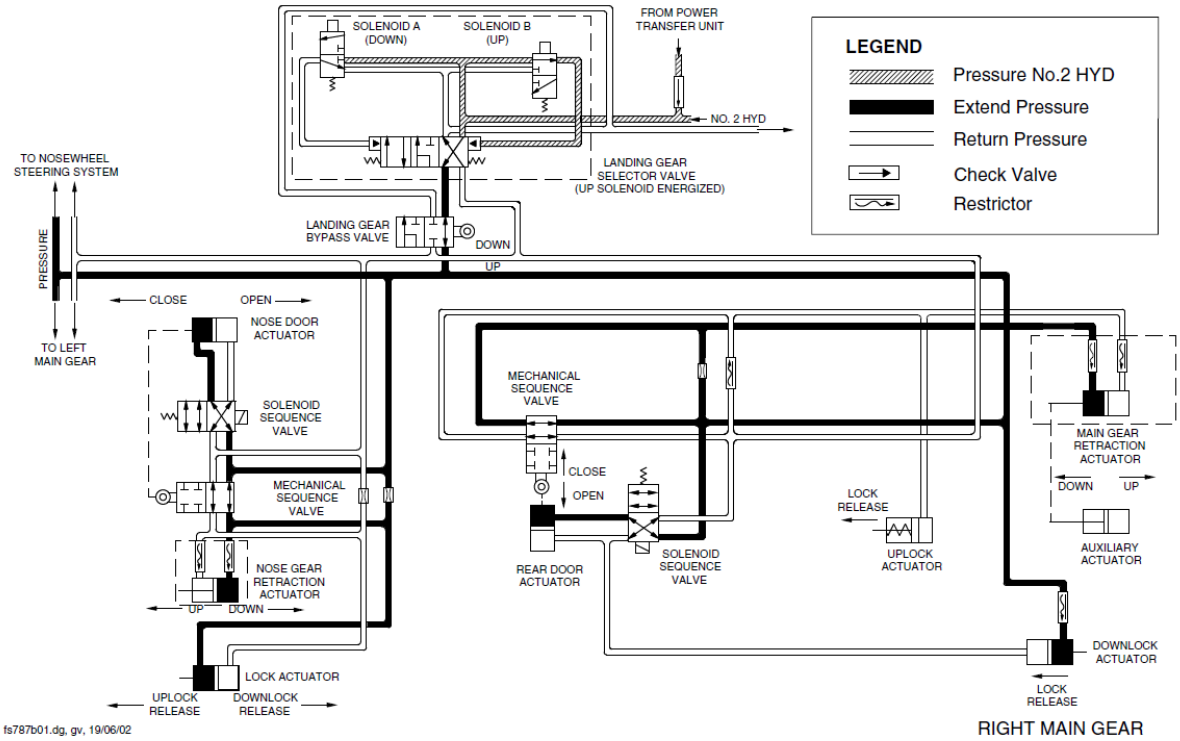

Fig. 10. Diagram of the hydraulic system for primary extension and retraction of the landing gear – Landing Gear Selector Lever in UP position [source: AMM 32-31-00]

The primary landing gear retraction or extension process starts when the Landing Gear Selector Lever is unlocked and moved to the UP or DOWN position (Fig. 8). The PSEU checks the status of the landing gear and its doors andand comparesit to the command selected. ThenPSEU controls the hydraulicsequences to either fully extend or fully retract the landing gear.

Three conditions are to be met to start the retraction process: Landing Gear Lever - UP, A/C - WOFW and NLG – Centered. If all three conditions are met, electrical power is supplied to the UP solenoid of the Landing Gear Selector Valveand pressure from the hydraulic system No 2 is connected to the retract line of the landing gear hydraulic system.

In the case of NLG retraction, hydraulic pressure is applied via a Solenoid Sequence Valve to NLG Forward Doors Actuator, which first initiate opening the forward doors. At approximately 92% travel of the forward doors the door linkage operates the Mechanical Sequence Valve and the pressure through this valve is applied to the NLG

Lock Actuator to release lock and at the same time via NLG Inline Restrictor to the retraction cylinder. When the PSEU receives signals that the NLG is fully retracted and locked, the SSV solenoid is de-energized, causing the valve to shift and supply pressure to the NLG FDA to close the doors.

Note:

In the investigated accident the NLG was not locked in the retracted position and the NLG doors remained open (Fig. 9, therefore the description of the retraction process has been also ceased at this stage. Then the landing gear was extended with the alternate system, therefore, in the next chapter the operation of the alternate landing gear extensiom system is presented.

1.6.3.7. Alternate landing gear extension system and its operation

The alternate extension system is used to extend and lock the landing gear in the extended position when hydraulic system No. 2 or the PSEU is inoperative. It is also used to open the landing gear doors for maintenance or inspection.

The MLG alternate release handle is located in the ceiling of the flight compartment on its right side. The NLG alternate release handle is located in the floor on the left side of the FO seat.

Fig. 11. Alternate release handles: A –MLG, B – NLG

After one of the alternate release handles has been pulled, the locks of the nose or main landing gear respectively are released via the cables and pulleys system. After opening the doors and removing the DSA lock, the NLG is forced by gravity and airstream to the down position.The NLG alternate extension system is schematically shown in Fig. 12.

The hand hydraulic pump fed from an auxiliary reservoir is used only to extend the MLG.

Selecting the Inhibit Switch to the INHIBIT position disables the PSEU.

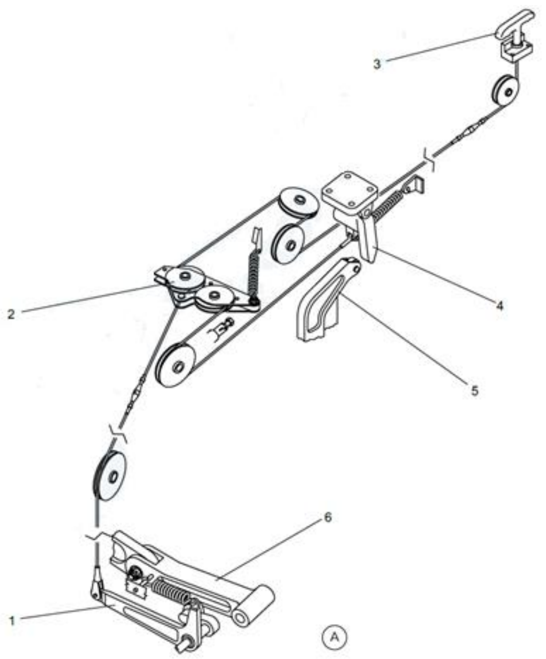

Fig. 12. NLG alternate extension system [source: DASH 8 Q400 MTM]

1.7. Meteorological information

<u>EPKK</u>

Date – 10 Jam 2018.

Time – 13:00 hrs UTC.

Wind direction – 60º.

Wind speed – 6kt.

Cloud cover and visibility – CAVOK.

Ambient temperature – 5ºC.

Dew point temperature – (+) 2ºC.

Pressure – QNH 1013 hPa.

<u>EPWA</u>

Date – 10 Jam 2018.

Time – 19:00 hrs UTC.

Wind direction – 100º.

Wind speed – 8 kt.

Cloud cover and visibility – CAVOK.

Ambient temperature – 0ºC.

Dew point temperature – (-) 3ºC.

Pressure – QNH 1016 hPa.

1.8. Aids to navigation

The LO3924 flight used standard navigation aids on the EPKK - EPWA route.

1.9. Communications

Radio communication was carried out in accordance with an applicable procedure. The crew declared EMERGENCY. Correspondence in both directions was readible. When the NLG failed, the crew switched to communication in Polish.

1.10. Aerodrome information

Warsaw Chopin Airport is approved and prepared to operate all aircraft up to the reference code letter 4E. Operations of aircraft with a higher code letter (B-748, A-380, C-5B Galaxy, An-124), are allowed in accordance with the procedure described in the Airport Operations Manual. Permitted air traffic: IFR/VFR, permitted ILS operations Category I, II and III and LVTO at RVR not less than 125 m. Allowed take-offs from intermediate distances, according to the published lengths declared in AIP Poland and Airport Operations Manual. Apron management service - by the airport operator. Rescue and firefighting service - category 9.

Tab. 1. EPWA declared distances

Designations RWY/NR	TORA	TODA	ASDA	LDA
RWY 11	2300	2300	2560	2560
RWY 29	2800	2800	2950	2950
RWY 15	3690	3690	3690	3690
RWY 33	3690	3690	3690	3690

Tab. 2. Types of approach on EPWA

Designations RWY/NR	Types of approach
RWY 11	Non-precision approach (IFR) Precision approach (IFR); Category I (CAT I), below Category I standard (LTS CAT I), Category II (CAT II)
RWY 29	Non-precision approach (IFR)
RWY 15	Non-precision approach (IFR)
RWY 33	Non-precision approach (IFR) Precision approach (IFR); Category I (CAT I), below Category I standard (LTS CAT I), Category II (CAT II)

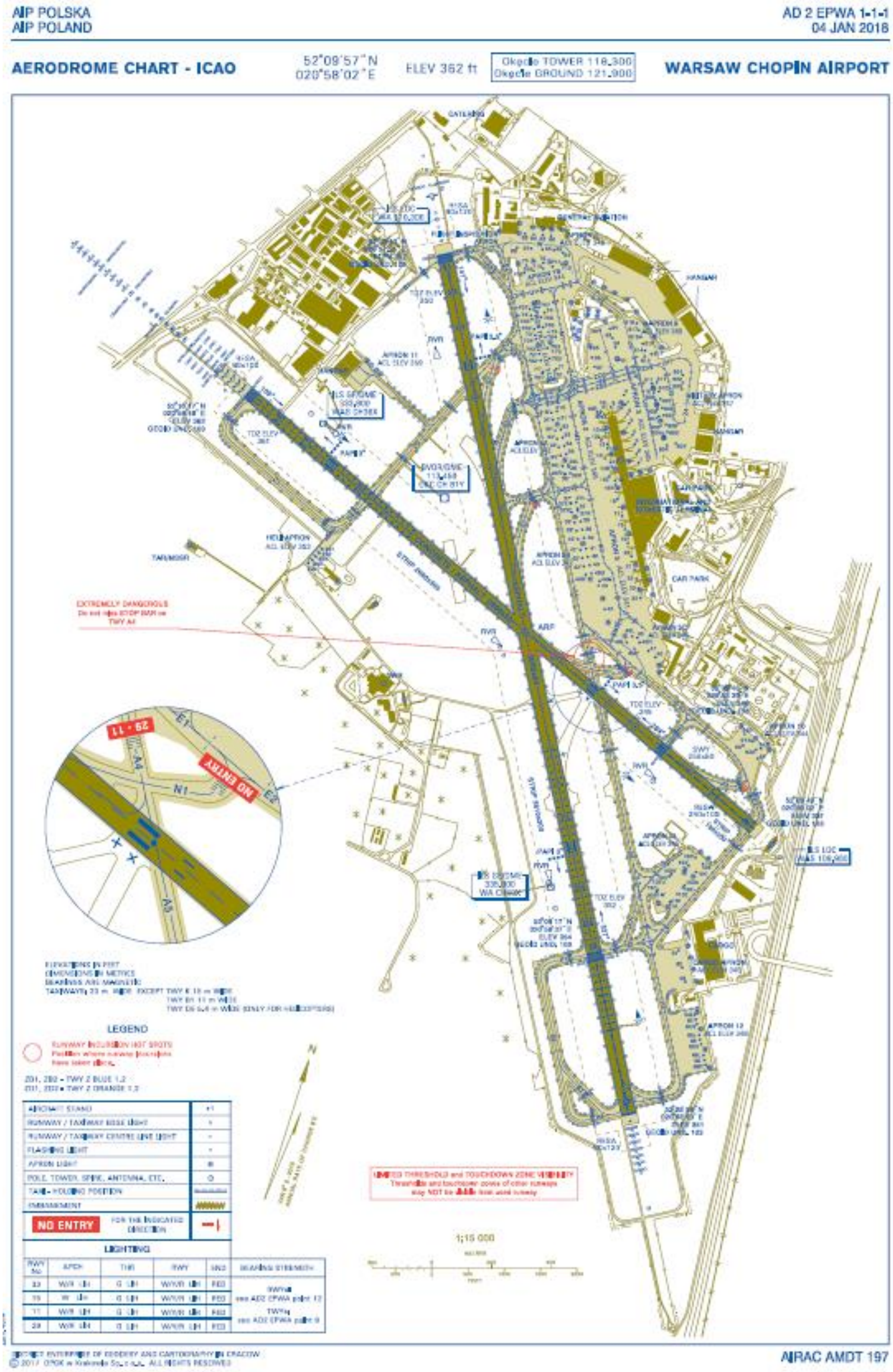

Fig. 13. EPWA Aerodrome Chart [source: AIP Polska]

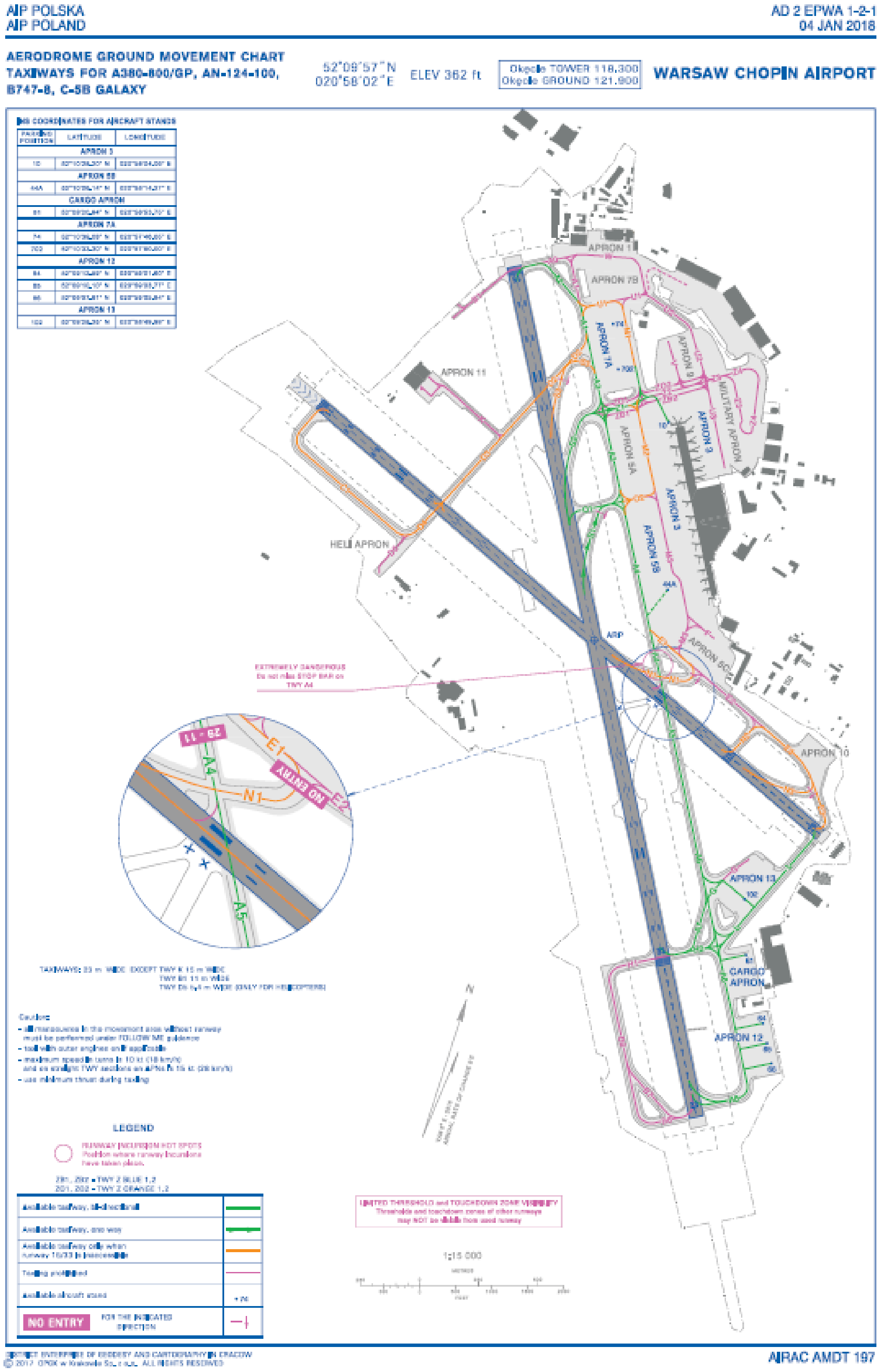

Fig. 54. EPWA Aerodrome Ground Movement Chart [source: AIP Polska]

1.11. Flight recorders

The aircraft involved in the accident was equipped with FDR, CVR and QAR.

1.11.1. FDR

Universal Avionics SSFDR,model FDR-25, P/N 1607-00-00, S/N 424,(Fig. 15A) was removed from the aircraft on the day of the accidentin the presence of members of the PKBWL Investigation Team and secured for download and read out. The recorder did not show any external signs of damage. The download of the data from the recorder semiconductor memory was completed on 11 January 2018 in the Accessories Maintenance Section (TTWA) of LOT AMS in Warsaw, under the supervision of representatives of the PKBWL Investigation Team in the presence of a prosecutor. The recorded data covered the last 25 flight hours prior to the accident and 294 parameters (141 discrete and 153 analog). The FDR data were used to analyze the operation of the aircraft on-board systems and to recreate the sequence of events during the flight LO 3924 from EPKT to EPWA. The Insight Analysis 4.9 and FDS 9 programs were used to analyze the parameters.

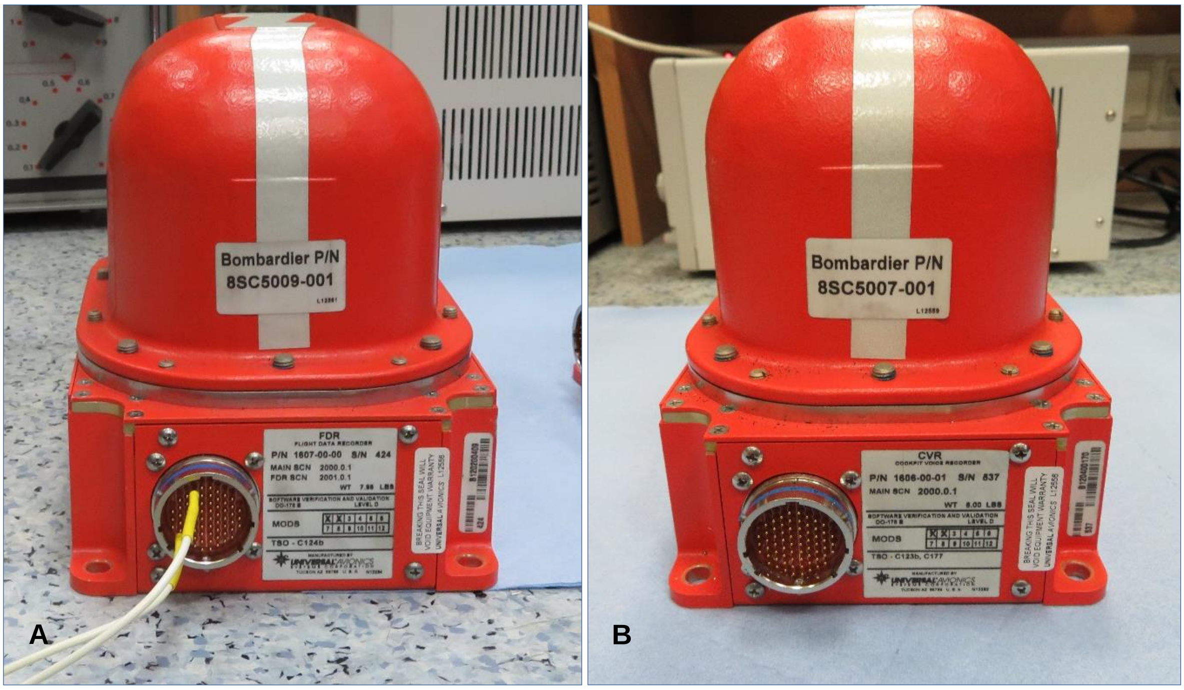

Fig. 15. Flight recorders: A - FDR, B – CVR

1.11.2. CVR

Rejestrator dźwięków w kokpicie typu SSCVR firmy Universal Avionics model CVR-120A, P/N 1606-00-01, S/N 537 (Fig. 15B), was removed from the aircraft on the day of the accidentin the presence of members of the PKBWL Investigation Team and secured for download and read out. The recorder did not show any external signs of damage. The download of the data from the recorder semiconductor memory was completed on 11 January 2018 in the Accessories Maintenance Section (TTWA) of

LOT AMS in Warsaw, under the supervision of representatives of the PKBWL Investigation Team in the presence of a prosecutor.

Good quality audio recording of the last 2 flight hours prior to the accident from all four tracks was obtained, including the entire flight LO 3924 - 1 hour 14 min and 50 seconds. The recording covering the crew conversations, cockpit sounds and radio communication was analyzed by the PKBWL Investigation Team at its headquarters in Warsaw. The data was used to evaluate the crew cooperation during preparation and performance of the flight, and during evacuation and was helpful in determining the sequence of events. Audacity 2.2.1 was used for sound analysis.

1.11.3. QAR

L3 Communications Quick Access Recorder,type µQAR, model QAR200 by, P/N QAR200-35-04, S/N 000802016, recorded parallely, in a solid state memory, the data sent to the SSFDR.

After the occurrence, the memory card was removed from the recorder without the knowledge of the PKBWL Investigation Team, which was inconsistent with the rules of procedure applicable to on-board recorders following an accident, as well as the Operator's procedures. The data stored on the card were downloaded, uploaded to the Aerobytes program and analyzed by the aircraft manufacturer without the knowledge and approval of the PKBWL. The card was handed over to the PKBWL on the next day, i.e. 11 January 2018.

1.12. Wreckage and impact information

The selected parameters in the touchdown phase are shown in Fig. 16.

The plane touched down on EPWA RWY11 at 18:18:56 hrs UTC with a ground speed GS = 111.5 kt and a vertical acceleration NA = 1.11 g, with a pitch angle PA = 2.3° and roll RA = 0.22° and with heading HEAD = 107.8°.

At the touchdown, both engines were operating and the registered propeller RPMs were: left NP1 = 850.6 RPM, right NP2 = 850.3 RPM.

As a result of the landing with the NLG not locked in the extended position, the NLG and the lower nose part of the fuselage were damaged.

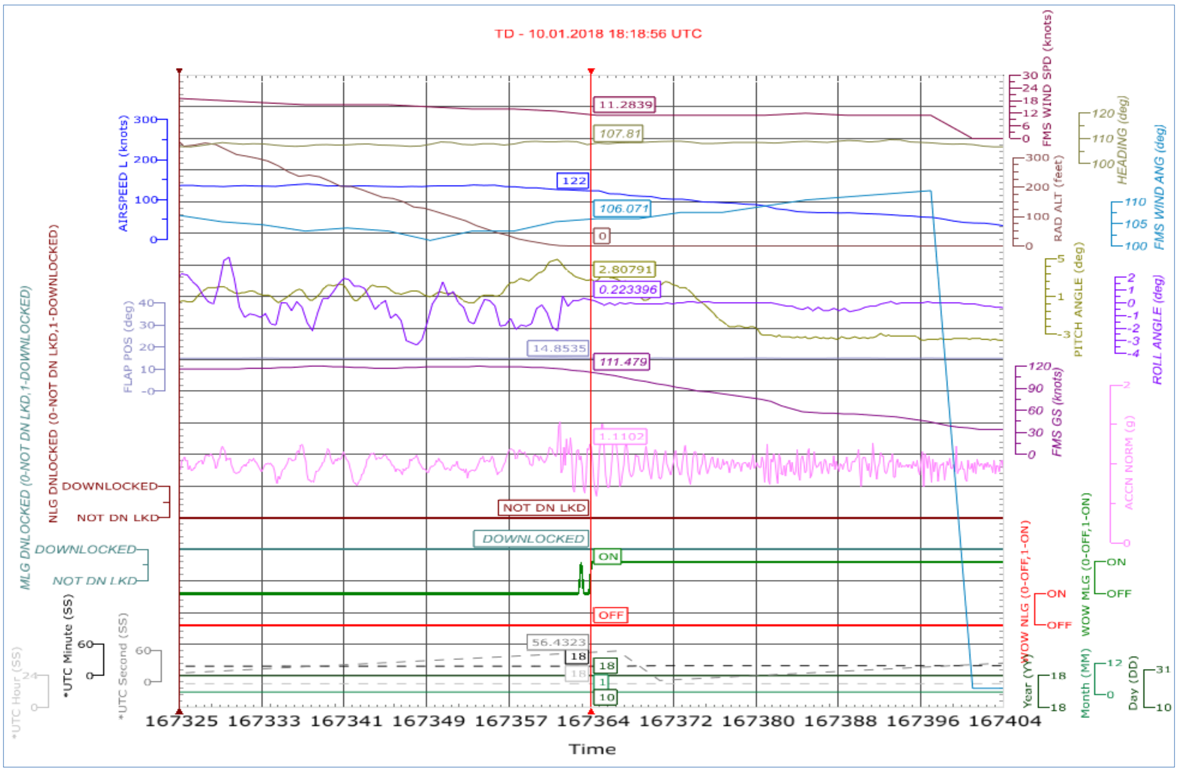

Fig. 66.The selected parameters in the touchdown phase - red vertical marker shows the moment of touchdown, the windows show the values of individual parameters [source: SCAAI]

1.13. Medical and pathological information

The performance of the crew members has not been found to be affected by physiological factors or any disability.

1.14. Fire

No signs of inflight fire were detected, no fire occurred after the emergency landing.

1.15. Survival aspects

1.15.1. Evacuation order

Before touchdown, the Captain agreed with the Cabin Service Manager (CSM) that the evacuation would be carried out on the left side. A few minutes before landing, the Captain ordered in Polish and English, POZYCJA AWARYJNA / BRACE POSITION. When the plane stopped, the captain ordered: EVACUATE TO THE LEFT SIDE and then the evacuation process began. After the evacuation of the passengers was completed, the CSM together with the flight crew checked the deck and then left it.

1.15.2. Information provided to passengers on the rescue equipment at their disposal

Briefing on the rescue equipment at the disposal of passengers was carried out in accordance with the applicable procedures. It covered an emergency landing on land, including the training of assistants for emergency exits and for directing passengers.

Briefing was conducted by the CSM. It included: time, place, specificity of the aircraft, additional information related to the aircraft failure and the specificity of evacuation of disabled passengers.

1.15.3. Briefing timing, its clarity (language) and audibility

Briefing for passengers consisted of three parts lasting several minutes, in two language versions - Polish and English.

In the first part, the CSM informed the passengers about the situation on board and the possible need for evacuation after an emergency landing.

The second and third part of the briefing contained detailed instructions on how to behave during the evacuation, including instructions on what to do with sharp objects, glasses and luggage. The attention was drawn to mutual assistance among passengers during the evacuation.

None of the passengers reported any problems related to the audibility of the briefing and the understanding of the messages provided.

1.15.4. Communication

Communication among the flight crew, the cabin crew and the passenger during the preparation for emergency landing and during the evacuation was carried out without any problems and was understandable for all passengers (commands and instructions related to the evacuation were provided in Polish and English).

1.15.5. Behavior of passengers

The passengers were disciplined and fully cooperating with the crew. During the evacuation one passenger showed symptoms of a panic attack. However, firm attitude of the CSM allowed to bring the situation under control. Several passengers tried to take their hand luggage with them. These attempts were thwarted by the crew and did not disturb the evacuation process.

1.15.6. Emergency exits

Emergency exits (forward and aft)on the left side of the planewere used for evacuation.

1.15.7. Injuries sustained during an evacuation

None of the passengers and crew were injured during the evacuation.

1.15.8. Evacuation time

The evacuation lasted several minutes. It was not possible to precisely determine the evacuation time (the CVR recording ended when the electrical power was turned off – 21 seconds after the evacuation was announced).

1.15.9. Rescue operations conducted by the crew

The crew assisted the passengers in leaving the plane. There were no signs of smoke or fire on board.

1.15.10. The manner of leaving the aircraft by the crew and passengers

The passengers left the plane via the two exits on its left side. Exit via the aft door was difficult because its threshold was over 2 m above the ground. Passengers sat on the threshold and then, assisted by the rescue services, jumped on the ground.

Two passengers on crutches left the plane via the left forward door.

1.15.11. The course of the rescue operation

The rescue operation was conducted in the following sequence:

- 18:34 hrs – EPKK duty officer informed EPWA that the flight LO 3924 had problems with the landing gear;
- 18.37 hrs – 1st level alarm for EPWA services was declared;
- 19:13 hrs – arrival of the handling agents service in concentration area No. 1;
- 19:14 hrs – arrival of 10 sections of the Airport Fire Service (LSP) and 5 ambulances at concentration area No. 2;
- 19:13 hrs – 2nd level alarm for EPWA services was declared. The LSP sections went to the waiting area. PSP notified;
- 19:18 hrs – arrival of the Military Fire Service (WSP) at the concentration area No.2;
- 19:19 hrs – landing of the plane;
- 19:20 hrs – announcement of the 3rddegree alarm. After the plane came to rest on the RWY 11, two foam currents were delivered on the nose part of the fuselage (in the area of the collapsed nose landing gear); passengers and crew were evacuated;
- 19:22 hrs – end of the evacuation of the crew and passengers;
- 19:20 hrs – notification of closing RWY 11/29;
- 19:30 hrs – release of PSP and WSP from the concentration area;
- 20:28 hrs – cancellation of the 3rddegree alarm;
- 03:27 hrs of 11 Jan 2018 – release of the LSP section (return of the section to the watchtower);

There was no crane at EPWA airport that would allow the removal of A/C from RWY. The crane arrived at the accident site after a few hours.

1.16. Tests and research

The Air Force Institute of Technology in Warsaw, commissioned by PKBWL, delivered two expert opinions which are summarized below.

1.16.1. "Damage Survey" – REPORT No. 1PKBWL/36/2018

The aim of the survey was to determine the technical condition of the Drag Strut Assembly (DSA), (P/N 47300) of the NLG of the Bombardier DHC-8-402 aircraft, registration marks SP-EQG, in terms of determining the causes of the failure. The scope of the surveyincluded:

- disassemblyof the DSA and visual inspection;
- cutting out blocked parts;
- material tests of damaged parts;

– tomographic examination of blocked parts;
– measurements of fits and clearances in the joints of the DSA;
– component damage survey.

CONCLUSIONS:

a) 18 elements (18 pcs) of the DSA were damaged.

b) Measurement of the clearances in undamaged assemblies of DSA did not show discrepancies with the manufacturer’s specifications.

c) There was no damage to the sealant of the press-fitted assemblies, no rotation or loosening of their bushings, except for F and AA assemblies (Fig. 17).

d) In F and AA assemblies damage to the sealant and minor traces of surface corrosion were found, but no traces of turning of the bushings were found.

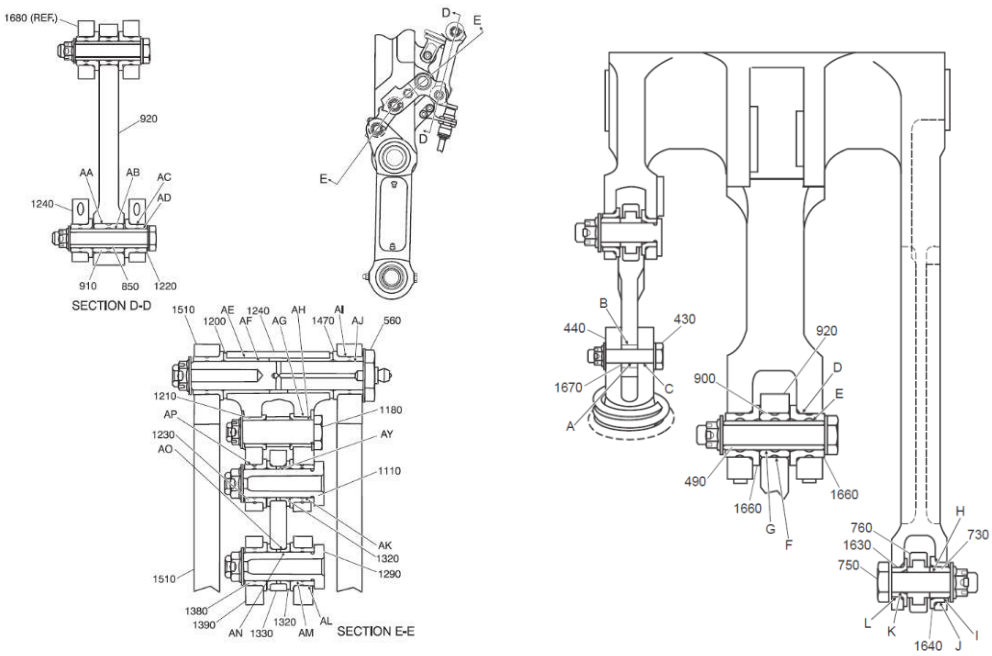

Fig. 17. Designations of selected joints of DSA [source: Bombardier]

e) Press-fit bushings in component seats had to be disassembledwith the use of a press, which most likely proved that the specifications for the assembly of these components and their technical efficiency were met.

f) The visual inspection revealed the direction of mounting of the bolt part number NAS6204-25D and (bolt) part number NAS6204-21D were inconsistent with the manufacturer's documentation, which, however, should not have affected the operation of the DSA.

g) Pin, lower lock, P/N 47309-3 was visibly plastically deformed – bent in one direction relative to the axis of rotation (0.7mm), which indicated excessive load resulting from impact of LLL, PN 47324-101. Bending of PN 47309-3 significantly affected the kinematics of the DSA.

h) Pin, sleeve 47326-13 showed visible damage, groovesand scratches around the whole perimeter. In the place of mating with the lock lever, a particularly significant material loss was found - a furrow with a depth of up to0.6mm, in relation to the part of the cylindrical surface of the sleeve not mating with the lock lever. The change in the position of the contact surface of the lock lever (LLL) with the sleeve significantly influenced the kinematics of the DSA.

i) Damage to the LLL, PN 47324-101 resulted in loss of the kinematic link of the mechanism – disconnection of the AN joint (Fig. 17).

j) The results of the fractographic tests indicated the ad hoc nature of the destruction of the elements provided for testing. No symptoms of fatigue cracks were observed.

k) Both pins, PN 47310-101 and PN 47309-3 are made of steel 4340. The LLL, PN 47324-101 is made of steel 15-5PH. The results of metallographic tests and hardness measurements showed no inconsistency with the above-mentioned data. The mechanical properties of the tested materials were consistent with the requirements from the documentation provided. The microstructure did not raise any objections and was consistent with the above mentioned types of steel. There were no material defects that could contribute to a damage to the items tested.

1.16.2. Expert opinion on kinematics " – REPORT No. 2 PKBWL/36/2018

The purpose of the work was to develop a computer model that would enable the determination of the phases of destruction of the NLG DSA, P/N 47300 of the Bombardier DHC-8-402 aircraft.

CONCLUSIONS:

a) The computer model of theNLG DSA of the Bombardier DHC-8-402 aircraftenables the determination of the phases of destruction of the DSA P/N 47300 components.

b) The research of the computer model of the NLG DSA of the Bombardier DHC-8-402 aircraftconfirmed that the destruction of the DSA locking mechanism was associated with the elimination of the overcenter/undercenterand strengthening o the strut. This resulted in the folding of the strut in the direction opposite to the designed direction.

c) The elimination of the overcenter/undercenter was likely due to the primary failure of the pin, PN 47310-101, in the Upper Lock Link, PN 47320-103.

d) Other damage to the NLG DSA of the Bombardier DHC-8-402 aircraft was of the secondary nature.

1.17. Organizational and management information

At 18:15 hrs UTC an alert was declared at EPWA. The airport services were directed to deploy to the waiting areas.

A crane with adequate lifting capacity arrived at the scene a few hours after the landing and resulted in a delay in vacating the runway. At 22:08 hrs UTC, NOTAM P0265 was issued opening EPWA airport.

1.18. Additional information

Before publication of the Final Report, SCAAI solicited comments from the persons and authorities concerned, including EASA.

The Draft Final Report was consulted with the crew of the accident aircraft and the operator. The comments of the crew and operator were included in the content of the report.

The Draft Final Report was circulated for consultation also to the TSB and EASA. Neither of them made any significant comments to the Draft Final Report.

1.19. Useful or effective investigation techniques

Standard investigation techniques were used.

2. ANALYSIS

2.1. Flight operation

2.1.1. The situation on board

During take-off from EPKK, the crew moved the landing gear control lever to the UP position, in accordance with the procedure. The MLG was retracted and locked, while the NLG was unlocked from the downlock position but not locked in the uplock position. That situation was reflected on the landing gear control panel (Fig. 9-B). The crew immediately noticed that fact and started solving the problem according to the checklists from QRH (version 34 of 29 April, 2014).

2.1.2. Checklists

The following checklists were available to the crew to solve the problem with the landing gear:

LANDING GEAR

ALTERNATE LANDING GEAR EXTENSION
or **"LDG GEAR INOP"** (Caution Light) 14.3

MAIN LANDING GEAR DOOR MALFUNCTIONS 14.4

NOSE LANDING GEAR DOOR MALFUNCTIONS 14.5

ALL LANDING GEAR FAIL TO RETRACT 14.5

LANDING GEAR INDICATOR
MALFUNCTION 14.6

"NOSE STEERING" (Caution Light) 14.6

"TOUCHED RUNWAY" (Warning Light) 14.7

"INBD ANTI-SKID" and/or **"OUTBD ANTI-SKID"**
(Caution Lights) 14.7

"WT ON WHEELS" (Caution Light) 14.7

Fig. 78. Checklists related to the landing gear [source: QRH Q400]

Since the QRH did not contain a checklist dedicated to NLG malfunction during retraction, the crew chose the NOSE LANDING GEAR DOOR MALFUNCTIONS checklist, which they found most relevant to the situation. That checklist required "DO NOT extend landing gear via normal selection" and instructed the flight crew to "extend landing gear via ALTERNATE LANDING GEAR EXTENSION" (Fig. 20).

NOSE LANDING GEAR DOOR MALFUNCTIONS

(Continuous Illumination of Amber Nose Gear Door Open Advisory Light after Landing Gear selection)

Landing Gear Up selected:

- Airspeed .... 185 KIAS (Max)

– DO NOT extend landing gear via normal selection.

Landing Considerations:

- Extend landing gear via ALTERNATE LANDING GEAR EXTENSION (Page 14.3).

Note: *Intermittent illumination of amber nose gear door open advisory light must be reported to maintenance.*

- END -

Fig. 19. Checklist – NOSE LANDING GEAR DOOR MALFUNCTIONS [source: QRH Q400]

The crew continued the flight to EPWA. In the meantime they were preparing to extend the landing gear with the alternate system and several times read the checklist “ALTERNATE LANDING GEAR EXTENSION or "LDG GEAR INOP" (Fig. 20).

During the landing approach to EPWA, the crew proceeded to carry out the ALTERNATE LANDING GEAR EXTENSION or “LDG GEAR INOP” checklist.

During execution of that checklist, when extending the landing gear with a hydraulic hand pump, the crew was surprised that when the maximum pressure was reached, the MLG had been extended and downlocked, while the NLG had not changed its position.

To solve the problem, the crew could also have selected the checklist ALL LANDING GEAR FAILTO RETRACT (Fig. 21), but they had not used that checklist. As the first step, that checklist requires the crew to move the landing gear selector lever to the DOWN position.

ALTERNATE LANDING GEAR EXTENSION or "LDG GEAR INOP" (Caution Light)

(One or more Landing Gear fail to extend)

Landing Considerations:

– Landing Gear cannot be retracted.
– Nosewheel steering will be inoperative.

Note: *The main and nose gear release handles pull force will be significantly higher than experienced during practice alternate landing gear extensions. The required pull force, to release the gear uplocks, can be as high as 41 kg (90 lb). It may require a repeated pull effort to achieve a landing gear down and locked indication.*

- Airspeed . . . . 185 KIAS (max)
- L/G Inhibit switch . . . . Inhibit
- Landing Gear selector . . . . Down
- Landing Gear Alternate Release door . . . . Open
- Main Gear Release handle . . . . pull fully down
  Check L & R DOOR amber open and LEFT & RIGHT green locked down advisory lights illuminate.
- Landing Gear Alternate Extension door . . . . . . Open

Note: *IF LEFT and/or RIGHT green gear locked down Advisory Lights do not illuminate, insert Hydraulic Pump handle in socket and operate until LEFT and RIGHT green gear locked down Advisory Lights illuminate.*

- Nose Gear Release handle . . . . pull fully up
  Check N DOOR amber open and NOSE green locked down advisory lights illuminate.

Note: *Leave Landing Gear Alternate Release and Alternate Extension Doors fully open and L/G Inhibit switch at Inhibit.*

- Gear–Locked–Down indicator . . . . . . On/check/Off
- Anti-Skid . . . . Test

After Landing:

As soon as possible after engine shutdown:

- Ground Locks . . . . install

Fig. 20. Checklist ALTERNATE LANDING GEAR EXTENSION or "LDG GEAR INOP" [source: QRH Q400]

ALL LANDING GEAR FAIL TO RETRACT

(3 Red Gear Unsafe and Landing Gear Lever Advisory Lights illuminated with Landing Gear Lever selected Up)

Note: *Landing Gear Doors may be open or closed (Amber Doors Open Advisory Lights illuminated or out).*

- Landing Gear selector .... Down
  Confirm 3 Green Gear Locked Down Advisory Lights illuminate.

Note: *If the Landing Gear Alternate Release door is open, the landing gear will not retract..*

– DO NOT re-select landing gear up.
– Land at the nearest suitable airport.

Fig. 21. Checklist ALL LANDING GEAR FAIL TO RETRACT [źródło: QRH Q400]

<u>Summary</u>

The process of closing the NLG doors (see 1.6.3.5 and 1.6.3.6) starts after retraction and uplock of the NLG. Since the NLG had not been retracted and uplocked, the illuminated message N DOOR was correct.

In the analyzed flight, the use of the MLG alternate landing gear extension system (see 1.6.3.7) resulted in isolation of the No. 2 hydraulic system (which in that case was operative) and created the necessity to use a manual hydraulic pump to extend the MLG. However, that had noimpact on the operation of the NLG alternate extension system.

The NLG alternate extension consists in opening the doors and releasing the DSA lock. In the analyzed flight, in the phase of the approach to landing, the NLG doors were open because they did not close after take-off, and the DSA was not locked, so using the release handle of the NLG alternate extension system did not change anything and could not lead to the extension and downlock of the NLG.

When an emergency occurs, the crew usually does not have time for a detailed analysis of a malfunction and must rely on checklists and their knowledge.

It should be noted, however, that if instead of the NOSE LANDING GEAR DOOR MALFUNCTIONS checklist, the crew had used the ALL LANDING GEAR FAIL TO RETRACT checklist (although the word ALL in the title did not fit exactly to the situation since only NLG did ot retract), then:

– firstly, after selecting LGSL to the DOWN, the MLG would have been extended by No. 2 hydraulic system, which was operative at that time;
– secondly, after selecting LGSL to the DOWN, just after take-off from EPKK and not only on the approach to EPWA the crew would have learned that the NLG was not downlocked, so the crew and the airport services would have had more time to prepare for the NLG malfunction. The crew would also have had time for possible consultations with the operator's services.

The use of the NOSE LANDING GEAR DOOR MALFUNCTIONS checklist, followed by ALTERNATE LANDING GEAR EXTENSION or "LDG GEAR INOP" checklist did not solve any problem on board, on the contrary – it caused isolation of the operative No. 2 hydraulic system and delayed identification of the true nature of the problem.

2.1.3. Weather

The weather forecast on the day of the occurrence did not contain any significant phenomena and allowed to perform the planned flight. The landing was performed under NVMC conditions. The weather had no effect on the occurrence.

2.1.4. Air traffic control

The flight crew kept the air traffic control informed about the situation on board and collision-free airspace throughout the flightwas ensured.

2.2. The aircraft

2.2.1. Landing gear load signaling

The MLG and NLG are equipped with Proximity Sensors, which inform about weight or lack of weight on respective wheels.

The presence of the weight on the respective wheels is recorded by FDR and QAR.

Fig. 22. Flight parameters from the landing of the SP-EQG on 10 January, 2018 at 9:19 hrs UTC. The arrow in the graphic on the left shows the moment when the NLG sensor recorded weight (horizontal brown line at the bottom); the moment when MLG sensors recorded weight is shown by the purple line (second from the bottom). The values of selected parameters at the time when NLG sensor recored weight are shown in the table on the right [source: SCAAI - FDS 9]

In the course of the aircraft operation QAR recordings are periodically downloaded and analyzed for exceeding the operational limits.

The analysis of the recorded parameters showed that apart from hard landings, there were also cases of landings, when the NLG wheels were loaded prior to MLG wheels. The data from 1st January 2017 to the date of the accident were analyzed.

As for SP-EQG, out of 2 854 landings in the analyzed period, 69 cases when the NLG wheels were loaded prior to MLG wheels were found, including one on the day of the accident in the morning hours (Fig. 22 and 23). The common feature for the aforementioned landings, in addition to the sequence of the NLG and MLG loading, was the negative pitch angle.

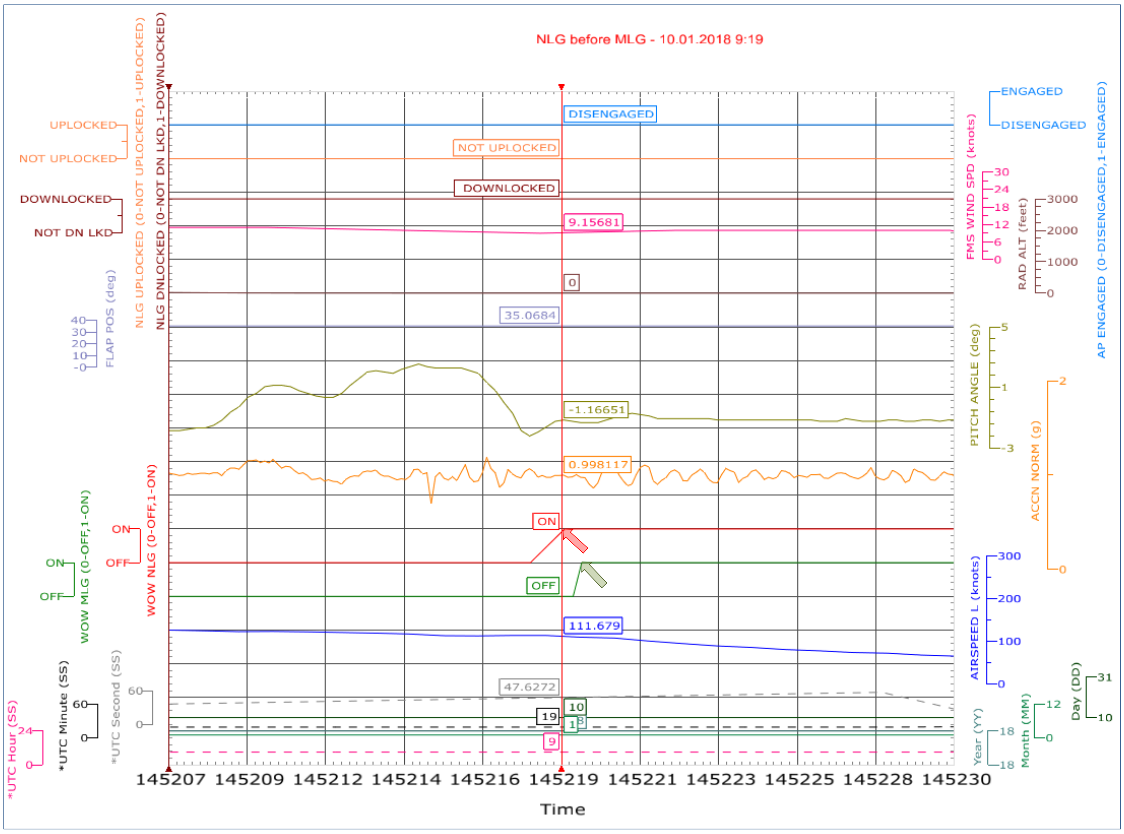

Fig. 23. Flight parameters from the landing of the SP-EQG on 10 January, 2018 at 9:19 hrs UTC. The red arrow in the graphic shows the time of NLG loading, the time of MLG loading is shown by the green arrow [source: PKBWL – Insight 4.9]

2.2.2. Statistical analysis of FDR data

PKBWL asked the operator to select the data for the cases when the NLG load signal was generated prior to MLG load signal combined with an additional condition – a negative pitch angle at the time of a touchdown.

The data related to ten Q400, from 1st Jan 2017 to 10th Jan 2018 were analyzed.

The PKBWL analysis showed that there were 398 landings (on ten Q400 aircraft) which had met the above conditions and that two aircraft were significantly above the average, including SP-EQG (see Fig. 24).

The data also showed that 32 landings of SP-EQG occurred at the negative pitch angle (PA) greater than 1.2º (Fig. 25).

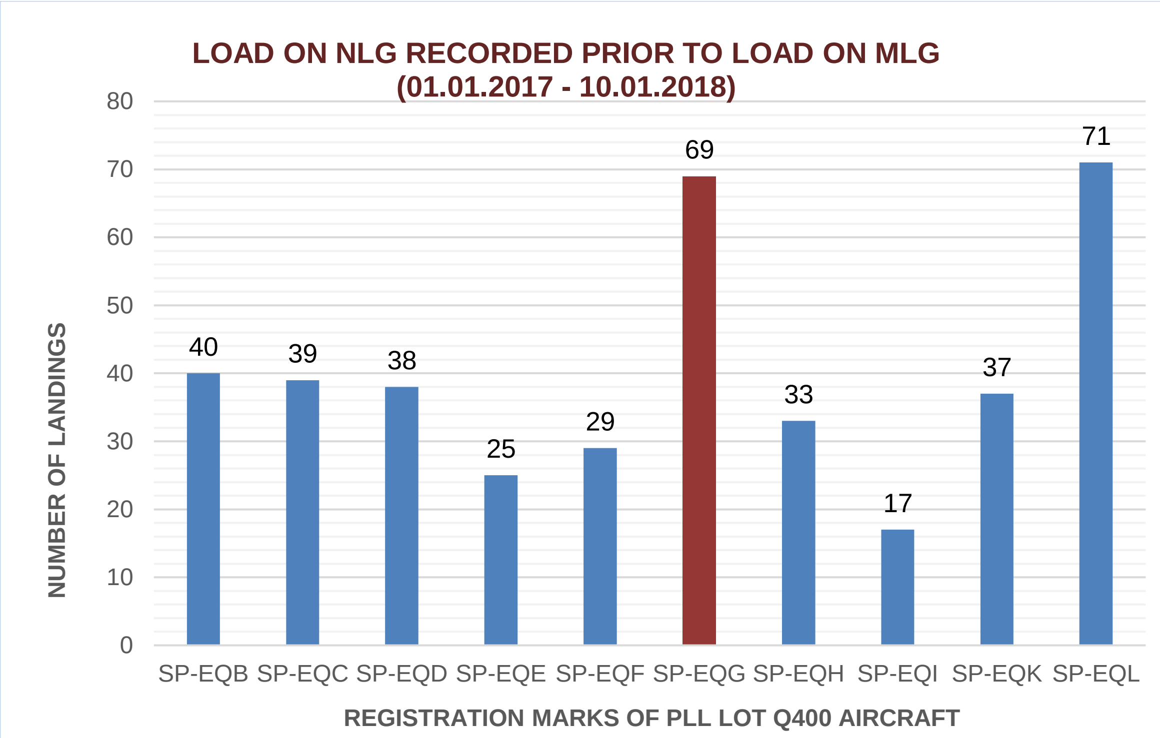

Fig. 24. Number of landings with weight on NLG signaled prior to weight on MLG - SP-EQG airplane is marked in brown

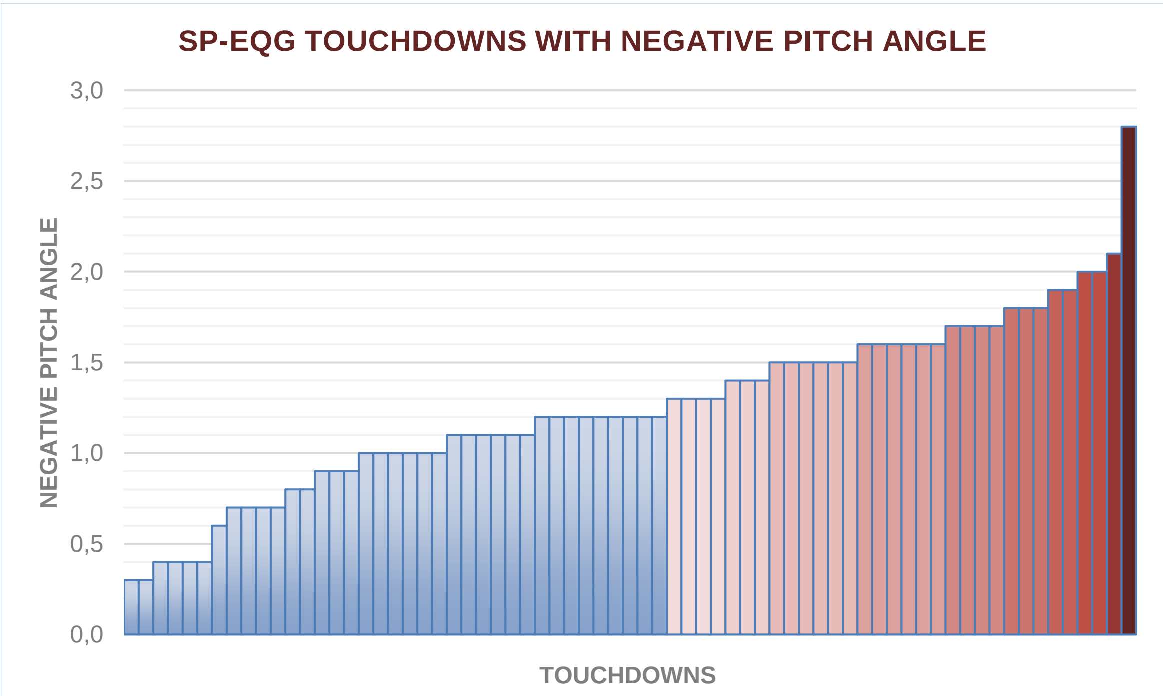

Fig. 25. Presentation of 69 landings of the SP-EQG with a negative pitch angle during the touchdown, when weight on NLG was signaled prior to weight on MLG – shades of burgundy color show touchdowns with a negative pitch angle equal or greater than 1.3^{o}. Note: the chart does not show the landings in the chronological order.

2.2.3. Hard landings

Until the accident, various cases of exceeding operational parameters had been routinely analyzed, including hard landings, i.e. landings on MLG with vertical overload exceeding the permissible value.

The procedure of the aircraft inspection has been launched when CPT reported the fact or suspicion of a hard landing or after detecting a hard landing during the analysis of the flight parameters recorded by the FDM.

Data from the QAR were downloaded and analyzed every 50 FH.

After the accident, the relevant data of the SP-EQG aircraft from 1st January 2017 to the date of the accident were analyzed. The analysis showed no cases of hard landings requiring respective inspection (HARD LANDING – INSPECTION/CHECK).

2.2.4. Direction of the DSA folding

During retraction of the NLG the DSA is folding in such a way that the articulated joint connecting the LDS and UDS is moving in the aft direction. Fig. 26 (A, B) below shows the correct placement of LDS in relation to UDS after the investigated landing.

In the course of lifting the airplane, it is not possible to move the above mentioned joint from the forward position to the aft position. Once the DSA folding has been initiated in a particular direction during landing, it is impossible to change that direction. Folding of the DSA in the opposite direction is possible only when the DSA is completely straight (when NLG is completely straight and free).

After lifting the aircraft, the LDS and UDS could be moved freely back and forward without jamming (Fig. 27). The photos clearly show the loss of the kinematic connection between the LLL and the LDS, which results in the inability to lock the DSA, and thus the NLG (here in the extended position).

After removing the DSA from the aircraft its detailed inspection was carried out. The inspection showed that the LDS, Electrical Harness as well as NGLK2 Proximity Sensor face and its target, presented corresponding signs of mutual contact – Fig. 28 and Fig. 29.

The collision of the above elements was possible only if the DSA folded in the wrong direction (forward), as shown in Fig. 27-A.

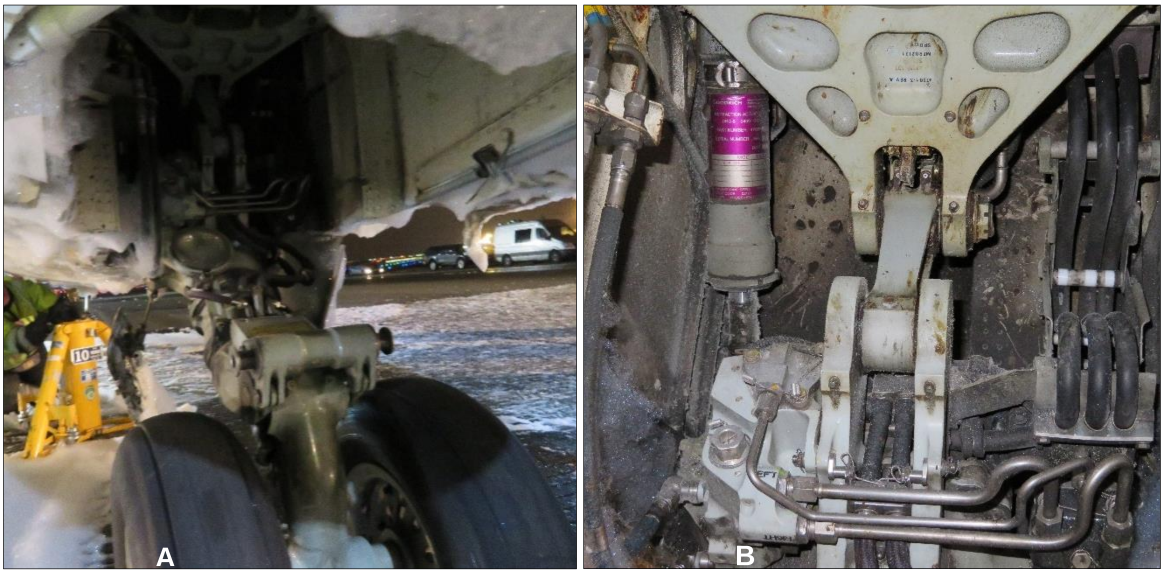

Fig. 26. Lifting the airplane – relative location of the Lower Drag Strut and Upper Drag Strut:
A – general view, B – close-up [source: PKBWL].

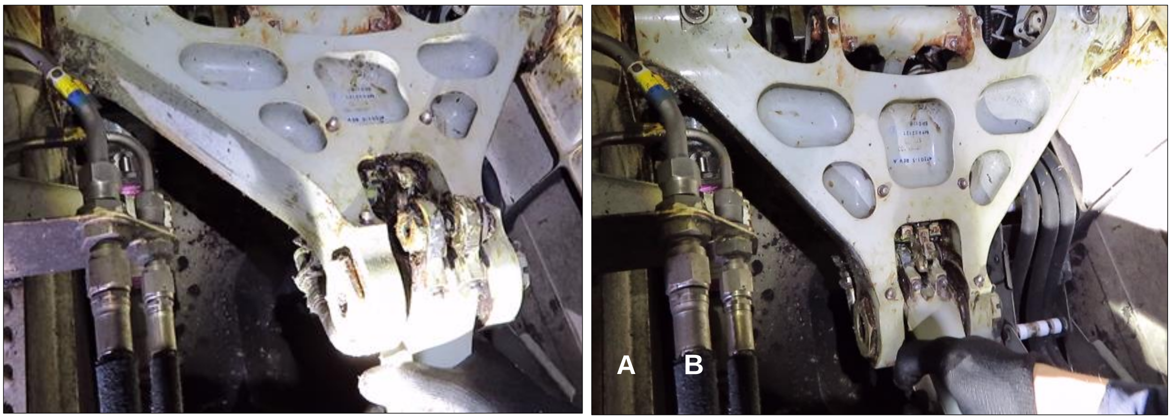

Fig. 27. Lower Drag Strut and Upper Drag Strut after lifting the plane: A – strut folded forward (incorrect direction), B – strut folded backwards (correct direction)

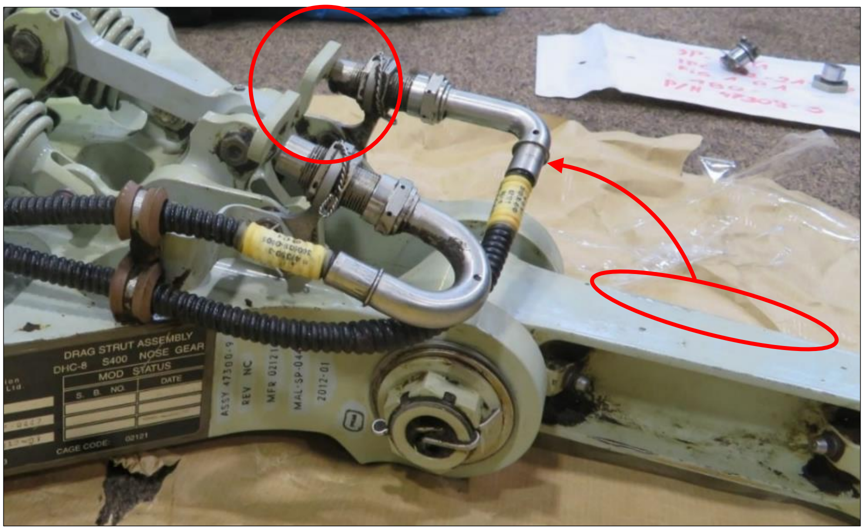

Fig. 28. Drag Strut Assembly - the red circle shows the place of the Proximity Sensor (NGLK2) collision with its target. The red ellipse shows the loss of the paint coating on the Lower Drag Strut and the arrow shows the direction of movement [source: PKBWL].

Details of the inspection and description of damage of individual components of the DSA are contained in the expert opinion developed by the Technical Institute of Air Force in Warsaw (ITWL).

Fig. 30-A shows the correct folding of DSA and Fig. 30-B shows incorrect folding of DSA, in which the LDS collides with the ELH.

The green arrow in Fig.30-A shows the PS NGLK2 face moving away from its target during the correct folding of DSA and in Fig. 30-B the folding direction in which the LDS collides with ELH.

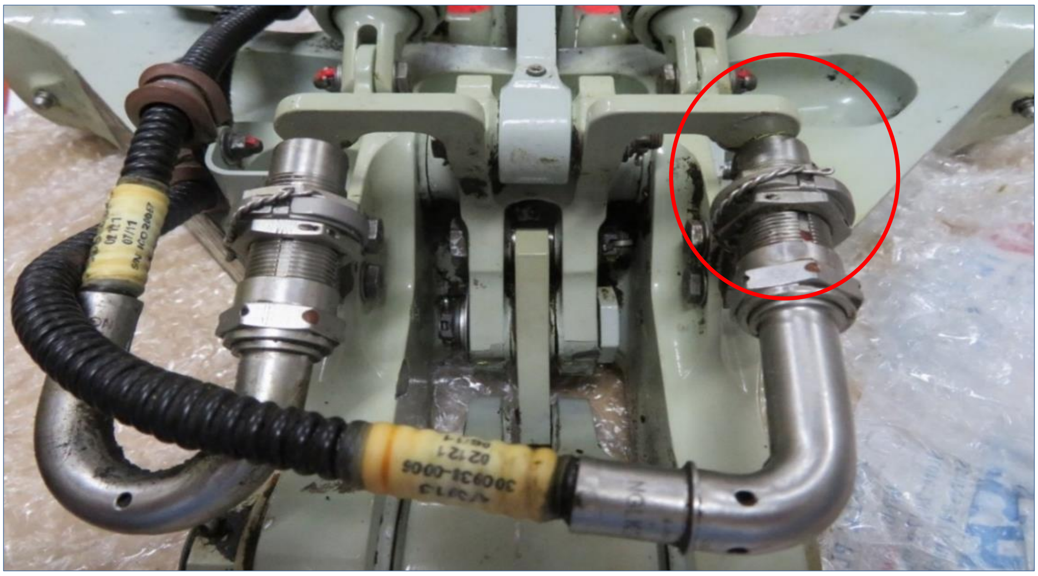

Fig. 29. Drag Strut Assembly – red circle marks the collision of the Proximity Sensor NGLK2 with its target [source: PKBWL]

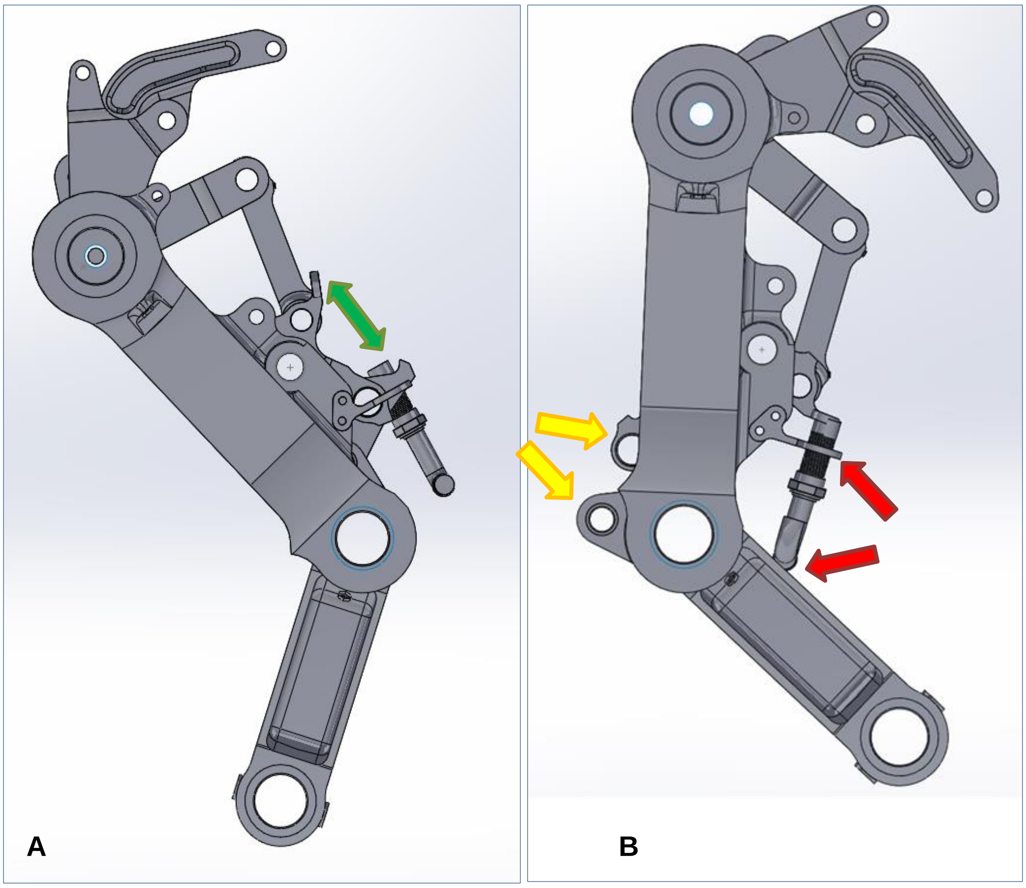

Fig. 30. NLG DSA in transit position during NLG retraction - side view: A – designerd direction of DSA folding, B - opposite direction of DSA folding- incorrect [source: ITWL expert opinion] - A and B markings aded by PKBWL

The green arrows in Fig. 30-A show the PS NGLK2 face moving away from its target when DSA is folding in the right direction. The red arrows in Fig. 30-B indicate collision areas when DSA is folding in the opposite direction and the yellow arrows show disconnected link between the LLL and LDS. That link was damaged (torn apart) during the accident.

2.2.5. Stop Pin damage analysis

The phases of the correct retraction of the NLG are shown in Fig. 31 A – D. In the initial phase LLL is pulled away from the "Stop Pin" (Fig. 32-A) and the sleeve (Fig. 31-B). LLL contact with the pin sleeve occurs only in the last phase of retraction, which, according to the FDR recording, did not occur.

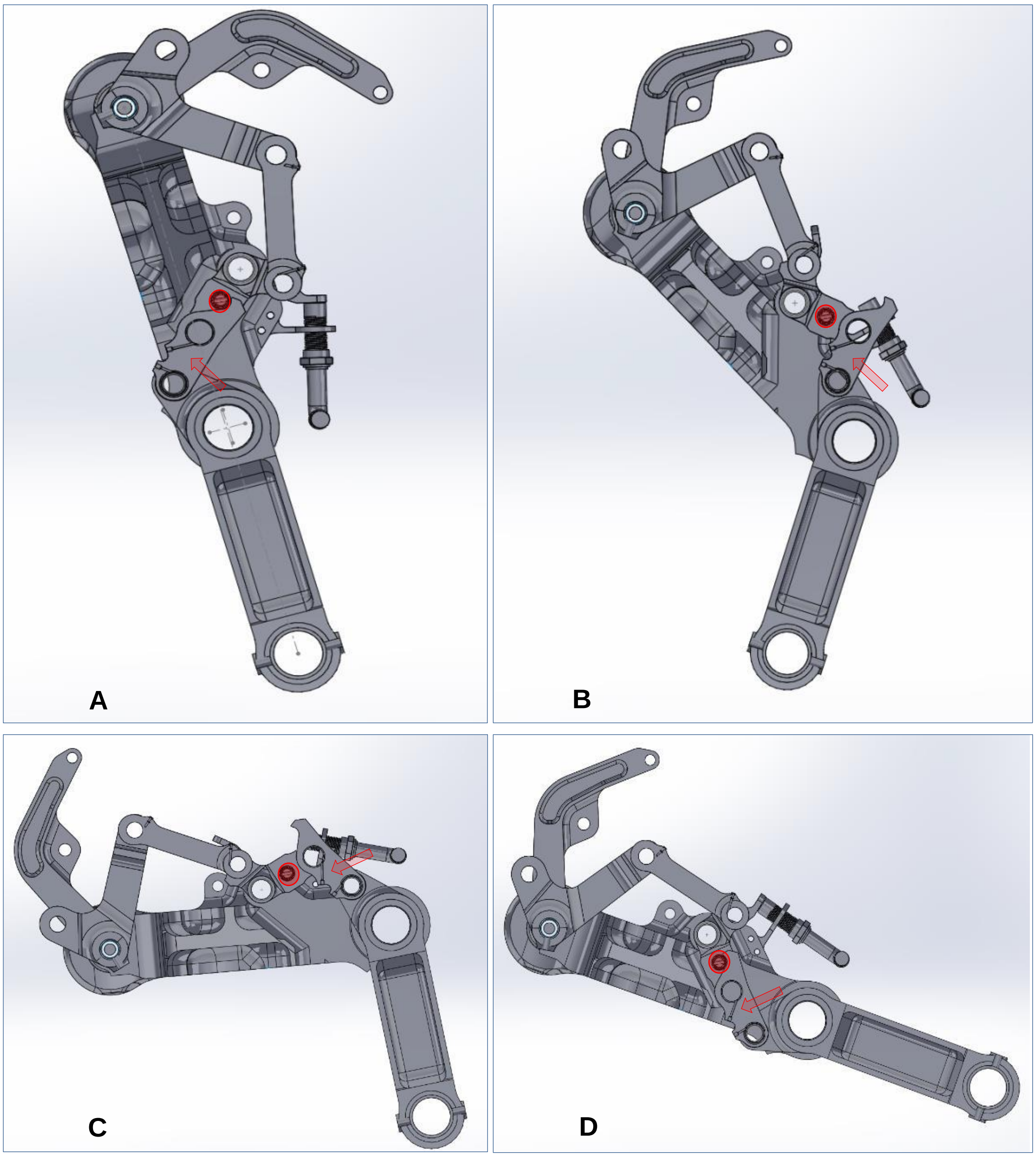

Fig. 31. NLG DSA model during correct retraction - longitudinal section: A - starting position (landing gear extended, downlocked), B - first phase after unlocking and start of retraction, C - final phase (before retracting and uplocking) , D – retracted and uplocked position. The red arrow shows LLL and the circle shows Stop Pin

Damage to the sleeve and pin shown in Fig. 32, could have occured only in the final phase of extension or the final phase of normal retraction of the NLG.

Since the NLG is completely within the contour of the fuselage when retracted, the Stop Pin cannot be damaged when the aircraft nose hits the ground.

The nature of the damage clearly shows that a force acting along the longitudinal axis of the aircraft in the aft direction was applied to the DSA. The force exceded the limit for which the system was designed.

Fig. 32. View: A - bolt (according to DSA CMM 1-1180, PN NAS6206-20D), B - sleeve (according to DSA CMM 1-1160, PN 47326-13)

2.2.6. LLL damage analysis.

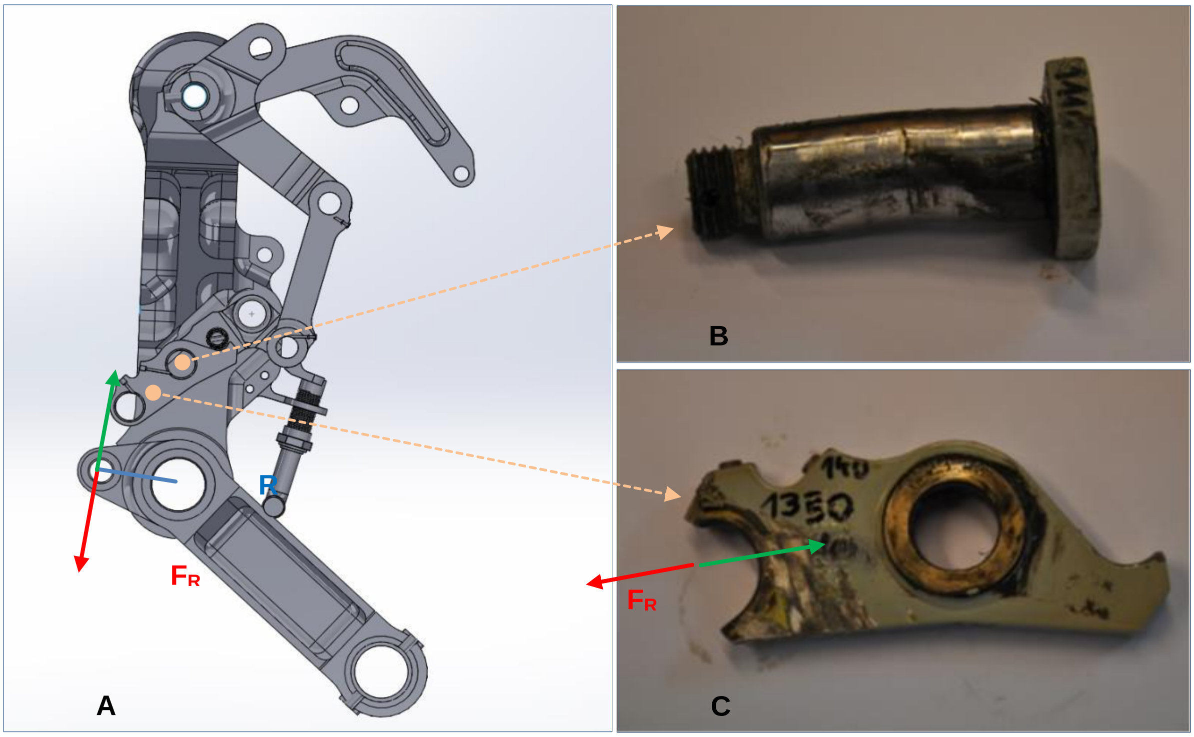

Fig. 33. Nature of damaging the NLG DSA during incorrect retraction of the NLG – cross-section in the longitudinal plane: A – LDS collision with ELH, B – bent bolt (axis of LLL rotation), C – damaged LLL

When LDS and UDS were folding in the wrong direction, the M_R moment (F_R force x R arm) was acting on LLL (through the bolt connecting LLL and LDS) – Fig. 33, red arrows.

The moment (F_R force) had a tearing effect on LLL at its smallest sectional area, which has been confirmed by the nature of the damage shown in Fig. 33-C.

During the proper retraction of the NLG, the force would have the opposite direction (green arrows), therefore it could not have caused the existing damage.

Damage (bending) of the LLL bolt (Fig. 33-B) indicates that the rotation of the bolt was blocked, which occurs when LLL rests on the stop pin.

2.3.7. Material analysis

All elements of the DSA were subjected to material tests, and the respective conclusions are given in para 1.16.1. The tests showed that all the damage was ad hoc/sudden. No material defects or signs of fatigue were observed. The alloys used for manufacturing of the parts were in accordance with the manufacturer's documentation. No damages to the sealant, no turned or loosened bushings were found.

2.3.8. Analysis of the FDR data

Analysis of the data recorded by the FDR showed that when the landing gear control lever is moved to the UP position, there is a temporary pressure drop in No.2 hydraulic system, as shown in the figures below. The pressure drop in the first phase of retraction is normal, because at this moment energy from the system is applied on the piston rod of the NLG actuator. The entire process of retracting of the landing gear (from the moment of selection of the UP position) takes approx. 10 seconds.

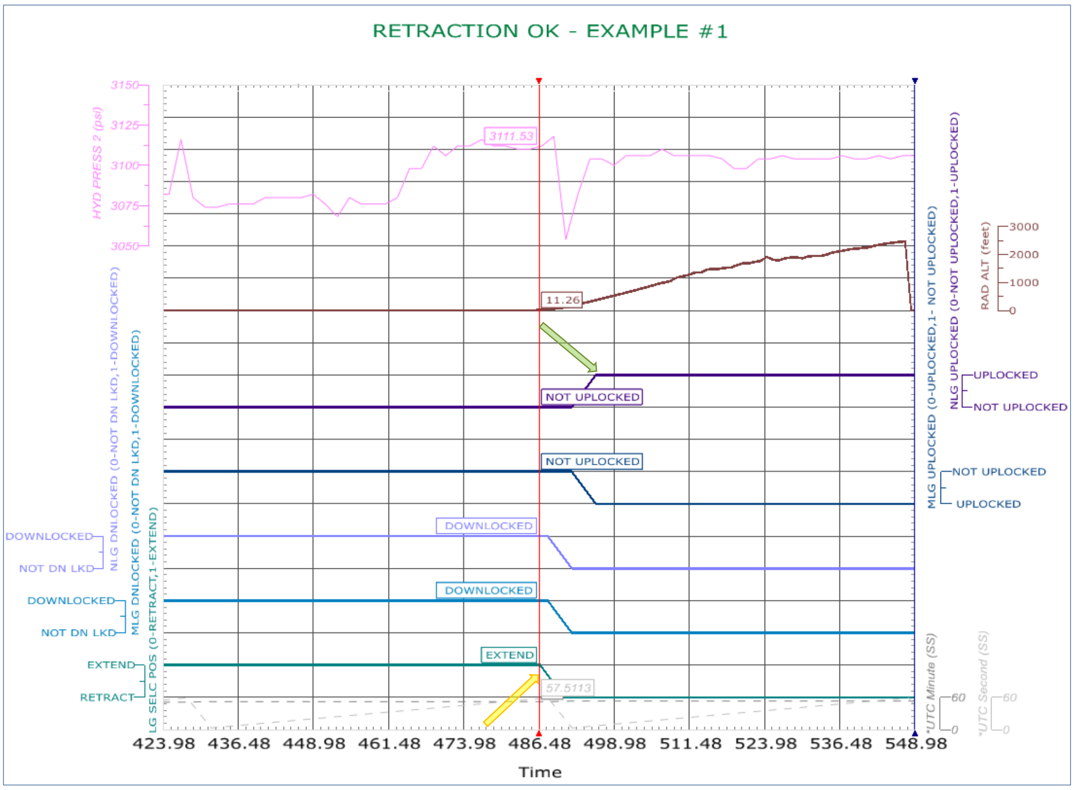

Fig. 34. Pressure change in No. 2 hydraulic system during a normal retraction of the SP-EQG landing gear and the status of NLG and MLG – the yellow arrow shows the moment of selecting the LGSL to the UP position; the green arrow shows the status of NLG – uplocked [source: PKBWL – Insight Analysis 4.9]

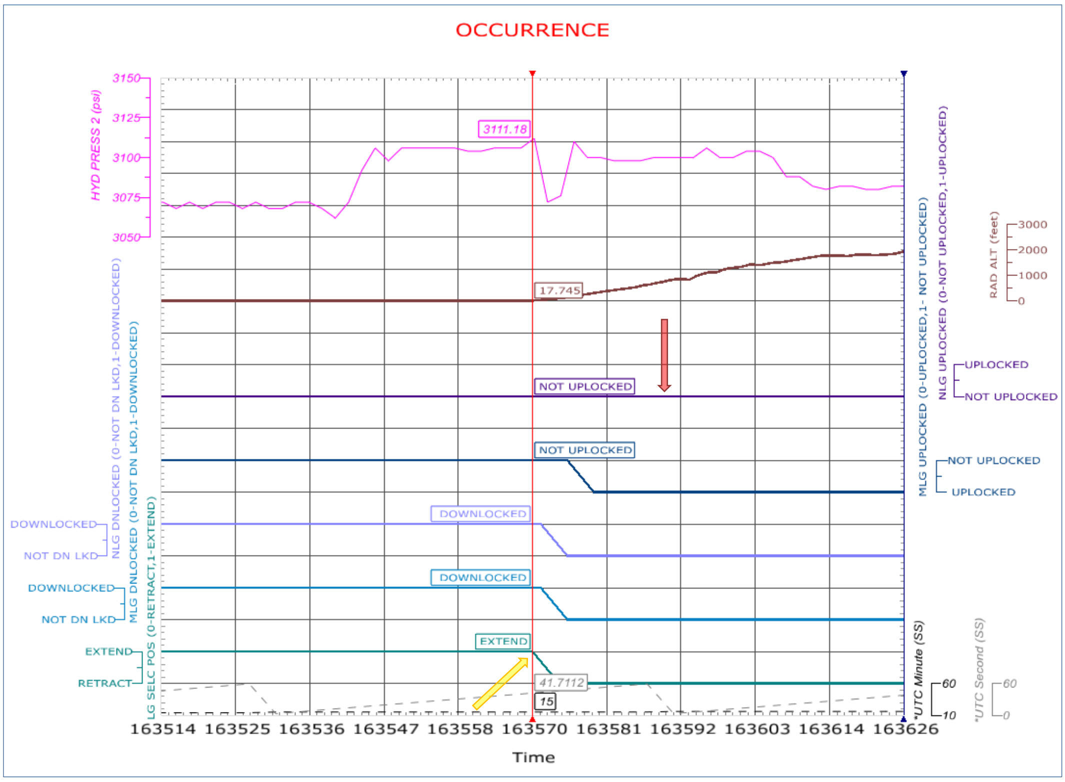

Fig. 35. Pressure change in No. 2 hydraulic system during retraction of the SP-EQG landing gear after the take-off from EPKK on 10 Jan 2018 and the status of NLG and MLG – the yellow arrow shows the moment of selecting the LGSL to the UP position; the red arrow shows the status of NLG – not locked in the retracted position [source : PKBWL – Insight Analysis 4.9]

No significant differences can be seen on the graphs of the pressure change in No. 2 hydraulic system during the normal retraction of the SP-EQG landing gear and retraction during the accident flight.

Downlock and uplock of the NLG and MLG are recorded by the FDR. The recorded data confirm that after take-off from EPKK for the accident flight the NLG was not uplocked.

2.2.9. Airplane maintenance documentation

The basic document for maintenance of the Bombardier DHC-8-402 SP-EQG aircraft was PLL LOT S.A. SCHEDULED MAINTENANCE PROGRAM FOR DHC-8 (Q400) – POT 3400. Revision 4 of the program of 10 August 2017, applicable on the day of the accident to all aircraft in the operator's Q400 fleet (approved by the President of the Civil Aviation Authority on 2 November 2017) was developed based on:

- BOMBARDIER Q400 MAINTENANCE REQUIREMENTS MANUAL, MAINTENANCE REVIEW BOARD REPORT - PART 1,PSM1-84-7,REVISION 13 (DATED 20TH JUNE 2017);
- BOMBARDIER Q400 MAINTENANCE REQUIREMENTS MANUAL,Airworthiness Limitation Items - PART 2, PSM 1-84-7, REVISION 8 (DATED 14TH MARCH 2017);
- BOMBARDIER Q400 MAINTENANCE PLANNING DOCUMENT, PSM1-84-7P, REVISION 43 (DATED 04TH AUGUST 2017);

– COMMISSION REGULATION (EC) NO 1321, ANNEX 1 PART M, (DATED 26TH NOVEMBER 2014).

Additional actions required by airworthiness directives and related to LOT planes or their equipment were not included in the Maintenance Program (part 2 and part 3). They are implemented in LOT by technical orders.

Nevertheless, the repetitive actions, required by the airworthiness directives for LOT aircraft, were listed in Part 1 of the Maintenance Program. If a repetitive action, resulting from a directive, was to end with a specific result (e.g. modification, replacement of parts), then that action was on the list until the result had been completed on the last aircraft (device) subject to a directive.

The list was updated as necessary during the next change to the Maintenance Program and additionally reviewed at least once a year during the overall evaluation of the program.

2.2.9.1. Maintenance scope

PLL LOT S.A. SCHEDULED MAINTENANCE PROGRAM for DHC-8 (Q400) assigns to each task a maintenance process, defining the scope of maintenance and inspection level.

Selected maintenance processes applicable to the maintenance of systems and powerplants (including NLG) are listed below:

GVI – GENERAL VISUAL INSPECTION

A visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure, or irregularity. This level of inspection is made from within touching distance unless otherwise specified under normally available lighting condition: daylight, hangar lighting, flashlight, droplight. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area.

DET – DETAILED INSPECTION

An intensive examination of a specific item, installation, or assembly to detect damage, failure, or irregularity. Available lighting is normally supplemented with a direct source of good lighting. Inspection aids as mirrors, magnifying lenses or other means may be necessary. Examination may include tactile assessment of component or assembly for tightness or security.

SDI – SPECIAL DETAILED INSPECTION

An intensive examination of a specific item, installation, or assembly to detect damage, failure, or irregularity. The examination is likely to make extensive use of specialized Inspection Techniques and/or equipment. Intricate cleaning and substantial access or disassembly procedure may be required.

FNC – FUNCTIONAL CHECK

A quantitative check to determine if one or more function of an item performs within specified limits. This is a potential failure findings task.

LUB – LUBRICATION

Any act of consumable lubricant replenishment (replacement) for the purpose of maintaining inherent design capabilities.

2.2.9.2. NLG maintenance

All the maintenance processes contained in the PLL LOT S.A. SCHEDULED MAINTENANCE PROGRAM for DHC-8 (Q400) and related to the NLG are listed below together with the interval and source document.

<u>Line service</u>

The "L50" check is performed every 50 FH or 12 calendar days, whichever comes first. The "L50" service does not replace the PDC. The "L50" check includes tasks that are part of the POT 3400 Program and additional tasks based on operator recommendations as part of its experience:

- GVI of Main and Nose Wheels - Q324000-201-A-00;
- Cleaning of MLG and NLG piston rods and shock absorbers – task 32-00-LOT implemented by the operator.

<u>Base service</u>

- **LUB of the Nose Landing Gear - Q 320001-201-A-00, after 6 MO or 500 FH;**
- DET of the Retraction Actuator Rod End, Jam Nut and Gland Nut NLG - Q322100-205-A-00 after 24 MO or 2400 FH;
- Internal GVI of the Nose Landing Gear Wheel Well - QZ100-04-A-00 after 24 MO or 2400 FH;
- External GVI of the Nose Landing Gear Doors - QZ700-02E-A-00 after 60 MO or 6000 FH;

- Replacement of the NLG DSA – Q32-21-00-701-A-01, after 60000 FC;
- Replacement of the NLG SSA – Q32-21-01-701-A-00, after 60000 FC;
- Replacement of the NLG Axle Spacer – Q32-41-06-701-A-01, co 60000 FC;
- Replacement of the NLG Axle Nut (LH) – Q32-41-06-702-A-00, co 60000 FC;
- Replacement of the NLG Axle Nut (RH) – Q32-41-06-702-A-00, co 60000 FC;
- Replacement of the NLG Trunnion Plate assembly (LH) – Q53-00-01-701-A-20, after 54822 FC;
- Replacement of the NLG Uplock Fitting Assembly – Q53-00-01-702-A-02, after 59642 FC.

The orange line above separates the maintenance processes at least once performed on the SP-EQG from the processes which, due to their interval, had not been performed on this airplane until the accident.

None of the processes listed above, except for lubrication (in bold), is directly related to the NLG DSA.

When analyzing the maintenance processes, the PKBWL asked the landing gear manufacturer/designer about the method of measuring the NLG clearances. The answer shows that at the time of the occurrence the AMM did not provide for any checks/measurements in this respect. When DSA is sent for overhaul, all elements are restored to original design limits according to CMM (**every 30 000 CY**).

2.2.10. Service Bulletin S.B. 84-32-153

On 22 September 2017, the aircraft manufacturer issued SERVICE BULLETIN S.B. 84-32-153. The subject of the bulletin was to perform a special inspection and rectification of the NLG locking mechanism. The bulletin covered DHC-8 Aircraft Models 401 and 402 all serial numbers with Lower Lock Link 47324-1 (Fig. 36), which was damaged during the accident. The manufacturer also informed that the relevant airworthiness directive was pending.

According to the manufacturer, the implementation of the bulletin did not require any special tools or materials and was estimated to take 2.5 man-hours.

The reason for issuing the bulletin was *"reports of the bushings on the lock link of the NLG locking mechanism becoming loose. This condition was caused due to insufficient interference fit and results with bushing outer diameter wear/fretting. Dislodged bushing will also cause sealant to break. The broken sealant allows moisture ingress and corrosion that can accelerate free play buildup. Excessive free play at the lock link can result with inability to retract/deploy NLG fully".*

The manufacturer left the completion of the bulletin at the discretion of operators.

According to the operator, the implementation of the bulletin required approximately 12 hours of airplane downtime and 36 man-hours. Until the day of the occurrence, the bulletin had not been implemented on the operator's aircraft due to the fact that it was planned to be performed during the next overhauls of Q400 aircraft and that the required spare parts were not available. In addition, according to the operator, the bulletin did not sufficiently emphasize the necessity of its urgent implementation.

Fig. 36. Lower Lock Link from SP-EQG plane damaged during the occurrence

2.2.11. CF-2018-01 Airworthiness Directive

On 10 January 2018 (the day of the accident) Transport Canada issued AIRWORTHINESS DIRECTIVE CF-2018-01 with the effective date 24 January 2018. The subject and scope of AD CF-2018-01 was identical with the Service Bulletin S.B. 84-32-153. The Airworthiness Directive directly referred to S.B. 84-32-153, ordering its implementation. The Directive stated that "*No person shall conduct a take-off or permit a take-off to be conducted in an aircraft that is in their legal custody and control, unless the requirements of CAR 605.84 pertaining to ADs are met".*

After the accident of 10 January 2018, during the four following days, the S.B. 84-32-153/AD CF-2018-01 were implemented on 9 out of 10 aircraft in the operator's DHC-8-402 fleet (with the exception of the accident aircraft). The Lower Lock Links on all nine aircraft did not meet the technical requirements and were replaced with new ones due to the detected corrosion and sealing defects. No mechanical damage was found.

2.2.12. Earlier occurrence involving SP-EQG NLG.

On 6 Dec 2017 at EPKT, prior to the SP-EQG pushback, when a tug was being attached to a tow bar, the tug hit the tow bar which had already been attached to the airplane. During the occurrence the tug was operative and the incident occurred as a result of human error.

The impact was felt by the crew, therefore the pushback was abandoned and the Captain required additional check of the aircraft.

A ground engineer performed NLG inspection according to the manufacturer's service documentation: TASK 05−50−51−210−801 *Inspection After Rough Towing* and TASK 32−21−00−210−801 *General Visual Inspection of the Nose Landing Gear.*

As a result of the completion of the above mentioned tasks no damage to NLG was found - the plane was released to service. The planned departure was delayed for about 3 hours.

The PKBWL was notified about the occurrence on 7 Dec 2017 and assigned it PKBWL reference number 3235/17.

2.2.13. Maintenance Summary

The aircraft maintenance was carried out in accordance with the maintenance program applicable on the day of the accident, airworthiness directives and manufacturer's service bulletins. All mandatory bulletins were implemented.

Pre-flight malfunctions - not detected.

Operation of the aircraft by the flight crew – in accordance with the applicable regulations and procedures.

2.2.14. Other occurrences involving Q400 NLG

Occurrences involving Q400 NLG have occurred many times in the past.

Cases of signaling the wrong position of the NLG or its dors during retraction or extension have been so frequent, that according to the manufacturer, they should not be a reason to declare emergency. However, that does not mean that it has been considered a normal operation. Each time an alternative system is used, a specialist inspection is required by maintenance services.

PKBWL analyzed in detail the final reports of two cases involving collapse of NLG during landing, whose circumstances showed similarity to the accident investigated.

The final reports on investigation into occurrences that took place prior to issuance of AD CF-2018-01R1 Airworthiness Directive were analyzed:

- the accident involving Bombardier DHC-8-402, aircraft registration marks 9A-CQC, which occurred on 27 September 2013 on LSZH airport (Zurich, Switzerland);
- the serious incident of DHC-8-402, aircraft registration marks YL-BAI, which occurred on 17 September 2016 on EVRA airport (Riga, Latvia).

After issuance of AD CF-2018-01R1, on 19 August 2019, another Q400 (N404AV) emergency landing was carried out in Lima, Peru.

2.2.15. Check of free play in the NLG system

Determination of the presence and assessment of the value of any free play is possible only after lifting the plane and applying to NLG an external force acting along the longitudinal axis of the airplane.

The force acting along the longitudinal axis of the airplane in the aft direction may cause the elimination of any free play and thus the elimination of the "under center" of the joint between the UDS and LDS. During take-off, this force is the sum of the air drag acting on the NLG and the component of NLG weight.

A positive result of functional checks performed on the ground in a horizontal plane without applying any force does not guarantee correct retraction or release of the NLG in flight (in the case of free play in DSA).

The development and introduction by the manufacturer/designer of an SDI dedicated to the verification and assessment of DSA free play is necessary for safe operation within the TBO designed for this assembly- 30 000 CY.

2.2.16. NLG free play - summary.

Free play in the NLG DSA can be caused by corrosion initiated by broken LLL sealant or by excessive load on the assembly components. The to date activities of the NLG manufacturer have been focused mainly on eliminating the first factor, i.e. corrosion. In the investigated case, the DSA elements were not corroded and the sealant was not damaged, so the play must have been caused by another factor or factors.

Looking for these factors, PKBWL Investigation Team conducted an examination of the damaged components, statistical analysis, analysis of records and similar occurrences, and noted the following facts:

- improper landings: three-point landings, hard landings and landings with a negative pitch angle;
- hitting the NLG by drawbar when attaching the tug;
- the inspection of the NLG after hard landing is superficial and limited to general visual inspection, which do not allow to determine the value of free play;
- the check procedure after hard landing is started after submission of ASR (which depends on a subjective assessment of the occurrence) or a warning generated by the FDM system;
- the effectiveness of the FDM depends, however, on the frequency of readout and analysis of the stored data. Until the day of the accident, the readouts were carried out every 50 FH, which created a real risk of not capturing immediately exceedances not reported by a crew. That means that if a Captain decided that there was no exceedance, but in fact it was, the airplane could have completed several dozen cycles before it was subjected to appropriate checks initiated by the detection of exceedances by the FDM;
- until the day of the accident, only hard landings were monitored;
- three-point landings or landings with a negative pitch angle were not taken into account at all, therefore FDM has not generated any warnings in this regard. There is also no dedicated procedure for such an occurrence. The manufacturer did not define the type and scope of the inspection in such a case.

3. CONCLUSIONS

3.1. Commission findings

3.1.1. THE AIRCRAFT

a) The aircraft had a valid Certificate of Airworthiness and was maintained in accordance with the applicable regulations.

b) According to the applicable regulations and procedures, the aircraft was airworthy at the time of the take-off.

c) The airplane mass and center of gravity were within the specified limits.

d) The NLG retraction/extension system was damaged during its retraction after take-off.

e) The lower nose area of the aircraft was damaged by direct contact with the runway during the landing roll.

3.1.2. THE CREW

a) The flight crew had valid licenses and qualifications in accordance with the applicable regulations.

b) The flight crew had a valid aero-medical certificate and was rested.

c) Due to the lack of a checklist, fitting exactly to the situation, the CPT and FO had to use several NNCs to cope with the failure.

3.1.3. FLIGHT OPERATIONS

a) The flight was performed in accordance with the procedures contained in the operator's Operations Manual.

b) The flight crew carried out routine radio communications with the relevant ATC units.

c) After identifying the NLG failure, the CPT decided to continue the flight to the destination airport.

d) After the touchdown, the pilot maintained an increased angle of attack in order to make the fuselage contact with the runway as late as possible.

3.1.4. OPERATOR

a) The automatic system for monitoring exceedances did not ensure their timely detection.

b) The memory card from the QAR was removed and read out without the consent of the PKBWL, which was also inconsistent with the operator's Operations Manual.

3.1.5. AIR TRAFFIC SERVICES AND AIRPORT FACILITIES

a) At the time of the accident, all navigation aids and the EPWA lighting were operating normally.

b) The airport was not equipped with a crane of adequate lifting capacity.

3.1.6. FLIGHT RECORDERS

a) The aircraft was equipped with FDR), CVR and QAR.
b) The data recorded by the recorders allowed to recreate the course of the occurrence.
c) The FDM database of the operator's Q400 fleet allowed for statistical analysis.

3.1.7. MEDICAL ISSUES

a) In a stressful situation, the flight crew and the cabin crew operated efficiently, cooperating with each other.
b) None of the crew members reported any complaints that could affect the efficiency of operation.

3.1.8. SURVIVABILITY

a) Passengers and crew disembarked using the emergency exits on the left side.
b) Due to the attitude of the airplane after the emergency landing (excessive nose down) - the rear exit did not provide conditions for safe evacuation without external assistance.

b) Passengers and crew did not suffer any injuries.

3.1.9. SAFETY OVERSIGT

The oversight by the Civil Aviation Authority (CAA - ULC) over the operator's procedures and activities had no imact on the occurrence and course of the accident.

3.2. Cause of the accident

The immediate cause of the accident was excessive free play in the retraction/extension system of the nose landing gear.

3.3. Contributing factors

3.3.1. Lack of procedures to measure and monitor the free play in the nose landing gear retraction/extension system during the Time Between Overhaul (30 000 Cycles or 14 years).
3.3.2. Lack of analysis of three-point landings which resulted in overload of NLG.
3.3.3. Lack of dedicated technological cards to verify possible damage caused by unusual events, such as hitting the drawbar connected to the airplane by a tug.

4. SAFETY RECOMMENDATIONS

4.1. Ad hoc recommendations and preventive actions taken by the operator

At the initial stage of the investigation, the PKBWL consulted the operator on the implementation of ad hoc recommendations. As a result, the operator has taken the following actions related to its fleet of Q400 aircraft:

- shortened the interval of reading and analyzing QAR data from 50 FH to 25 FH;
- analyzed FDM data for the sequence of WOW sensors activation over the period of one year preceding the accident;
- introduced monitoring of landings with the reverse order of WOW sensors activation;
- performed a one-time inspection of the PN 47310-101 pin and its seat at SDI level.

4.2. Safety Recommendations

4.2.1. Z-1/67/18

The investigation of the accident and the analysis of previous occurrences involving Bombardier DHC-8-402 airplanes showed that excessive free play in the NLG kinematic system resulted in the inability to retract or extend NLG. The free play arise in the process of normal operation, but excessive loads and corrosion contribute to their development. The TBO for the NLG is 30 000 CY or 14 years and free play is not measured during this period.

Based on the above facts, PKBWL recommends that:

Bombardier Incorporation in consultation with Transport Canada take actions aimed at development and implementation of a system to monitor the mechanical condition of the NLG kinematic system during the TBO to ensure that excessive free play is detected at an early stage allowing for corrective action.

4.2.2. Z-2/67/18

The investigation of the accident revealed that apart from the hard landings monitored by FDM, other types of landings had occurred, which could cause very serious consequences, but had not been analyzed. Those landings have consisted in activation of the NLG WOW sensors prior to the MLG sensors activation with a negative pitch angle during the touchdown, which indicates landings, which could lead to an excessive load of the NLG.

Based on the above facts, PKBWL recommends that:

Bombardier Incorporation in consultation with Transport Canada consider the necessity of introducing mandatory monitoring of landings during which WOW sensors have signalled the load of the NLG wheels earlier than on the MLG, specifying the procedure for their detection and necessary checks after their occurrence.

4.2.3. Z-3/67/18

During the investigation it was revealed that a month earlier, while preparing for the push-back operation, the tug hit the drawbar attached to the NLG with considerable force. In the opinion of the PKBWL, that fact may have contributed to the creation or increase of free play in the NLG system.

Such cases may also involve other airplanes, but the manufacturer did not provide for a dedicated check in such a case.

Based on the above facts, PKBWL recommends that:

Bombardier Incorporation in consultation with Transport Canada consider the necessity of developing a dedicated procedure for check the NLG kinematic system after the occurrence of abnormal forces acting along the longitudinal axis of the aircraft, e.g. after hitting a drawbar attached to the aircraft.

5. ANNEXES

None

END

Investigator-in-Charge

signature on the original