Transporta nelaimes gadījumu un incidentu izmeklēšanas birojs

Transport Accident and Incident Investigation Bureau of the Republic of Latvia

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FINAL REPORT No. 4-02/1-17(2-2018) on
THE AIRCRAFT SERIOUS INCIDENT

RUNWAY EXCURSION RIGA INTERNATIONAL AIRPORT (RIX), ON 17 FEBRUARY 2017
AIRCRAFT BOEING 737-524, VP-BVS

The Aircraft Accident and Incident Investigation Bureau of the Republic of Latvia is a governmental, independent of all aviation authorities, organization established by law to investigate and determine the cause or probable cause of accidents and serious incidents that occurred in the civil aviation, as well if necessary for enhancing flight safety incidents. The sole objective of the safety investigation in accordance with Annex 13 to the Convention on International Civil Aviation, the Regulation (EU) No.996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in Civil as well as Cabinet Regulation No.423 of May 31, 2011 “Procedures of Civil Aviation Accident and Incident investigation” is the prevention of future accidents and incidents. The Report shall contain, where appropriate, safety recommendations.

Safety investigation is separate from any judicial or administrative proceedings and investigation **Report is not deal with purpose to apportion blame or liability but only for purpose of the safety enhancement**. The Report shall protect the anonymity of any individual involved in the accident or serious incident.

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The Aircraft Serious Incident

Runway excursion Riga International airport (RIX), on 17 February 2017 aircraft Boeing 737-524, VP-BVS

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Abbreviations

ATM	Air Traffic Management
ATPL	Airline Transport Pilot's License
CAM	Cockpit Area Microphone
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
FDR	Flight Data Recorder
METAR	METAR Report
OFC	Operational Flight Check
QNH	Altimeter setting to obtain aerodrome elevation when on the ground
RTL	Rudder Travel Limit
TO/GA	Take-Off/Go-Around thrust
UTC	Coordinated Universal Time
P	Pilot
PIC	Pilot-in-Command
FO	First Officer
PM	Pilot Monitoring (First Officer)
PMC	Power Management Control
MEC	Main Engine Control
AAIB	UK investigation branch
HPC	High Pressure Compressor
LPC	Low Pressure Compressor
LPT	Low Pressure Turbine
HPT	High Pressure Turbine
RVR	Runway Visual Range (sensor)
RTO	Rejected Take-Off
NTSB	National Transportation Safety Board (US)
EGT	Exhaust Gas Temperature
AMM	Aircraft Maintenance Manual
TLA	Thrust Lever Angle
V_{mcg}	Minimum control speed on the ground
FMA	Flight Mode Annunciator
VBV	Variable Bypass Valve

Synopsis

Unless stated otherwise the time in this Report is UTC

On 17 February 2017 the aircraft Boeing 737-524, VP-BVS, taking off from the Runway (RWY) 18 at Riga International Airport deviated sharply to the right, traveled along the grass to the side of the runway for approximately 600m and collided with the RVR installation and power boxes before regaining the runway, therefore both engines were full of mud, dirt and grass.

The aircraft involved in serious incident was on the scheduled flight from Riga International airport (**EVRA**) to Ufa International airport (**UWUU**), the aircraft call sign was MOV-9945. This was the first flight on that day for the flight crew.

Notification

The Transport Accident and Incident Investigation Bureau of the Republic of Latvia (TAIIB) was notified about the incident immediately after occurrence. Notification about occurrence was sent to TAIIB after 15 minutes from Safety Department of Riga International Airport (EVRA) Operational Control Centre.

TAIIB investigators without delay drove to the serious incident scene in order to carry out the necessary procedures at the scene to preserve material evidence in accordance with the laws and regulations.

TAIIB initiated collecting data from involved institutions according this serious incident and the CVR/FDR download was performed at the laboratory of the AAIB (UK), under the provisions of Annex 13 to the Convention on International Civil Aviation (Chicago 1944) and the REGULATION (EU).

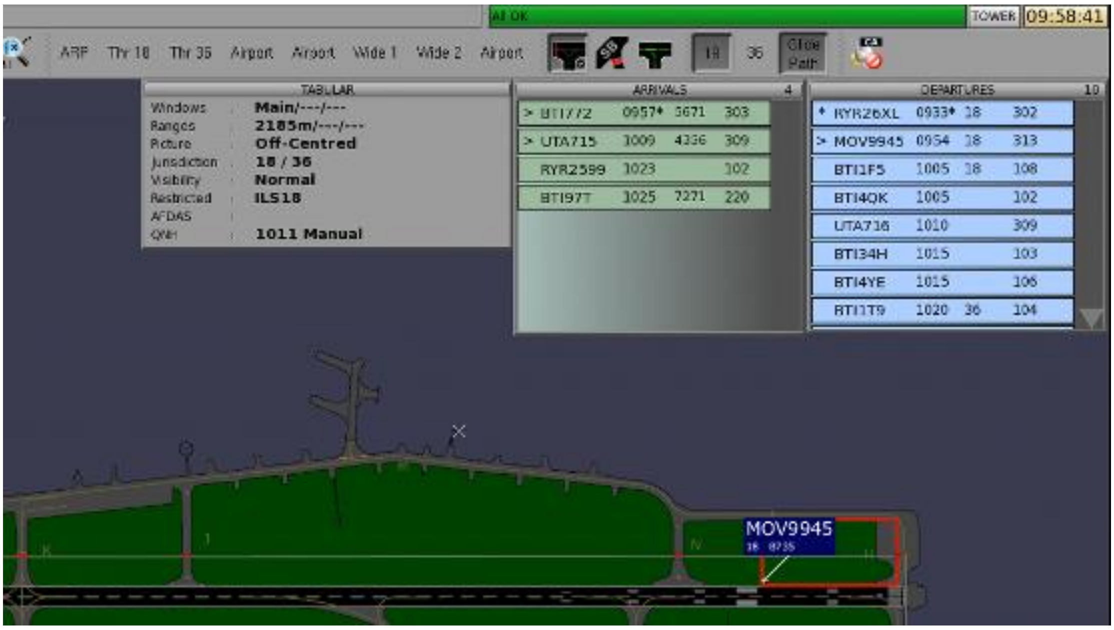
Regarding with Regulation 996/2010 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 October 2010 notified without delay about the serious incident and forwarded request relevant available information regarding to the incident and personnel data of pilots and aircraft history of maintenance.

1.FACTUAL INFORMATION

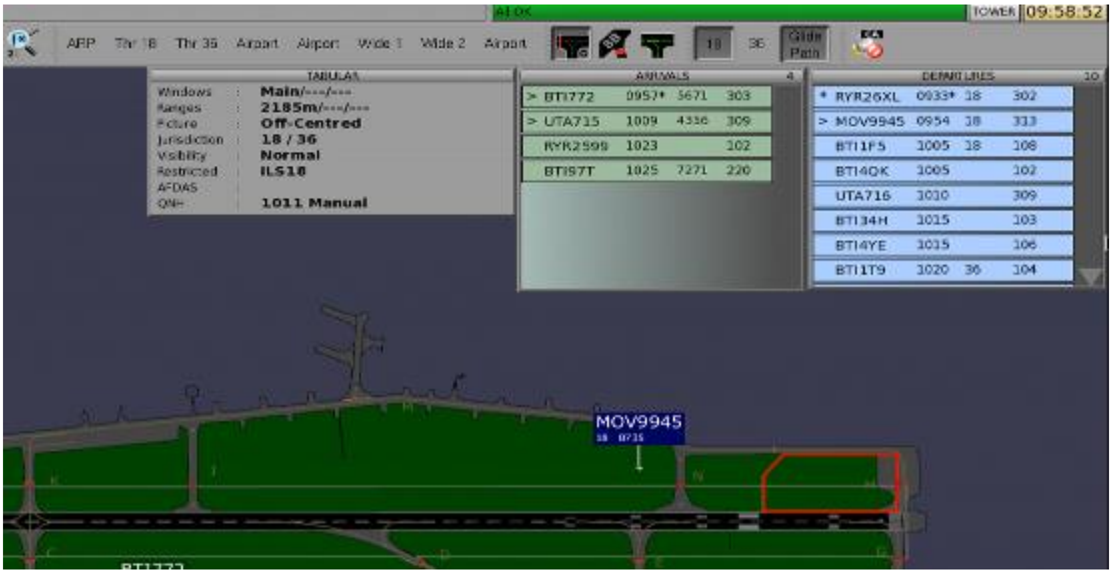
1.1 History of the Flight

1.1.1 Sequence of events

09:38:00	Flight crew of MOV-9945 established contact on 118,8MHz with “Ground” controller.
09:53:50	“Ground” transferred traffic on 118,1MHz Riga TWR Controller frequency.
09:54:44	Flight crew of MOV-9945 established contact on 118,1MHz with Riga TWR Controller.
09:58:19	Riga TWR Controller issued clearance for take-off from runway 18.
09:58:41	Traffic vacated runway to the West.



09:58:52 Traffic at distance about 80m from verge of the runway.



09:59:15 Traffic on runway 18.

10:00:45 Riga TWR Controller issued Emergency at airport Riga.
10:10:36 Traffic vacated the runway 18 via “D” taxiway.

1.1.2 Initial information

The charts of FDR data after decoding show following: shortly after the takeoff was initiated, the aircraft began a slight left turn followed by a sharp right turn.

1.1.3 Aircraft trajectory

Scheme 1 the aircraft Boeing 737-524, VP-BVS movement's scheme on the RWY 18

1.2 Injuries to persons

NIL

1.3 Damages of the aircraft

Performing the visual inspection of the aircraft fuselage were established following damages:

- L/H Main gear (Photo 1, 2),

Photo 1: L/H Main gear Center door

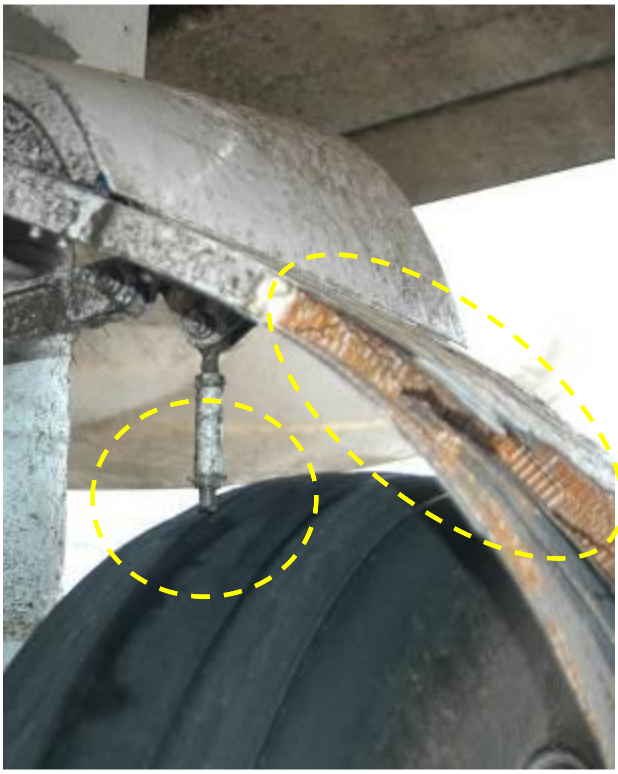


Photo 2: L/H Main gear Inner door with broken Inner pushrod

- L/H Engine (Photo 3),

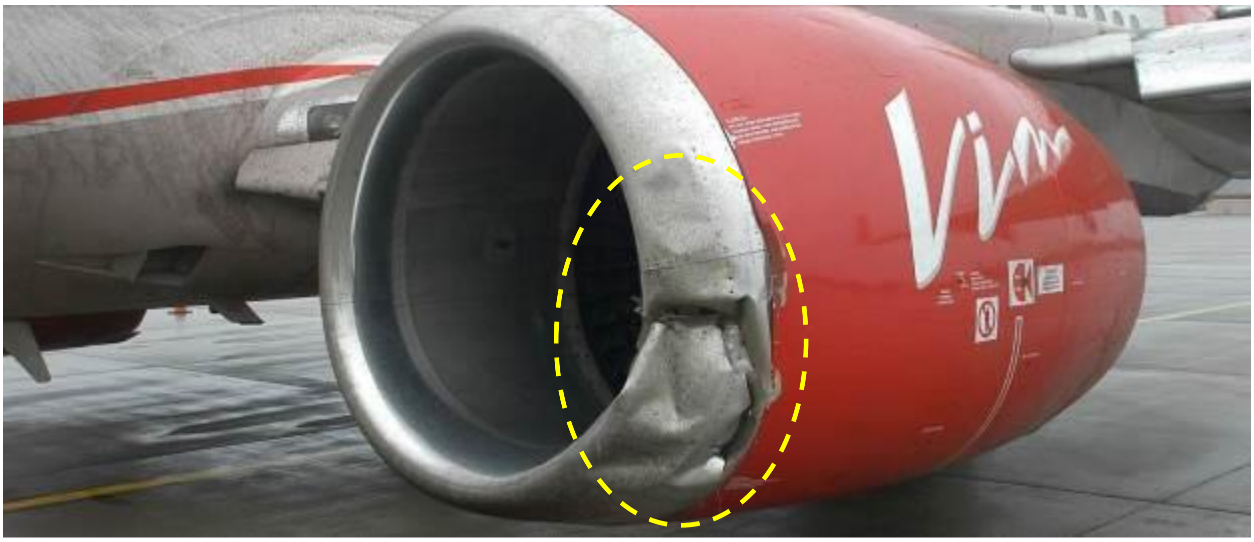


Photo 3: L/H Engine Inlet Cowl Inner and Outer, Overboard Fan Cowl Panel

- R/H Wing (Photo 4),

Photo 4 R/H Leading Edge Slat No 5 damages

- Each landing gear (nose and main) tires had marks of cut, wear and tear.

1.3.1 Engines

Performing the visual inspection of the both engine's LPC Stators it were established that it consists dirt, mud and grass due to the aircraft excursion from RWY, therefore it was made decision to perform the nondestructive inspection with borescope of the both engines.

1.3.2 Engines' borescope inspection (BSI)

L/H engine: Because the engine has ingested with in large amounts of dirt and grass in Boost section, it was not possible to perform and verify borescope inspection in Boost section and first stage of High Pressure Compressor. Dirt/ mud built up was found in VBV outlet, condition not normal.

As a result of BSI it was concluded that there are the need to carefully perform the gas path cleaning and re-inspection of Boost and HPC sections for verification of cleanliness and lack of damage in Boost and HPC sections.

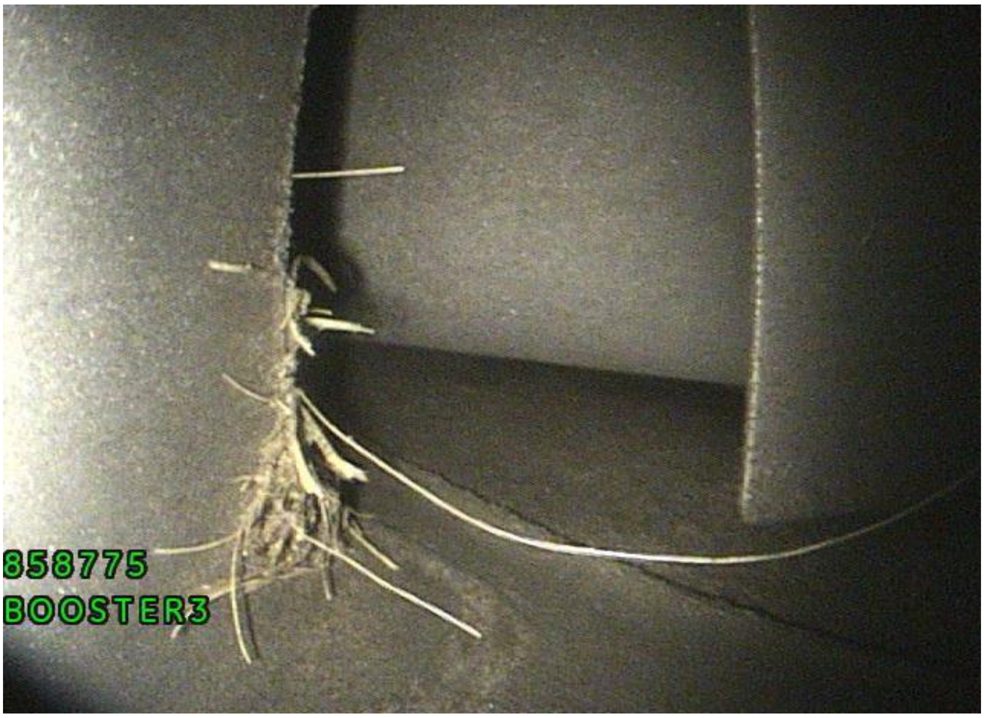


Photo 5: Grass and mud on the booster ST2

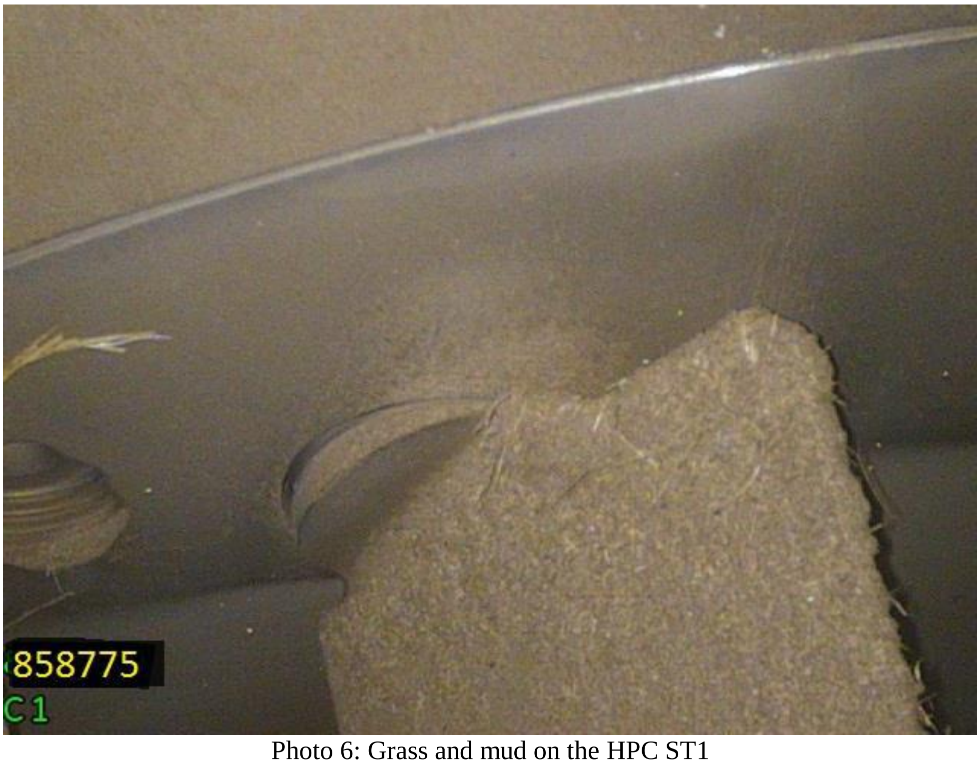


Photo 6: Grass and mud on the HPC ST1

Photo 7: Grass and mud on the HPC ST2

Photo 8: HPC ST4 surface damage

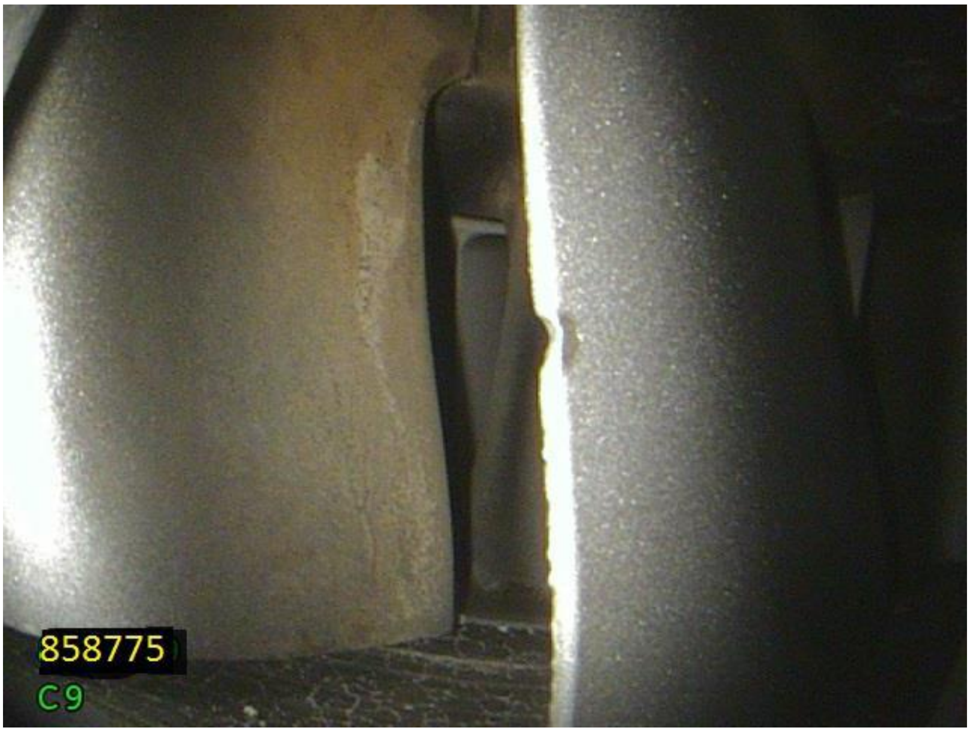


Photo 9: HPC ST9 surface damage

Photo 10: Dirt on the Nozzle Guide Vanes

<u>R/H engine</u>: Because the engine has ingested with in large amounts of dirt and grass in Boost section, it was not possible to perform and verify full gas path borescope inspection in Boost section and first stage of High Pressure Compressor. Dirt/ mud built up was found in VBV outlet condition, not normal.

Photo 11: Grass and mud on the booster ST3

Photo 12: Grass and mud on the HPC ST1

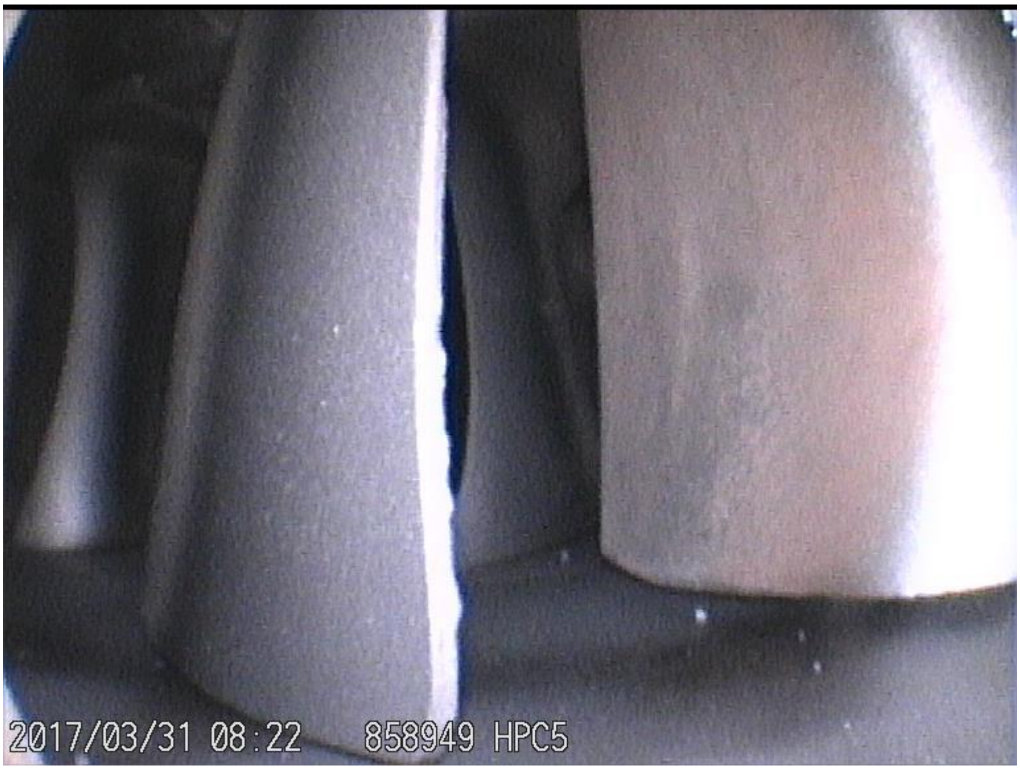


Photo 13: HPC ST5 damaged surface

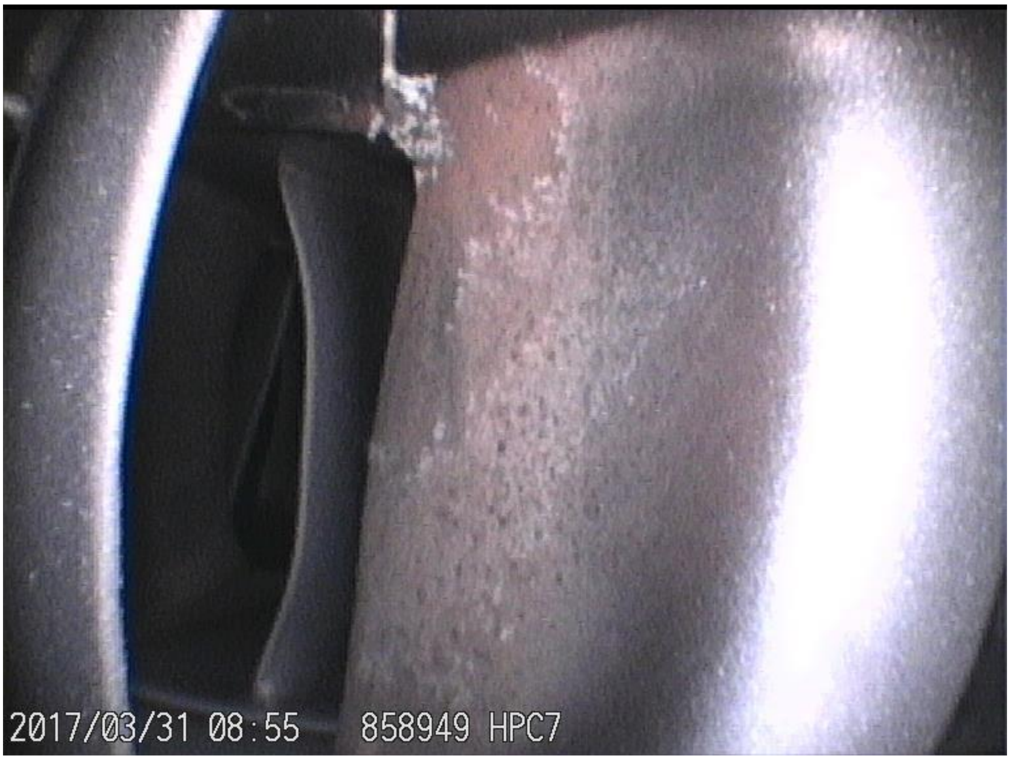


Photo 14: Corrosion marks on the HPC ST7

Photo 15: Corrosion marks on the HPC ST9

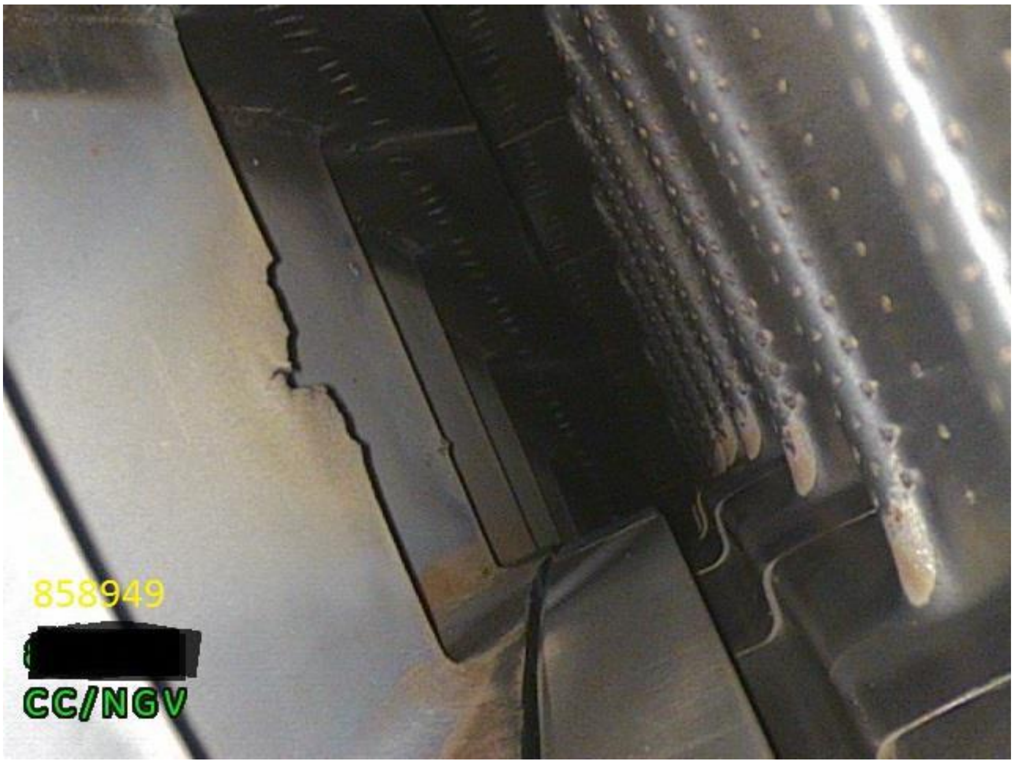


Photo 16: Nozzle Guide Vanes and HTP

Photo 17: LPT ST2 surfaces damages

As a result of BSI it was concluded that there are the need to carefully perform the gas path cleaning and re-inspection of Boost and HPC sections for verification of cleanliness and lack of damage in Boost and HPC sections.

Preliminary conclusion

It is necessary for both engines to perform more inspections and special gaspath cleaning with cleaning solvent and verify it condition before new BSI and operation of engines is done.

1.4 Other damages

Due to the runway excursion occurred the aircraft collided with the runway signs, broke two RVR sensors (Photo 18) and a power box (Photo 19).

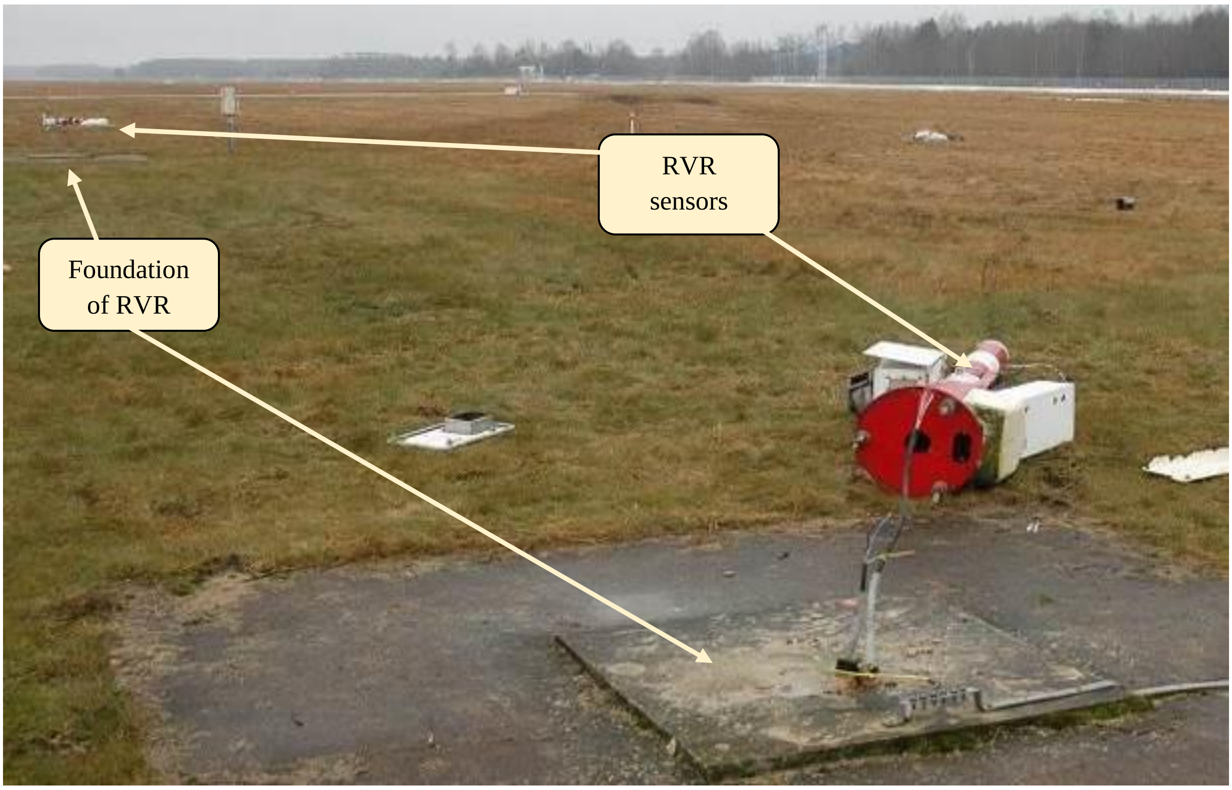


Photo 18

Photo 19

The above mentioned aerodrome equipment damages didn’t affect the operation of Riga International Airport, which resumed its work after the primary investigations at the serious incident place.

1.5 Personnel information

1.5.1 Pilot

Sex	Male
Age	50
Aviation education	Кировоградское ВЛУГА (1989)
Airline Pilot Licence	No 013304; valid
Medical Certificate (Medical conclusion)	No 256038; valid
Total flying hours	14452
Hours on type	5586
A/C captain hours	2930
Last base check	02.11.2016
Accident/Incident	Nil
Hours last 45 days	40h 35min
Hours on incident day	Nil
Flight hours in 3 day period	1h 00min

1.5.2 First Officer

Sex	Male
Age	54
Aviation education	Актюбинское ВЛУГА (1989)
Airline Transport Pilot Licence	No 0049611; valid
Medical Certificate (Medical conclusion)	No 256804; valid
Total flying hours	7543
Hours on type	2640
A/C captain hours	2930
Last base check	13.10.2016
Accident/Incident	Nil
Hours last 45 days	29h 55min
Hours on incident day	Nil
Flight hours in 3 day period	1h 00min

1. 6 Aircraft information

1.6.1 General information

The aircraft first registration was N14654, on February 11, 1998, operator Continental Airlines (United States) until October 2008.
The next aircraft operator was Transaero Airlines (Russia), the registration EI-UNG, operated until 4 May 2011.
Since August 2, 2016 the aircraft Boeing 737-524, s/n 28915 was operated by VIM-Airlines (Russia), the aircraft registration VP-BVS.

1.6.2 Airframe

Manufacturer	Boeing
Type	B737-524
Aircraft serial number	28915
Registration number	VP-BVS
Year of manufacture	02.11.1998

Name of Registered Owner	TFM Aviation Limited
Operator name	VIM-Airlines
Total running time/ Cycles	43117/21841
Certificate of Airworthiness	No 2042 of 19 September 2016 issued by Authority of the Governor of Bermuda

1.6.3 Engines

Manufacturer	CFM International (CFMI)	
Type	CFM56-3B1	
Power plant	**Engine 1** (left)	**Engine 2** (right)
Serial number	858775	858949
Total running time/ Cycles	41374/20916	42796/21908
Running time after last maintenance/ Cycles	15734/7582	20574/10043

1.6.4 Aircraft Maintenance

18.05.2016. Within 1000h framework inspection was carried out (Special Detailed) and borescope left engine combustion chamber by "Jat Tehnika" in Belgrade according to VIM-Airlines Work Order.
10.12.2016. within 1000h framework were inspected (Detailed) engines inlet and fan blades by "Sibir Technics Lic".
13.12.2016. Within 1000h framework were inspected (Special Detailed) engine HPT nozzles and blades for distress by borescope "Sibir Technics Lic".
23.12.2016. **C-CHECK+ADD JOB'S** (Work Order WO#12-094) by Maintenance organization "Sibir Technics Lic" (The PART-145 organization BDA/AMO/330) approved by EASA.
26.12.2016. Maintenance organization "Sibir Technics Lic" issued Aircraft Certificate of Release to Service No ST-2016-2-01467.
12.01.2017 last periodical maintenance 40DY-CHECK

1.6.5 Fuel

- Fueling in Riga International Airport by SIA "RIXJET Riga" (Aviation fuel JET A-1, density (g/cm^3) on 15^{0}C – 0.7954) – 4480 L (3609.7kg);
- Remained fuel before refueling – 5200kg;
- Take-off fuel **total on board** – 8809.7kg.

A 1L of fuel sample was taken from the aircraft main fuel tank from the low fuel test point and tested in the authorized laboratory "LATSERT". The laboratory confirmed the compliance of the fuel parameters and standards LVS EN ISO 12937:2002.
(The Aircraft Fueling Invoices in RIX are in Appendix 5)

1.6.5 Aircraft loadsheet data

- The aircraft dry operating weight – 33,654kg;
- Take-off fuel – 8,600kg;
- Total Passenger (44 pers.) weight – 3,400kg;
- Goods weight – 1,054kg (After unloading goods from the airplane and weighing, Photo 20a,b);

Photo 20 a,b: Goods unloading from aircraft

- Total take-off weight – 46,708kg;
- The Certified maximum Take-off weight (MTOW) is 55,395kg;
- Trip fuel – 5,500kg;
- Landing weight – 41,208kg.

1.7 Meteorological information

Riga International Airport (EVRA)

Time (UTC)	**Wind/KT**	**Visibility, km**	**Clouds OVC, FT**	**t, °C**	**RWY 18 Report**	**QNH (QFE), hPA**
09:02	230/5	5	400	3	SFS WET BA GOOD	1011
09:20	230/8	5	400	3	SFS WET BA GOOD	1011
09:50	230/6	8	400	3	SFS WET BA GOOD	1011
10:20	240/5	4.4	400	4	SFS WET BA GOOD	1011
10:46	240/5	4.4	400	4	SFS WET BA GOOD	1011
10:50	230/7	5	400	4	SFS WET BA GOOD	1011

METAR (MET REPORT):
EVRA 171220Z 24006KT 8000 OVC006 04/04 Q1011 R18/290195 NOSIG
EVRA 171150Z 24005KT 210V280 8000 OVC005 04/04 Q1011 R18/290195 NOSIG
EVRA 171120Z 24006KT 210V280 9000 -RA OVC004 04/04 Q1011 R18/290195 NOSIG
EVRA 171050Z 24007KT 210V270 7000 -RA OVC004 04/04 Q1011 R18/290195 NOSIG
EVRA 171020Z 23008KT 5000 -RA BR OVC004 04/04 Q1011 R18/290195 NOSIG
EVRA 170950Z 23007KT 210V270 8000 -RA OVC004 03/03 Q1011 R18/290195 NOSIG
EVRA 170920Z 23008KT 6000 -RA OVC004 03/03 Q1011 R18/290195 NOSIG
EVRA 170850Z 23008KT 9000 -RA OVC005 03/03 Q1011 R18/290195 NOSIG
EVRA 170820Z 23008KT 9000 -RA OVC003 03/03 Q1011 R18/290195 TEMPO 4000 BR
EVRA 170750Z 23007KT 200V260 5000 -RA BR OVC003 03/03 Q1011 R18/290195 TEMPO 4000
EVRA 170720Z 23007KT 4100 -RA BR OVC003 03/03 Q1011 R18/290195 NOSIG

1.8 Aids to Navigation

NIL

1.9 Communications

Transcripts of recorded Radio communications by crew with the Riga TWR controller on frequency 118.1MHz were available for evaluation purposes. The Controller used standard phraseology, it was mainly in compliance with the instructions given in ICAO ANNEX 10 and there were not principal errors in the used phraseology. In the audio files and in the Communication Transcripts there were not essential inaccuracies in radio communication from both sides.

1.10 Aerodrome information

According to information from the Riga International Airport (EVRA) competent service – RWY 18 at time of event was at normal condition.

DATIS-TEXT; EVRA ATIS_ARRDEP; L

RUNWAY REPORT:

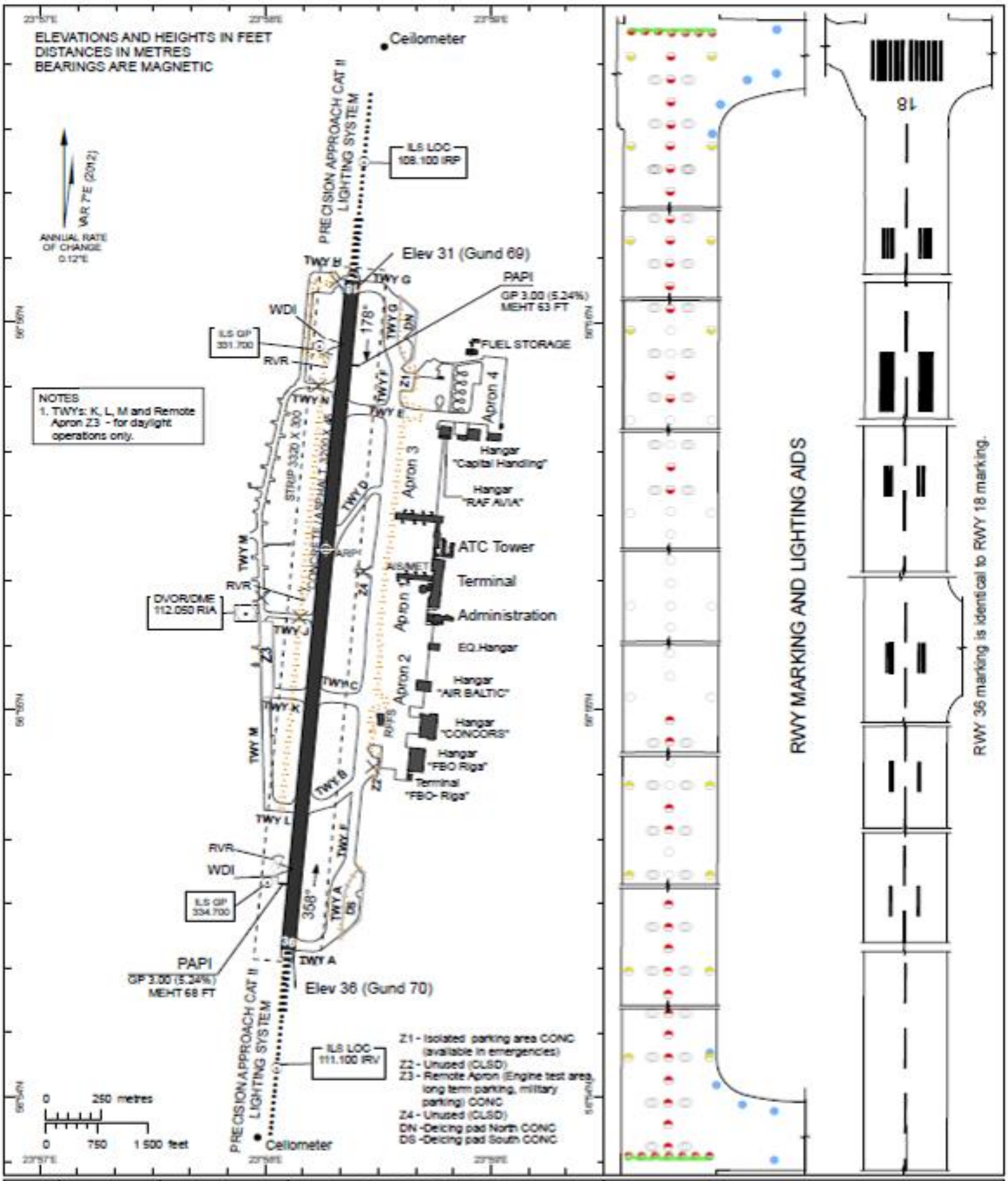
RWY SFC WET.
BA GOOD. (Friction coefficient or Braking Action)
TWY SFC WET.

AIP LATVIA

EVRA AD 2.24.1 - 1
02 MAR 2017

AERODROME CHART - ICAO | 56°55'25"N 023°58'16"E | ELEV 36' | RIGA

TWR	118.100
GMC	118.800
APRON	131.600
ATIS	120.175



RWY	TRUE DIRECTION	THR
18	185.18°	56°56'06.25"N 023°58'23.07"E
36	005.17°	56°54'23.22"N 023°58'06.08"E

BEARING STRENGTH	
PCN 89/F/C/X/T	runways and taxiways A, E
PCN 84/F/A/W/T	taxiways B, K
PCN 89/F/C/W/T	taxiway C
PCN 50/F/C/X/T	taxiway D
PCN 64/F/A/W/T	taxiway F
PCN 100/F/C/X/T	taxiway G
PCN 50/R/B/W/U	taxiways L, M

Remarks:
1. APPROACH and RWY lighting see EVRA AD 2.14
2. RWY marking see EVRA AD 2.9
3. The rapid-exit TWY D is designed for Code C (max. wingspan 36m) or smaller ACFT.

AIS Latvijas Gaisa Satiksme

AIRAC AMDT 002/2017

(Information source: https://ais.lgs.lv/eAIPfiles/2017-03-30-AIRAC/html/index.html)

1.11 Flight recorders

In accordance with the regulations, the aircraft was equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR).
According with signed MoU with AAIB (UK) the Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were removed from the aircraft and conveyed to the AAIB (UK) laboratory. The TAIIB investigator delivered the recorders and was present during the data downloading and decryption.
Received flight data analysis TAIIB investigators carried out taking into account the AAIB specialist opinions on the FDR data of plots on February 28, 2017.

1.11.1 Cockpit Voice Recorder (CVR)

The CVR was a 2hr recorder. Track 2 was 30 minutes.

- Manufacturer: Allied Signal (Honeywell)
- Type number: 980-4700-042
- Serial number : 6865

The following tracks were recorded:
1. VHF and public address, of thirty minutes duration,
2. VHF and headset microphone of the First Officer (right seat), of two hours duration,
3. VHF and headset microphone of the Pilot (left seat), of thirty minutes duration,
4. Cockpit Area Microphone (CAM), of two hours duration,
5. Tracks 1, 2 and 3 mixed, of two hours and five minutes duration.

The aircraft CVR recording transcripts are provided by TAIIB

Time (UTC)	The voice owner	The recordings
09:54:02	P (Pilot)	Riga “Tower” good morning MOV-9945 hold point “G” runway 18.
09:54:12	C (Controller TWR)	MOV-9945, Riga “Tower” roger hold at holding point “G”.
9:54:20	P	Hold point “G”, MOV-9945.
9:54:27	C	Turkish-7US vacate left “Charlee” when runway vacate contact “Ground” 118.8.
9:54:33	P	Vacate via “C” when vacated 118.8. See You. Turkish-7US.
9:54:38	C	Good day.
9:55:01	C	Air Baltic – 772 wind 230 degrees 6 knots runway 18 cleared to land.
9:56:07	P	Cleared to land. Air Baltic-772.
9:56:53	C	MOV-9945, line up runway 18 and wait via “G”.
9:57:05	P	Lining up runway 18. MOV-9945.
9:57:06	C	Line up and wait.
9:57:08	P	And wait. MOV-9945.
9:57:25	P	Take-off check list.
9:57:36	C	Visu labu, Air Baltic-772.
9:57:38	P	Bay bay. Thank You.
9:58:02	C	MOV-9945 wind 240 degrees 8 knots visibility 7 kilometers runway 18 cleared for take-off.

9:58:12	P	Cleared for take-off runway 18 MM… MOV-9945. Have a nice day. Bye.
9:58:20	C	Bye. Bye.
9:58:26	P	Steady line.
9:58:32	P	$N_{1,}$ TO/GA.
9:58:38	FO (First Officer)	[Pilot's name]!!!
9:58:42	FO	[Pilot's name], что ты творишь![[Pilot's name], what are you doing]
9:58:54	P	Не знаю, что он поделал...[I don't know what happened]
9:58:56	FO	Зачем так резко РУДы дал..? [Why have you pushed the throttle levers so sharply?]
9:58:57	P	Я не дал резко.[I haven't pushed sharply…]
9:58:58	FO	Выезжай, пока здесь не остановились...[Move until we stopped here]
9:59:08	FO	Выезжай на полосу, только не на фонарь.[Move to the RWY, not to the RWY light]
9:58:09	P	Хорошо.[Ok]
9:59:16	C	Wind 230 degrees 6 knots emergency services have been alerted.
9:59:18	P	Доложи.[Inform]
9:59:23	UK (Fire Department)	Tower Fire 55.
9:59:28	FO	MOV-9945, stop on runway 18.
9:59:32	C	MOV-9945, emergency services have been alerted, hold position. Do you need any assistance? Wind 230 degrees 6 knots.
9:59:41	P	Внимание...Внимание, экипаж, оставайтесь на местах. Что у нас? [Attention ... Attention, crew, keep your seats. What do we have?]
9:59:45	FO	Всё в порядке, всё на месте. [Everything is all right, everything is in place]
9:59:49	P	Всё в порядке, всё на месте. [Everything is all right, everything is in place]
9:59:53	UK	Tower Fire 55.
9:59:55	P	MOV-9945, we can vacate runway on own pover.
10:00:04	C	MOV-9945, Roger hold position shortly may be a fire department should inspect your conditions.
10:00:17	P	We have not any fire on board MOV-9945.
10:00:27	UK	Tower Fire 55.
10:00:29	C	Fire 1 Tower approved occupied runway from Charly "C" all units.
10:00:36	P	Что случилось, я не понял, почему он полез туда... Я дал TO/GA и всё. Я на 50% включил...[What happened, I didn't understand why it has moved there... I pressed TO/GA and that was it. I switched on 50% ...]
10:00:36	UK	Occupied runway via "C" 4 units.
10:00:08	P	Я на 50% TO/GA нажал. [I've pressed at 50% TO / GA]
10:00:11	FO	Сразу убрать не мог? [Couldn't you remove it immediately?]
10:00:12	P	Да я сразу убрал. Ты видел? [I've removed immediately. Have you seen?]
10:00:14	FO	Время события. [Event time.]

10:00:28	P	Не знаю, пошли РУДы непонятно куда. Несимметрично, я ничего не смог сделать, их убрал, но...[I don't know, the TLA moved incorrectly. Unsymmetrically, I couldn't do anything, I removed it, but...]
10:00:34	FO	Повредили предкрылок правый и левый двигатель об антену. [We damaged the right slat and the left engine against the antenna]
10:00:53	FO	Параметры двигателя посмотри. [See the engine parameters]
10:00:55	P	Да всё нормально с двигателями. [Everything is fine with the engines]
10:00:57	FO	Капот повредили, да? [Is the inlet cowl damaged, isn't it?]
10:01:35	P	Что ты видел? [What did you see?]
10:01:38	FO	Я видел, как ты нажал TO/GA, мы сразу поехали вправо… мгновенно. [I saw how you pressed TO/GA, we moved to the right... instantly]
10:01:40	P	Да, это я тоже видел, но я же убирал...[Yes, I saw it too, but I removed it…]
10:01:41	FO	Поздно убрал. [Late removed]
10:01:43	P	Я убрал двигатель, но он...[I removed the engine, but it ...]
10:01:44	FO	Коэффициент сцепления? [The Runway Friction coefficient?]
10:01:45	P	Да нормальное сцепление, я не понял, в чём дело...[The friction coefficient is normal, I didn't understand what's the matter ...]
10:02:04	P	Давай затушим левый. [Let's shut down the left (engine)]
10:02:05	FO	Выключай левый.[Turn off the left (engine)]
10:02:22	FO	Вызывать буксир? [Have we to call a tug?]
10:02:23	P	Нет, не нужно, на одном выжмем...[No, it isn't necessary, we'll drag with one… (engine)]
10:02:52	P	А, у нас в Минске было тоже туда...то же самое было. [Ah, we moved in Minsk also there... the same thing happened] ***Note:*** *Information about a similar case at the Minsk airport was not mentioned in the pilot's interviews and appeared only after the CVR recording decryption.*
10:02:53	FO	В Минске было то же самое, поэтому с момента страгивания я держал ногу влево. [In Minsk, it was the same, that's why I kept my foot to the left from the very moment of strife]
10:02:54	P	Я тоже ногу постоянно держал, ты же видел, а потом это... [I kept my leg constantly too, you saw it, and then it ...]
10:02:56	FO	Останавливаться нужно было. [It was necessary to stop]
10:03:43	Leader 2	Tower Leader 2.
10:03:51	Leader 2	Tower Leader 2.
10:03:55	C	Leader 2, approved occupy.

Cockpit Area Microphone (CAM)

10:23:57	P	[FO's name], ты видел, какое [значение оборотов двигателей], где то 50%, я на 50% нажал [TO/GA]. [FO's name, did you see what was [N_1], approximately 50%, I pressed [TO/GA] by 50%.]
10:23:59	FO	Правый был на 51%, левый на 50%, как я увидел. [The right was 51%, the left was 50%, as I saw.]
10:24:01	P	Это нормально... я нажал [TO/GA], дальше что произошло? [This is normal ... I pressed (TO/GA)], then what happened?]

10:24:07	FO	Он сразу с места. [It moved from the spot immediately]
10:24:08	P	Резко левый пошел вперёд, а этот [правый] остался. [The left one moved sharply forward, and this (right) remained.]

1.11.2 Flight Data Recorder (FDR)

The FDR was a protected recorder with a solid state memory capable of reproducing at least the last twenty-five hours of recording:

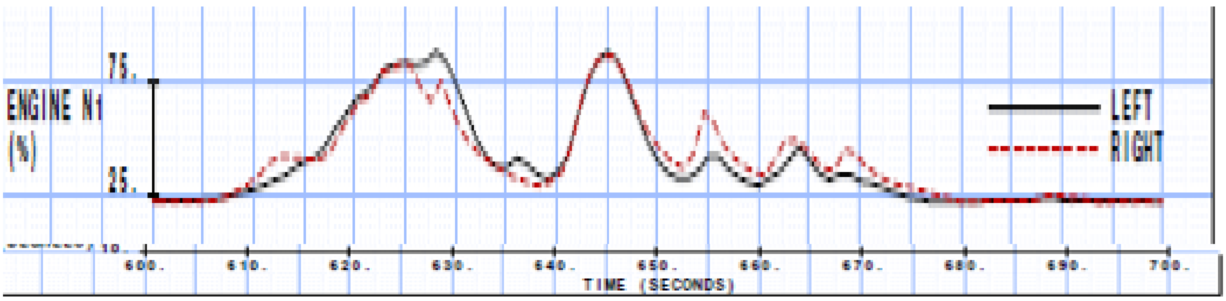
- Manufacturer: Honeywell
- Type number: 980-6022-001
- Serial number: 980

1.11.2.1 Investigation after Preliminary received data analysis from Boeing

(The Preliminary downloaded data plots of FDR records provided by Boeing on March 10, 2017 are in Appendix 4)

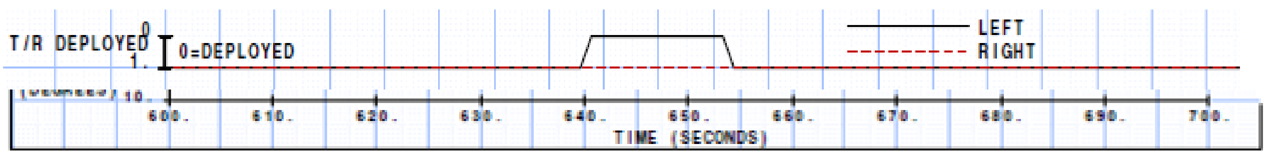
The FDR data shows that:

LH engine N1 was about 87% while RH engine N1 was about 66% therefore the difference was about 21%. The left engine N1 spooled up faster than the right engine which caused aircraft to deviate slightly right of centerline. Small amounts of left rudder were commanded to correct the heading.



Fragment 1 from FDR data plots of 10.03.2017

The crew returned the rudder to neutral position shortly before time 640 seconds. Simultaneously, reverse thrust was commanded on only to the left engine which caused the airplane to continue turning left.



Fragment 2 from FDR data plots of 10.03.2017

Taking into account the results of borescope inspection, which confirmed the impurity of both engines with mud, grit and grass, it was not possible to carry out the engines operation tests in different regimes and the comparison with the technical characteristics of the engine manufacturer's manual.

Therefore TAIIB performed preliminary FDR data plots' analyses based upon data provided of Boeing company and carried out of preliminary observations of the UK (State of Registry) investigation branch (AAIB), specialists of the engine type CFM56 and the Boeing company engineers for to understand the difference of engines' thrust parameters N1 at the moment of the aircraft takeoff roll when the TO/GA button had been put on.

TAIIB decided at the next stages of investigation to involve the representatives of the engine CFM56-3B1 manufacturer and to send the right engine thrust power units MEC and PMC to the engine manufacturers GE Aviation and SAFRAN companies for the units' inspection in the engine manufacturer's industrial laboratories.

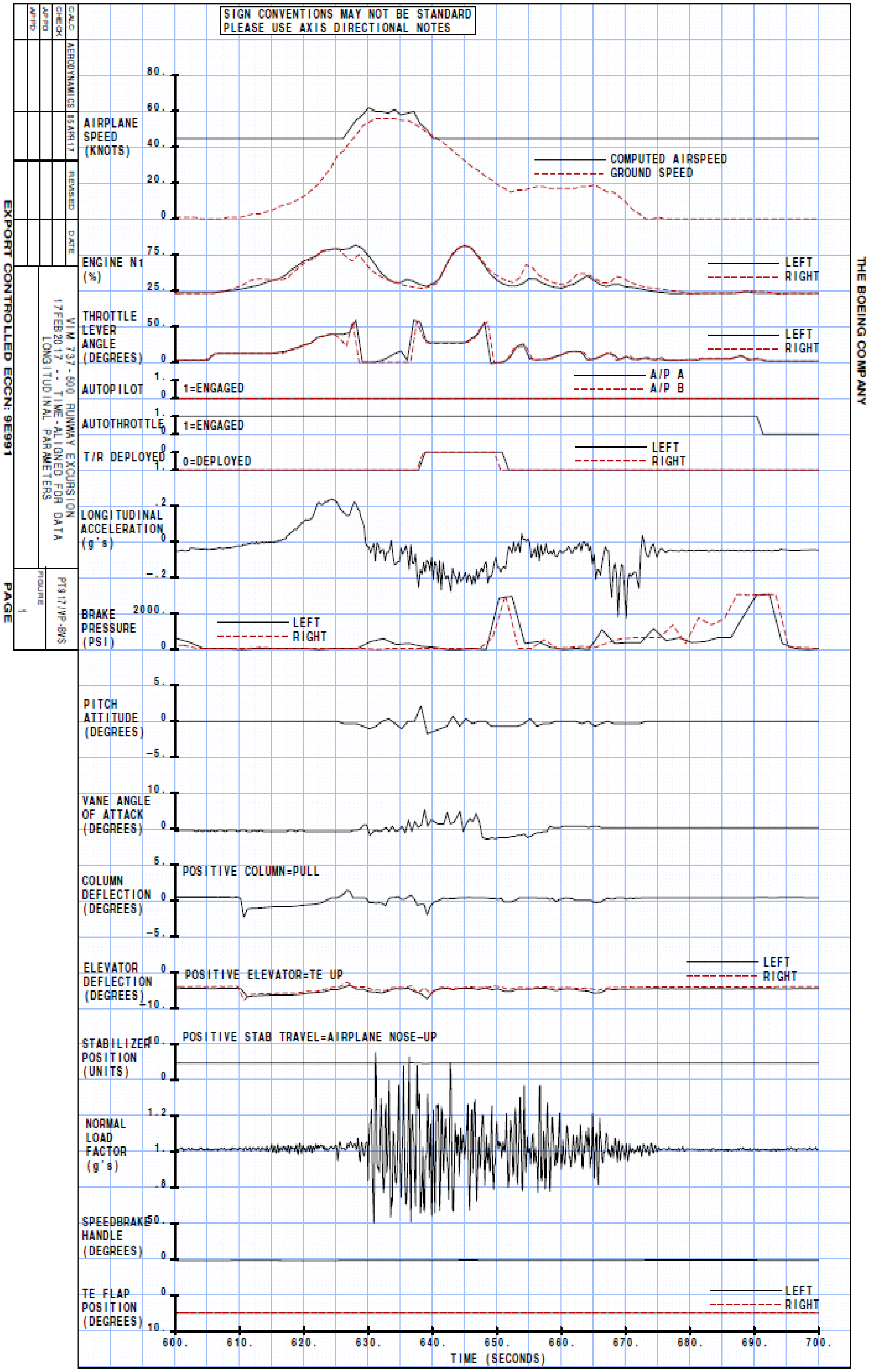
After receiving of the confirmation from the engine manufacturers, TAIIB investigators and the VIM-Airlines staff dismounted the PMC and MEC units from the aircraft and sent both for further testing:

- According to the engine manufacturer - GE Aviation (USA) - recommendation TAIIB sent the MEC unit for investigation to the Woodward Aircraft Engine Systems in Prestwick (UK). The investigation program was agreed and accepted by TAIIB and AAIB Accredited Representative presence.
- The PMC unit was sent to BAE Systems (USA) on receipt of the consent of the NTSB about their representative's readiness to participate in the PMC investigation.

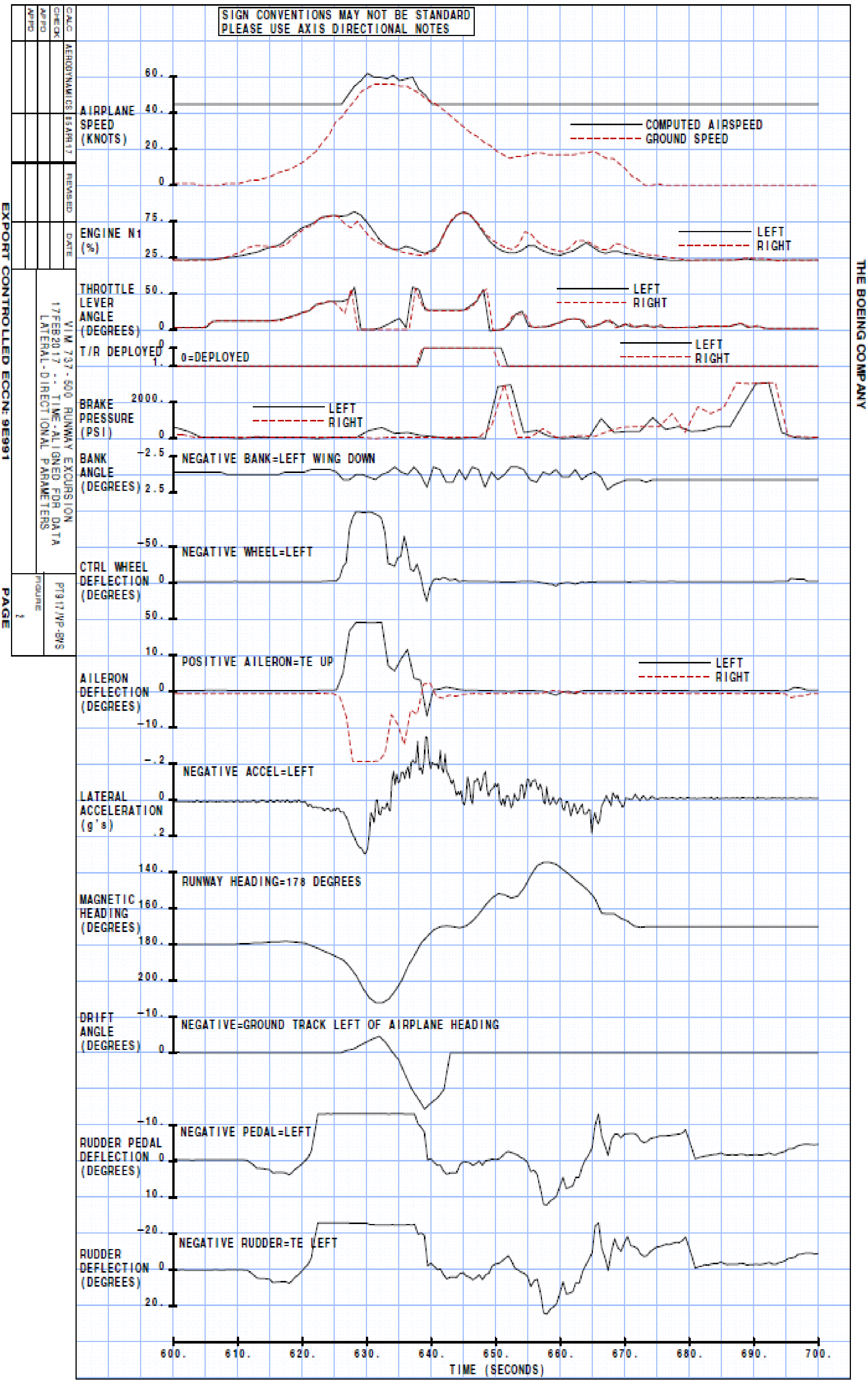
1.11.2.2 The final analysis of FDR data from Boeing Company on April 24, 2017

Time history plots of the pertinent longitudinal and lateral-directional parameters are attached as Plots 1 and 2. In addition to an evaluation of the recorded parameters, a kinematic analysis was conducted on the provided FDR data, to correct inherent inconsistencies often present in recorded data due to sample rate differences, multiple independent data sources, and the presence of instrumentation biases. The kinematic analysis used integrated acceleration data to ensure basic inertial parameters such as altitude, ground speed, and drift angle were compatible and comparable. The output was a cinematically consistent set of data with acceleration biases removed, allowing for calculations of wind data, ground track information, and other parameters not recorded on the FDR.

The FDR data show a flaps 5 takeoff was initiated from Riga's Runway 18 (based on recorded heading data) [Plots 1]. Throttles were initially advanced to 15 degrees at time 605 seconds. Once the engines began spooling up for takeoff, the crew advanced the throttles to command takeoff thrust. At time 611 seconds, the crew applied a right pedal input of 3 degrees, presumably to maintain runway heading (Plots 2). Beyond time 620 seconds, heading began to deviate to the right of runway heading more rapidly. Simultaneously, the crew began to input full left pedal to arrest the yaw rate to the right. The rejected takeoff (RTO) was initiated at 58 knots computed airspeed (time 629 seconds) with a reduction in the throttles to idle. The auto speedbrakes did not deploy because wheel speed was below the 60-knot threshold required for deployment. Fluctuations in normal load factor increased beyond time 630 seconds, indicating the likely time the airplane departed the runway. Heading continued increasing to the right – despite a full left rudder input – until heading reached 212 degrees at time 631 seconds. The airplane began turning to the left at time 632.5 seconds. Shortly thereafter, reverse thrust was commanded. The left pedal input was removed at time 637.5 seconds, as heading approached the runway heading. Right pedal was briefly commanded at time 642 seconds, which temporarily arrested the heading change to the left. Thrust reversers were stowed at time 652 seconds when ground speed was 15 knots. Three degrees of left pedal was commanded at time 652 seconds, which caused the airplane to turn left to 134 degrees. Twelve degrees of right pedal was commanded at time 657.5 seconds, which caused a heading change to the right. An increase in brake pressure at time 665 seconds brought the airplane to a complete stop (Plots 2).


SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
AIRPLANE SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
ENGINE N1 (%)
THROTTLE LEVER ANGLE (DEGREES)
AUTOPILOT
1=ENGAGED
A/P A
A/P B
AUTOTHROTTLE
1=ENGAGED
T/R DEPLOYED
0=DEPLOYED
LEFT
RIGHT
LONGITUDINAL ACCELERATION (g's)
BRAKE PRESSURE (PSI)
PITCH ATTITUDE (DEGREES)
VANE ANGLE OF ATTACK (DEGREES)
COLUMN DEFLECTION (DEGREES)
POSITIVE COLUMN=PULL
ELEVATOR DEFLECTION (DEGREES)
POSITIVE ELEVATOR=TE UP
STABILIZER POSITION (UNITS)
POSITIVE STAB TRAVEL=AIRPLANE NOSE-UP
NORMAL LOAD FACTOR (g's)
SPEEDBRAKE HANDLE (DEGREES)
TE FLAP POSITION (DEGREES)
TIME (SECONDS)
VIM 737-800 RUNWAY EXCURSION
17FEB2017 -- TIME-ALIGNED FDR DATA
LONGITUDINAL PARAMETERS
EXPORT CONTROLLED ECCN: 9E991
THE BOEING COMPANY
PAGE
FIGURE 1
CALC
CHECK
APPD
APPD
AERODYNAMICS
REVISED
DATE

Plots 1

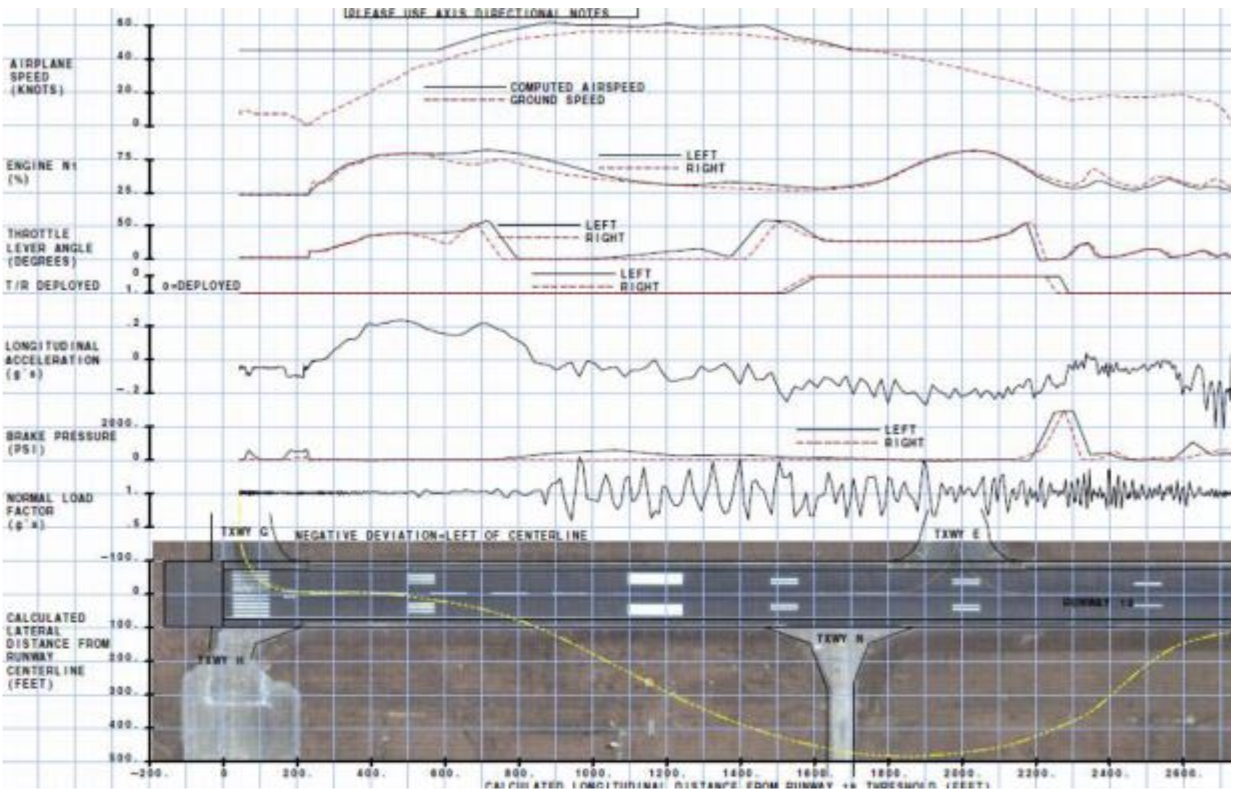

SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES
AIRPLANE SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
ENGINE N1 (%)
LEFT
RIGHT
THROTTLE LEVER ANGLE (DEGREES)
T/R DEPLOYED
0=DEPLOYED
BRAKE PRESSURE (PSI)
BANK ANGLE (DEGREES)
NEGATIVE BANK=LEFT WING DOWN
CTRL WHEEL DEFLECTION (DEGREES)
NEGATIVE WHEEL=LEFT
AILERON DEFLECTION (DEGREES)
POSITIVE AILERON=TE UP
LATERAL ACCELERATION (g's)
NEGATIVE ACCEL=LEFT
MAGNETIC HEADING (DEGREES)
RUNWAY HEADING=178 DEGREES
DRIFT ANGLE (DEGREES)
NEGATIVE=GROUND TRACK LEFT OF AIRPLANE HEADING
RUDDER PEDAL DEFLECTION (DEGREES)
NEGATIVE PEDAL=LEFT
RUDDER DEFLECTION (DEGREES)
NEGATIVE RUDDER=TE LEFT
TIME (SECONDS)
VIM 737-500 RUNWAY EXCURSION
17FEB2017 -- TIME-ALIGNED FOR DATA
LATERAL-DIRECTIONAL PARAMETERS
EXPORT CONTROLLED ECCN: 9E991
THE BOEING COMPANY

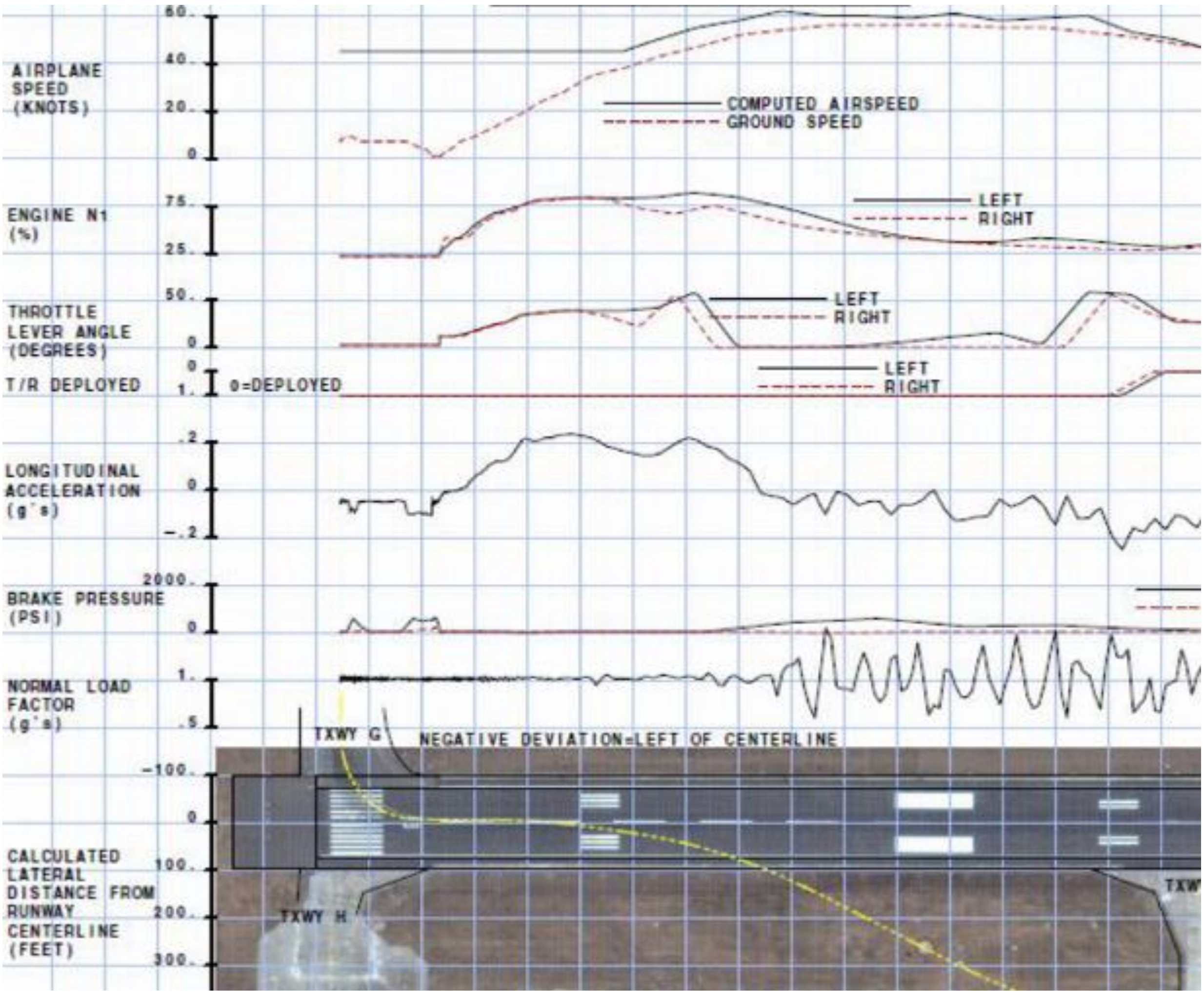
Plots 2

Ground Track Analysis

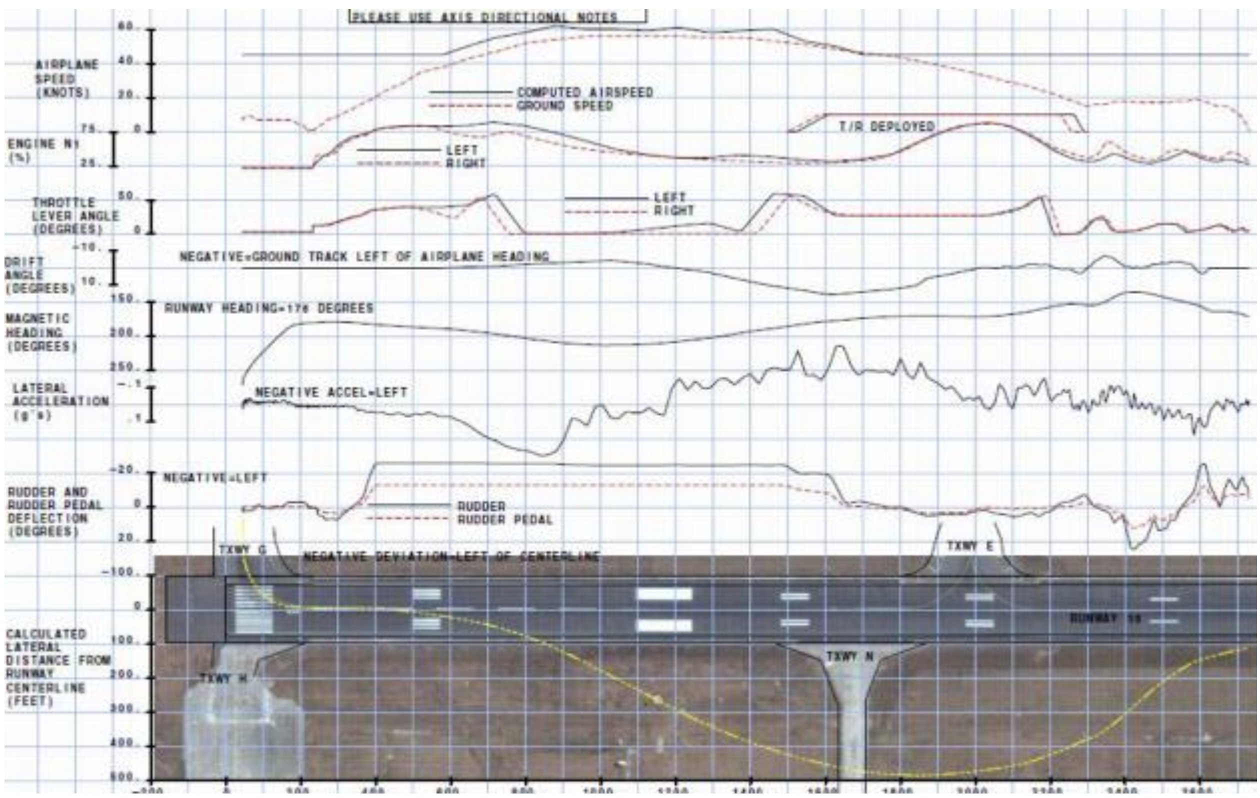
A ground track was generated to show the airplane's path during the approach and landing rollout (Plots 3 and 4, respectively). Riga's Runway 18 has a length of 10,499 feet and a width of 148 feet. Longitudinal and lateral distances were calculated using a combination of inertial data (ground speed, drift angle, heading), and airport information (runway dimensions, taxiway dimensions, etc.). The distances were then referenced to the runway based on the turn onto the runway at the start of the takeoff roll.

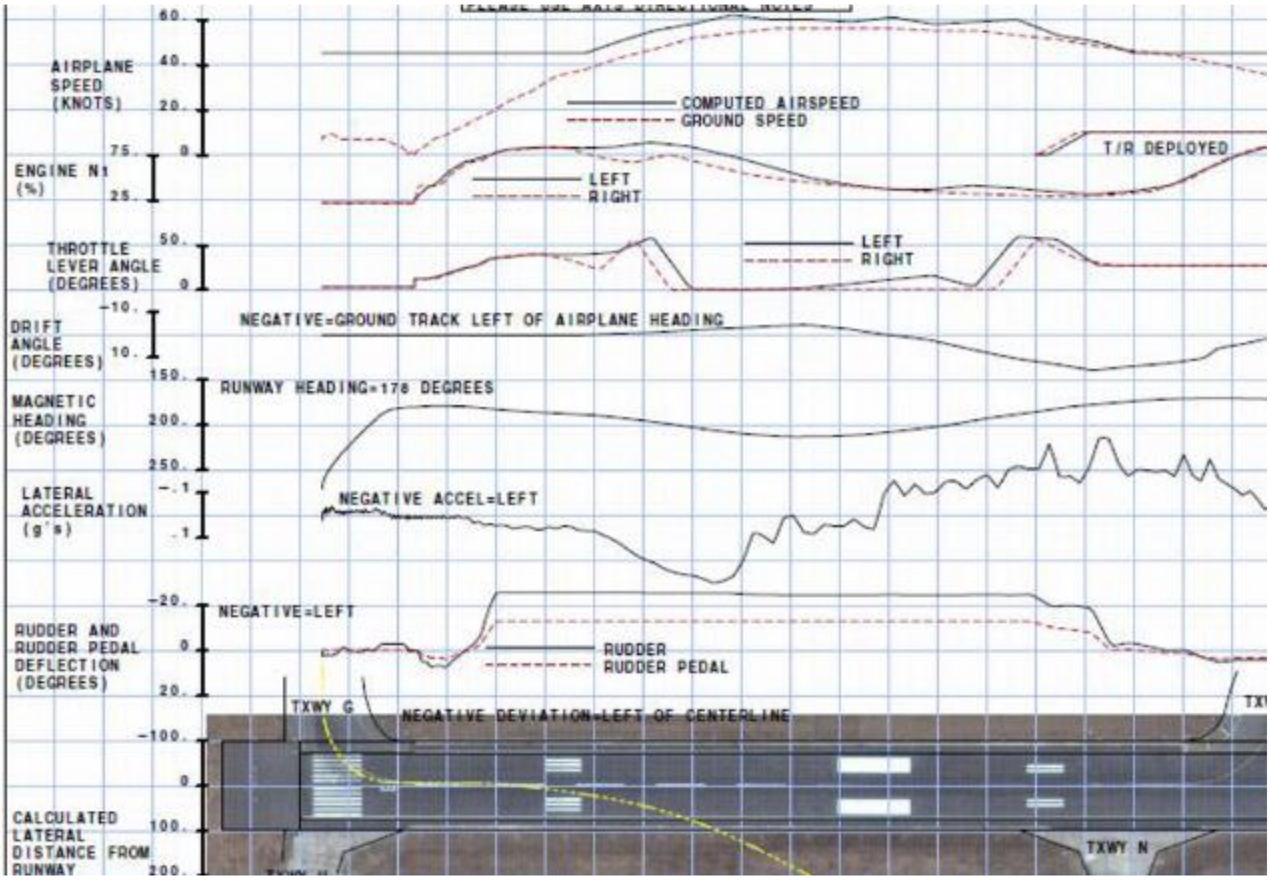
The ground track analysis results indicate the takeoff roll was initiated from the start of Runway 18 at taxiway G (Plots 3 and 4). At 400 feet beyond the threshold, the airplane began deviating right of centerline. Simultaneously, full left rudder was commanded (Plots 4). The RTO was initiated 750 feet beyond the threshold once the airplane deviated 60 feet to the right of centerline. The airplane departed the right edge of the runway surface 850 feet beyond the threshold at a computed airspeed of 60 knots. Heading continued increasing to the right after departing the runway surface. Once heading reached 210 degrees, at 1100 feet beyond the threshold, the airplane began yawing to the left. The left rudder pedal input was relaxed once the lateral deviation reached 470 feet to the right of centerline. Reverse thrust was simultaneously commanded. Upon crossing taxiway N, heading was close to the runway heading. Nearly 200 feet after crossing taxiway N, the airplane began returning towards the runway. The thrust reversers were stowed 2250 feet beyond the threshold at about 400 feet to the right of centerline. At the same time, maximum brake pressure was briefly commanded. The analysis indicates that the airplane center of gravity (c.g.) came to a complete stop 2730 feet beyond the threshold and 110 feet to the right of centerline.




AIRPLANE SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
ENGINE N1 (%)
LEFT
RIGHT
THROTTLE LEVER ANGLE (DEGREES)
LEFT
RIGHT
T/R DEPLOYED
0=DEPLOYED
LEFT
RIGHT
LONGITUDINAL ACCELERATION (g's)
BRAKE PRESSURE (PSI)
NORMAL LOAD FACTOR (g's)
TXWY G
NEGATIVE DEVIATION=LEFT OF CENTERLINE
CALCULATED LATERAL DISTANCE FROM RUNWAY CENTERLINE (FEET)
TXWY H

Plots 3


PLEASE USE AXIS DIRECTIONAL NOTES
AIRPLANE SPEED (KNOTS)
COMPUTED AIRSPEED
GROUND SPEED
ENGINE N1 (%)
T/R DEPLOYED
LEFT
RIGHT
THROTTLE LEVER ANGLE (DEGREES)
LEFT
RIGHT
DRIFT ANGLE (DEGREES)
NEGATIVE=GROUND TRACK LEFT OF AIRPLANE HEADING
MAGNETIC HEADING (DEGREES)
RUNWAY HEADING=176 DEGREES
LATERAL ACCELERATION (g's)
NEGATIVE ACCEL=LEFT
RUDDER AND RUDDER PEDAL DEFLECTION (DEGREES)
NEGATIVE=LEFT
RUDDER
RUDDER PEDAL
TXWY G
NEGATIVE DEVIATION=LEFT OF CENTERLINE
TXWY E
CALCULATED LATERAL DISTANCE FROM RUNWAY CENTERLINE (FEET)
TXWY H
TXWY N



Plots 4

Simulation

A Boeing proprietary desktop engineering simulation was used to re-create the takeoff roll up until the takeoff was aborted. The simulation offers flexibility in being able to drive the simulation control positions. Recorded data or mathematical pilot models may be used to produce the desired airplane state/flight path. The simulation is a six degrees of freedom non-linear model that has been updated to match flight data. A mathematical pilot applies inputs to track a specified parameter(s) (e.g. heading), in an attempt to minimize the error between the flight data and simulation. The simulation was set up with similar initial conditions (e.g. weight, speed, etc.) and control inputs, throttles inputs, and brake inputs to the FDR. For the purposes of this simulation, the following assumptions were made based on METAR data:

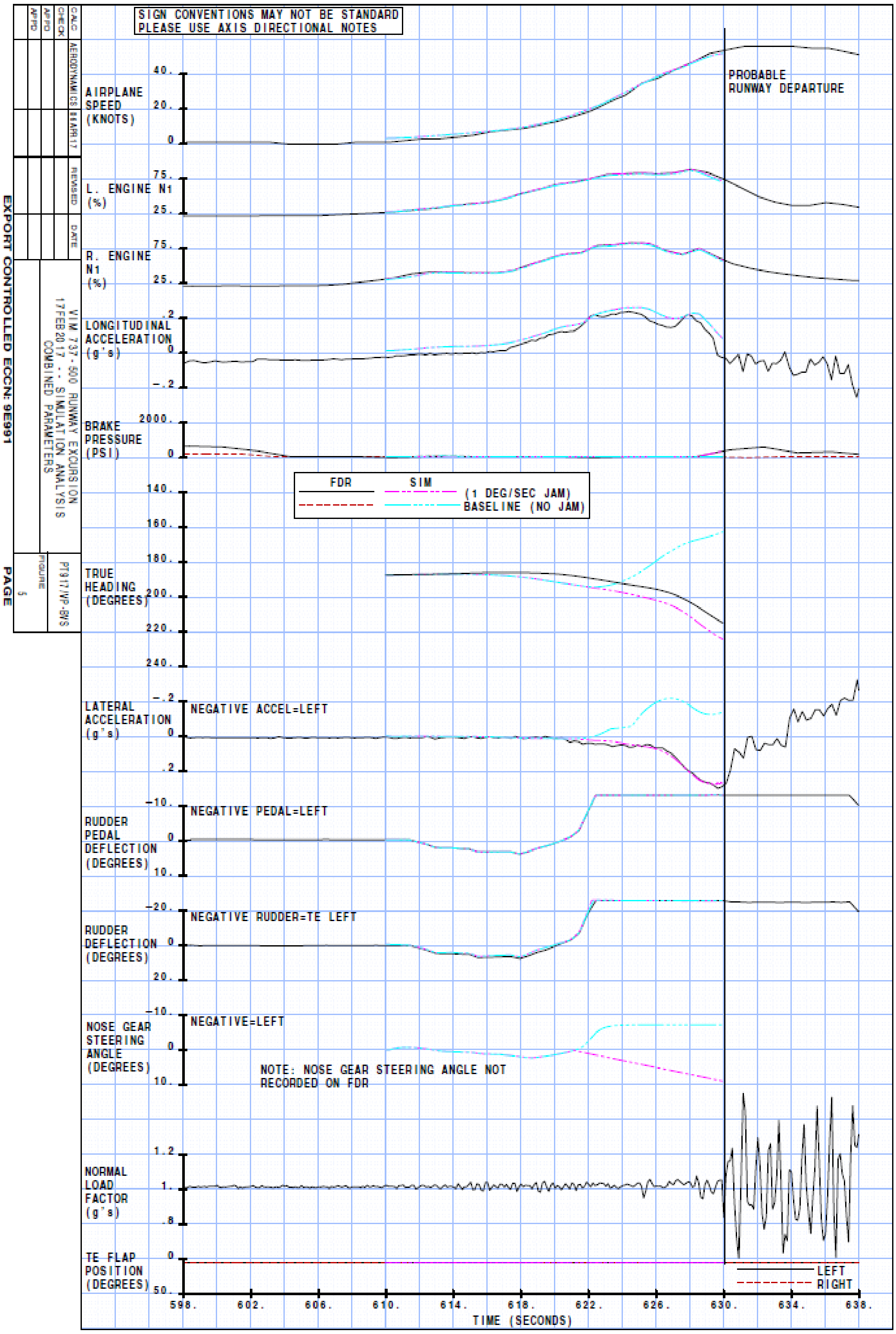
1) The wind was out of the southwest (230 degrees true) at 7 knots. Ship's system on-ground wind data are invalid.

2) A wet runway.

3) A temperature of 4 degrees Celsius.

The first simulation was run without a nose gear steering rate jam (Plots 5). The simulation was driven with rudder pedal. Results show heading deviated right of the FDR data at time 616 seconds. Between times 620 and 622 seconds, heading increased to the right at the same rate as the FDR data. Beyond time 622 seconds, the airplane began yawing to the left as a result of the full left pedal input. The simulation was stopped at time 630 seconds where the airplane presumably departed the paved runway surface as the simulation does not model a non-paved surface.

A nose gear steering rate jam of 1 degree/second was evaluated (Plots 5). There have been previous 737 suspected nose gear steering rate jams that left no evidence of why they occurred. In most cases, it is theorized that a piece of debris, internal or external to steering metering valve, caused the nose gear steering metering valve to jam in an off-null position, forcing it to stay open. This led to a continuously increasing (at a constant rate) nose gear steering angle. It is also theorized that a subsequent large rudder pedal input freed the jam, and the nose gear returned to normal functioning. In one case, the improper installation of a nose wheel steering system pulley bolt resulted in an interference condition between the pulley bolt and nose wheel steering system cover, which caused an interruption in the normal steering system feedback, refer Boeing Service Letter 737–SL–32–070. This also led to the nose gear steering metering valve to jam in an off-null position. The rate jam was introduced at time 621 seconds - immediately after the crew used a small amount of right pedal. Initially, heading data matched the baseline case (without jam); however, beyond time 622 seconds, the airplane continued turning to the right as in the FDR data. The lateral acceleration in the simulation matched the FDR well throughout the simulation run. The simulation was stopped at time 630 seconds where the airplane presumably departed the paved surface.



Plots 5

Conclusion of the Boeing report

Analysis of the FDR data indicates that the airplane deviated right of centerline in opposition to a full left rudder pedal input. The airplane departed the runway at approximately 60 knots airspeed. The heading change and deviation from runway centerline could not be arrested with full left pedal. Simulation results indicate that a 1-degree/second nose gear steering rate jam is consistent with the recorded airplane motion.

1.12 Wreckage and impact information

NIL

1.13 Medical and pathological information

The police performed breath analysis of the Pilot and the First Officer immediately after the serious incident. The test results were zero alcohol in the expiration.
Later, the police attended the flight crew in the hospital, where blood samples were taken from the Pilot and the First Officer to establish any presence of narcotics or medicines. No such substances were found in the screening.

1.14 Fire

There was no fire

1.15 Survival aspects

NIL

1.16 Tests and research

1.16.1 MEC investigation

The representatives from the AAIB (UK) and the TAIIB (LV) were present at Woodward's Prestwick facility to witness the investigation of the MEC unit.

Photo 21: The MEC equipment unpacking

As-received inspection of the MEC revealed all external linkages to move normally. Similarly, the input drive gear was noted to rotate normally. No anomalies were observed during completion of as-received inspection.


Photo 22a/b: The MEC equipment visual check

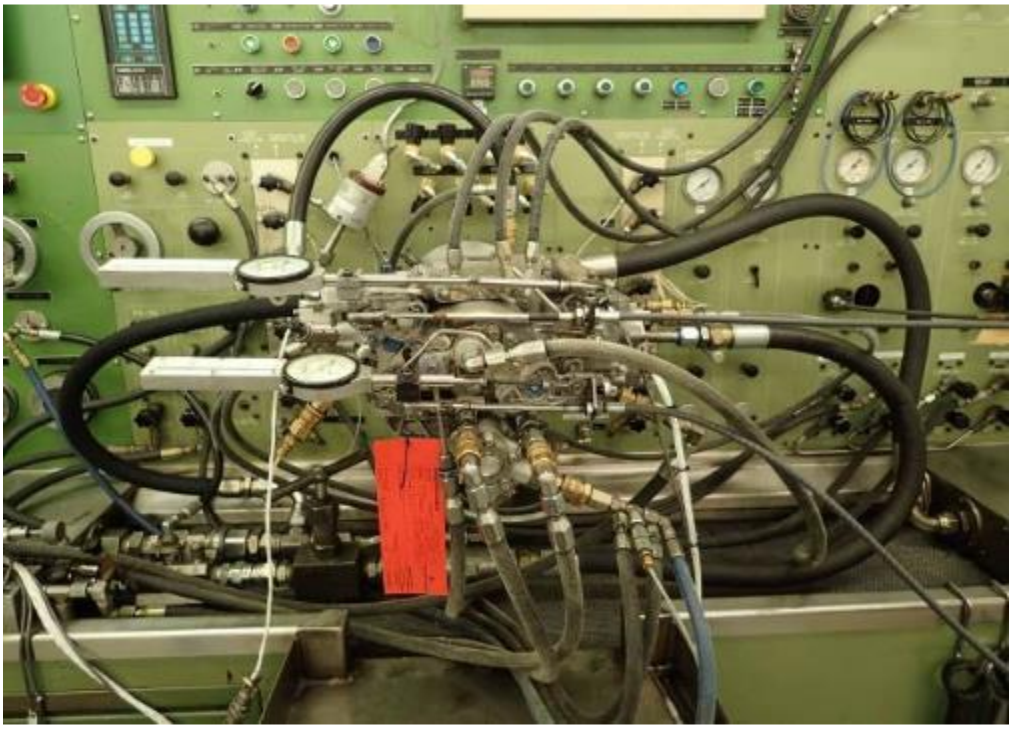


Photo 23: The MEC equipment at the test bench

Power lever schedules, transducer, electrical speed trim, and VSV schedules were in or very close to new part tolerances.

VBV schedules were within tolerances except for one point which will be rerun. Even if the point is found to be out of tolerance when it is rerun, it would only open the bleed doors slightly. This would cause a slight increase in EGT. No discernible effect on thrust would have taken place. The accel and decel schedules were found up to 15% higher to nominal but 10-12% in the takeoff region. This has been noted in past field experience on engines as cycles and time accumulate which is within acceptable operating parameters as long as acceleration requirements defined in AMM 71-00-00, Test number 8 are met.

Photo 24: The MEC equipment testing work

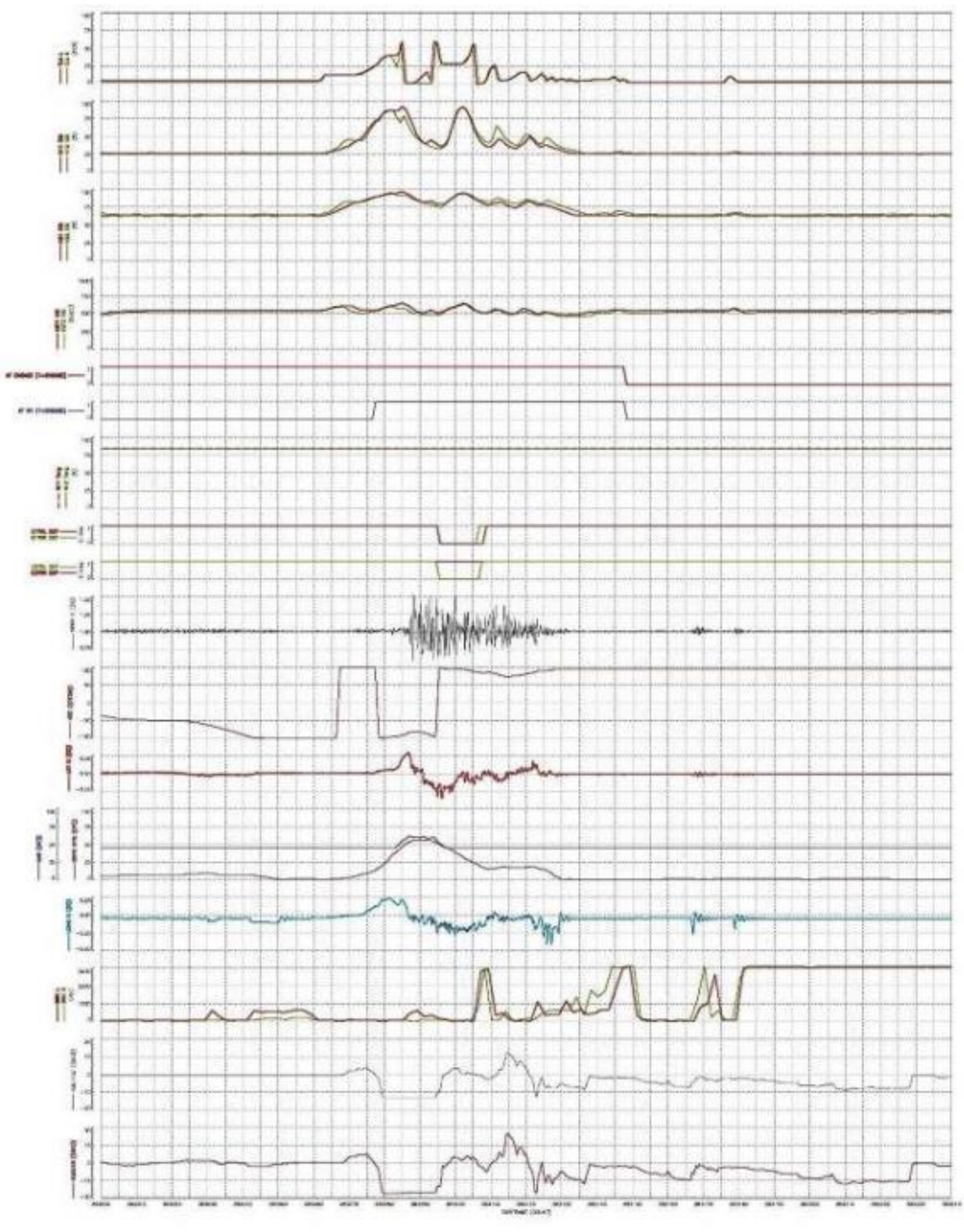


Photo 25: MEC data testing plots

Conclusion of the MEC examination

The right engine lags slightly but this appears to be a result of the PLA movement. This indicates the higher acceleration flows are not an issue on the engine.

Although the accel and decel schedules were slightly high, the power lever schedules were close to acceptance limits and it appears did not have any real effect on the incident.

1.16.2 PMC investigation

The GE Aviation Safety team and representative from the NTSB were present at BAE Systems laboratory test to witness the investigation of the PMC.

Photo 26

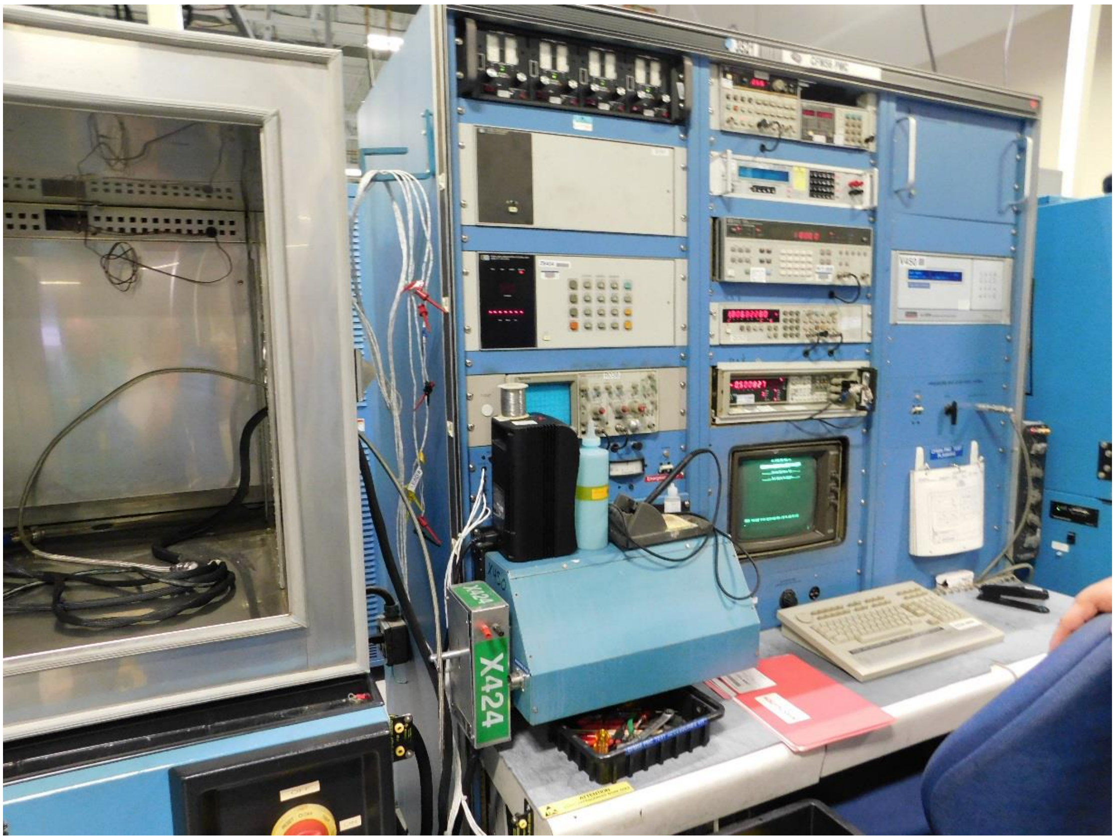


Photo 27: PMC test stand

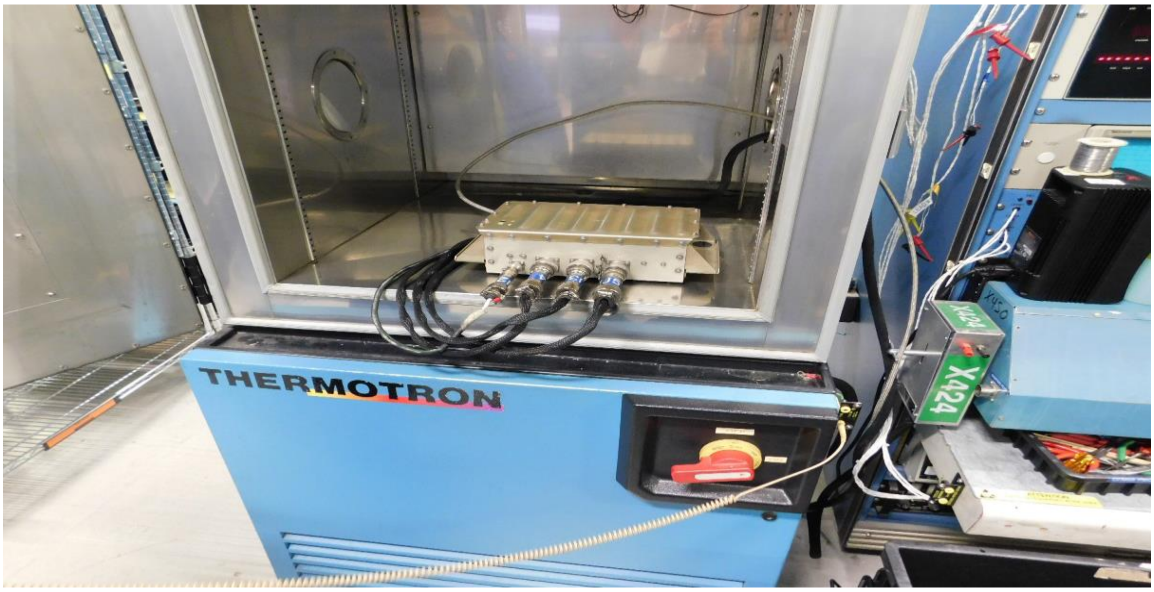


Photo 28: PMC in test chamber

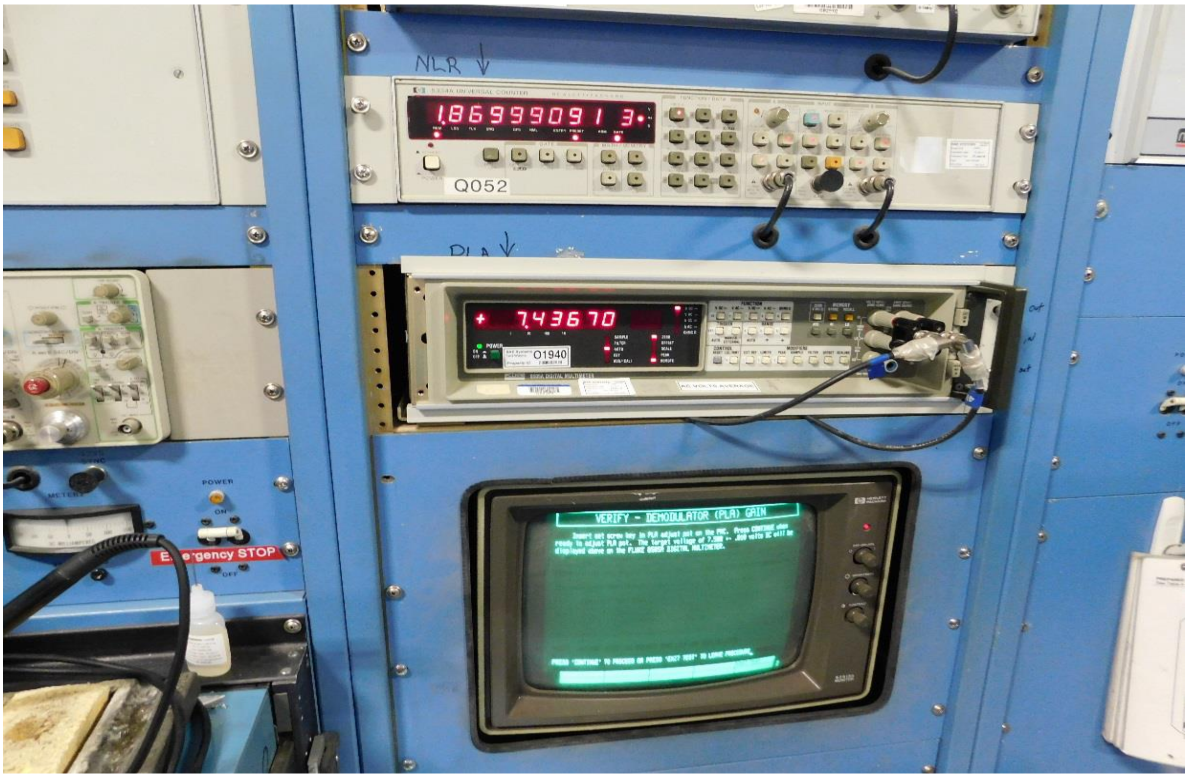


Photo 29: PMC as received PLA pot setting

Incoming ATP Tests were performed at Room (75°F), Cold (-20°F), and Hot (180°F) Temperatures. The PMC passed incoming Tests.
No troubleshooting was performed on the PMC and the unit was not opened with the exception of the pot cover to access the PLA pot which is adjusted as part of the room ATP.

Conclusion of the PMC examination

BAE Systems the ATP test of the PMC dates not found deviation from requirements of unit manufacturer.

1.16.3 The nose gear steering metering valve investigation

With reference of Boeing Company specialists' conclusion (see Article 1.11.2 "Ground Track Analysis"), TAIIB investigators and the VIM-Airlines staff dismounted the nose gear steering metering valve from the aircraft and sent it to the BAE Systems laboratory (USA) for testing.

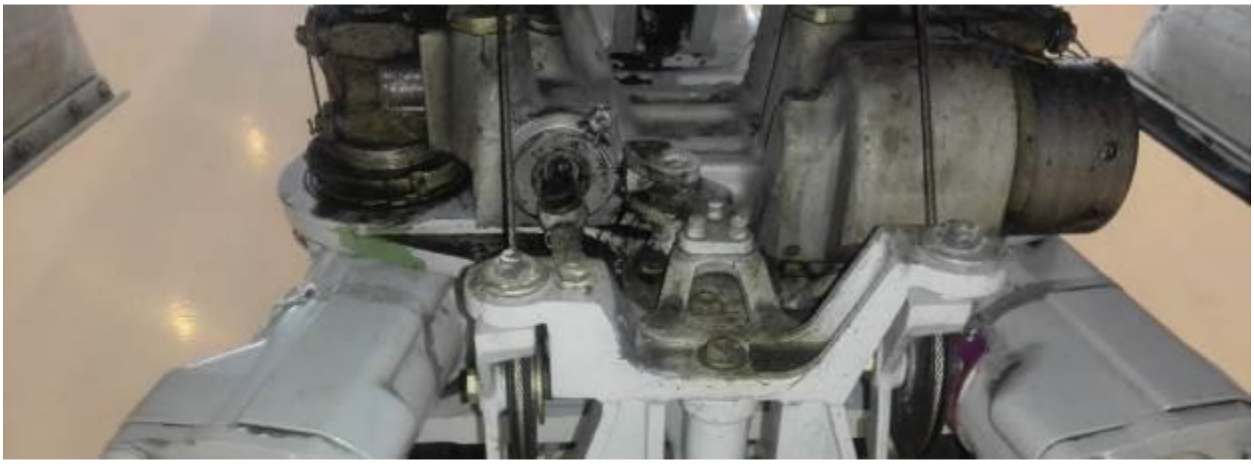


Photo 30: The nose gear steering metering valve before disassembly

The nose gear steering metering valve during disassembly of the protective cover did not reveal any wear and tear, abrasion of ropes and signs of tension roller inclination (Photo 31).

Photo 31: The protective cover inside after disassembly

Disassembly and examination of the subject steering metering valve was performed in the Boeing Equipment Quality Analysis (EQA) laboratory in Seattle, WA (US) on July 18 and 19, 2017.

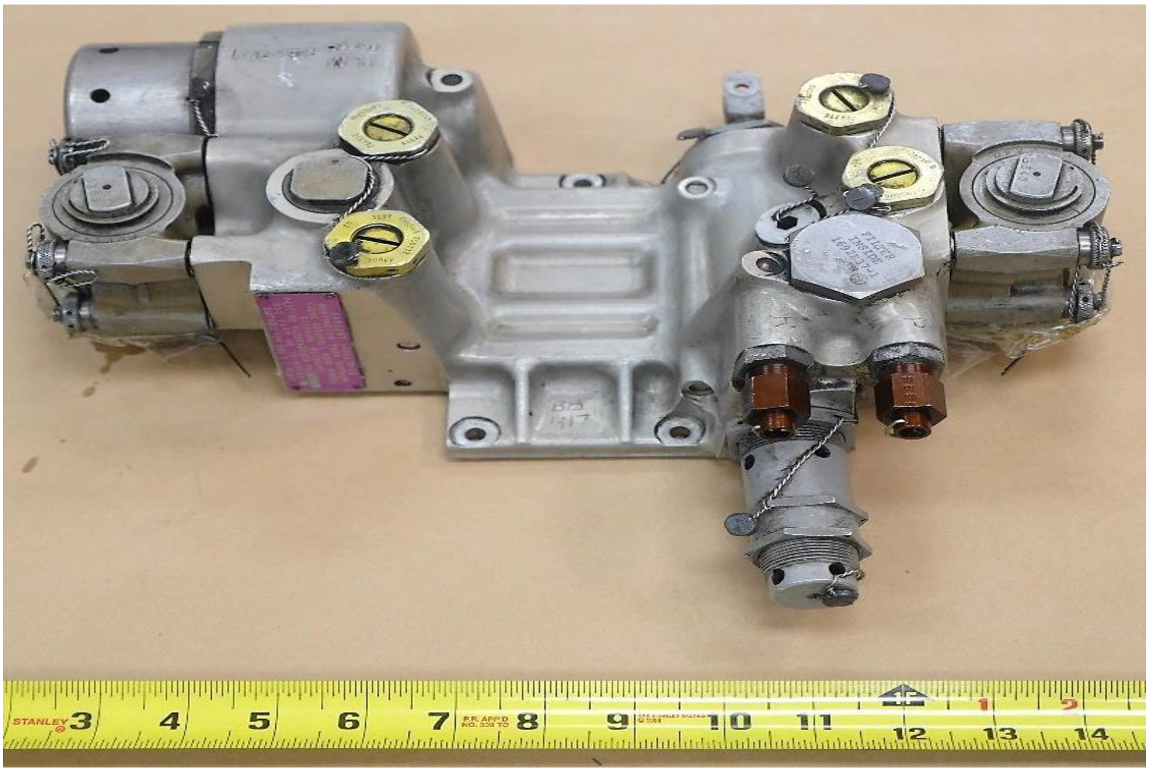


Photo 32: Overview of steering metering valve

The steering metering valve was examined using digital radiography (DR), with the focus of the DR examination being placed on the spool, sleeve and return spring; see Photo 33 and Photo 34. The spool appeared to be centered in the sleeve, and the centering spring was intact.

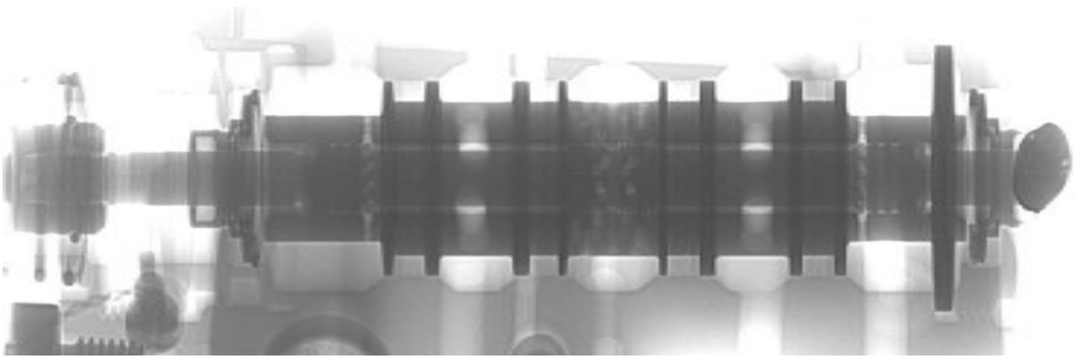


Photo 33**:** DR image of the spool and sleeve

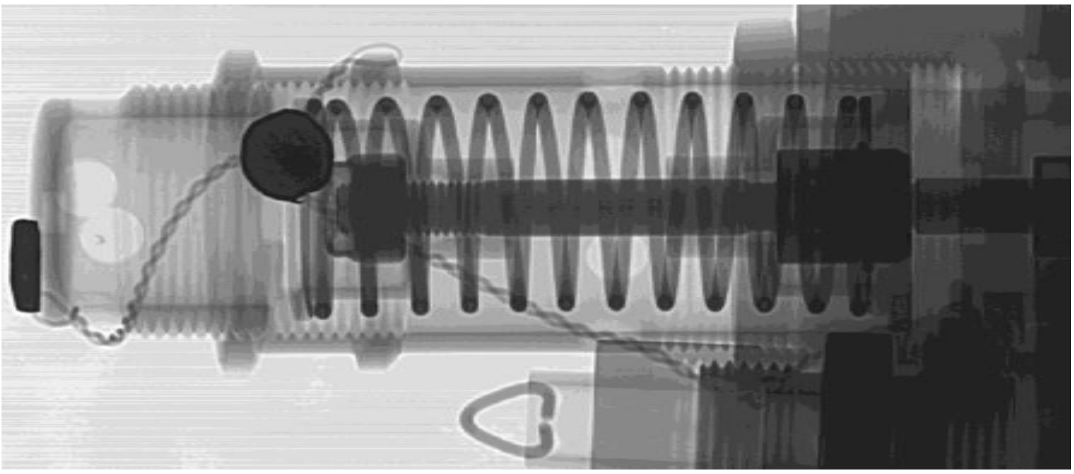


Photo 34**:** DR image of the return spring

The filter cap and filter were removed; see Photo 35 and Photo 36.

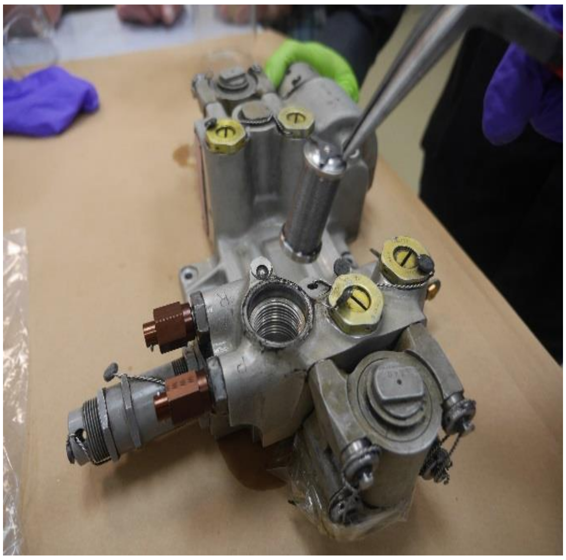


Photo 35**:** Filter being removed from steering metering valve

Photo 36**:** Filter removed from steering metering valve

The filter appeared to be clean and free of debris.

The spool, sleeve and centering spring assemblies were removed from the steering metering valve. After the sleeve was removed, a piece of fibrous debris was found in the body of the steering metering valve inside.

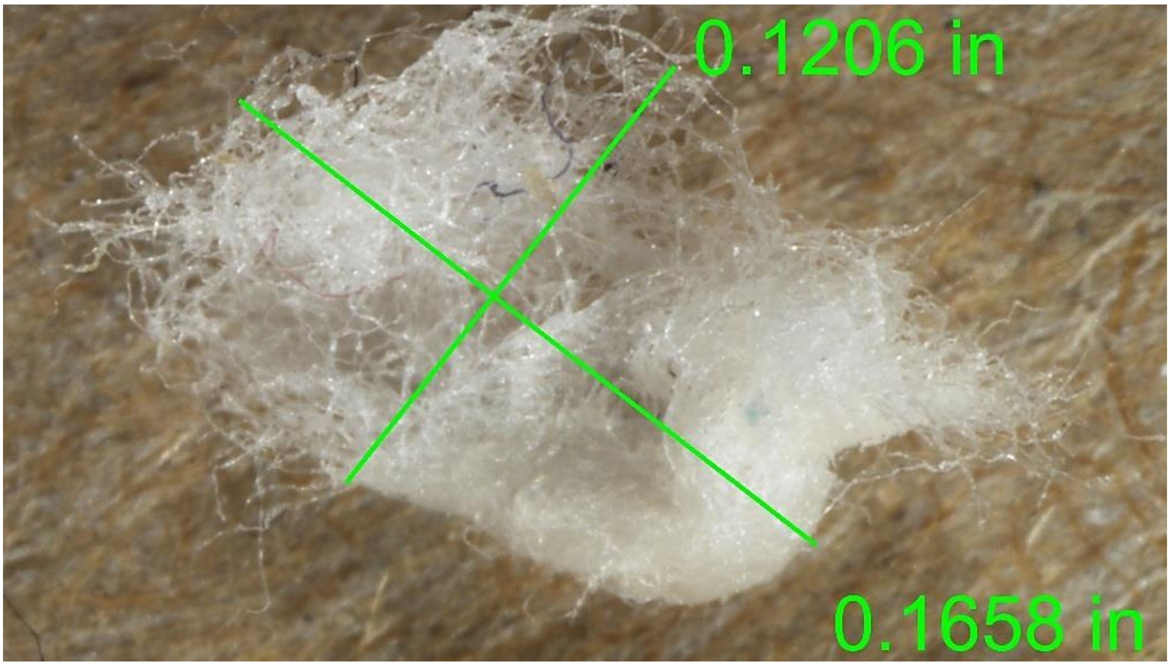


Photo 37**:** Detailed view of fibrous debris with measurements

The fibrous debris that was removed from the steering metering valve was sent to Boeing Research and Technology for material analysis. The fibrous material was identified as cellulose acetate.

The disassembled centering spring assembly, along with other parts associated with the removal of the spool and sleeve assembly.

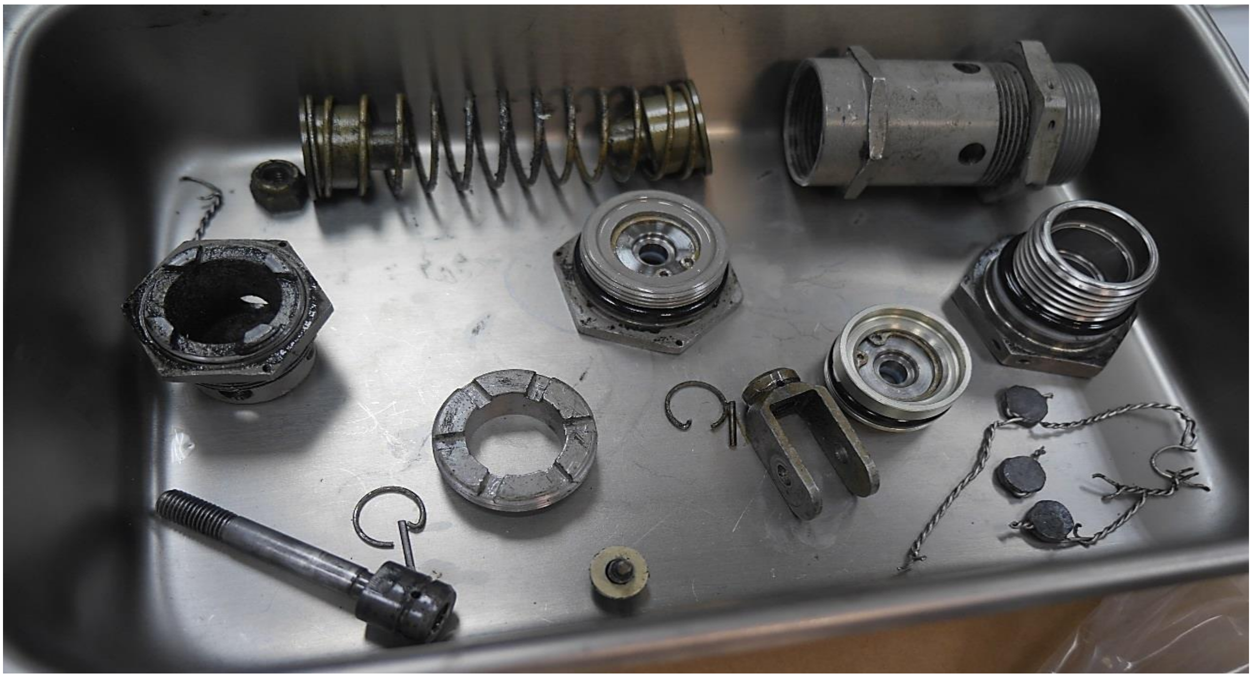


Photo 38: Centering spring assembly, and other parts associated with the spool and sleeve assembly

A borescope was used to examine the interior of the sleeve. A few scratches were found near some of the port holes in the sleeve.
The spool was inserted back into the sleeve and they were placed into the environmental chamber at 225°F, for approximately one hour. The force required to move the spool within the sleeve was measured at approximately 0.1 pound in either direction.
The inlet check valve, cross-over check valve, two bypass check valves, bypass relief valve, bleeder orifice, and orifice filter were removed.

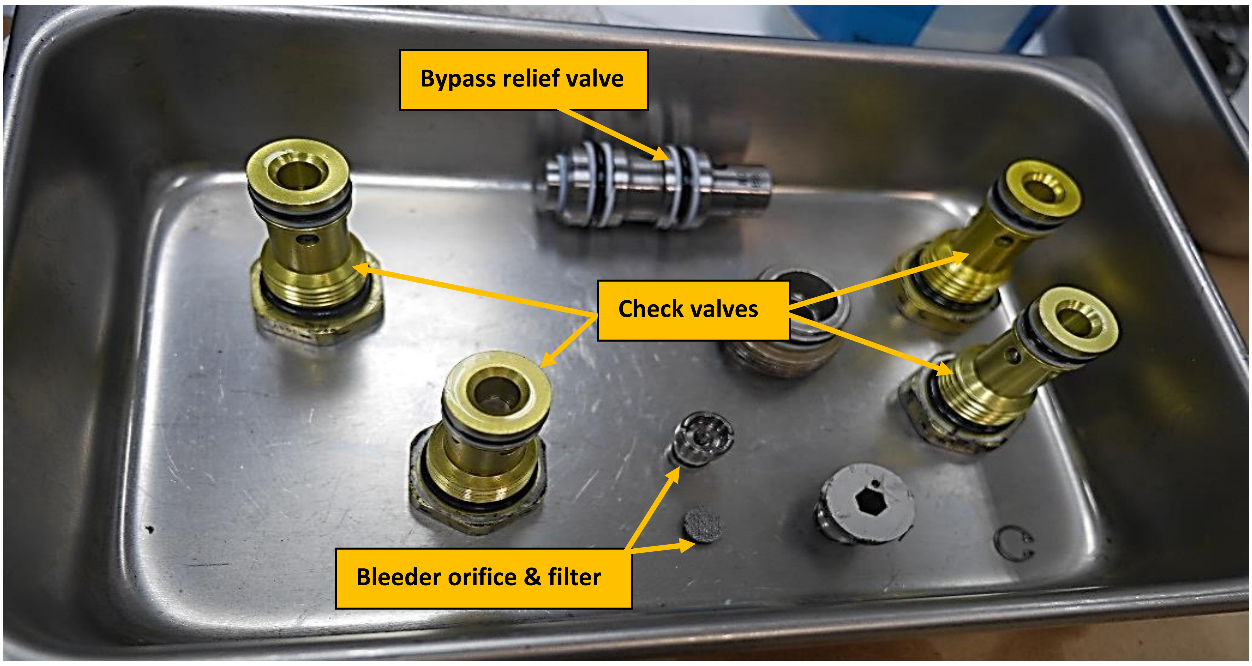


Photo 39: Valves and bleeder orifice removed from steering metering valve

The bleeder orifice filter was a two-layer filter. One layer was coarse mesh, and the other was fine mesh. The filter was separated into the two layers and examined. The fine mesh filter appeared to have debris in it. A tear 0.0255 inch long was found in the fine mesh filter.

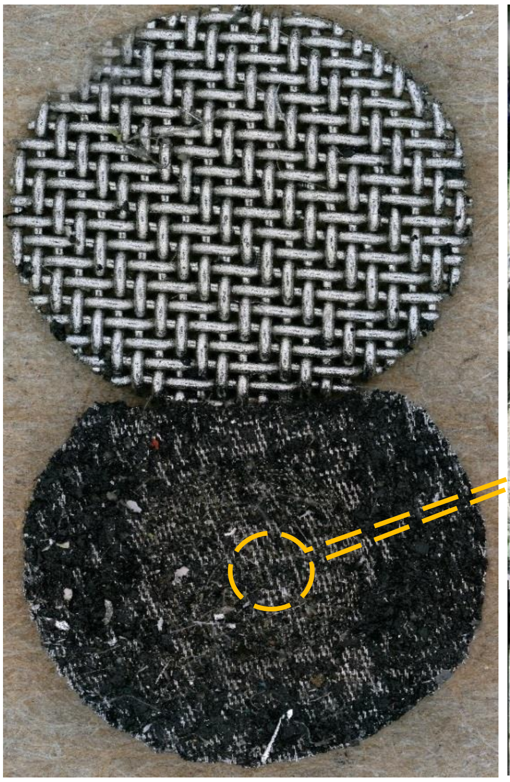


Photo 40a: Bleeder filter separated in two

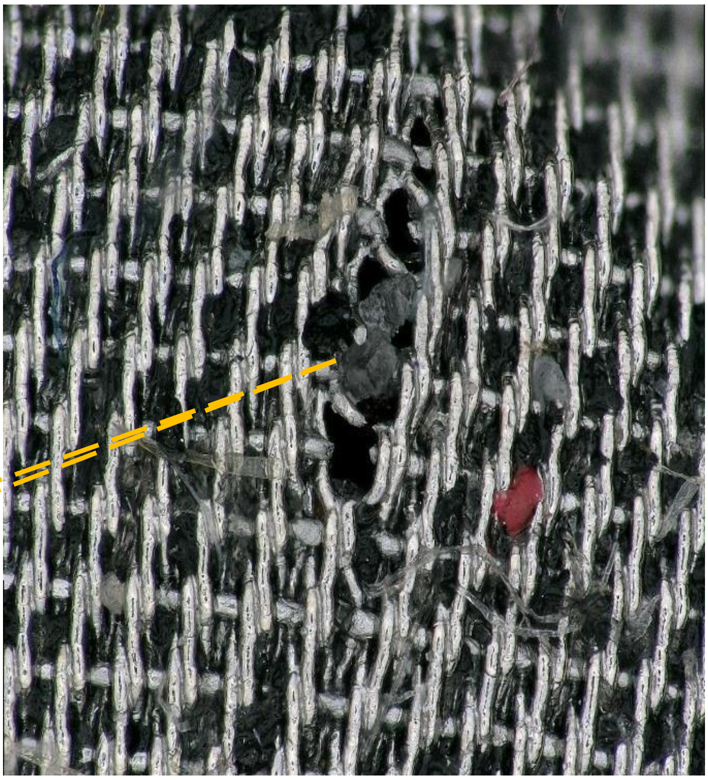


Photo 40b: Magnified view of tear

<u>Conclusion of the Boeing report</u>

Boeing has determined the material can be easily sheared by the motion between the valve's sleeve and spool. Therefore, Boeing does not believe that the presence of this material would interfere with the valve's operation.

1.16.4. Test of the aircraft fuel sample

The aircraft fuel test was carried out at the LATSERT (Latvian Certification Center) in accordance with the standard "LVS EN ISO 12937: 2002" and "LVS EN ISO 12937: 2002 A" on February 22, 2017.
The results of the fuel sample Test Report No 80054 are similar to those of the fuel supplier quality certificate.

1.16.5. Test of the the thrust levers moving

Due to the fact that in the course of the investigation there was no possibility to carry out a thrust levers moving test on running engines after TO/GA button press according to procedure 72-00-42 "Differential Engine Acceleration From Low Idle", therefore was performed a mechanical thrust levers movement check, which not indicated a thrust levers failure or interruption in the thrust levers movement sector.

1.17. Organizational and management information

The aircraft operator VIM-Airlines provided its pilots with a company Standard Operational Procedures in addition to the Boeing aircraft manuals. The company VIM Airlines Operations Manual was primarily designed to address the company procedures <u>(Appendix 5)</u>.

<u>The investigation has been considered and used the following documents:</u>

- Boeing 737-300/400/500 Aircraft Maintenance Manual.

- Boeing B737-500 Flight Crew Operation Manual (FCOM) for VIM-Airlines Boeing aircraft, Document number D6-27370-5Y0-VIM, December 16, 2016;

- Boeing B737 Flight Crew Standard Operational Procedures, delivered with April 21, 2016 by VIM-Airlines company based on the FCOM, FCTM Boeing 737, Boeing company recommendation accordingly ICAO and IATA standards of operation procedures.

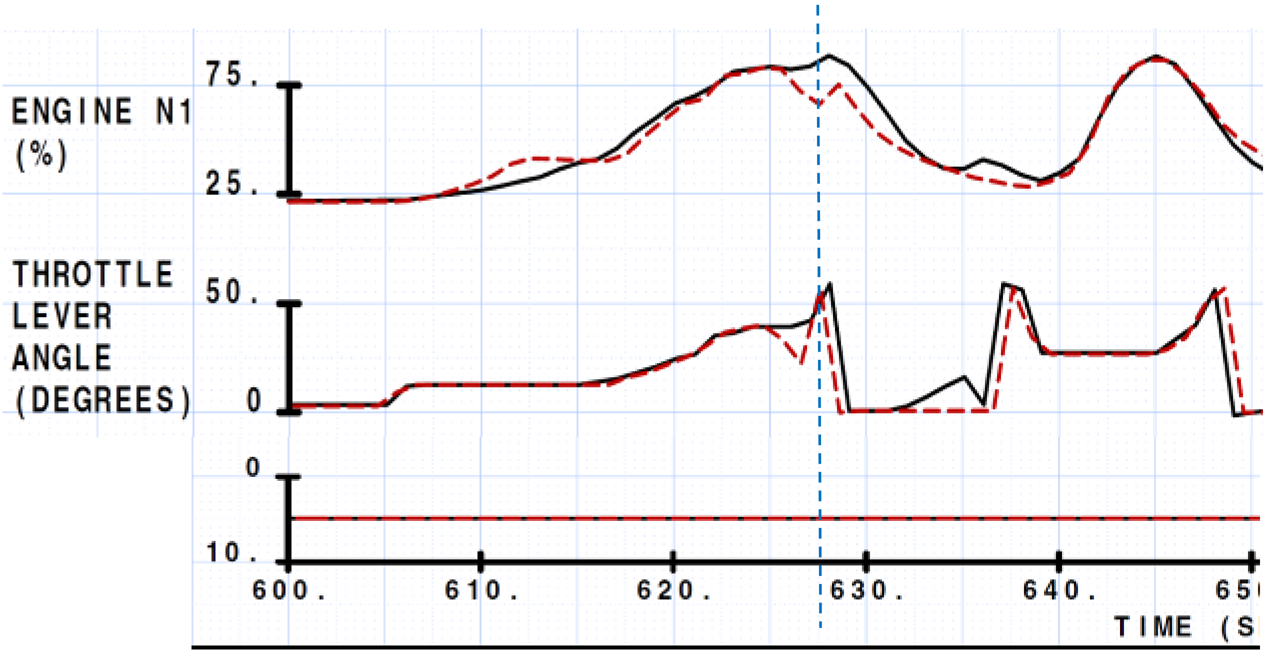
1.18 Additional information

The engine acceleration

High bypass turbo-fan engines of the type found on Boeing 737 aircraft do not accelerate in a linear manner when thrust is increased. The thrust control system consist of a hydromechanical MEC unit and PMC unit mounted on each engine. The PMC is an electronic system with limited authority over the MEC.

The PMC uses MEC power lever angle, N1 speed, and inlet temperature and pressure to adjust, or trim, the MEC to obtain the desired Ni speed. The PMC adjust fuel flow as a function of thrust lever angle.

Aircraft Boeing 737-524, VP-BVS, after TO/GA button press at the take-off roll position the difference of thrust on both engines were reached max approximately 21%, for left engine N1 was 87% and 66% for right engine thrust, which can also be seen from the FDR data plots respective depicted in Fragment 3.



Fragment 3 from FDR data plots of 28.02.2017

1.19 Useful or effective investigation techniques

The incident has been investigated in accordance with Annex 13.

2. ANALYSIS

Scenarios

During the early stages of the takeoff roll and well below V_{mcg} (Minimum control speed on the ground) the engines' thrust asymmetry occurred suddenly that caused the aircraft movement to the right. The PIC [aircraft pilot] attempted to counter the right yaw with full left rudder pedal input but unsuccessfully. The pilot hadn't start immediately RTO, as a result the aircraft left the runway and after colliding with the airport navigation equipment damaged its fuselage and both engines became unserviceable.

Sequence of events

The aircraft was taking off from Riga International Airport (EVRA), before the takeoff the aircraft was standing on the holding point at the center line on the runway 18. At time 617.5 seconds the pilot pressed TO/GA button and the TLA were fluently increased to 40 degrees. When the throttles levers reached 40 degrees, the ground speed was approximately 30 knots and engines' thrust stabilized (FDR data plots). The heading began deviating to the right at time 617.5 and at time 620 seconds the aircraft heading had deviated to the right of the runway's heading. Both engines' thrust accelerated together until 625 seconds and further the left engine's thrust increased without a hitch, but the right engine's thrust reduced rapidly, concurrent to a reduction in the right TLA. The difference of engines' trust N1 was about 21%. The higher thrust from the left engine produced a torque about the aircraft's normal axis, that led to the loss of directional control, which the full left rudder input was capable of arresting.

Note: It's been indicated by Woodward company's experts that when higher acceleration and deceleration schedules on the MEC are observed it is typically the result of mechanical wear in linkages or linkage pins. This is also shown by the attached data plots which show the two engines accelerating together both at 625 seconds and 640 seconds. The right engine lags slightly but this appears to be a result of the TLA movement. This indicates the higher acceleration flows are not an issue on the engine.

Following a right rudder input, most likely to correct a left deviation from the runway centerline, a left rudder input was initiated at time 620 seconds. The aircraft continued to turn right. The left rudder input was increased and at time 622.5 the rudder had reached its trailing edge left limit [the pilot pressed TO/GA button when both engines N1 were around 50%]; suddenly, the airplane started turning right at time 620 until the heading reached 210 degrees at time 631 seconds. As the speed of the aircraft was low the rudder was ineffective and thus the airplane continued turning right.

When the heading deviated 20 degrees right (~200 degrees) of the runway heading, the crew initiated the RTO by pulling the throttles back to idle.

The airplane began turning left at time 632.5 seconds. The crew returned the rudder to neutral shortly before time 640 seconds. Simultaneously, reverse thrust was commanded and aircraft to continue turning left. Maximum brake pressure was commanded in both brakes at time 650 seconds.

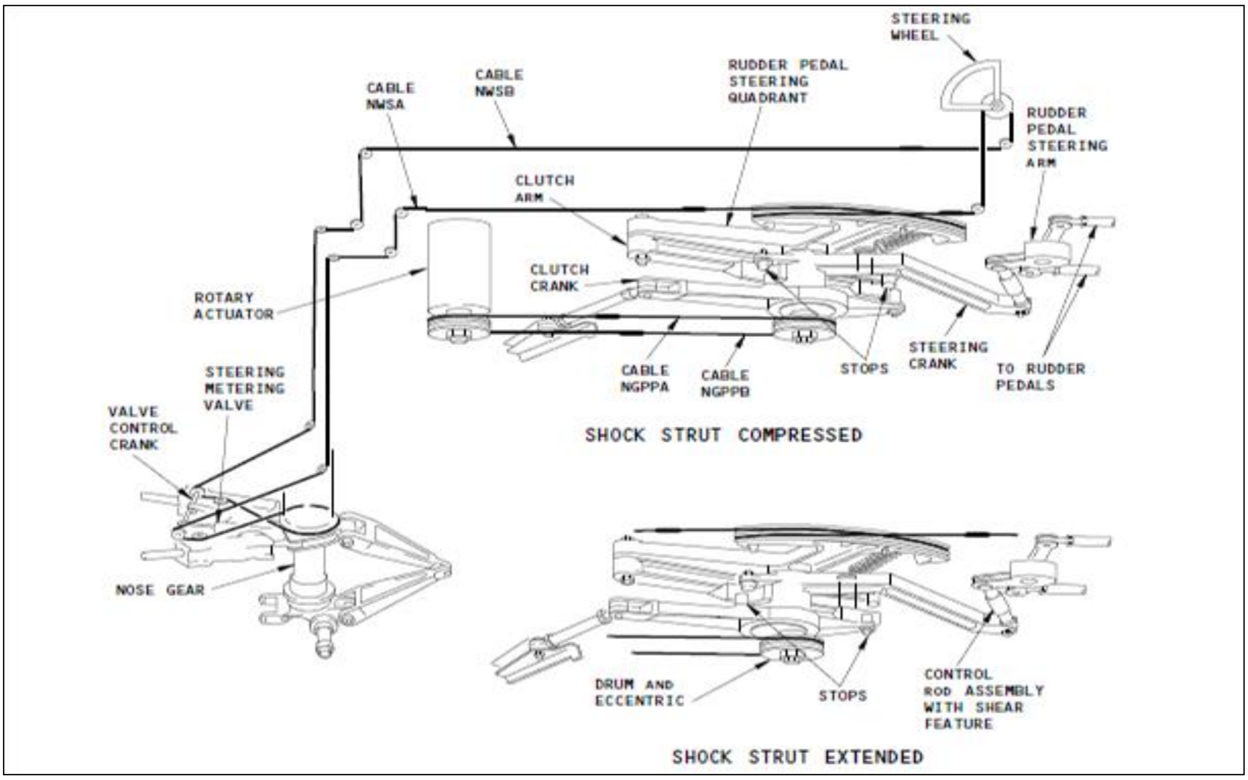
Over 20 degrees of right rudder was commanded at time 655 seconds to arrest the yaw rate to the left. At time 673 seconds the aircraft came to a full stop.

Nose wheel steering

After thrust is set, a small deviation in N_1 between engines should not warrant a decision to reject the takeoff unless this deviation is accompanied by a more serious event.

Use of the nose wheel steering wheel is not recommended above 30 Knots. However, pilots must use caution when using the nose wheel steering wheel above 20 Knots to avoid over-controlling the nose wheel resulting in a possible loss of directional control.

737-345 AWW AMM 32-51-00*: "Rudder pedal steering is available during takeoff, landing, and taxiing when small directional changes are required. <u>Full deflection of the rudder pedals produces about 7 degrees of nose wheel steering</u>."*



Scheme 2: Nose wheel steering Schematic

The insignificant nose wheel deflection (up to 7 degrees) and the low speed on takeoff didn't compensate the aircraft turn to the right through the use of the nose wheel steering pedal. Due to the asymmetric thrust from the engines the moving of the aircraft led to the nose wheel skidding and to the loss of the directional control of the aircraft.

Note: Boeing company technical specialist opinions of Contributing causes "*The nose gear steering metering valve became jammed*" not practically proved because the aircraft nose gear steering metering valve testing results in the BAE Systems laboratory (USA) hadn't showed evidences of the steering metering valve abnormal operation and any technical jamming.

Photo 41, Aircraft takeoff roll trajectory

The smaller space between the trajectory of the right main gear wheel "R" mark and the nose gear wheel "N" mark than the left main gear wheel "L" mark and the nose gear wheel mark evidently points of increasing the aircraft's moving turn right from the runway heading (Photo 41).

Flight Crew operations

Before starting to apply take-off thrust, the aircraft operator's procedures required the crew to:
• align the aircraft with the runway heading
• release the nose-wheel steering wheel
• stabilize both engines at an equal thrust.

Crew actions of rolling takeoff procedure

Flight crew actions in according with VIM-Airlines Boeing 737 Flight Crew Standard Operational Procedures Point 2.4.2 "Takeoff Procedure":

1. Before the TO/GA button switched on;

- The Pilot Flying should advance the thrust levers to approximately 40% N_1, allow the engines stabilize [is important as setting symmetrical thrust], observe engine instruments stabilized and normal.

- The Pilot Monitoring should verify that engines parameters are stable, call "Stable".

2. When the Pilot Flying has pushed the TO/GA switch;

- The Pilot Flying should ensure that thrust levers move towards takeoff N1, follow the movement by hand, and call "Set Takeoff Thrust".

- The Pilot Monitoring should read FMA [Flight Mode Annunciator] N_1, TO/GA, HDG SEL [Heading Select]. When takeoff thrust is set, the PM should call "Thrust set, Parameters Normal", monitor the engine instruments throughout the takeoff, call out any abnormal indications, and adjust the takeoff thrust before 60 knots.

According to the CVR conversation recordings, the Pilot Monitoring hasn't undertaken his duties and hasn't warned the Pilot Flying of the abnormal engine operation, as well as in the Pilot

Monitoring interview it is not mentioned about of any abnormal indications in the takeoff rolling phase.
It was therefore possible that neither of the pilots had the necessary awareness of the engine thrust indications because the crew attention was directed on the aircraft deviation.
This diversion of attention could be a reason why the Pilot Flying hadn't any information about the thrust asymmetry during the start of the takeoff and therefore he wasn't aware of the reason for the difficulty in maintaining of the directional control of the aircraft.
From the Pilot Flying interview and CVR recordings it has been established that, the Pilot Flying believed the difficulty was based on problems with the nose wheel steering.

Crew actions in the Rejected takeoff (RTO)

Flight crew actions in according with Boeing 737 Flight Crew Emergency Operational Procedures in the point 5.7.2 "Rejected takeoff":

The Rejected takeoff (RTO) maneuver during the takeoff roll to expeditiously stop of the aircraft on the runway.

- The Pilot Monitoring should closely monitor essential instruments during the takeoff roll and immediately announce abnormalities calling for example "Engine Failure" or any adverse condition significantly affecting the safety of the flight.
- The Pilot Flying should initiate the RTO procedure.
- The Pilot Flying is responsible for the decision of the RTO. If the decision on the RTO had been accepted, the Pilot Flying should clear announce "Stop (I have Control)" and immediately start the RTO maneuver.
- The Pilot Monitoring verifies his actions following to the Pilot Flying operation and calling out of any omitted action items.

But the FDR data and CVR recordings show that the Pilot Flying hadn't decided to start the Rejected takeoff procedure when the airplane deviated heading more than 20 degrees and the aircraft was from the runway.

Crew action in Runway excursion

According with the VIM-Airline's Flight Operation Manual Article 6.12.1 "Flight crew action in Runway excursion":

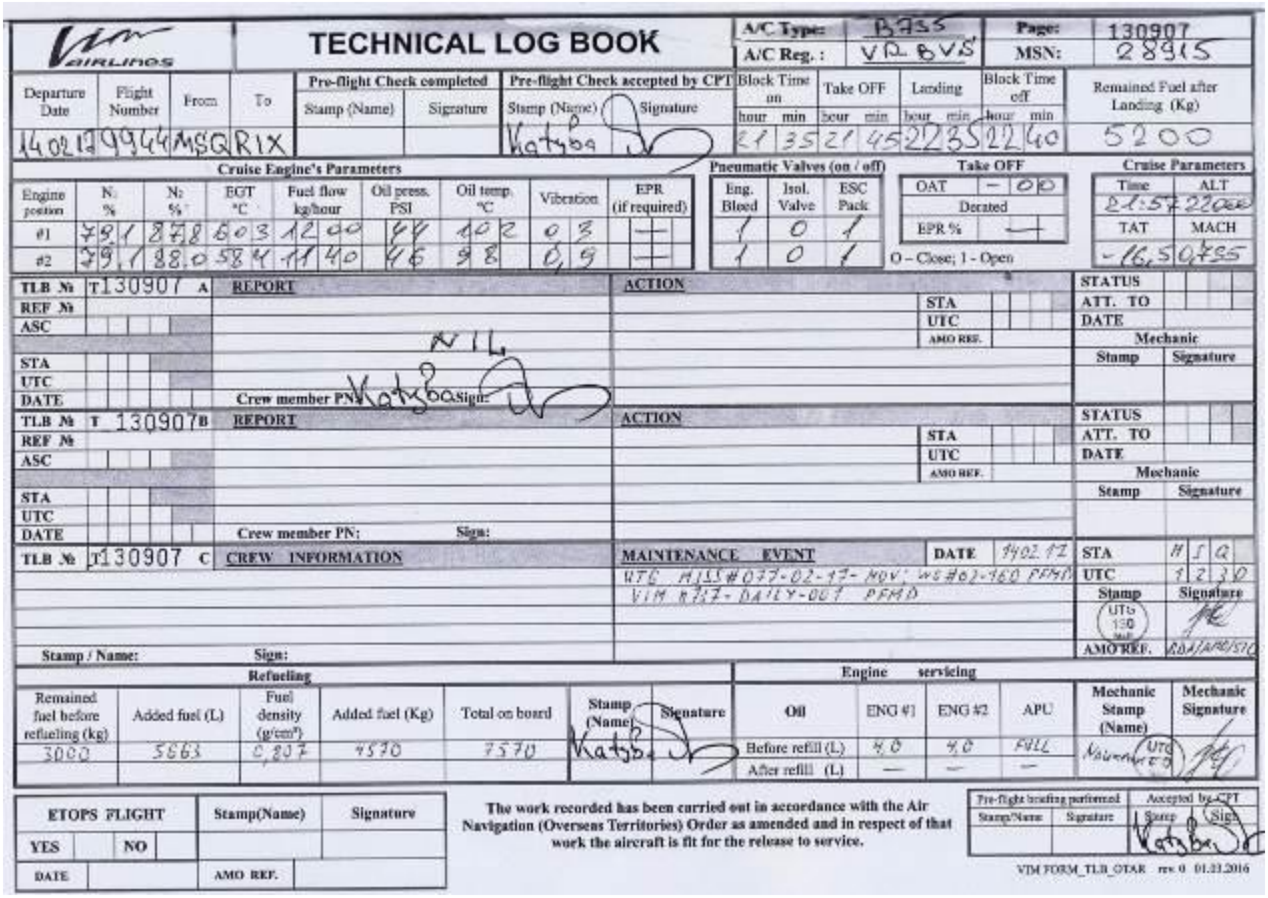
- Check the pressure of the hydraulic system.
- <u>Don't attempt continue taxi after run off from runway.</u>
- <u>Shut down engines</u> if they not be switched off before skidding from Runway.
- Register the time of event.
- Inform Tower supervisor about event and require airport traffic controller of Runway Friction coefficient.
- Require of towing vehicle and, etc.

According to the FDR data the aircraft continued to move to the right from the straight line, partial braking had been applied to the left main wheels at 628 seconds. The aircraft left the RWY at 630 seconds.The PIC hadn't stopped the aircraft but continued moving about 600 m.
No skid marks of wheels were found on the runway surface after using of brakes of the main landing gears (Photo 43).

Photo 43, Runway 18 right border

Crew action due to technical failure information

The flight crew didn't report about any engine anomalies neither before the occurred serious incident nor in their interviews after the incident. The information of the similar situation in Minsk airport was clarified from the downloaded CVR data (see point 1.11.1) after the serious incident in Riga International Airport.



VIM AIRLINES — TECHNICAL LOG BOOK

A/C Type: B755 | A/C Reg.: VP-BVS | Page: 130907 | MSN: 28915

Departure Date	Flight Number	From	To	Pre-flight Check completed: Stamp (Name)	Signature	Pre-flight Check accepted by CPT: Stamp (Name)	Signature	Block Time on (hour min)	Take OFF (hour min)	Landing (hour min)	Block Time off (hour min)	Remained Fuel after Landing (Kg)
14 02 17	9944	MSQ	RIX			Katyba		21 35	21 45	22 35	22 40	5200

Cruise Engine's Parameters

Engine position	N1 %	N2 %	EGT °C	Fuel flow kg/hour	Oil press. PSI	Oil temp. °C	Vibration	EPR (if required)
#1	79.1	87.8	603	1200	44	102	0.3	—
#2	79.1	88.0	584	1140	46	98	0.9	—

Pneumatic Valves (on / off)

Eng. Bleed	Isol. Valve	ESC Pack
1	0	1
1	0	1

O – Close; 1 - Open

Take OFF: OAT −00; Derated; EPR % —

Cruise Parameters: Time 21:57; ALT 22000; TAT −16.5; MACH 0.755

TLB № T130907 A — REPORT: NIL — Crew member PN: Katyba Sign: — ACTION — STA / UTC / AMO REF. — STATUS / ATT. TO / DATE / Mechanic Stamp / Signature

TLB № T 130907B — REPORT — Crew member PN: Sign: — ACTION — STA / UTC / AMO REF. — STATUS / ATT. TO / DATE / Mechanic Stamp / Signature

TLB № T130907 C — CREW INFORMATION — Stamp / Name: Sign:

MAINTENANCE EVENT — DATE 14.02.17 — STA MSQ — UTC 1230
UTG MISS#077-02-17- MOV; WS#02-160 PFMD
VIM B757-DAILY-001 PFMD
Stamp: UTG 150 — Signature — AMO REF. RDA/AMO/510

Refueling

Remained fuel before refueling (kg)	Added fuel (L)	Fuel density (g/cm³)	Added fuel (Kg)	Total on board	Stamp (Name)	Signature
3000	5663	0,807	4570	7570	Katyba	

Engine servicing

Oil	ENG #1	ENG #2	APU	Mechanic Stamp (Name)	Mechanic Signature
Before refill (L)	4.0	4.0	FULL		
After refill (L)	—	—	—		

ETOPS FLIGHT: YES / NO — Stamp(Name) — Signature — DATE — AMO REF.

The work recorded has been carried out in accordance with the Air Navigation (Overseas Territories) Order as amended and in respect of that work the aircraft is fit for the release to service.

Pre-flight briefing performed: Stamp/Name, Signature — Accepted by CPT: Stamp, Sign: Katyba

VIM FORM_TLB_OTAR rev 0 01.11.2016

Photo 42, Flight Minsk – Riga on February14, 2017

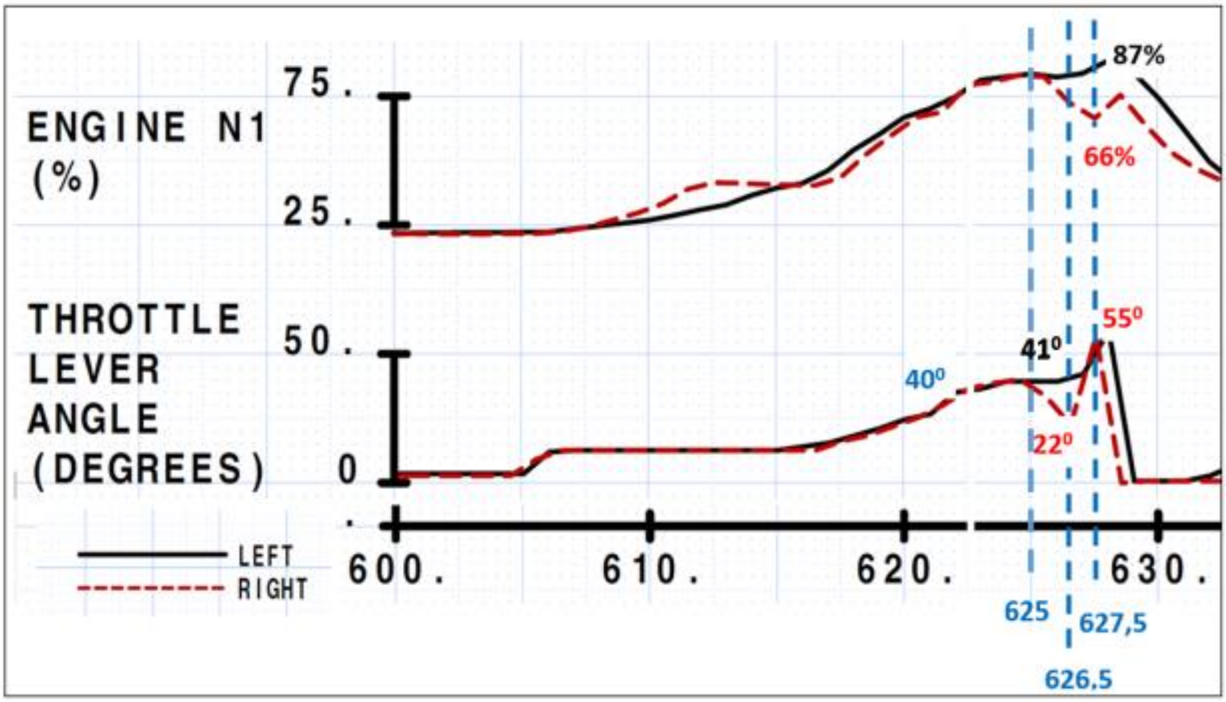
Note: As the flight crew hadn't reported in the aircraft Technical Log Book of any technical failures in the previous flight (Photo 42), the maintenance company in Riga International airport didn't accomplish any check procedures for the thrust control system according with the Aircraft Maintenance Manual AMM 71-00-49, Figure 101 "Thrust Lever Binding" and Figure 104 "Thrust Lever Does Not Move During Autothrottle Operation" to prevent this serious incident.

Unsynchronic trust lever operation

Regardless of which pilot is making the takeoff, the Pilot Flying should keep one hand on the thrust lever until V1 in order to respond quickly to a rejected takeoff condition.

The aircraft FDR data show possible unsynchronic movement of the aircraft thrust levers that appeared after the TO/GA button was pressed. Until 625 seconds both thrust levers (TLA) had moved equally, but suddenly the thrust control of the right and left engines developed unsynchronic movement (Excerpt 4 from FDR data plots of 24.04.2017). At 626.5 seconds the thrust levers position difference became 19 degrees, the left - 41^0 and the right - 22^0 accordingly. At 627.5 seconds the thrust levers sync had reverted.

The difference of the aircraft thrust levers moving approved graphically, because the PMC and MEC units technical examination results didn't established it influenced movement of the thrust levers as well as not possible performed the check procedures for the thrust levers operation on the running engines. In the context of the above mentioned it is possible thrust levers unsynchronic moving due to technical scuffing, as a result the Pilot Flying hadn't noticed thrust difference and didn't initiate the RTO procedure in according with Boeing 737 Flight Crew Emergency Operational point 5.7.2 "Rejected takeoff".



Excerpt 4 from FDR data plots of 24.04.2017

The max difference of the engines N_1 thrust (Excerpt 4 from FDR data plots of 24.04.2017) happened 1 second later after TLA failure that depends on the thrust control system inertly. The indication of the retarded operation of the thrust N_1 control system of the right engine is explained in 737-345 AWW AMM 76-11-00: "*B. The forward thrust control system consists of a thrust lever* *assembly for each engine, connected to each main engine control (MEC) by control cables, an engine control drum and a push-pull cable. The forward thrust control system regulates the engine fuel flow and hence forward thrust".*

3. CONCLUSIONS

During the process of the investigation the following conclusions were made and these are not to be read as apportioning blame or liability to any particular organization or individual.

3.1 Findings

- The engine thrust on the both engines was stabilized before the Take-Off/Go-Around (TO/GA) button was pressed.
- At the initial stage of the aircraft takeoff the flight crew attention was focusing on the aligning of the aircraft to the runway centerline.
- The FO (Pilot Monitoring) hadn't monitored the engine parameters during of takeoff roll and didn't announce timely when the difference of engines' thrust increased.
- After the TO/GA had been engaged, the thrust levers (TLA) had moved not synchronically within 2.5 seconds.
- The aircraft engines' thrust difference during the early stages of the takeoff roll initiated the torque about the aircraft's normal axis that led to the loss of directional control.
- The nose wheel steering had been turned to the left with full left rudder pedal and was not released before thrust increased.
- The rejected takeoff (RTO) wasn't initiated with the application of maximum wheel braking.
- The nose wheel steering below V_{mcg} was ineffective; the asymmetric thrust of the led to the nose wheel skidding.
- The pilot (PIC) didn't attempt to stop the aircraft and continued the moving after run off the runway without regard to Flight Operation Manual requirements.
- The aircraft flight crew didn't accomplish the Non-standard Operational Procedures requirements in the runway excursion.
- The aircraft flight crew didn't inform the airport Riga Maintenance Company about the similar problem with the aircraft in the previous flight.

3.2 Causes

3.2.1 Proximate Cause

The flight crew operation was not coordinated in accordance with the take-off procedure.

3.2.2 Root Cause

- The FO (copilot) didn't act upon the aircraft Flight Manual requirements in the takeoff procedure.
- Insufficient training skills of the flight crew in the Standard Operational Procedures.
- The flight crew didn't report of any technical failures in the previous flight.

3.2.3 Contributing causes

- Short-term technical failure of the thrust control system.
- The rejected takeoff (RTO) procedure wasn't initiated immediately after the technical abnormality.
- Erroneous decision to continue the moving after the run off from the runway surface.

3.2.4 Primary cause

Human Factor in an abnormal flight situation.

4. SAFETY RECOMENDATIONS

The Transport Accident and Incident Investigation Bureau (TAIIB) following Safety Recommendations were addressed to the Federal Air Transport Agency (Rosaviatsia):

Recommendation – LV 2018-001

Due to the flight crew operations and disagreements in the Takeoff Procedure according with the Flight Crew Manual, the TAIIB recommended to Rosavacia to consider the necessity to make possible some amendments in the Pilot Training programs for recurrent and the induction training included briefing and assessment on the correct procedure for start of the takeoff roll, including the runway alignment prior to thrust application, the engine stabilization with symmetrical thrust after thrust levers to takeoff thrust (to switch TO/GA) and the use of the nose-wheel steering wheel during the takeoff.

Recommendation LV 2018-002

Due to the flight crew's erroneous actions in a non-standard situation (Runway excursion), **TAIIB recommended to the Rosaviatsia** to review the Pilot Training programs of aircraft operators and consider the necessity to include in the training syllabus for recurrent the analyses of occurred aviation incidents to train the flight crews in abnormal flight situations.

Riga, September 07, 2018

Investigator in Charge — Vilis Ķipurs

Head of the Aircraft Accident and
Incident Investigation Department — Visvaldis Trubs

Director of the Transport Accident and
Incident Investigation Bureau — Ivars Alfrēds Gaveika