NATIONAL BUREAU
OF AIR ACCIDENTS INVESTIGATION OF UKRAINE

ACCIDENT

FINAL REPORT

RUNWAY EXCURSION AT LANDING AT KYIV (ZHULYANY) AERODROME

AIRCRAFT OPERATOR:	Bravo Airways
AIRCRAFT TYPE:	DC-9-83 (MD-83)
REGISTRATION NUMBER:	UR-CPR
PLACE OF OCCURRENCE:	Kyiv (Zhulyany) Aerodrome
STATE OF OCCURRENCE:	UKRAINE
DATE OF OCCURRENCE:	June 14, 2018

The report is published for the sole purpose of air accidents prevention in the future

APPROVED

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Igor MISHARIN
Acting Director
National Bureau of
Air Accidents Investigation
"___" October 2020

FINAL REPORT

of Investigation into Accident (Runway Excursion), Which Took Place with MD-83, Reg. UR-CPR, Aircraft on June 14, 2018, at Landing at Kyiv (Zhulyany) Aerodrome

City of Kyiv **June 14, 2019**

The investigation into the accident was conducted by the Investigation Team of the National Bureau of Air Accidents Investigation of Ukraine (hereinafter referred to as NBAAI.)

Brief Description of Occurrence (ACCIDENT)

Aircraft Operator:	Bravo Airways
Aircraft Type and Registration:	MD-83 UR-CPR
Number and Type of Engines:	2, Pratt&Whitney - JT8-219 s/n 728120; JT8-219 s/n 717873
Occurrence Date and Time:	June 14, 2018, 05:40 pm UTC (08:40 pm local time)

On June 14, 2018, in the afternoon, in the thunderstorm activity conditions, at 05:40 pm UTC, at landing on the wet Runway 08 covered with water layer up to 3 mm at the aerodrome of the Kyiv International Airport (Zhulyany) (hereinafter referred to as Kyiv (Zhulyany) Aerodrome), the MD-83 UR-CPR aircraft of Bravo Airways operating the flight BAY 4406 en-route Antalya Airport, Turkey – Kyiv International Airport (Zhulyany), Ukraine, suffered a runway excursion.

Note: Hereinafter, Universal Coordinated Time (UTC) is indicated. The difference between the local time and UTC is +3 hours.

The accident report was received by NBAAI on 14.06.2018 from the Central Dispatch Service of the State Aviation Administration of Ukraine, and on June 15, 2018 – from Municipal Enterprise (ME) Kyiv International Airport (Zhulyany.) From Bravo Airways, the report about the accident was not forwarded to NBAAI. In turn, according to item 4.1 of Annex 13 to the Convention on International Civil Aviation, on June 15, 2018, NBAAI forwarded the report about the accident to the US National Transportation Safety Board (NTSB), i.e. to the State of Design and Manufacture. NTSB appointed the Accredited Representative and respectively informed NBAAI on June, 18, 2018.

According to the Standards and the Recommended Practices of the International Civil Aviation Organization, this report is published for the sole purpose of prevention of air accidents in the future.

The present report and materials of the technical investigation cannot be used by administrative, official, public prosecutor's, judicial authorities, insurers for establishment of fault or responsibility (according to requirements of Art. 119 of the Air Code of Ukraine.)

The investigation has been conducted according to provisions of the Annex 13 to the Convention on International Civil Aviation.

The Final Report shall be forwarded to the following addressees:

- National Bureau of Air Accidents Investigation (original copy);
- State Aviation Administration of Ukraine (copy);
- Bravo Airways (copy);
- ME Kyiv International Airport (Zhulyany) (copy);
- Ukrainian State Air Traffic Services Enterprise (copy);
- International Civil Aviation Organization (copy);
- US National Transportation Safety Board (NTSB) (copy);

The investigation was launched on June 14, 2018 and completed on June 14, 2019.

List of Abbreviations Used in Report

CVR	- Cockpit Voice Recorder
CTR	- Control Traffic Region (control area);
FDR	- Flight Data Recorder
FL	- flight level;
FPL	- flight plan;
ICAO	- International Civil Aviation Organization
ILS	- Instrument Landing System
METAR	- regular METeorological Airport Report in a coded form;
NOTAM	- NOTice to AirMen – a notice delivered by means of telecommunication. It contains the information on introduction, status or change of any air navigation equipment, service and rules; or information on danger, timely prevention of which is important for the personnel involved in the flight operation;
OM	- Operation Manual
PCN	- Pavement Classification Number
P/N	- part number;
S/N	- serial number;
SPECI	- Aviation Selected Special Weather Report for the aerodrome in a coded form;
TAF	- weather forecast for the aerodrome;
TMA	- terminal control (maneuvering) area;
QFE	- atmospheric pressure on the runway;
QNH	- Altitude above mean sea level;
RVR	- Runway visibility range;
UTC	- Universal Time Coordinated;

Contents

1. Factual Information

1.1 Flight History

On June 14, 2018, according to the flight assignment, BAY 4406 charter flight en-route Antalya - Kyiv (Zhulyany) on MD-83 aircraft, state and registration number UR-CPR of Bravo Airways, was operated by PIC, co-pilot and five flight attendants.

According to PIC's Statement, the flight was delayed by 6 hours (departure time - 03:30 pm.) The Investigation Team did not establish the departure time from Antalya Airport. According to the PIC, the crew arrived at the airport at 02:00 pm. The take-off time was 03:41 pm. The airline said the flight was delayed because of the aircraft non-arrival.

Bravo Airways is the aircraft operator responsible for the flight and technical operation of the aircraft, maintaining its airworthiness and ensuring the flight safety.

The Pilot Flying duties were performed by the PIC, and the Pilot Monitoring was the co-pilot. In accordance with the flight assignment, the PIC cross checked the co-pilot.

According to his Statement, the flight preparation of the crew was carried out one and a half hours before the actual departure at Antalya Airport (PIC received aeronautical and meteorological information from a representative of Turkish Ground Services), after which, the PIC took a decision to perform the flight.

Note: Investigation Team could not receive evidential documentation about carrying out by crew of flight preparation at the Antalya Airport in full.

Climb and level flight were performed in a normal mode.

Landing approach was carried out to RW08 in the conditions of thunderstorm activity with ILS system. At 05:40 pm, at landing on the aerodrome of the Kyiv International Airport (Zhulyany) (hereinafter – Kyiv (Zhulyany) Aerodrome), during the landing run, at the distance of 1260 m from the entrance threshold, the aircraft suffered a runway excursion to the left of the air strip and stopped outside the cleared and graded area of the air strip at the distance of 123 m from the runway center line (according to the tire footprints at the occurrence site.) As a result of the accident, the aircraft has sustained substantial damage, in particular, to the structural elements. None of passengers or crew members received serious injuries.

Photo 1

Aircraft runway excursion site

1.2 Injuries

Onboard the aircraft, there were 169 passengers and 7 crew members – all citizens of Ukraine.

Injuries	Crew	Passengers	Other Persons
Fatal	0 / 0	0 / 0	0 / 0
Serious	0 / 0	0 / 0	0 / 0
Minor/None	0 / 7	9/160	0 / 0

Following the accident, 26 passengers have filed health complaints with the medical aid station of the airport. According to an extract from the Medical Aid Station Log, as a result of the accident, 9 passengers received minor injuries (bruises of soft tissues, scratches, grazes), in particular, 5 passengers were injured during evacuation, 4 – during the runway excursion. 17 more passengers visited the medical aid station with complaints on stress resulted from the emotional upset.

1.3 Aircraft Damage

According to the Certificate of Release to Service and Inspection of MD-83 UR-CPR Aircraft dated 05.07.2018 approved by the General Director of Bravo Airways, it is established that:

1) On June 14, 2018, the aircraft works were executed in the volume of SERVICE CHECK, DAILY CHECK, BEFORE DEPARTURE CHECK reflected by a record No. 026782 in AIRCRAFT TECHNICAL LOG (the aircraft log book). At the time of departure from the base Kyiv International Airport (Zhulyany), the aircraft was operable, there were no critical comments on the technical equipment.

2) as a result of the accident, the aircraft sustained the following damage:

- lower front VHF p/n S65-8262DC10A antenna was broken off (destroyed)

- slat No.1 of the right wing was damaged at the end part (substantial damage)

- flaps fitting fairing – 5 pieces of the right wing were damaged (substantial damage)

- flaps of the right wing, in root section are crumpled, the second part is crumpled with shift (substantial damage)

- main right landing gear MLG p/n5930999-5504 s/n606959 was broken (destructed), the landing gear door was also broken and jammed by the undercarriage (destroyed) (see Photo)

Photo 2

Location of main right landing gear destruction

- landing lamp p/n 45-0067-9 of the right wing was pulled out (destroyed)
- logo light p/n 7910525-505 of the right wing was broken (destroyed)
- fuselage skin from emergency door to back luggage hold was corrugated (substantial damage)
- upper aircraft in root section of the right wing was punched (substantial damage)
- left anti collision p/n 30-1099-1A was broken (destroyed)
- left MLG p/n 5930999-5503 s/n 477753 was broken (destroyed)
- left logo light p/n 7910525-505 has damaged electric cables and fittings (minor damage)
- AFT position light p/n GE 16720-010-6 was broken (minor damage)
- second rail of the left flap was broken (destroyed)
- left wing top panels were damaged (substantial damages)
- brake flap cylinder and brake flap itself were damaged (substantial damage)
- left main gear support frame was damaged (destroyed)
- electric cables and tubes of the landing gear hydraulic system were damaged (substantial damage)
- transverse beam of the first monorail fitting was damaged (destroyed)
- root section of the left wing flap was damaged (destroyed)

- left landing gear door was damaged (destroyed)
- second fairing of the flap rail was damaged (destroyed.)

The NBAAI Investigation Team, together with the engineering personnel of Bravo Airways, performed the works subject to AMM 05-51-03 "HIGH DRAG/SIDE LOADS OR UNUSUAL GROUND HANDLING CONDITIONS-CHECK" (the aircraft inspection after application of heavy braking, runway excursion to the soil, considerable lateral loads, etc.)

Inspection and check of the aircraft engines was executed – damage was not found.

Inspection of wheels of the nose and main landing gear was conducted according to the AMM 32-40-00 "WHEELS AND BRAKES-INSPECTION/CHECK" TASK CARD 32-40-00-720-801. According to the above documents, the wheels are in conformity with the specifications.

Inspection of brakes according to AMM 32-40-00 was executed; the brakes are in conformity with the specifications.

ANTI-SKID SYSTEM (skid sensors) operation had no critical remarks. Check of ANTI-SKID SYSTEM was conducted according to TASK CARD 32-045-01-01 "DUAL ANTI-SKID CONTROL VALVES" CHECK C2.

The nose gear control had no critical remarks. The landing gear turned by the angle input synchronously with the control handle.

A kerosene smell was present at the aircraft site. At the aircraft recovery, the fuel spilled out from the right wing.

1.4 Other Damage

As a result of the runway excursion, two runway side row lights – No. 89 and No. 90 – were brought down. The lights were completely destroyed beyond repair and were recovered by the flight electrical and lighting service by way of replacement with the new ones.

1.5 Personnel Data

a) Crew Data:

Position	Aircraft PIC
Sex	Male
Date of Birth	27.11.1972
Education	Higher, Balashovsky VVAUL, 1995
Total Flight Hours	11548
PIC's Hours	2639
Flight Hours on the Type	5580
Flight Hours for June 13, 2018	0
Flight Hours for Accident Day: June 14, 2018	02 h. 00 min.
Flight Hours for Last 90 days	189
Meteorological Minimum	CAT I ICAO; (DH = 200 ft; RVR = 550m; LVTO = 400m)
Number and Period of Validity of Pilot Certificate	Certificate of Transport Pilot TA No. 004172, Validity period till 23.04.2019
Medical Certificate	Class – 1. Validity period – till 30.04.2019
Date of Last Qualification (Professional) Check	20.03.2018
Date of Last Flight (Certification) Check	20.07.2017
Date of Advanced Training in Aircraft Type Completion	11.10.2017 (valid for 1 year)
Period of Validity of ICAO Certificate of 4th Level of English Proficiency	03.10.2018

Position	Co-pilot
Sex	Male

Date of Birth	06.03.1960
Education	Higher, State Flight Academy of CA of Ukraine
Total Flight Hours	12514
Flight Hours on the Type	3580
Flight Hours for June 13, 2018	0
Flight Hours for Accident Day: June 14, 2018	02 h 00 min
Flight Hours for Last 90 days	177
Meteorological Minimum	Not specified in Pilot's Certificate
Number and Period of Validity of Pilot Certificate	Certificate of Transport Pilot TA No.002473, Validity Period – till 23.03.2019
Medical Certificate	Class 1. Validity Period – till 23.03.2019
Date of Last Qualification (Professional) Check	19.12.2017
Date of Last Flight (Certification) Check	08.06.2018
Date of Advanced Type-Training Course Completion	25.01.2018 (valid for 1 year)
Period of Validity of ICAO Certificate of 4th Level of English Proficiency	06.12.2018

The break between the previous and last flights of the crew was more than 24 hours. According to PIC, the crew rested at a hotel before performance of the flight.

The crew earlier repeatedly carried out flights to the Kyiv (Zhulyany) Aerodrome.

b) Aerodrome Service Personnel Data

Shift aerodrome service engineer

Age – 24 years old.

Education – complete higher education, National Aviation University, 2015, specialty – Highways and Aerodromes (specialist.)

Aviation work experience – 3 years.

Work experience at the position occupied – 3 years.

Retraining: Aerodrome Flight Support, National Aviation University, April 2016.

c) ATS Personnel Data

Airways ATC Supervisor, born in 1985.

Place of work – Kyiv ACC.

Air Traffic Service Controller Certificate – TC001968.

Validity of the Medical Certificate is till 25.05.2019.

Education – complete Specialized Higher Education, DLAU (Specialist), Kirovograd, 2007.

Flight Operations Director Courses – 2010.

Qualification Support – Leadership Retraining Courses, 2015.

Qualification Development – English Language Testing, 2016.

Instructor Courses – 2016.

ACC Flight Operations Director – chief of duty shift, born in 1980.

Place of work - Kyiv ACC.

Air Traffic Service Controller Certificate - TC001671.

Validity of the Medical Certificate – till 01.09.2019.

Education – complete Specialized Higher Education, DLAU (Specialist), Kirovograd, 2002.

Flight Operations Director Courses – 2006.

Qualification Support – Leadership Training Courses, 2016.

Qualification Development – English Language Testing, 2016.

Instructor Courses – 2015.

ATC Controller, born in 1966.

Place of work – Kyiv ACC.

Air Traffic Service Controller Certificate - TC000656.

Validity of the Medical Certificate – till 10.10.2019.

Education - Secondary Specialized, RLTU CA, Riga, 1989.

Qualification Support - Instructor Retraining Courses, 2014.

Qualification Development – English Language Testing, 2017.

Instructor Courses - 2009.

Flight Operations Director, born in 1959

Education – complete higher education, KII CA.

Air Traffic Service Controller Certificate – valid, effective till April 5, 2020.

Medical Certificate is valid.

ICAO Level 4 English Proficiency (until November 30, 2020.)

Admitted to work as the Tower Flight Operations Director.

ATC Tower Controller, born in 1978

Education - complete higher education, DLAU.

Traffic Service Controller Certificate is valid, the validity term – till November 08, 2019.

Medical Certificate is valid.

ICAO Level 4 English proficiency (until January 25, 2020).

1.6 Aircraft Data

Aircraft type	MD-83
State and registration number	UR-CPR
Serial number, MSN	49946
Manufacturing plant	McDonnell Douglas - Boeing USA
Aircraft manufacture date	01.09.1991
Aircraft owner	"AIR FLEET MANAGEMENT S. A. L.", Lebanon, Beirut
Aircraft operator	Bravo Airways
Aircraft registration certificate	No. RP 4397 Issued by State Aviation Administration on 29.11.2016, validity period - till 31.10.2019
Airworthiness Certificate	No. 0679 of 30.11.2016

Airworthiness Review Certificate	No. 0679/1 from 30.11.2017 valid through 29.11.2018.
Flight hours since the beginning of operation	43105
Number of cycles from the beginning of operation	46810
Last basic maintenance under Form 1A, 2A, 4A, 1C Check + ADD works at Bravo Airways. Certificate of Release to Service of 22.03.2018 No.BR70.	22.03.2018 (at flight hours of 42115 h and 46 474 cycles)
CHECK 1A, 2A Check Bravo Airways Certificate of Release to Service of 04.06.2018 No. BR80.	04.06.2018 (at flight hours of 42975 h and 46761 cycles)
Service check MD80 SVC No. 05-001-02-01	June 14, 2018
Preflight inspection "PFI" at the Antalya Airport	Completed in volume of "Preflight inspection" June 14, 2018.

Engine Data

Engine	**Left**	**Right**
Engine type	JT8-219	
Manufacture date	01.10.1996	01.04.1987
Serial number of engine	728120	717873
Manufacturer	Pratt&Whitney (USA)	
Total time since placed in service (hours, cycles)	43857 hours, 22846 cycles	72941 hours, 37643 cycles
Date and place of the last repair	03.11.2016, Global Engine Maintenance, USA	16.01.2017, Aero Trust Holding, USA

APU Data

APU	**GTCP85-98DHF**
Party number	381276-1
Serial number	p-482
Manufacturer	Honeywell (Garret)
Date of installation onboard the aircraft	09.01.2018
Operating time	36096 hours
Operating time since the last repair	858 hours

Aircraft:

1. Type – MD-83.

State registration identification mark – UR-CPR.

MSN – 49946.

2. Operator – Bravo Airways.

3. Manufacturing plant – McDonnell Douglas-Boeing USA. Manufacture date – 01.09.1991.

4. Resources and service life: Check type 1A, 2A, 4A, 1C CHECK + ADD.

Operating time – 42115 h, 46474 landings, Check was executed on 22.03.2018 by Bravo Airways, Boryspil Airport. Certificate of Release to Service of 22.03.2018 No. BR70. Life Limit extension – 3600 h. After the Life Limit extension, the aircraft operated for 991 hours.

5. Total operating time since placed in service - 43105 h, 46810 landings.

6. Number of repairs - repair 1A, 2A Check, operating time - 42975 h., 46761 landings. Check was executed on 04.06.2018 by Bravo Airways, Boryspil Airport. Certificate of Release to Service of 04.06.2018 No.BR80.

7. Airworthiness data:

Registration Certificate No.RP 4397 issued by the State Aviation Administration of Ukraine on 29.11.2016.

Certificate of Airworthiness No.0679 issued by the State Aviation Administration of Ukraine on 30.11.2016.

Airworthiness Review Certificate No. 0679/1 was issued by the State Aviation Administration of Ukraine on 30.11.2017 with validity until 29.11.2018.

Permit No.7698 on use of airborne radio stations of civilian aircraft MD-83 UR-CPR, issued by the State Aviation Administration of Ukraine on 27.12.2017.

Noise Certificate No.4709 issued by the State Aviation Administration of Ukraine on 10.01.2017.

Engine: (left)

1. Type – Pratt&Whitney JT8-219 s/n 728120.

2. Manufacturing plant – Pratt&Whitney USA, manufactured on 01.10.1996, operating time - 43857 hours and 22846 cycles:

3. Repair was completed on 03.11.2016 at Global Engine Maintenance USA at 39791 hours and 21359 cycles. After repair, the engine had 4066 hours and 1487 cycles. Certificate of Release to Service of 03.11.2016 No.Y2R496Y.

Engine: (right)

1. Type – Pratt&Whitney JT8-219 s/n 717873.

2. Manufacturing Plant – Pratt&Whitney USA, manufactured on 01.04.1987, operating time - 72941 hours and 37643 cycles.

3. The repair was completed on January 16, 2017 at Aero Trust Holding USA at 69932 hours and 36413 cycles. After repair, the engine operated for 3009 hours and 1230 cycles. Certificate of Release to Service of 16.01.2017 No. 522R849B.

Auxiliary Power Unit: Honeywell (Garret) GTCP85-98DHF p/n 381276-1, s/np-482Ai-9B, operating time 36096 hours. Certificate of Permitted Transfer Form 1 No. 027584 was issued on 09.01.2018.

Landing Gear: nose landing gear p/n 5910447-5071, s/n CPI1133 with 1527 flight cycles after overhaul. Residual life: 18473 flight cycles till 04.05.2026. The major overhaul was performed at Jet Landing System LLC USA on December 7, 2016. Certificate No.9JYR206C.

Wheel No.1 of the nose landing gear p/n 9550267-7 s/n JAN95-5367. Repair: 11.05.2018. The mounted tire: p/n APS00281-B s/n 217FM018. AVIADYNAMIKA Certificate No. 004297. Wheel No.2 of nose landing gear p/n 9550267-6 s/n NOV90-4080/JUL87-1574. Repair: 24.05.2018, tire: p/n 266122-3, s/n 33275734. Certificate of Bukovyna Airlines No.3065.

Photo 3

Nose landing gear wheels

The left main landing gear (LMLG) p/n 5930999-5503, s/n 477753 with the operating time of 313 flight cycles after a major repair. Residual Life Limit - 19687 cycles till 11.05.2027. Major repair was executed at Jet Landing Systems LLC USA on 11.05.2017. Certificate No.9JYR206C.

The right main landing gear (RMLG) p/n 590999-5504, s/n 606959 with the operating time of 313 flight cycles after a major repair. Residual Life Limit – 19687 cycles till 11.05.2027. Major repair was executed at Jet Landing Systems LLC USA on 11.05.2017.

The left main landing gear has the following wheels mounted:

wheel No.1 p/n 5007897-3 s/n MAY88-0115/S-AUG03-0495. Repair: 08.06.2018. Tire p/n APS01440 s/n 612WC038. AVIADYNAMIKA Certificate No. 004334;

wheel No.2 p/n 5007897-2 s/n JUL88-0296. Repair: 17.05.2018. Tire p/n APS01440 s/n 708WC012. AVIADYNAMIKA Certificate No.004306.

Photo 4

Left main landing gear (LMLG)

The right main landing gear has the following wheels mounted:

wheel No.3 p/n 5007897-3 s/n APR97-1191/S-MAR02-0407. Repair: 01.06.2018. Tire: p/n APS 01440 s/n 511WC011. AVIADYNAMIKA Certificate No. 004325;

wheel No.4 p/n 5007897-3 s/n APR01-1678. Repair: 12.09.2017. Tire: p/n APS 01440 s/n Y16WC117. AVIADYNAMIKA Certificate No. 004005.

Photo 5

Right main landing gear (RMLG)

Wheel Tire Condition:

In accordance with the terms of reference, the Investigation Team carried out the works to check the condition of the tires of the aircraft landing gear wheels. According to the inspection results, it is established that the wheel tires do not have characteristic damage, which would indicate to aquaplaning. Wheel tread depth is:

Front wheels: left - 2 mm; right - 3 mm.

Main, braking wheel tires:

Left	Right
External - 12 mm	External - 5 mm
Internal - 5 mm	Internal - 5 mm

Note: According to AMM 32-40-03 Operation Manual (page 205), if the tread depth is less than 0.79 mm (1/32 inch), then a tire should be taken out of service.

Braking Devices

No.1-p/n 5007898-3 s/n MAY88-0004E. Repair: 11.05.2018. AVIADYNAMIKA Certificate No.004290.

No.2-p/n 5007898-3 s/n NOV86-0217. Repair: 22.08.2017. TP Aerospace Technics LLC USA Certificate No.HW9R799J.

No.3-p/n5007898-3 s/n FEB91-0614. Repair: 03.08.2017. AVIADYNAMIKA Certificate No.003946.

No.4-p/n 5007898-3 s/n JAN01-0096. Repair: 11.05.2018. AVIADYNAMIKA Certificate No.004294.

Conclusion: The braking devices operated in a normal mode.

Automatic Wheel Unlock System (ANTISKID)

Control valve for automatic wheel unlocking p/n 39-249-2 s/n5297. Repair: 12.08.2016. Elite Aerospace USA Certificate No.EOTR2921.

Control valve for automatic wheel unlocking p/n 39-249-2 s/n 4150ABC. Repair: 31.03.2014. Genesis Aviation Inc USA Certificate No.G3NR788J.

Control valve for automatic wheel unlocking p/n 39-249-2 s/n 4194. Repair: 20.06.2014. Genesis Aviation Inc USA Certificate No.G3NR78.

Control valve for automatic wheel unlocking p/n 39-249-2 s/n 1400ABC. Residual Life Limit: 3158 cycles till 18.08.2018.

Wheel tires do not have the characteristic damage indicating failure of the automatic wheels unlocking system.

Conclusion:

- The above listed valves operated in the normal mode.

- Automatic Wheel Unlock System (ANTISKID) operated in the normal mode (this system prevents wheel locking during braking.)

According to decoded CVR and FDR data, the hydraulic fluid pressure in the left and right brake systems was 3000 psi, which is the operating pressure of the brake system according to the Flight Crew Operation Manual (FCOM) and Aircraft Maintenance Manual (AMM 32-42-00.) There were no critical remarks to the operation of the MD-83 UR-CPR wheel brake system. Automatic Wheel Braking System (AUTOBRAKE) on MD-83 aircraft is optional. The automatic wheel braking system (AUTOBRAKE) is not installed at the UR-CPR aircraft.

Conclusion: The engine thrust reverse system reduces the speed of the aircraft after landing. According to the decoded flight parameters of the MD-83 UR-CPR aircraft, the engine thrust reverse system operated without critical remarks.

UR-CPR landing video footage and CVR and FDR decoded data showed that no spoilers were deployed during the aircraft run till the stop. This could be only in three cases:

- failure of the spoiler deployment system;

- the spoiler control lever was not set to ARM position (automatic spoiler deployment mode) before the aircraft landing;

- spoilers were not deployed by the spoiler control lever (manual spoiler deployment mode.)

Description of Spoiler Deployment System Operation in Automatic Mode.

The automatic spoiler deployment system operates when at least two of the four wheel speed sensors rotate up to 700 rpm, and the spoiler control lever is in the ARM position. If the wheel rotation speed measurement system failed, the automatic spoiler deployment command is given by the switches on the front landing gear after its lowering and compression. In the event of failure of the automatic spoiler deployment system after aircraft landing, the spoilers shall be released by the spoiler control lever by the crew in the manual mode (AMM 27-60-00 page10.)

The ground (braking) spoilers are controlled by the SPEED BRAKE CONTROL HANDLE on the central panel of the cockpit (Photo 6). The ground spoilers system can operate in the automatic mode. The system consists of two control valves, spoiler control unit, four wheel speed sensors, and two switches on the front landing gear (Fig. 1.)

Photo 6

Speed brake control handle

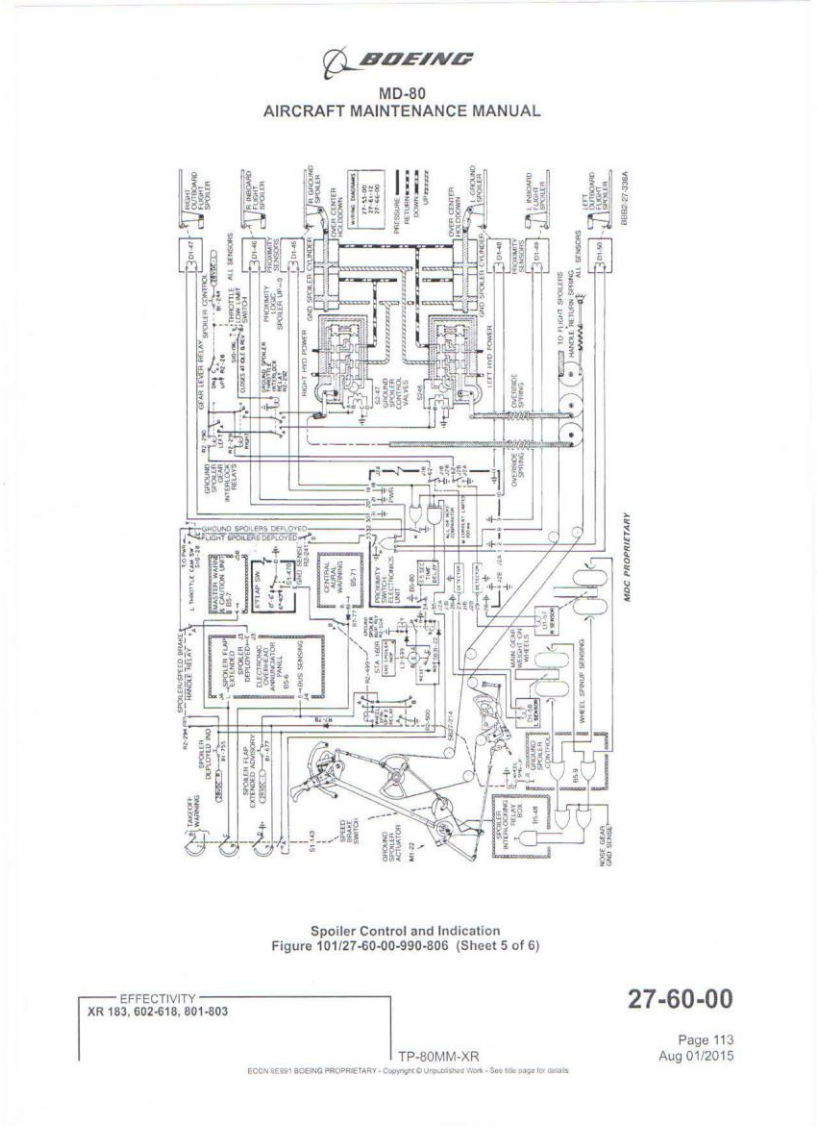

Figure 1

Automatic spoiler control system diagram

To use the spoiler deployment system automatically, the PIC must set the spoiler control lever to the ARM position, opening the red bar (Photo 7.) The red bar indicates to the crew that the spoiler automatic control system is ON. The automatic spoiler control system activates the spoiler control actuator at each landing, regardless of whether the lever is in the ARM position or not (AMM 27-60-00.)

Photo 7

Speed brake control handle in ARM position

In the event of the automatic spoiler deployment system failure, the PIC must deploy spoilers in the manual mode (MD-88/90 Operations Manual Normal Procedures-Introduction Landing NP.10.12).

Aircraft Loading:

Calculation of the take-off, landing weights and Center-of-Gravity position of MD-83 UR-CRP aircraft during flight BAY 4406 on June 14, 2018:

Total Take-Off Weight:	**144793 lb**
dry operational weight	87014 lb
full loading	33464 lb
fuel weight on take-off	25000 lb
used fuel	16200 lb
Landing weight:	**128778 lb**
Aircraft Center-of-Gravity position:	
on take-off	8.2% CAX
on landing	5.5% CAX

Note: 1 lb = 0.453592 kg

The investigation found that the take-off, landing weights and Center-of-Gravity positions are within the operating range and are not beyond the limits. Relevant AOM Operation Manual p.1-01-05 with weight and balance restrictions is attached.

No malfunctions or failures of the aircraft and engine systems were detected.

1.7 Meteorological Information

According to PIC, on June 14, 2018, on the day of departure from the airport of Antalya he received from the representative of the Turkish Ground Services company the meteorological documentation package containing weather forecasts in TAF code, the actual weather in METAR code for Kyiv (Zhulyany) Aerodrome and air navigation information (NOTAMs and navigation calculations.) The stated package of meteorological and air navigation information has not been provided by the crew, nor by the airline to the Investigation Team, no explanation of the reason was given.

TAF weather forecast for landing aerodrome – Kyiv (Zhulyany) Aerodrome, valid from 12.00 UTC June 14, 2018 to 12.00 UTC June 15, 2018, received upon the Investigation Team's request from the Aerodrome Meteorological Station Civilian Kyiv, was as follows:

Expected: wind 100° 4 gusts 9 m/s, visibility over 10 km; overcast at 900 m; maximum air temperature +29°C at 12 UTC 14.06.; minimum air temperature +16°C at 02 UTC 15.06.;

time 12.00 to 18.00 UTC 14.06.: wind 10 gusts 17 m/s, visibility 1000 m, moderate rain, thunder, hail, squall; significant cloudiness at 180 m, significant cumulonimbus at 750 m;

time 18.00 14.06. to 03.00 UTC 15.06.: light air wind gust 9 gusts 14 m/s, visibility 1500 m, moderate rain, thunderstorms, significant cloudiness at 150 m, significant cumulonimbus at 750 m;

gradually at 03.00 to 05.00 UTC 15.06.: wind 130° 3 gust 8 m/s; time 05.00 to 12.00 UTC 15.06.: wind variable 10 gusts 15 m/s, visibility 1000 m, moderate rain, thunder, hail; significant cloudiness at 210 m, significant cumulonimbus at 750 m.

The said weather forecast did not interfere with the decision on departure, but demanded special care from the crew. At the time of the aircraft arrival at the Kyiv (Zhulyany) Aerodrome, difficult weather conditions were forecasted (wind of variable directions with gusts up to 17 m/s, showers of moderate rain, thunderstorms, hail, and squall.)

According to the meteorological data, lightning activity was observed at the Kyiv (Zhulyany) Aerodrome while approaching and landing.

According to the PIC, before the pre-flight preparation, he received the meteorological and RW-status information for the Kyiv (Zhulyany) Aerodrome by listening to an ATIS FM radio broadcast for 5:00 pm:

"Wind magnetic. Landing zone 100 degrees, 4 m/s. Gusts maximum 7, minimum 3 m/s. Runway end: 100 degrees, 5 m/s. Gusts maximum 8, minimum 3 m/s. The weather is good. Temperature 25; dew point 17; QNH 1007 hPa, QFE 986 hPa. Runway condition for 16:28: dry, measured friction Mu-factor 0.7/0.7/0.7. Estimated braking action: Good.

Landing forecast: no significant changes.

Ground-based radar data: thunderstorm, with a squall line from 161 to 262º, distance from 40 to 100 km, thunderstorm, with a squall line and hail. Azimuth 182º, distance 59 km, shifting to the north at the speed of 40 km/h, strengthening.

After take-off, work with Kyiv-Radar 125.3 immediately, confirm receipt of Bravo information. For arrival: Kyiv-Radar 127.72 or 124.67. For departure: Zhulyany-Taxiing 119.0»

The meteorological conditions during the aircraft run after landing, according to SPECIAL Local Special Report for 05:40 pm, were as follows:

«Wind in the landing zone 090º 9 m/s, maximum wind speed 13 m/s, minimum wind speed 6 m/s, varies from 060º to 170º, at the end of the runway 130º, 5 m/s, varies from 060º to 200º, visibility in the landing zone 10 km, weather phenomenon - thunderstorm, light rain, scattered cumulonimbus at 630 m, broken cloudiness at 1230 m, air temperature 22ºC, temperature of dew point 19ºC, QNH 1006 hPa, atmospheric pressure at the level of the runway threshold: 0986 hPa,

forecast for landing: sometimes, the surface wind direction is variable, wind speed 10 m/s with gusts up to 17 m/s, visibility 1000 m, thunderstorm, moderate rain, squall, broken cumulonimbus at 750 m, wind at 500 m: 120º, 13 m/s , a thunderstorm, line of squalls with azimuth sector from 071º to 270º, distance of 12/96 km, shifting to the northeast with 30 km/h, weakening."

According to the local special report SPECIAL for 05:40:50 pm (upon the Alarm signal), the actual meteorological conditions at the Kyiv (Zhulyany) Aerodrome were as follows:

"Wind in the landing zone 140º, 9 m/s, maximum wind speed 13 m/s, minimum wind speed 4 m/s, varies from 060º to 250º, at the end of the runway: 150º, 6 m/s, maximum wind speed 12 m/s, minimum wind speed 3 m/s, varies from 060º to 210º , visibility in the area of landing 10 km, weather phenomenon - thunderstorm, light rain, scattered cumulonimbus at 630 m, broken cloudiness at 1230 m, air temperature 22º, dew point 19º, QNH 1006 hPa, atmospheric pressure at the level of the runway threshold: 986 hPa,

forecast for landing: sometimes surface wind direction is variable, wind speed 10 m/s with gusts up to 17 m/s, visibility of 1000 meters, thunderstorm, moderate rain, squall, broken cumulonimbus at 750 m, wind at 500 m: 120° 13 m/s, a thunderstorm, line of squalls with azimuth sector from 071° to 270°, distance of 12/96 km, shifting to the northeast with 30 km/h, weakening."

According to the actual weather reference data for the Kyiv (Zhulyany) Aerodrome, the value of the averaged 2-minute wind speed during the time period of 05:00-05:41 pm did not exceed 13 m/s; wind direction fluctuated 80 to 100 degrees. Significant changes in the wind speed and direction occurred at 05:41 to 05:51 pm – increase in the wind speed up to 20 m/s, and changes in the wind direction from 160 to 250 degrees. According to the KRAMS-4 Integrated Aerodrome Weather Station, from the runway threshold fly-over (05:39:49 pm) till full stop of the aircraft (05:40:18 pm), the wind fluctuated from 139º to 194º and 5 to 12.3 m/s.

According to the PIC, he does not remember whether he listened to SIGMET information as part of VOLMET broadcasts. According to the VOLMET Broadcasting Archive, there were VOLMET radio broadcasts about the 5th SIGMET information for that day.

According to the data of the Aerodrome Meteorological Station Civilian "Kyiv", the 5th per day SIGMET information for the Kyiv FIR/upper FIR compiled by the meteorological watch office (UKOW); acting from 05:00 till 08:00 pm UTC June 14, 2018. Embedded thunderstorms obscured by overcast skies are observed, the hail is in the southwest from the line with the coordinates of: (51 degree of northern latitude, 30 degrees of east longitude – 50 degrees of northern latitude, 34 degrees of east longitude), the upper limit reaches flight level 480, will move to the northeast with speed of 15 km/h, the intensity will not change.

According to the provided data of KRAMS-4 meteorological station, the values of the wind force and direction, measured by the main and reserve sensors, significantly differ (up to 4.4 m/s and 20° respectively.)

TREND weather forecast for Kyiv (Zhulyany) Aerodrome for the aircraft landing period has not come true.

In general, organization of meteorological service of flights at the Kyiv (Zhulyany) Aerodrome, which was provided by the Aerodrome Meteorological Station Civilian "Kyiv", met the requirements of Aviation Regulations on Ukraine "Meteorological Service of Civil Aviation."

The crew and ATS controllers were timely provided with the objective data on weather conditions at the Kyiv (Zhulyany) Aerodrome.

1.8 Navigation Aids

Use of ATS radio engineering means has no relation to the accident.

The list of the radio navigation means servicing the zone of responsibility of Tower of Kyiv International Airport (Zhulyany) and their technical characteristics are provided in the section AD 2.19 of the Aeronautical Information Publications of Ukraine.

According to item 8 of the Annex to the Certificate of Aerodrome of the Kyiv International Airport (Zhulyany) No. AP 09-02, the Kyiv International Airport (Zhulyany) Aerodrome is equipped with landing systems SP-90-type OPRS-A, RMS.

1.9 Means of Communication and ATS

The investigation has analyzed the following transcripts of communication of Kyivcenteraero Regional Branch and Kyiv ATS Service, which were provided by the Ukrainian State Air Traffic Services Enterprise:

1) transcript of communication between the aircraft crew and controller of sector BVO of the Kyiv ACC at the frequency of 131.375 MHz;

2) transcript of communication between the aircraft crew and controller of sector BV-1 of the Kyiv ACC at the frequency of 127.725 MHz;

3) transcript of communication between the aircraft crew and controller of sector BVL of the Kyiv ACC at the frequency of 135.825 MHz;

4) transcript of communication between the aircraft crew and controller of sector BV-5 of the Kyiv ACC at the frequency of 125.3 MHz;

5) transcript of communication between the aircraft crew and controller of the Tower of the Kyiv International Airport (Zhulyany) at the frequency of 120.7 MHz;

6) transcript of the tape recording of pre-shift briefing of the Tower shift #2 of the Kyiv ATS Service;

7) transcript of the tape recording of loud-speaking communication "Idustronik" for interaction with the airport services (announcement of the signal "Alarm" by the flight operations director of the Tower of the Kyiv International Airport (Zhulyany))

8) transcript of the tape recording of PGS-5-6a loud-speaking communication device at the workplace of the ATC Tower controller;

9) transcript of the communication tape recording made by the aviation ground telecommunication radio station ICOM F-320 (163.950 MHz) between the Tower controllers of the Kyiv International Airport (Zhulyany) and engineers of Aerodrome Service;

10) transcript of record of communications between the Tower sector controller and aircraft crew at the frequency of 120.7 MHz.

1.10 Aerodrome Data

The Kyiv (Zhulyany) Aerodrome, on the territory of which the accident occurred, is a certified civil aviation aerodrome entered into the State Register of Civil Aerodromes of Ukraine. The Aerodrome Certificate No. AP 09-02 is valid until March 16, 2020. The owner of the Aerodrome is the Kyiv City State Administration, the operator is the Municipal Enterprise International Airport Kyiv (Zhulyany.)

The runway dimensions are 2310x45m, pavement type – mixed, PCN 46/R/C/X/T. The runway is equipped for I category precision landing approach. From Mag Heading 259°, the runway threshold is displaced for 48m, Mag Heading 79° - 150 m.

The Aerodrome Class is B (4C).

The Aerodrome is operational day and night, all year-round.

The Aerodrome is equipped with the landing systems of SP-90 OPRS-A, RMS and lighting of high intensity runway lights (SSO VVI-I).

Level of the required fire protection - Category 7.

The Aerodrome marking is made according to the Certification Requirements to Civil Aerodromes of Ukraine.

At the end of the runway (threshold 26), the runway expansion takes place at the expense of which, the runway width with the expansion makes 75 m. Availability of the expansion is caused by absence of a taxiway adjoining the runway end (threshold 26). Before both runway thresholds, there are strengthened parts of the air-strip: 45 m wide and 50 m long. The air-strip stretches behind RW26 threshold for a distance of 60 m and has the total length of 2370 m. Behind the air-strip ends, the runway end safety areas have the dimensions of 90x90 m. The air-strip dimension on both sides from the runway center is 150 m (the total width of the air-strip is 300 m.) The cleared and graded area of the air-strip stretches from the runway center line to both sides for the distance of 75 m (the total width of the cleared and graded area of the air-strip is 150 m.) At the ends of the declared available take-off runs with both headings, the free zones are available. The free zone with Mag Heading 79° has the length of 150 m and stretches for the distance of 75 m to each side from the RW center line extension. The free zone with Mag Heading 259° has the length of 60 m and stretches for the distance of 75 m to each side from the runway center line extension.

Aerodrome reference point coordinates: 502407N; 0302707E.

Aerodrome elevation – 179 m.

Magnetic dip – 7°.

Available Distances:

With Mag Heading 79°:

Take-Off Run = 2310m;

Take-Off = 2460m;

Aborted Take-Off= 2310m;

Landing = 2160m.

With Mag Heading 259°:

Take-Off Run = 2250m;

Take-Off = 2310m;

Aborted Take-Off = 2310m;

Landing = 2262m.

According to clause 9 of the Appendix to the Certificate, the Aerodrome is capable to accept Index 4 (code 4C with restrictions) aircraft, helicopters of all types and lighter aircraft.

Note:

- in accordance with ICAO Doc 9981 "Air Navigation Service Rules. Aerodromes", edition two, 2016 – the MD-83 aircraft has Code 4C;

- Kyiv (Zhulyany) Aerodrome is a base aerodrome for Bravo Airways.

- According to Appendix 4 to paragraph 6.8 of the Certification Requirements for Civil Aerodromes of Ukraine, the pavements shall be operated with no restrictions, if the condition ACN ≤ PCN is fulfilled. In case of non-fulfillment of this condition, it is necessary to introduce restrictions on the aircraft mass or intensity of its movement on the aerodrome elements. According to Appendix 5 to ICAO Doc 9157 "Aerodrome Design Manual", Part 3 "Pavements", ACN of aircraft MD-83 with a maximum mass (73023 kg) shall be 53. Depending on PCN/ACN ratio for hard pavements, the operation of aircraft of this type shall be limited by 10 aircraft-flights per day (PCN/ACN = 46/53 ≈ 0.87, condition 1>PCN/ACN>0.85 is fulfilled.) However, the operating documents of the Kyiv (Zhulyany) aerodrome contain no restrictions on the operation of MD-83 aircraft.

The available landing distance with Mag Heading 79° stated in the Flight Operation Instructions at the Kyiv (Zhulyany) Aerodrome is 2160m.

According to the aerodrome service engineer, he took over the shift at 4:30 am on June 14, 2018 and, for 24 hours, was monitoring the aerodrome pavement surface

condition. During the day, watering of the runway pavement for the purpose of its cooling was carried out from 7:55 am till 12:55 pm.

Note: according to item 4.2.6 of the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86, during the dry and hot period, for the purpose of cooling of pavements and removal of dust, they need to be watered (the consumption rate of water shall be 0.3 l/m².)

Information on the runway status was recorded in the Airfield Status Log and transmitted to the Tower controller and duty technician-meteorologist of the Aerodrome Meteorological Station Civilian "Kyiv" for the further inclusion in METAR/SPECI weather reports.

Note: The requirements for reporting the actual information on the runway status are stated in subparagraphs 2.2, 2.3 of the Technology for Interaction of Flight Support Services at Works on Aerodrome Movement Area of ME IA "Kyiv" (Zhulyany) dated 22.02.2018 #7.4-06-01 and item 1 of Technologies for Reporting Encoded Information on Runway Status to Specialists of the Aerodrome Meteorological Station Civilian "Kyiv" for Inclusion It Into Weather Reports, approved by the General Director of the ME IA "Kyiv" (Zhulyany) on 26.02.2018 and Director of the State Enterprise "UAMC" on 27.02.2018.

Prior to onset of rainfall, the runway status did not change.

The information on beginning of precipitation was reported in the SPECI report for 05:21 pm: *"... thunderstorm, light rain, broken cumulonimbus 780m high ..."*

Runway Status Data

Records in Airfield Status Log	**Information as Part of ATIS Radio Broadcasts and Report to Tower Controller**
RW Mag Heading 79°, dry, **Friction Mu-factor = 0.7/0.7/0.7,** evaluated braking action is "good", R08/CLRD70, record for **5:09 am**	Information was not considered
RW Mag Heading 79°, **Friction Mu-factor = 0.7/0.7/0.7,** evaluated braking action is "good", R08/CLRD70, record for **6:44 am**	Information was not considered
RW Mag Heading 79°, damp as a result of watering, **Friction Mu-factor =**	Information was not considered

0.6/0.6/0.6, evaluated braking action is "good", R08/190060, record for **7:55 am**	
RW Mag Heading 79°, damp as a result of watering, **Friction Mu-factor = 0.6/0.6/0.6,** evaluated braking action is "good", R08/190060, record for **9:18 am**	Information was not considered
RW Mag Heading 79°, damp as a result of watering, **Friction Mu-factor = 0.6/0.6/0.6,** evaluated braking action is "good", R08/190060, record for **10:22 am**	Information was not considered
RW Mag Heading 79°, damp as a result of watering, **Friction Mu-factor = 0.6/0.6/0.6,** evaluated braking action is "good", R08/190060, record for **11:25 am**	Information was not considered
RW Mag Heading 79°, damp as a result of watering, **Friction Mu-factor = 0.6/0.6/0.6,** evaluated braking action is "good", R08/190060, record for **12:55**	Information was not considered
RW Mag Heading 79°, dry, **Friction Mu-factor = 0.7/0.7/0.7,** evaluated braking action is "good", R08/CLRD70, record for **02:35 pm**	The relevant information on the runway status **for 02:34 pm** was reported as part of ATIS from 03:00:55 PM* to 04:27:50 pm. The runway status was reported by the aerodrome service engineer to the Tower controller at 02:33:38 pm.
RW Mag Heading 79°, dry, **Friction Mu-factor = 0.7/0.7/0.7,** evaluated braking action is "good", R08/CLRD70, record for **04:29 pm**	The relevant information on the runway status **for 04:28 pm** was reported as part of ATIS from 04:30:15 pm to 05:24:24 pm. The runway status was reported by the aerodrome service engineer to the Tower controller at 04:27:33 pm.
RW Mag Heading 79°, wet, covered with sheet of water to 3 mm, **Friction Mu-factor = 0.54/0.54/0.54;** evaluated braking action is "good", R08/290354, record for **05:30 pm.**	The relevant information on the runway status **for 05:25 pm** was reported as part of ATIS from 05:27:22 pm to 06:31:45 pm. The runway status was reported by the

	aerodrome service engineer to the Tower controller at 05:24:58 pm
RW Mag Heading 79°, wet, covered with sheet of water to 3 mm, **Friction Mu-factor = 0.54/0.54/0.54,** evaluated braking action is "good", R08/290354, record for **06:05 pm** (as per the provided protocol of measurement for **05:01:05 pm****, **Friction Mu-factor = 0.52/0.49/0.53**)	From 06:34:30 pm till 06:57:52 pm, the information on closing of aerodrome for technical reasons was reported. The engineer of aerodrome service asked the clearance from the Tower controller to occupy the runway for inspection at 05:54:49 pm, however, he did not report about the subsequent runway vacation and inspection results.
RW Mag Heading 79°, wet, covered with sheet of water to 3 mm, **Friction Mu-factor = 0.54/0.54/0.54,** evaluated braking action is "good", R08/290354, record for **07:14 pm** (as per the provided protocol of measurement for **07:14:22 pm, Friction Mu-factor = 0.56/0.54/0.52**)	The relevant information on the runway status was reported by the engineer of aerodrome service to the Tower controller at 07:24:03 pm
RW Mag Heading 79°, wet, covered with sheet of water to 1 mm, **Friction Mu-factor = 0.56/0.56/0.56,** evaluated braking action is "good", R08/290156, record for **08:05 pm** (as per the provided protocol of measurement for **08:05:07 pm, Friction Mu-factor = 0.54/0.60/0.61**)	The relevant information on the runway status was reported by the engineer of aerodrome service to the Tower controller at 08:20:14 pm.

Note:

** - The Investigation Team has the ATIS data recording from 03:00:55 pm till 06:57:52 pm;*

*** - According to the Statement of the aerodrome service engineer, who carried out the Friction Mu-factor measurement, in the course of setup of ATT-2 Breeze-KS device to operation, its time became incorrect and did not correspond to the actual one (the actual measurement time - 06:05 pm.) The time difference was corrected.*

Information on the value of the measured Friction Mu-factor, which is set out in the Airfield Status Log for 06:05 pm, 07:14 pm and 08:05 pm, does not correspond to the measurement results set out in measurement protocols for the respective time.

At 8:05 p.m. in connection with runway excursion of the aircraft, the Investigation Team consisting of the head and engineer of aerodrome service, head of the air safety control and navigation support service of the Kyiv International Airport (Zhulyany), deputy general director for the aviation safety of Bravo Airways and members of the NBAAI Investigation Team conducted the inspection of aerodrome pavements. By results of the inspection, the following runway status was recorded: "RW Mag Heading 79 is wet, the sheet of water is up to 1 mm, the Friction Mu-factor = 0.54/0.60/0.61. The estimated braking action is "Good", with no foreign objects."

Note: The results of Friction Mu-factor measurement are confirmed with the protocol of measurement for 08:05:07 pm (the protocol is in the investigation materials.)

The aerodrome service of the Kyiv International Airport (Zhulyany) operates three devices for measurement of the friction Mu-factor: two aerodrome brake carts ATT-2 with no option of recording the friction Mu-factor measurement results, and one aerodrome brake cart ATT-2 Breeze-KS, which has the friction Mu-factor measurement recorder.

ATT-2 Breeze-KS was calibrated on 23.03.2018.

In the Airfield Status Log, which is kept by the aerodrome service, before aircraft landing, at 5:30 pm, the following record was made about the runway status: The Runway is wet, the sheet of water is up to 3 mm, the friction Mu-factor = 0.54/0.54/0.54. However, having watched a video from the surveillance camera, which was near the fire station (the image allows to view approximately one third part of the RW), the Investigation Team established that for inspection of the aerodrome status, the aerodrome service vehicle arrived without a device for measurement the friction Mu-factor. Its movement was recorded only in one direction – landing Mag Heading 079°. Measurement of the precipitation layer by aerodrome service employees was also not made at this site. According to the transcript of the tape recording of communications between Tower controllers of the Kyiv International Airport (Zhulyany) and aerodrome service engineers, an engineer of the aerodrome service asked for the controller's clearance to enter the runway from TW1 at 05:19:10 pm and got the clearance. Already at 05:24:58 pm, the aerodrome service engineer reported to the controller about vacating the runway. Thus, the runway inspection lasted for about 5 min, which, taking into account the technique for friction Mu-factor measurement and runway length, was not capable to conduct the friction Mu-factor measurements. In the Statement to Investigation Team, the aerodrome service engineer reported that he wrote down this information on the runway status from his experience.

Note: *according to the Annex 16 to the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86, an aerodrome brake cart ATT-2 is represented by the uniaxial two-wheeled trailer with the corresponding devices and metering*

equipment, which is connected with to the towing car. According to item 2 of the Annex 16 to the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86 and section 8 of Technology of Work of Shift Chiefs and Shift Engineers of Aerodrome Service for Aerodrome Status Evaluation and Measurement of Friction Mu-Factor on RW Pavement dated 13.03.2017 #7.4-06-02 approved by the General Director of ME IA Kyiv (Zhulyany), measurements of the friction Mu-factor shall be carried out at the speed of 40-45 km/h to both sides of the RW at the distance of 5-10 m from its center line; there should be 8 measurements on each 1/3 runway length, that is, 4 measurements from each side from the runway center line. According to the item 5.2.11 Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86, the thickness of a precipitation layer shall be measured by the optical rule OL-1.

Thus, taking into account the fact that measurements of the friction Mu-factor and thickness of the layer of precipitations on the RW were not carried out by the aerodrome service personnel, the Investigation Team is not capable to objectively establish the actual values of the friction Mu-factor and precipitation layer on the runway at the time of touchdown and occurrence.

The last aircraft landing before landing of MD-83 UR-CPR aircraft on the aerodrome of the Kyiv International Airport (Zhulyany) took place at 05:03 pm (Da-42 aircraft.)

At 05:36 pm, C 560X YU-PNK aircraft took off.

1.11. Aircraft Recorders

The MD-83 UR-CPR aircraft is equipped with an encapsulated FDR: FA2100 PN 2100-4042 SN 00856 and encapsulated CVR: FA2100 PNR 2100-1020-02 SER 000211650 manufactured by L3 Communications.

The FDR has the recording time of 98 hours and 64 recording channels.

The CVR has 4 recording channels and stores information about the last 30 minutes of the flight, which does not meet the requirements of the Operational Directive of the State Aviation Administration of Ukraine ED-05k-15 dated 29.12.2015 in terms of ensuring the information recording for the last 2 hours of the flight.

The actual duration of the record on the CVR does not correspond to the recorder with this part number (the duration of record on the recorder with this part number should have been 2 hours, not 30 minutes, as it actually was.)

According to the list of recorded parameters, the decoded data revealed absence of the signal of the analog parameter of Radio Altitude (Coarse).

The list of parameters recorded on the FDR of the MD-83 UR-CPR aircraft is in the investigation materials (IRISH AIR-6 document.)

1.12. Wreckage and Impact Information

Not relevant.

1.13 Medical Information and Brief Results of Post-Mortem Studies

Not relevant.

1.14 Fire

There was no fire during the accident.

1.15 Survival Factors

Actions of Rescue and Fire Teams.

Emergency and rescue works, including works to prevent fire at the aircraft and site of occurrence, were organized and carried out by the personnel of the emergency and rescue team (ERT) of the Kyiv (Zhulyany) Aerodrome in accordance with the Plan for Emergency Situations with Aircraft at Kyiv (Zhulyany) Aerodrome (hereinafter – the Emergency Plan.)

In accordance with par 1.1 of Supplementary Agreement No.3 to Appendix B No.MA 120/16 of 01.04.2016 to the Standard Ground Service Agreement of January 2013, the airport shall organize and carry out emergency rescue and firefighting support of aircraft flights in its area of responsibility.

Kyiv (Zhulyany) Aerodrome Category is 7 by the required fire fighting level (hereinafter – RFPL.)

The number of ERT participating in carrying out of emergency and rescue works (ERW) according to the Shift Plan of Search, Rescue and Fire-Prevention Flight Support at ME IA Kyiv (Zhulyany) Aerodrome, which acted from 08:00 am June 14, 2018 to 08:00 am June 15, 2018, met the standards determined by the Appendix 4 to the Regulations on Rescue and Fire-Prevention Flight Support in Civil Aviation of Ukraine, approved by the Order of the Ministry of Infrastructure of Ukraine of 07.05.2013 No.286 and registered with the Ministry of Justice on 24.05.2013 under No.809/23341 (hereinafter - Regulations on RFPFS.) In total, for carrying out ERW, the ERT consisting of 46 people and 12 pieces of equipment was involved.

Recording of voice communication through channels of radio exchange at performing ERW by ground recorders was not made, which does not conform to requirements of Regulations on RFPFS.

Note: *according to item 4.11 of Regulations on RFPFS, the voice communication through direct communication and radio exchange channels when performing emergency rescue works are subject to automatic recording by recorders.*

In accordance with clause 12.3.9 of ICAO Doc 9137 "Airport Services Manual" Part 7 "Airport Emergency Planning", it is recommended to install recording equipment with time units to ensure recording of all voice communication at operational centers and/or mobile controls with a view to the further analysis. Besides, it is reasonable to record all emergency communication, including letter-printing one.

According to the Shift Plan and Statement of the guard chief of the rescue team of the fire fighting unit, three fire trucks headed to the site of occurrence - KAMAZ 45105 № 45-13 KIM, MAZ 631708 № t 01437 AI and Ural 375 № 0273 KIM (two main and one reserve respectively), fully filled with water and foaming agent. According to the General Purpose Foam Passport for fire fighting "Pirena-4" used in ME IA Kyiv (Zhulyany), the critical delivery rate of the working solution of the foaming agent during extinguishing with a foam having a medium expansion ratio – 0.029 $dm^3/(m^2 \cdot s)$, hence, the foam meets the characteristics of Level B (in accordance with Appendix 3 to the Regulations on RFPFS.)

Note: *according to table 3.2 of the Appendix 3 to Regulations on RFPFS, for Aerodrome Category 7 at using foam, which corresponds to characteristics of level B, the minimum quantity of fire trucks makes 2 units.*

At the same time, according to the General Purpose Foaming Agent Passport for fire fighting "Pirena - 4", the date of manufacture of the foaming agent is 12.06.2015, and its warranty storage period is 36 months from the date of manufacture.

Thus, on the accident day, the fire trucks were filled with a foaming agent, which storage period had expired. As of July 19, 2018, the purchase of foaming agent was not carried out.

In connection with the aircraft runway excursion, Alarm was declared at 05:40:17 pm. At 05:40:33 pm, the Alarm receipt was confirmed by a fire fighting unit, at 05:40:36 pm – ERT chief came into contact with ERT units.

Due to the absence of records of communication through radio exchange channels during ERW, the Investigation Team established ERW chronology (after announcement at 05:40:17 pm by the Tower Control of Alarm to ERT units in connection with the runway excursion) by review of records from the surveillance

cameras installed at the aerodrome (near apron Z and fire station) and explanations of the personnel involved in ERW.

As a result of the analysis of the mentioned information, the following sequence of events was established:

- 05:42:46 pm - arrival to the occurrence site of the first fire truck;

- 05:43:33 pm - passengers start leaving the aircraft through open left doors near the pilots cockpit by means of inflatable ladder and start moving towards TW2;

- 05:43:45 pm - arrival to the occurrence site of the second fire truck;

- 05:43:50 pm - arrival to the occurrence site of the third fire truck;

- 05:44:30 pm - arrival of the aerodrome shift chief's car to the occurrence site;

- 05:45:03 pm - arrival to the occurrence site of the car with a technical first-aid kit;

- 05:45:45 pm - arrival of the ambulance car to the accident site;

- 05:45:55 pm - arrival of ERT car the occurrence site;

- 05:47:02 pm – water delivery by the first fire truck;

- 05:49:46 pm - arrival of the first bus for transportation of passengers

- 05:50:01 pm - arrival of the second bus for transportation of passengers

- 05:51:08 pm - arrival of the third bus for transportation of passengers.

The instruction on announcement of All-Clear via public address system of Tower Control was transmitted by the aerodrome shift chief at 06:08 pm.

As a result of the accident, the aircraft suffered a runway excursion and came to rest at the distance of 123 m from the runway center line within the air strip (outside the cleared and graded area of the air strip). The Tower Control has transferred at 05:40:29 pm to the controller of ACC BV5 sector the information on a temporary closure of the aerodrome. For technical reasons, the information on the aerodrome closure started being transmitted by ATIS-type UHF radio broadcasts since 06:30 pm.

For the purpose of recovery of the aerodrome operation and ensuring safe operation of the runway, the aerodrome operator, prior to the aircraft evacuation, issued NOTAM Ts 1623/18 on restriction of the flying strip dimensions from the North side up to 120 m (active from 01:25 pm 15.06.2018 to 11:59 pm 22.06.2018.) The aircraft was recovered from the aerodrome on 21.06.2018.

The first fire truck arrived to the occurrence site in 2 minutes 29 seconds after the announcement of Alarm signal, the second and third ones – in 3 minutes 28 seconds and 3 minutes 33 seconds, respectively. The water delivery by the first fire truck (on the left side of the fuselage) began in 6 minutes 45 seconds from the time of the Alarm announcement.

Note: *according to item 5.4.3 of the Emergency Plan, a fire fighting unit should arrive to the site in no longer than 3 minutes and start fire suppression.*

According to item 13.3.4 of Certification Requirements to Civil Aerodromes of Ukraine approved by the Order of State Aviation Administration of 17.03.2006 No. 201 (hereinafter – SRCAU), the deployment time in any point of the runway of the first fire truck (from the quantity providing the established RFPL) should not exceed 3 minutes, and the subsequent ones – 4 minutes from the time of announcement of Alarm signal until the agent delivery.

According to section 5 of the Emergency Plan, all ERT units, except the fire fighting ones, have to arrive to the site in no longer than 6 minutes. From the analysis of recordings from surveillance cameras, it was not possible to record the arrival time of all ERT units, at the same time, the time of arrival of the medical aid station and ERT chief car did not exceed the normative time.

Note: *the quality of videos and features of arrangement of surveillance cameras do not allow determining the time of water delivery to the right side of the fuselage, where the fuel leak was observed. According to the ERT chief, the beginning of water delivery to the left side of the fuselage is caused by the fact that for passengers evacuation, the emergency exit on the right side of the fuselage was opened.*

According to the chief of guard of the rescue unit of the fire fighting service, on arrival to the occurrence site and visual assessment of nature of aircraft damages, he made the decision to cover the fuel leak place with water and spill large amount of water over the aircraft wing, which does not conform to requirements of the Emergency Plan.

According to the ERT chief and chief of guard of the rescue unit of the fire fighting service, due to the absence of fire and smoke at the aircraft, there was no need in immediate use of the agent, therefore, the decision was taken to apply not foaming agent, but water for cooling of the fuselage and dissolution of fuel leaking from the right fuel tank. For prevention of fire at the aircraft, the water was used from the Ural fire truck and most part of water from MAZ truck, which does not conform to requirements of the Emergency Plan.

Note: *according to item 3 of section B1 of the Emergency Plan, the tactics of rescue and fire fighting operations obliges creation of a protective layer (covering with foam) on the areas covered with fuel.*

According to the aerodrome shift chief and ERT chief, at arrival to the occurrence site, the front doors were on the left side open and the emergency escape slide was unrolled, by which the passengers left the aircraft. Also, the emergency exit on the right side of the fuselage was open. There was no need for cutting of the fuselage skin. After escape from the aircraft, the passengers started running towards TW2, where they were stopped by the aerodrome shift chief for their delivery to the place of gathering at the terminal A (border control area.)

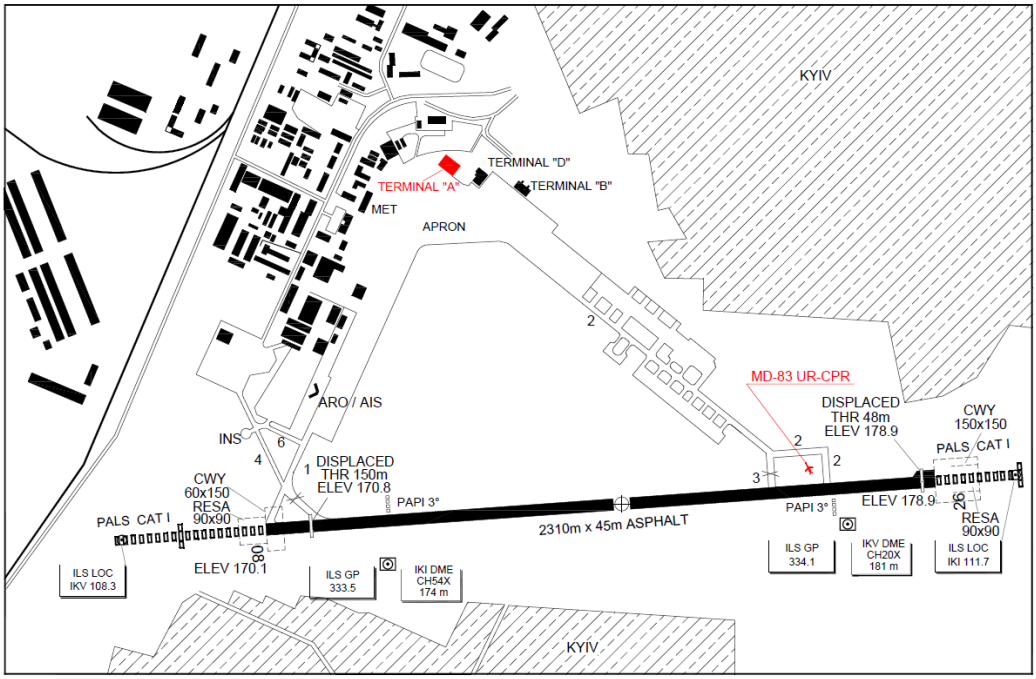

Fig. 2

Layout of aerodrome elements, terminal A and aircraft position following the runway excursion

Certificate of Conformity No.IEV-PARZP-40-03 of the Rescue and Fire-Fighting Service of ME International Airport "Kyiv" (Zhulyany) was issued by the State Aviation Administration on 25.12.2015 with validity till 25.12.2018.

According to the section B15 of the Emergency Plan, the general responsibility for organization of and works on aircraft recovery from the aerodrome is assigned to the General Director of ME IA Kyiv (Zhulyany) Aerodrome. The organization of the direct performance of the recovery works in the territory of the aerodrome is carried out by the coordinator of works, who shall be appointed by the order of the General Director of ME IA Kyiv (Zhulyany) Aerodrome. The direct performance of the recovery works in the airport area shall be carried out by forces and means of the airport under agreement with the operator, or by the aircraft operator independently. The airport authority should have an agreement with operators on providing the corresponding services. In addition to the information provided in the Emergency Plan, the procedures for the aircraft recovery are separately described in the Disabled Aircraft Recovery Plan approved by the top management of ME IA Kyiv (Zhulyany) in 2016 and the Disabled Aircraft Recovery Instruction approved by the General Director of the Bravo Airways in 2017.

All of these documents have differences in the parties' responsibility for the aircraft recovery.

***Note**: The aircraft recovery from the site was carried out by Bravo Airways with participation of the aerodrome operator. No any coordinator of the recovery works was appointed at ME IA Kyiv (Zhulyany), and there is no agreement (in the form of official contractual relations) between the aerodrome operator and Bravo Airways.*

In the given case, in accordance with the classification given in paragraph 1.8 Doc 9137 of ICAO "Guide to Airport Services", Part 5 "Disabled Aircraft Recovery", the “recovery” method is required to remove an aircraft from the aerodrome whereas the aircraft suffered significant damage.

Actions of members of the flight and cabin crews during evacuation of passengers from the accident site:

According to the senior flight attendant, immediately after stop of the aircraft, he went into the cockpit and received a verbal command from PIC to evacuate. The evacuation began immediately and was carried out in accordance with the Cabin Crew Manual. Exits L1 and R1 were activated. Passengers were given commands established by the company. Exit L2 was not activated due to the fact that it was not possible to evaluate the external conditions and suitability of the exit. The rear emergency exit could not be actuated due to the aircraft position. After the evacuation of passengers, the senior flight attendant, together with PIC, made sure that no one was left on board.

1.16. Tests and Research

For the functional check of the automatic spoiler deployment system during landing of the aircraft MD-83 UR-CPR, the Investigation Team performed works according to the technical acts and MD-83 Operation Manual.

According to the BRAVO technical act of 16.08.2018, the inspection of condition of tires of landing gear wheels was conducted according to the MD-83 Operation Manual AMM 32-40-03:

All wheels meet the specification standards.

RPM sensors of landing gear wheels were removed from the aircraft MD-83 UR-CPR:

p/n 40-62575 s/n 8787 A, p/n 40-62575 s/n 9305 A, p/n 40-62575 s/n 9191 and inspected for operability according to the MD-83 Operation Manual AMM 32-43-02. According to the BRAVO Act of Performed Works No.1.3-1.9/506 of 21.08.2018, the RPM sensors of landing gear wheels are operable.

Check of the technical condition of the spoilers control system, spoilers control handle, condition of spoilers control cable, limit switch S 1-143 p/n 48-1990

according to the MD-83 Operation Manual AMM 27-60-00 was conducted. According to the BRAVO Act of Executed Works No.1.3-1.9/511 of 27.08.2018, all units were operable.

For the purpose of functional check of the automatic spoiler control system - Automatic Ground Spoiler (AGS), the Investigation Team addressed the aviation units and components services organization of Sweden (Advantage Aviation Services Sweden AB.)

For the functional check of AGS system, the units have been removed from the aircraft and checked according to the Operation Manual. The research was conducted at the certified stations HYDRO-AIR, INC. EASA.145.4560 and GENESIS AVIATION INC, EASA.145.4483.

On May 10, 2019, the results of testing the operability of GROUND SPOILERS ACTUATOR units (left, right cylinders of deployment and retraction of spoilers), SPOILERS CONTROL BOX were received.

According to the Acts of Performed Works by Genesis Aviation, Inc.:

W/O #: H 154298 and W/O #: H154299 hydraulic cylinders p/n 5936965-5501, s/n CML1765, s/n CML2449 GROUND SPOILERS ACTUATOR were **operable.**

According to the Act of Performed Works by ICON AeroSpace W/O W 112013:

the spoilers control unit p/n 42-091-3 s/n 2874 SPOILERS CONTROL BOX was **operable.**

The Investigation Team, on the basis of the conducted research has come to conclusion that the system of automatic deployment and retraction of spoilers (AGS) was operable during the accident.

According to the flight decoded data and logbook records, there were no critical comments on the AGS system operation.

According to the decoded data, at the time of UR-CPR aircraft landing run, the spoilers were operated in the aileron mode. This means that the spoilers deployment and retraction system in the automatic mode was not prepared for operation (not in ARM position.)

Conclusion: The AGS system was operational during the occurrence.

The research was conducted at certified stations: Hydro-Aire, Inc. EASA.145.4560; Genesis Aviation, Inc. EASA.145.4483.

The following investigation materials were used for the investigation:

- NTSB report based on results of the investigation into air accident – runway excursion of MD-82 N215AA, Arkansas, June, 1999 (AIRCRAFT ACCIDENT REPORT PB-2001-910402 NSTB/AAR-01/02 DCA99MA060 RUNWAY

OVERRUN DURING LANDING AMERICAN AIRLINES FLIGHT1420 MD-82 N215AA, LITTLE ROCK, ARCANSAS, JUNE, 1999.)

- NTSB report based on results of investigation into air accident – runway excursion of MD-88 N909DL, New York, March, 2015 (AIRCRAFT ACCIDENT REPORT PB-2016-104166 NSTB/AAR-16/02 RUNWAY EXCURSION DURING LANDING DELTA AIRLINES FLIGHT 1086 BOEING MD-88, N909DL NEW YORK, NEW YORK, MARCH 5, 2015.)

1.17 Information on Organizations and Administrative Activity Related to Occurrence

Bravo Airways was founded in 2012. The valid Operator Certificate CE No. UK 031 was issued by the State Aviation Administration of Ukraine of 03.01.2018 valid until 29.03.2019 with the Operation Specifications dated 12.04.2018. The airline operates the international and domestic scheduled and charter flights. Certificate of Maintenance Organization Approval No. UA.145.0078. Date of initial issue by the State Aviation Administration of Ukraine: November 19, 2013, rev. #01.

Addendum to the Certificate of Maintenance Organization Approval No. UA.145.0078. Date of initial issue: October 21, 2013. Date of last approved amendment: February 11, 2016.

ME International Airport Kyiv (Zhulyany)

The owner of the aerodrome certificate is the Municipal Enterprise International Airport Kyiv (Zhulyany), which is in the Kyiv municipal property. It is located 8 km southwest of the city of Kyiv. The airport includes an aerodrome, terminals, complex of ground structures, airport services for arrival and departure of aircraft, passengers, luggage, mail and cargo, aircraft servicing. The airport operates around the clock and has an international status.

Ukrainian State Air Traffic Services Enterprise

Air Navigation Service Provider: State Air Traffic Services Enterprise of Ukraine (UkSATSE). State regulation of UkSATSE activity in accordance with the Charter is carried out by the Ministry of Infrastructure of Ukraine.

Air Navigation Services Certificate was issued by the State Aviation Administration of Ukraine on 22.12.2017.

State Aviation Administration of Ukraine

The State Aviation Administration is a central executive body, which activities are directed and coordinated by the Cabinet of Ministers of Ukraine through the Minister of Infrastructure, who shall implement the state policy in the field of civil aviation and use of Ukrainian airspace and shall be a civil aviation authority.

Pursuant to the Regulation on the State Aviation Administration, the State Aviation Administration shall adopt and implement the aviation Regulations on Ukraine, supervise and control the aviation activity entities' compliance with the legislative requirements, aviation Regulations on Ukraine.

1.18 Additional Information

The investigation considered possible onset of aquaplaning due to the presence of a water layer on the surface of the runway. ICAO Doc 9137 "Airport Services Manual", Part 2 "Pavement Surface Conditions", describes three main types of aquaplaning that can occur if the runway surface is covered with water.

Viscous Aquaplaning

The typical decrease in braking action on a wet surface, as well as decrease in the braking action vs. increasing aircraft speed, are caused by a combined action of the viscous dynamic water pressure, which affects the tire and surface. This pressure causes a partial loss of "dry" contact, which tends to increase vs. increasing speed. There are conditions, under which the loss could be almost the whole one, and the braking action is reduced to insignificant values. This phenomenon is attributed to either the viscous dynamic aquaplaning or aquaplaning caused by rubber reversion. In case of the viscous aquaplaning, the braking action may be lost at relatively low speeds due to the effect of viscosity, which prevents the displacement of water from under the tire. However, this requires a very smooth runway surface, and such a surface may be in places covered with a significant layer of rubber that remains from the wheel tires at wheel spin-up during touchdown, or which were worn down during movement. Viscous aquaplaning is associated with mild/wet runways or ice-covered runways and, when it occurs, proceeds to very low speeds. Viscous aquaplaning can occur at braking during an aborted take-off or landing run.

Dynamic Aquaplaning.

Dynamic aquaplaning can occur on runways filled with a liquid to a small depth and appear at critical ground run speeds during landing and take-off. The higher the pressure in the tire, the higher the speed at which the dynamic aquaplaning occurs. The presence of only 0.5 mm of standing water is considered a sufficient condition to maintain the dynamic aquaplaning.

Aquaplaning Caused by Rubber Reversion

Aquaplaning due to the rubber reversion can occur in any situation and at any speed, when the tire is not rotating for a prolonged period of time. This phenomenon is caused by emergence of superheated steam at a temperature of about 200ºC between the wheel tires and runway surface, which causes melting of the affected area of the tire. Following incidents when rubber reversion and overheating is known to have occurred, white marks characteristic of "steam cleaning" action were observed on the runway surface. Accordingly, avoidance of wheel lock-up is an important preventative measure in such situations.

In order to examine the issue of possible occurrence of the aquaplaning phenomenon during the aircraft landing run, the NBAAI addressed the NTSB (USA) for consultation and received the following comments.

If the runway surface is characterized as a slippery one due to the presence of moisture on it, then the viscous aquaplaning may occur.

Aquaplaning caused by rubber reversion (steam aquaplaning) can be identified by the presence of traces of skidding on an overheated tire rubber. If there are no traces on the tires, then this type of aquaplaning may not be considered.

As for dynamic aquaplaning, it may be very difficult to detect its occurrence, but it can often be identified by taking into account the actual friction Mu-factors achieved during braking, landing, and combination of the factors: water layer on the runway and aircraft speed during landing run. Both characteristics, such as the minimum water layer and minimum speed of the aircraft, are required for dynamic aquaplaning to occur. The aquaplaning models used today consider 3 mm layer of water on the runway surface as a minimum one required for onset of aquaplaning. In addition, the minimum speed for occurrence of aquaplaning, having assumed that the non-rotating tire touches a water-covered runway, is:

$$V_{p,\ \text{spin-up}} = 7.7\sqrt{p}$$ (non-rotating tire), where

p is the tire pressure in psi *(pound-force per square inch)*, and $V_{p,\ \text{spin up}}$ is the minimum aquaplaning speed in knots. Therefore, for a tire with a pressure of 195 psi, $V_{p,\ \text{spin-up}} = 108$ knots.

The UR-CPR aircraft recorder data indicate that it exited the runway to the left at a speed of about 100 knots. This means that the speed during the landing run was high enough to contribute to onset of the dynamic aquaplaning if the water layer was sufficient for it to occur. Runway inspections conducted prior to the accident indicate that, prior to the accident, the runway was covered with a layer of water up to 3 mm thick (with a “Good” braking action rating.) Thus, any deterioration in the braking action is likely to be caused only by the viscous aquaplaning.

In the case of the UR-CPR accident, the aircraft direction deviated to the left, and the aircraft exited the runway to the left side, contrary to the rudder input to the

right. This is proof that the tires were in contact with the runway, providing turning forces, which would have been impossible in case of the aircraft aquaplaning.

In the absence of a strong crosswind, the aquaplaning is usually an obstacle by itself for slowing down the aircraft, which may result in rolling out beyond the runway end. Vice versa, in the presence of a strong crosswind, the aircraft must maintain the direction with the rudder, but it will move away from the runway centerline, as the tires cannot provide sufficient lateral force to prevent the aircraft shifting. The UR-CPR accident does not correspond to any of these scenarios. At the same time, the evidence is that the main landing gear tires were in good contact with the runway and provided the turning forces keeping the aircraft on a curved path to the left, into the grass, following the nose deviation to the left. Records of the parametric recorder indicate that the lateral load factor reached approximately -0.3 Gs, which should obviously come from the forces of the tires. Again, the lateral load factor, as a result of the rotational forces of the tire, is an evidence against the dynamic aquaplaning occurrence.

Steam aquaplaning can be identified by the presence of traces of skidding on the tires, but based on the fact that there were no such traces on the tires of the MD-83 landing gear, it can be concluded that there was no steam hydroplaning.

Dynamic aquaplaning occurs when the water thickness is 3 mm or more. Based on the fact that the thickness of the water on the runway at the time of landing was less than 3 mm, we can assume that there was no dynamic hydroplaning. Confirmation of the absence of dynamic hydroplaning is a high value of the friction Mu-factor on the runway (continuous contact of the aircraft wheels with the runway), which would not be the case at the aircraft aquaplaning.

When the runway is wet, some level of viscous aquaplaning will always be observed. Due to the fact that the runway was wet, viscous aquaplaning could occur, but its level was insignificant and did not affect the movement of the aircraft on the runway.

1.19 Useful or Effective Methods Used at Investigation

Standard methods were applied in the investigation.

2. Analysis

On June 14, 2018, at 05:40 pm, during landing at Kyiv (Zhulyany) Aerodrome in thunderstorm conditions, MD-83 UR-CPR aircraft of Bravo Airways, flight BAY 4406, en-route Antalya (Turkey) – Kyiv (Zhulyany), suffered a runway excursion to the left.

As a result of the excursion, no serious injuries were sustained by any of the passengers and crew. The aircraft received substantial structural damage.

According to the PIC, the crew arrived at Antalya Aerodrome on June 12, 2018, by flight from Lviv on MD-83 UR-COC aircraft. From June 12 to 14, 2018, the crew was at the hotel.

The Investigation Team analyzed preparation of the crew members, PIC and co-pilot, for flight operations. All qualification and certification marks were made in accordance with the requirements of regulatory documents, they are in the personal files of each pilot, and the corresponding records are entered into the certificates of pilots (attached.) The crew performed the flight to Antalya on 12.06.2018, the break between the previous and last flights of the crew was more than 24 hours, the rest period norms were in compliance with the Regulations on Determination of Working Time and Rest Time of Civil Aviation Crews of Ukraine, approved by the Order of the Ministry of Transport of Ukraine dated 02.04.2002 No.219 and registered with the Ministry of Justice on 24.04.2002 under No. 390/6678.

On June 14, 2018, according to the PIC, the crew arrived at Antalya Airport 1.5 hours before the departure time, at 02:00 pm, and began the flight preparation. The flight preparation was carried out at Antalya Airport by the crew independently. According to the PIC, at the flight preparation, the crew received METAR and TAF for Kyiv (Zhulyany) and Boryspil aerodromes, NOTAMS and navigational flight calculations. Documents used in flight preparation were received from the crew by a Turkish Ground Services representative. According to him, at the time of decision on departure, the crew used METAR for 09:00 and TAF for 06:00 am to 06:00 pm. The updated information about the actual meteorological conditions at the Kyiv (Zhulyany) Aerodrome was not available at the time of the decision for departure.

According to METAR weather reports for 03:00 pm and 03:30 pm, at Kyiv (Zhulyany) Aerodrome, there was a wind of 110º 4-5 m/s, visibility over 10 km, clear, air temperature of 27ºC, QNH 1007-1006 hPa, Runway 08 clean, friction Mu-factor 0.7, no changes are expected. These reports were not received by the crews during flight preparation at Antalya aerodrome.

According to the information provided by the Aerodrome Meteorological Station Civilian (AMSC) "Kyiv", on June 14, 2018, 24-hour TAF forecasts were made for the Kyiv (Zhulyany) Aerodrome. The crew did not receive these weather forecasts during the flight preparation. Weather forecasts for the period from 06:00

am to 06:00 pm are not made by AMSC "Kyiv" (daily forecasts are made). Thus, the crew used TAF weather forecast for Kyiv (Zhulyany) Aerodrome, which origin was not determined.

According to the TAF weather forecast for Kyiv (Zhulyany) Aerodrome, from 12:00 June 14, 2018 to 12:00 June 15, 2018, the wind was expected to be 100º 4 gusts 9 m/s; visibility greater than 10 km; overcast at 900 m; maximum air temperature +29°C at 12:00 14.06.18; minimum air temperature +16ºC at 02:00 15.06.18;

at times, *12:00 to 18:00 14.06.18, the wind of variable directions 10 gusts 17 m/s,* visibility of 1000 m moderate rain, *thunder*, hail, *squall*; significant cloudiness 180 m high, significant cumulonimbus at 750 m;

at times 18:00 14.06.18 to 03:00 15.06.18, the wind variable 9 gusts 14 m/s, visibility 1500, moderate rain, thunderstorm, significant cloudiness 150 m high, significant cumulonimbus at 750 m;

gradually, 03:00 to 05:00 15.06.18 wind 130º 3 gust 8 m/s; from 05:00 to 12:00 15.06.18, the wind variable 10 gusts 15 m/s, visibility 1000 m, light rain, thunder, hail; significant cloudiness 210 m high, significant cumulonimbus at 750 m.

At the time of arrival of MD-83 UR-CPR aircraft at Kyiv (Zhulyany) Aerodrome, difficult weather conditions were forecast with variable winds up to 17 m/s, 1000 m visibility, moderate rain, thunderstorm, hail, squall, significant cloudiness 180 m high, significant cumulonimbus at 750 m (METAR and ATIS are in the investigation materials.)

The Investigation Team has not received any documents used by the crew during flight preparation at Antalya Aerodrome and cannot conclude whether the crew conducted the flight preparation. The Investigation Team requested the PIC to present the package of documents that the crew had received prior to departure. The PIC has not provided such a package of documents.

The Investigation Team analyzed the correctness of the crew's decision to take off from Antalya Airport for landing at the Kyiv (Zhulyany) Aerodrome. The crew did not provide the full package of aeronautical and meteorological information to the Investigation Team for consideration. However, the actual and forecasted meteorological conditions for the route flight and landing at the Kyiv (Zhulyany) Aerodrome were analyzed (attached) by the Investigation Team, and they did not interfere with the decision to perform the given flight. However, the thunderstorm activity was forecasted for the time of landing for the Kyiv (Zhulyany) Aerodrome. Given that the flight was delayed by about 6 hours, this information should have alerted the crew to the presence of thunderstorm activity at the landing aerodrome area.

Before taking off from Antalya, the crew calculated the take-off weight and required landing distance (calculations are attached.)

Take-Off Weight	144793 lb
Weight of empty aircraft	87014 lb (AFM)
Total weight of passengers	29938 lb (OM-A 8.1.8)
Cargo	-
Baggage	3526 lb
Total load	33464 lb
Total fuel	25000 lb
Fuel for taxiing	500 lb
Take-off fuel	24500 lb
Flight time	2 hours
Fuel for flight	16200 lb
Calculated landing weight	128778 lb

The calculations meet the requirements for take-off and landing.

On June 14, 2018, SIGMET information was released for the Kyiv Flight Information Region.

According to SIGMET No.1, which was valid from 12:00 to 03:00 pm, for Kyiv FIR, hailstorms were forecasted, which were hidden, obscured in the cloudiness, over a large space, or forming a line with squalls within the entire FIR up to FL460. **It was forecasted that dangerous weather phenomena would move northeast at the speed of 15 km/h.**

SIGMET No.2, which was valid from 1:00 pm to 3:00 pm, contained the information on the actual observation of obscured hailstorms forming a line with squalls southwest of the line with the coordinates of: (51ºN, 30ºE – 50ºN, 34ºE), the upper limit reaches FL480. Dangerous weather phenomena moved northeast at the speed of 15 km/h.

SIGMET No.5, which was valid from 5:00 pm to 8:00 pm, contained the similar SIGMET No.2 information.

The SIGMET information was transmitted through the VOLMET radio broadcast channels and was accessible to all crews operating flights within the Kyiv FIR.

The PIC's statement is not true that the weather forecast for the Kyiv (Zhulyany) Aerodrome did not indicate the presence of dangerous weather phenomena.

The aircraft took off from the Antalya Airport at 03:41 pm. The flight was delayed by about six hours. The reason for the flight delay was non-arrival of the aircraft. There is no information on the repeated flight preparation due to a significant flight delay.

The aircraft climbing and level flight were performed in the normal mode.

The flight en-route, before entering the airspace of the Kyiv ACC, was in the normal mode.

At 05:10 pm, the MD-83 UR-CPR aircraft, at FL320, entered the Kyiv Control Area. ACC controller of BVO Sector informed the crew of the standard arrival route and informed of the presence of thunderstorm activity en-route of the aircraft.

The pilot confirmed receipt of the standard arrival route and requested the route alignment to waypoint KK820. A minute later, the pilot received clearance to alignment of the arrival route to waypoint KK820.

According to the PIC, the crew listened to ATIS "Bravo" radio broadcast for 5:00 pm:

«Kyiv Zhulyany ATIS Information Bravo 05:00 pm: ILS approach, runway-in-use 08. Runway condition for 04:28 pm: dry, measured factor 07, 07, 07, estimated braking action on the surface is good. Transition flight level FL 120. Attention!: The ILS localizer beacon range is 10° to either side of the runway centerline. The control clearance for departure is issued by Zhulyany-Taxiing 119.0. Attention! Bird flights are observed in the area of the aerodrome and on the final approach track.

Airport weather: Wind magnetic: landing area: 100° 4 m/s, gusts maximum 7, minimum 3 m/s, runway threshold: 100° 5 m/s, gusts maximum 8, minimum 3 m/s. The weather is good. Temperature 25, dew point 17, QNH 1007 hPa, QFE 986 hPa.

Landing forecast: no significant changes.

Ground-based radar data: thunderstorm, with a squall line, sector from 161 to 262°, distance from 40 to 100 km, thunderstorm, with a squall line and hail. Azimuth 182°, distance 59 km, moving to the north at the speed of 40 km/h, strengthening.

After take-off, operate Kyiv-Radar 125.3 immediately, confirm receipt of Bravo information. For arrival: Kyiv-Radar 127.72 or 124.67. For departure: Zhulyany-Taxiing 119.0 ».

***Note**: The frequency of 127.725 MHz is used by BV-1 sector, and frequency of 124.675 MHz – by BV-2 sector.*

Thus, ATIS broadcast at 05:00 pm gave instruction to crews arriving at the Kyiv (Zhulyany) Aerodrome to confirm to ATS at 127.725 or 124.675 MHz the receipt of BRAVO information.

In accordance with clause 4.7.16 of the Regulations on Aircraft Flights and Air Traffic Services in Classified Airspace of Ukraine, approved by the Order of the Ministry of Transport of Ukraine dated 29.04.2003 No.293 and registered with the Ministry of Justice of 05.05.2003 under No.346/7667, in case, if ATIS is provided, the aircraft shall confirm receipt of the radio broadcast information after establishing communication with ATS office, which shall provide, respectively, approach control or aerodrome control services.

However, the crew did not confirm receipt of ATIS information to the BV-1 Sector controller at 127.725 MHz, based on the analysis of the crew-controller and intra-cabin voice communication.

According to the information transmitted by ATIS and METAR, at 05:00 pm, at Kyiv (Zhulyany) Aerodrome, the visual flight rules weather conditions were observed with a wind of constant direction, 8 m/s, with a visibility of more than 10 km and no clouds. Although the meteorological information contained the information about the presence of thunderstorms at the distance of 40 km from the aerodrome, which was moving towards the aerodrome at the speed of 40 km/h and was strengthening, the landing forecast erroneously informed the crews that the weather conditions would not worsen.

TREND weather forecast for the landing period of time did not come true.

The Investigation Team did not establish the start time point of the pre-landing preparation because of absence of CVR recording.

During the interview, the PIC reported that on the pre-landing preparation, the crew listened to the weather for the Kyiv (Zhulyany) Aerodrome as visual flight rules weather conditions. 5 minutes before touchdown, during the intra-cabin talks, the crew surprisingly discussed the weather saying the phrase "they gave us CAVOK" (at 05:34:39 pm.)

Note: *METAR reports for 03:30 pm, 04:00 pm, 04:30 pm and 05:00 pm for Kyiv (Zhulyany) Aerodrome contained the good weather information (CAVOK), and 2-hour landing forecast (TREND) did not forecast any deterioration of the meteorological conditions or onset of hazardous conditions (NOSIG.)* ***In this part, the forecast did not come true****.*

At 05:10:25 pm, the controller of the BVC sector of the Kyiv ACC, after contacting the crew, alerted it of the thunderstorm activity en-route *("… there are thunderstorm activity direct your route")*.

At 05:35:02 pm, the crew was asked if they would be able to approach for landing, taking the thunderstorm into account: *"... due to thunderstorm are you able approach?"*, to which the crew answered affirmative and, in turn, asked the controller about the weather: *"Affirmative, and what is the weather like in Zhulyany?"* The controller provided the crew with the following meteorological information:

"... the weather right away: 90º surface wind, 4 m/s, gusts 8, 10 km visibility, cloudbase 630 m at the touchdown point."

At 05:38:02 pm, after contacting the crew, the Kyiv (Zhulyany) Tower controller informed him of the wind information (080º direction, 5 m/s, gusts 8 m/s) and pressure of QNH 1007 and granted the clearance to land. After confirmation by the crew of the clearance, at 05:38:30 pm, the controller provided the crew with the information on the runway status (wet, covered with a layer of water up to 3 mm, friction Mu-factor = 0.54, braking action is Good.)

At 05:39:17 pm, just before landing at the Kyiv (Zhulyany) Aerodrome, the aircraft crew asked the Kyiv (Zhulyany) Tower controller to clarify information about the actual wind: *"Wind check, please", to which he received the following response: "Wind 080 deg 7 gust 11 m/s » (wind 080º, 7 m/s, gusts 11 m/s.)*

However, the information about thunderstorms and light rain came at 05:21:31 pm in ATIS Charlie report for 05:20 pm. In total, within the period from 05:20 pm till the time of landing, 4 ATIS reports were broadcast, 5 local special reports SPECIAL were compiled, 1st regular report - MET REPORT, 1st METAR and 1st SPECI were broadcast.

The information on the thunderstorm activity, which was observed at the distance of 40 km from the aerodrome and moved towards the aerodrome, **was not discussed by the crew at the flight preparation and, probably, not listened to within ATIS information**.

Due to the thunderstorm activity in the Kyiv FIR, the aircraft performed maneuvers to bypass hunderstorm areas during the descent. Below are 4 photos of meteorological phenomena cards, which show the weather radar data for the Kyiv (Zhulyany) Aerodrome.

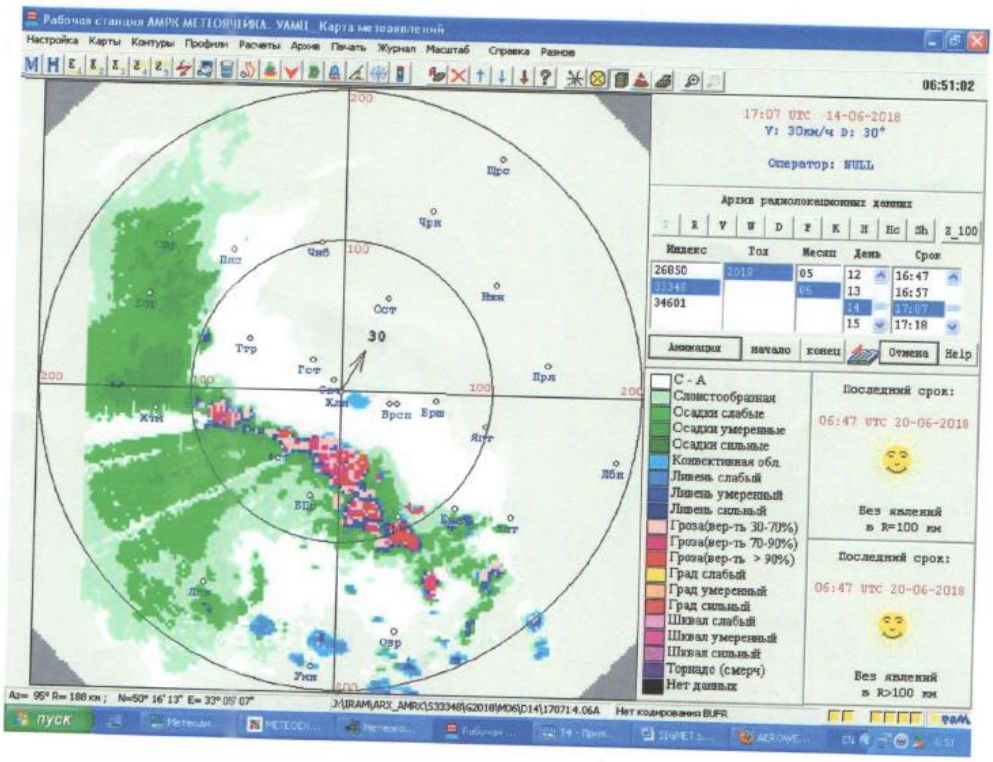

Photo 8
Weather radar data for 17:07

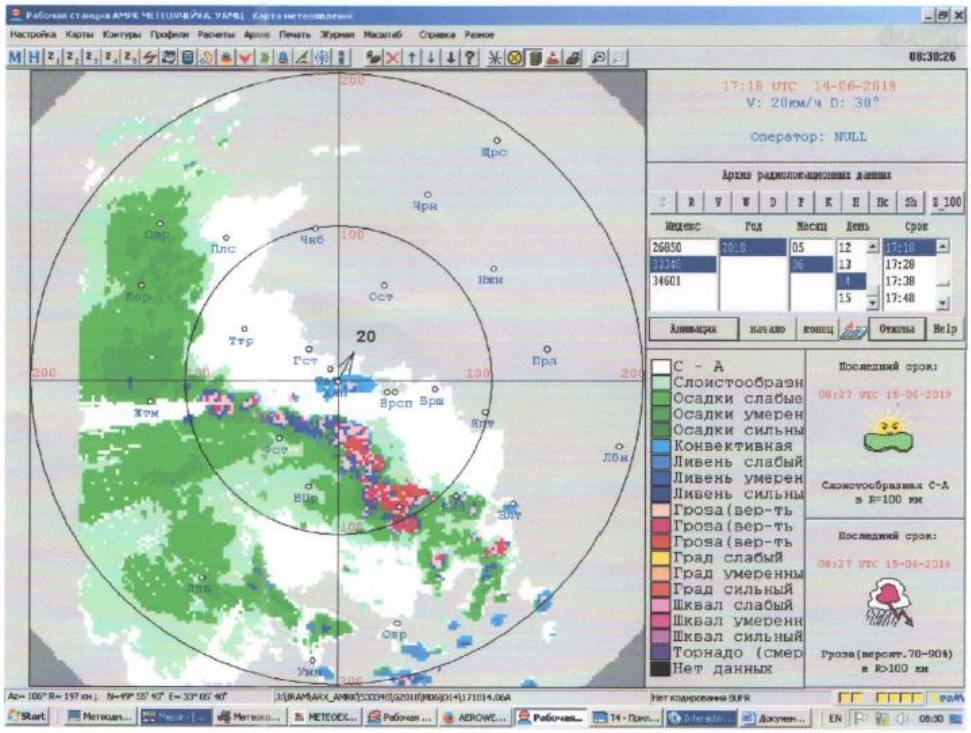

Photo 9
Weather radar data for 17:18

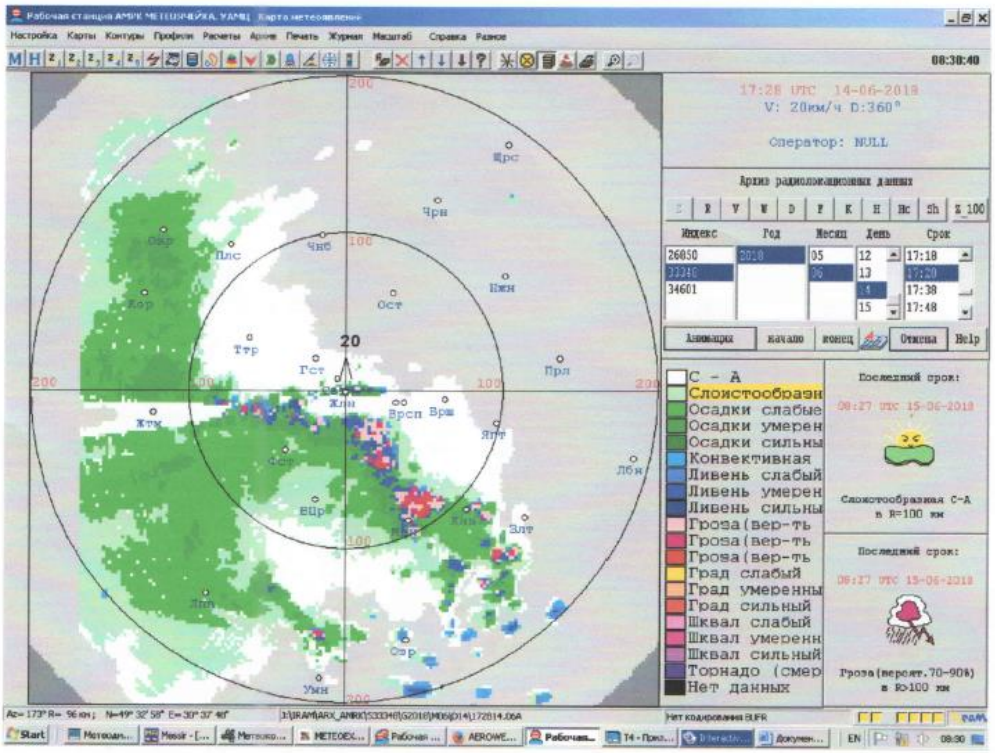

Photo 10
Weather radar data for 17:28

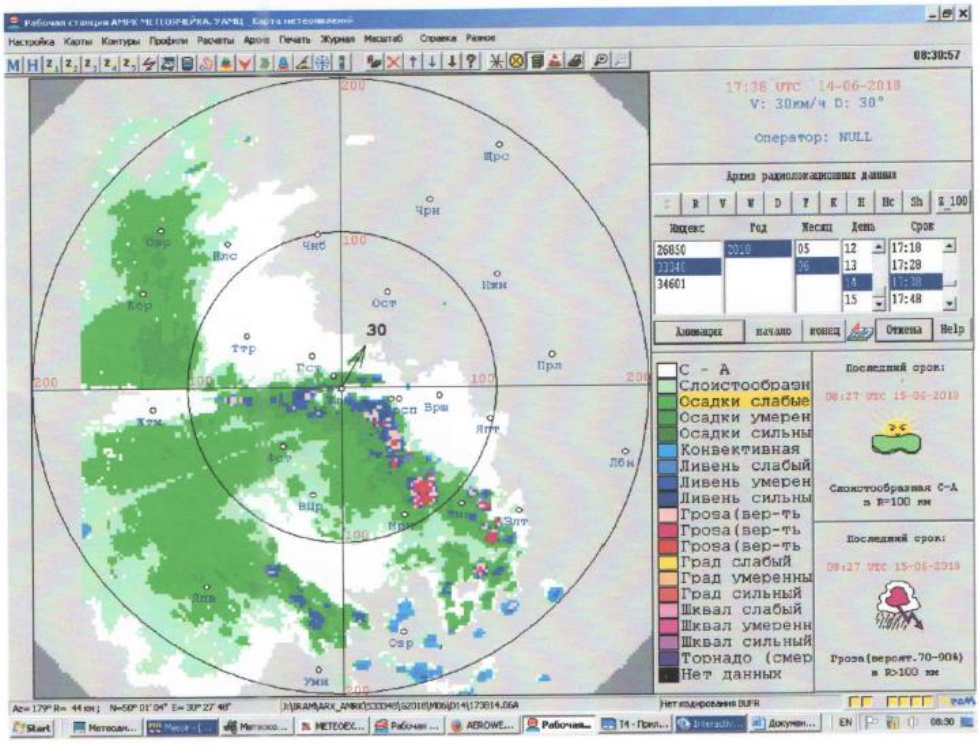

Photo 11
Weather radar data for 17:38

Note: this aircraft is equipped with one radar station (Weather - Radar) of Bendix King RTA - 4A type (Permission to use the radio station No. 7698 was issued by the State Aviation Administration of Ukraine on 27.12.2017). The evidence that the crew used the weather radar during the flight was recorded on the CVR.

At 05:16:44 pm, the pilot requested BVO controller and received a control clearance to descend down to FL170.

The thunderstorm information at the Kyiv (Zhulyany) Aerodrome appeared in an ATIS Charlie report for 5:20 pm at 5:21:31 pm (attached.)

At 05:25:17 pm, the crew switched to the frequency of the BVL sector of the Kyiv ACC.

After contacting the BVL sector controller, the pilot did not confirm the receipt of ATIS broadcast information.

Note: *according to subparagraph (e) of clause 4.7.16 of the Regulations on Aircraft Flights and Air Traffic Services in Classified Airspace of Ukraine, approved by the Decree of the Ministry of Transport of Ukraine dated April 29, 2003 No. 293, in case where the ATIS radio broadcast information is provided at the arrival airport, the aircraft shall confirm receipt of ATIS information after establishing communication with ATS office, which shall provide, respectively, the approach control or aerodrome control services.*

In accordance with paragraph 4.7.21 of the said Regulations, if the aircraft confirms the acceptance of an already outdated ATIS broadcast, any item of the updated information shall be ***urgently*** *transmitted by the controller to that aircraft.*

After reaching FL170, the crew requested the further descent and received a clearance to descend down to FL120.

At 05:28:55 pm, the pilot informed the controller that the aircraft was coming near to FL120 and requested clearance for the further descent. The controller reported QNH, transition flight levels and cleared the crew to descend to an absolute altitude of 9,000 feet.

At 05:29:47 pm, the MD-83 UR-CPR aircraft crew switched to the frequency of the sector BV1 controller of the Kyiv ACC.

After establishing communication with the BV1 sector controller, the pilot did not confirm the receipt of ATIS radio broadcast information, and the controller did not check that ATIS information was available to the crew.

At 05:29:47 pm, the BV1 sector controller informed the crew of the aircraft's radar identification, the runway-in-use of the Kyiv (Zhulyany) Aerodrome and cleared descending down to the absolute altitude of 5,000 feet, and later – down to the altitude of 4,000 feet.

Pursuant to paragraph 4.7.2.15 of the Operating Instruction of the Kyiv ACC, the aircraft, which established communication with BV1, BV2 or BV1 + BV2

sectors, shall be provided with the information except for the information already received by this aircraft, including:

meteorological information about:

- direction and speed of the surface wind, including significant changes;

- current weather;

- other available information on specific meteorological phenomena/weather conditions in the landing approach area;

- TREND landing forecast, if available.

At the time of communication of the MD-83 UR-CPR aircraft crew with the BV1 sector controller, there were **significant changes in weather conditions at the Kyiv (Zhulyany) Aerodrome. According to ATIS at 05:21:31 pm for 05:20 pm at Kyiv (Zhulyany) Aerodrome, there was a thunderstorm, which was accompanied by significant changes in wind direction in the sector from 080 to 140º. According to the TREND forecast for landing, an unstable wind with gusts up to 17 m/s was expected at the aerodrome.** This information was not transmitted to the crew.

Due to the fact that the controllers did not receive confirmation from the crew of receipt of the ATIS radio transmission and they did not know if the crew listened to it (and if it did, then for which time), ***the controllers should have provided the crew with the up-to-date meteorological information and runway status information***.

At 05:32:24 pm, the crew switched to the frequency of sector BV5 of the Kyiv ACC.

After contacting the BV5 sector controller, the pilot did not confirm receipt of ATIS radio information, and the controller did not assure himself that ATIS information was available to the crew.

The BV5 sector controller informed the crew of the aircraft's radar identification, ILS approach, runway-in-use 08, cleared the aircraft to continue the descent down to the altitude of 4,000 feet and bypass thunderstorms along the route. The crew had information about the thunderstorm activity, but did not report to the controller that it had listened to the ATIS data.

At 05:35:02 pm, the controller asked the crew if it could approach for landing in thunderstorm conditions. The crew confirmed the readiness to continue approach for landing and requested the weather at the Kyiv (Zhulyany) Aerodrome.

On the crew’s request about the weather, the controller provided the following information:

"90º surface wind, 4 m/s, gusts 8 m/s, 10 km visibility, cloud base 630 m at the landing point."

Having received the weather information, the PIC decided to proceed with the approach and informed the BV5 sector controller of Kyiv ACC.

Note: *in accordance with clause 3.2.10 of the Regulations on Aircraft Flights and Air Traffic Services in Classified Airspace of Ukraine, approved by the Order of the Ministry of Transport of Ukraine of 29.04.2003 No.293 and registered with the Ministry of Justice on 05.05.2003 under No.346/7667, during an IFR flight, the PIC shall be responsible for, in particular, the decision to make a take-off or landing under the actual weather conditions, runway status and other factors known to him, which affect the flight safety.*

According to clause 5.2.2 of the Operating Instruction of the Kyiv ACC, if the ATIS radio broadcast is used for flight-and-information servicing, *at the request of the crew, the controller shall provide the information to be included in the ATIS radio broadcast or instruction to the crew to listen to the radio broadcast ATIS frequency*, complying with the requirements of clause 4.7.21 of the Regulations on Aircraft Flights and Air Traffic Services in Classified Airspace of Ukraine, approved by the Order of the Ministry of Transport of Ukraine of 29.04.2003 No.293.

According to the ground-based recorders, ATIS provided at this time the following weather information for 05:30 pm for the Kyiv (Zhulyany) Aerodrome:

"Aerodrome weather: Wind magnetic: landing area: 080° 7 m/s. Changing from 060 to 120°. Runway threshold: 080° 6 m/s, gusts max 9, min 4 m/s. Changing: from 070 to 130°. Visibility 10 km, thunderstorm with light rain. Cloudiness scattered cumulonimbus, 630 m, significant 1290 m. Temperature: 23, dew point 19. QNH 1007 hPa, QFE 986 hPa.

Landing forecast: occasionally, wind is unstable 10 m/s, gusts maximum 17 m/s. Visibility 1000 m, thunderstorm, with moderate rain, storm. Cloudiness: significant cumulonimbus 750 m.

Ground-based meteorological radar data: thunderstorm, with a squall line. Sector 0 to 360°. Distance 0 to 101 km, moving to the North at the speed of 20 km/h, weakening. After take-off, work immediately with Kyiv Radar 125.3. Confirm receipt of Hotel information. For arrival: Kyiv Radar 127.72 or 124.67. For departure: Zhulyany-Taxiing 119.0 .»

Thus, the BV5 sector controller provided the crew with incomplete weather information that was included into the ATIS radio broadcast as set out in clause 5.2.2 of the Kyiv ACC Operating Instruction, but included only the information about the surface wind, visibility and cloud base at the landing point. In particular, the controller provided the crew with the information regarding wind direction and speed differing from that contained in ATIS broadcast, did not indicate wind direction and strength at the end of the runway, information on significant changes in wind direction on the runway, the presence of thunderstorm and light rain, air temperature, dew point and atmospheric pressure. In addition, the controller did not provide the crew with a landing forecast that reported the probability of unstable

wind with gusts of up to 17 m/s, storm, data from a ground-based meteorological radar indicating a thunderstorm in 0 to 360º sector and distance from 0 to 101 km, and did not instruct the crew to listen to the frequency, on which ATIS was radio broadcasted. Most likely, the controller provided the weather information for the Zhulyany Aerodrome, which had been obtained from the meteorological display.

Note: *during the investigation into the serious incident, which occurred on 01.09.2017 with Emb-145 UR-DNF aircraft during landing at the "Zaporizhzhya" Aerodrome, the Investigation Team found that the controllers of Dnipropetrovsk ACC and Tower of Zaporizhzhya did not provide the crew with the information about the runway status in full, whereas, in the present case, the controllers of the Kyiv ACC provided the crew with an incomplete weather information. Thus, there is a recurrence of cases, where the controllers provide poor consultations and information to the crews not in full volume, which contradicts paragraph 4.1. of the Regulations on Aircraft Flights and Air Traffic Services in Classified Airspace of Ukraine registered with the Ministry of Justice 05.05.2003 under No. 346/7667.*

According to the PIC, the crew received information from the controller about the ground surface wind, visibility and cloudbase at the point of landing, as well as thunderstorm, at the Kyiv (Zhulyany) Aerodrome, but, at that time, the crew had already seen the runway lights, and it informed the controller about the decision to proceed with the approach.

Pursuant to item 7.9 of the Procedures for Taking Decision on Departure and Arrival of the Civil Aviation Aircraft of Ukraine under Instrument Flight Rules, approved by the Order of the State Aviation Administration of Ukraine dated 28.04.2005 No. 295 and registered with the Ministry of Justice on May 27, 2005, under No.577/10857, PIC should discontinue the descent and go around if, in particular, dangerous meteorological phenomena are observed. According to ATIS reports for 5:30 pm, a thunderstorm with a line of squalls at the aerodrome was observed and forecast for landing from 5:33:39 pm till the aircraft accident. The PIC did not comply with the requirements of the Procedures for Taking Decision on Departure and Arrival of the Civil Aviation Aircraft of Ukraine under Instrument Flight Rules and continued the approach for landing.

At 05:37:40 pm, at the distance of 6 nm to the landing point, the BV5 sector controller informed the crew that the aircraft was positioned to the left of the landing heading and asked, if it would continue to approach for landing in this configuration. To that, the crew replied that the runway is observed, and it continues the approach for landing.

According to the onboard recorders, the aircraft was at the altitude of 680 m, had a speed of 159 knots, magnetic heading was 93º, the distance to the runway threshold was 11 km, the lateral deviation to the left was 476 m, which allowed the crew to stabilize the aircraft for landing.

According to ground-based recorders data, the crew of MD-83 UR-CPR aircraft did not confirm the receipt of ATIS radio information to any of controllers on the descent route. At the same time, according to the information provided by the PIC, the crew had information from ATIS "Bravo" for 5:00 pm and information about the thunderstorm activity provided by controllers. Information about the thunderstorm at the aerodrome was provided by ATIS channel, starting from 05:21:31 pm.

At 05:38:02 pm, the crew switched to communication with the Kyiv (Zhulyany) Tower controller. According to the recorder, the aircraft was at the altitude of 510 m, had a speed of 160 knots, magnetic heading of 91º, distance to the runway threshold was 9 km, lateral deviation 276 m, which allowed the crew to stabilize the aircraft for landing.

After the crew contacted him, the Tower controller informed the crew of the wind at the runway touchdown point, QNH value, runway-in-use “wind 80°, 5 gusts 8 m/s, *QNH 1007, RW 08”)* and gave clearance to landing. A few seconds later, at 05:38:30 pm, the controller informed the crew of the runway status: *"Runway is wet, water up to 3 mm, friction Mu-factor 0.54, braking action is “Good."* The crew confirmed receipt of all information provided by the controller.

According to subparagraph (a) of paragraph 5.3.8.2 of the Operating Instruction of the Kyiv (Zhulyany) Airport Control Tower, the information on significant changes in the mean direction and speed of the surface wind must be transmitted at the beginning of the final approach segment. The Tower controller did not provide such information to the aircraft.

Note: Meteorological and aeronautical information was transmitted in full as part of ATIS radio reports: "D" for 17:22, "G" for 17:26 and "H" for 17:30.

At 05:39:17 pm, the pilot asked for the actual value of the wind and received the answer: *"wind 080º, 7 gusts 11 m/s."*

In accordance with paragraph 5.1.4.2 of the Operating Instruction of the Kyiv (Zhulyany) Airport Control Tower, the controller shall, at the request of the pilot, provide the information contained in the relevant radio broadcast or instruct to listen to an appropriate frequency. At the time of the crew's inquiry about the actual value of the wind, the ATIS broadcast contained the following information about the wind at the aerodrome (at 05:36:39 pm for 05:30 pm): "wind magnetic, landing zone 080º 7 m/s, varies from 060 to 120º, runway threshold 080º 6 m/s, gusts maximum 9 minimum 4 m/s, varies from 070 to 130º." In accordance with paragraph 5.1.4.3 of the Operating Instruction of the Airport Control Tower of the Kyiv (Zhulyany) Airport, upon receipt of the information not yet included into the relevant radio broadcast, but which may affect flight operations, the controller shall transmit this information to the respective aircraft.

Note: At the request of the crew, the Tower controller provided the information on the wind direction and speed.

According to clause 5.3.7 of the Operating Instruction of the Kyiv (Zhulyany) Airport Control Tower, the ATC Tower controller shall report to aircraft crews the significant meteorological information and weather conditions in the control area, including those related to thunderstorm activities.

The aircraft touchdown was performed at 05:39:53.

Note: According to SPECIAL Local Special Report for 05:40 pm, the weather conditions were as follows:

«Wind in the landing zone 090º 9 m/s, maximum wind speed 13 m/s, minimum wind speed 6 m/s, varies from 060º to 170º, at the end of the runway 130º, 5 m/s, varies from 060º to 200º, landing zone visibility 10 km, weather phenomenon - thunderstorm, light rain, scattered cumulonimbus at 630 m, broken cloudiness at 1230 m, air temperature 22ºC, dew point temperature 19ºC, QNH: 1006 hPa, atmospheric pressure at the level of the runway threshold: 0986 hPa, forecast for landing: occasionally, surface wind direction variable, wind speed 10 m/s with gusts up to 17 m/s, visibility 1000 m, thunderstorm, moderate rain, squall, broken cumulonimbus at 750 m, wind at altitude of 500 m 120º, 13 m/s, thunderstorm, squalls line with azimuth from 071º to 270º, distance 12/96 km, moving to the northeast with 30 km/h, weakening."

The Tower Flight Director was watching the aircraft run on the runway. Having seen that the aircraft suffered the runway excursion, the Flight Director instantly, at 05:40:17 pm, announced Alarm to rescue teams.

According to the SPECIAL Local Special Report for 05:40:50 pm (upon the Alarm), the actual meteorological conditions at the aerodrome were as follows:

"landing zone wind 140º, 9 m/s, maximum wind speed 13 m/s, minimum wind speed 4 m/s, changes from 060º to 250º, at the end of runway 150º, 6 m/s, maximum wind speed 12 m/s, minimum wind speed 3 m/s, varies from 060º to 210º, landing zone visibility 10 km, weather phenomenon - thunderstorm, light rain, scattered cumulonimbus at 630 m, broken clouds at 1230 m, air temperature 22º, dew point temperature 19º, QNH: 1006 hPa, atmospheric pressure at the level of the runway threshold: 986 hPa, landing forecast: occasionally, variable wind direction, wind speed 10 m/s with gusts up to 17 m/s, visibility of 1000 meters, thunderstorm, moderate rain, squall, broken cumulonimbus at 750 m, wind at 500 m altitude: 120º 13 m/s, thunderstorm, line of squalls azimuth sector from 071º to 270º, distance of 12/96 km, moving to the northeast with 30 km/h, weakening."

In accordance with the requirements of subparagraph d) paragraph 4.1. of the Regulations on Aircraft Flights and Air Traffic Services in Ukraine's Classified Airspace, one of the main tasks of the ATM, namely, provision of advice and information to ensure the safe and efficient operation of flights, was not fully

implemented by BVO, BVL, BV1 and BV5 controllers. In the course of the investigation, it was established that the ATS working shift of the Kyiv ACC was fully prepared in accordance with the current legislation.

The Investigation Team analyzed the requirements of clause 4.4.6 Runway Definitions of the Bravo Airways Operation Manual (OM-B), approved by the State Aviation Administration of Ukraine on 17.07.2017, and it compared them to the requirements for runway status types definitions listed in ICAO Annex 14 and national document of Ukraine – Acceptable Methods for Determination of Conformity (AMC) and Guidance Materials (GM) developed in compliance with the Aviation Regulations on Ukraine "Technical Requirements and Administrative Procedures for Certification of Aerodromes", approved by the Order of the State Aviation Administration of 06.11.2017 No. 849, which entered into force on 01.09.2018.

According to the Acceptable Methods for Determination of Conformity (AMC) and Guidance Materials (GM) and ICAO Annex 14, if a runway has a layer of water, the runway surface status report should be provided using the following terms:

DAMP – the surface changes the color due to the presence of moisture;

WET – the surface is saturated with water but there is no standing water;

STANDING WATER – the surface, where more than 25% of the area (whether or not is this area isolated) is covered with water more than 3 mm deep within the length and width used.

At the same time, paragraph 4.4.6 “Runway Definitions” of the Bravo Airways Operation Manual (OM-B) lists four types of the runway status: “dry”, “contaminated”, “damp” and “precipitation-covered” runway:

CONTAMINATED RUNWAY – such runway, on which the water layer is not shiny, does not require special calculations;

DAMP RUNWAY – such runway, which has a shiny water layer not exceeding 3 mm;

PRECIPITATION-COVERED RUNWAY – such runway, which is covered with precipitations on more than 25% of the length and, in particular:

- thickness of a layer of water or other precipitations is exceeding 3 mm.

Paragraph 4.4.5 of the Runway Specifications of the Bravo Airways Operation Manual (OM-B) states:

“Use the data for a dry runway in case of:

- dry runway;

- contaminated runway.

Use the wet runway data in case of:

- 3 mm standing water;

- friction Mu-factor greater than 0.40.

Use the data for the precipitation-covered runway in case of:

- 25% or more of the runway is covered with more than 3 mm of water."

Item 4.4.3.2 of the OM-B "Landing Weight Calculations" states that "(dry) landing strip limitation is based on stopping the aircraft along 60% of the landing distance. For a wet runway, the distance should be 115%." At the same time, according to item 4.4.6.3 of the OM-B "Landing Characteristics and Definitions", "the required length of the landing strip is the length of the landing strip (OM-B document contains an incorrect translation of OM-B English version, correctly – the landing distance) multiplied by the operating factor of 1.67 (for a dry runway) and increased by 115% of this value for a wet runway."

Note: *The Bravo Airways Operation Manual does not provide what specific operating factor should be used for a contaminated runway.*

Thus, the Bravo Airways Operation Manual contains various readings of definitions of runway statuses (inside the OM-B document, as well as differences with the definitions given in ICAO Annex 14 and Acceptable Methods for Compliance (AMC) and Guidance Materials (GM) developed to comply with the Aviation Regulations on Ukraine "Technical Requirements and Administrative Procedures for Certification of Aerodromes", approved by the Order of the State Aviation Administration of 06.11.2017 No. 849.) In addition, in a part of the OM-B Manual, the methods for calculating landing characteristics and weights are not clearly understood, which can significantly affect the flight safety.

Similar differences in the use of the terms are in the Regulations on ATM Reporting approved by the Order of the Ministry of Infrastructure of Ukraine dated 27.05.2012 No. 277, registered with the Ministry of Justice on 14.06.2012 under No. 958/21270.

It is established that the crew shall use a special Electronic Flight Bag when calculating flight parameters. The Electronic Flight Bag allows to take into account the following parameters: temperature, wind, runway slope, reverse position (ON/OFF); 5 to 20 knots should be added to the speed Vref in the calculations, and also, the runway status and pressure QNH should be taken into account. The same Electronic Flight Bag with the appropriate software shall be used to calculate the required landing distance. This software takes into account four types of runway statuses. It is not possible to enter into this software code a value of the runway threshold fly-over speed (Vref), friction Mu-factor and the corresponding braking

action. There is also no provision for entering into this software code a value of the thickness of the runway deposits and contamination degree. Moreover, when calculating the required landing distance, the Electronic Flight Bag does not show its length in meters, but only determines, whether this value is within the normative range.

The Investigation Team did not receive from the airline the documents confirming the Electronic Flight Bag use approval by the State Aviation Administration of Ukraine.

In such a way, the Investigation Team has come to the conclusion that this Electronic Flight Bag is inappropriate and cannot be used by flight crews to calculate the required landing distances – until it is finalized and approved by the State Aviation Administration of Ukraine under the established procedure.

The Investigation Team analyzed the actions of the aerodrome service personnel, who carried out aerodrome flight support at the time of the occurrence, and established the following. Due to the absence of precipitations, the runway status did not change until 05:20 pm.

The information on precipitation onset was transmitted by ATIS at 05:21:31 pm for 05:20 pm: *"thunderstorm with light rain, scattered cumulonimbus"* and corresponds to the information declared in the local special report SPECIAL.

In the Airfield Status Log kept by the aerodrome service, before the aircraft landing, at 05:30 pm, the following record was made of the runway status: *"Runway is wet, water layer is up to 3 mm, friction Mu-factor = 0.54/0.54/0.54"*. This information was transmitted, as required, by the aerodrome service engineer to the Tower controller at 05:25 pm.

However, having watched the video from the CCTV camera (mounted on the fire depot tower), the Investigation Team found that the aerodrome service vehicle inspected the aerodrome status with no friction Mu-factor measuring device, its movement is recorded only in one direction – Magnetic Heading 079 for landing. Measurement of the precipitation layer by the aerodrome service employees at the mentioned area was also not carried out. According to the extract from a tape record of communication between the Kyiv (Zhulyany) Tower controllers and aerodrome service engineers, the aerodrome service engineer asked the controller for clearance to enter the runway from TW1 at 05:19:10 pm, for which he received the clearance. Already at 05:24:58 pm, the aerodrome service engineer informed the controller about vacating the runway and its status. Thus, the runway inspection lasted for about 5 minutes, which, taking into account the friction Mu-factor measurement technique and the runway length, did not allow to conduct the friction Mu-factor measurement. In his Statement, the aerodrome service engineer stated that he provided the information about the runway status based on his experience.

According to paragraph 2 of Appendix 16 to the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86 and section 8 of the Technology for

Work of Shift Chiefs and Shift Engineers of Aerodrome Service for Assessment of Aerodrome Status and Measurement of Friction Mu-factor on Runway Pavement dated 13.03.2017 No.7.4-06-02, approved by the Director General of ME IA "Kyiv" (Zhulyany), the friction Mu-factor measurement shall be done at speeds of 40-45 km/h in both runway directions at the distance of 5-10 m from its center line; 8 measurements shall be made for each 1/3 of the runway length, i.e. 4 measurements on each side of the runway center line. According to paragraph 5.2.11 of the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86, the thickness of the precipitation layer shall be measured by the OL-1 optical rule.

Thus, due to the fact that measurement of the friction Mu-factor and precipitation thickness on the runway was not carried out by the aerodrome service personnel, the Investigation Team cannot objectively determine the actual values of the runway friction Mu-factor and precipitation layer at the time of the accident.

In addition, during the investigation into the serious incident involving B-737-300 UR-GBA aircraft during landing at the Kyiv (Zhulyany) Aerodrome on 16.01.2016, the Investigation Team found that the control measurement of the friction Mu-factor was performed by the aerodrome service personnel in violation of the friction Mu-factor measurement procedure (the friction Mu-factor measurement was carried out with ATT-2 aerodrome brake trolley only in one direction, but not in both directions, as required by the Aerodrome Maintenance and Supply Service Manual in Civil Aviation-86.)

According to item 6 of the Procedure for Dissemination of Aeronautical Information on Status of Areas-in-Use of Civil Aerodromes of Ukraine, approved by the Order of the Ministry of Transport of Ukraine dated 28.05.2004 No.443 and registered with the Ministry of Justice on June 11, 2004 under No.723/9322, the aerodrome operator (owner) shall be responsible for the accuracy and timeliness of rendering the air navigation information on status of an aerodrome area-in-use.

Due to the fact that it is impossible to check the accuracy of the runway status information transmitted to the crew as regards the thickness of the precipitation layer, and a water layer on the runway surface could exceed 3 mm, the Investigation Team calculated the required landing distance for a dry, damp, wet runway and runway covered with a layer of water more than 3 mm thick. The calculations showed that for a dry and damp runways, the required landing distance was 1696 m, for wet one – 1950 m, which is almost equal to the length of available runway distance (2160 m), and for a runway covered with a water layer more than 3 mm thick – 2854 m, which considerably exceeds the length of the landing distance available (calculations are in the investigation materials.)

Subsequently, the Investigation Team analyzed the stages of the aircraft flight from the altitude of 1000 feet (300 m) to the runway threshold fly-over, runway touchdown, landing run, runway excursion – till the aircraft full stop, and it

approved the tire footprints at the occurrence site (the sketch is in the investigation materials.)

The recorders decoding and analysis was performed by the staff of the Flight Data Decoding and Flight Parameters Calculation Sector of the National Bureau of Air Accidents Investigation of Ukraine.

During the analysis, the National Transportation Safety Board (NTSB, USA) was requested to clarify and compare the results of the NTSB's decoding of FDR with the results obtained by the NBAAI. There were no discrepancies found in the decoded FDR data.

Synchronization of Flight Data Recorder with Cockpit Voice Recorder Data

For the purpose of solving the tasks of complex assessment of crew actions, calculation of the aircraft path and other investigative purposes, the FDR and CVR data synchronization was conducted versus the recorded FDR binary signals "Radio keying VHF-1" and phrases (sounds) recorded by CVR.

CVR record disappearance and/or CVR and FDR record mismatch were not detected. CVR recording through the common microphone channel is indistinct. CVR recording time (30 minutes) does not meet the requirements of ED-05k-15 Operational Directive of the State Aviation Administration of Ukraine.

Flight Time Conversion to UTC

The FDR is recording vs. hours and minutes in UTC. However, when comparing FDR data and synchronized CVR data with the Excerpt of Communication Between Kyiv (Zhulyany) Aerodrome Tower Controller and BAY 4406 flight crew, a time difference of 5 seconds was found (FDR time is 5 seconds less). The "controller's" time is assumed as the actual one, and FDR time is increased by 5 seconds to convert it to UTC. Hereinafter, the indicated FDR time is the corrected one (UTC.) The decoded CVR record is in the investigation materials.

Determination of Rudder Values Signs

In order to determine the pilot's actions and analyze the aircraft movement on the runway, the check and determination of the physical meaning of the recorded values of the rudder position were carried out. 37 flights stored on the FDR were decoded and analyzed.

It was established that the recorded positive value of the rudder position corresponds to the left turn, and the negative one corresponds to the right turn.

Figure 3 shows the decoded fragment of one of the previous flights at performance of the left aircraft turn. The Heading (red line) decreases – the turn to the left, at that, the values of the Roll are negative, and the rudder position values (Rudder) are positive.

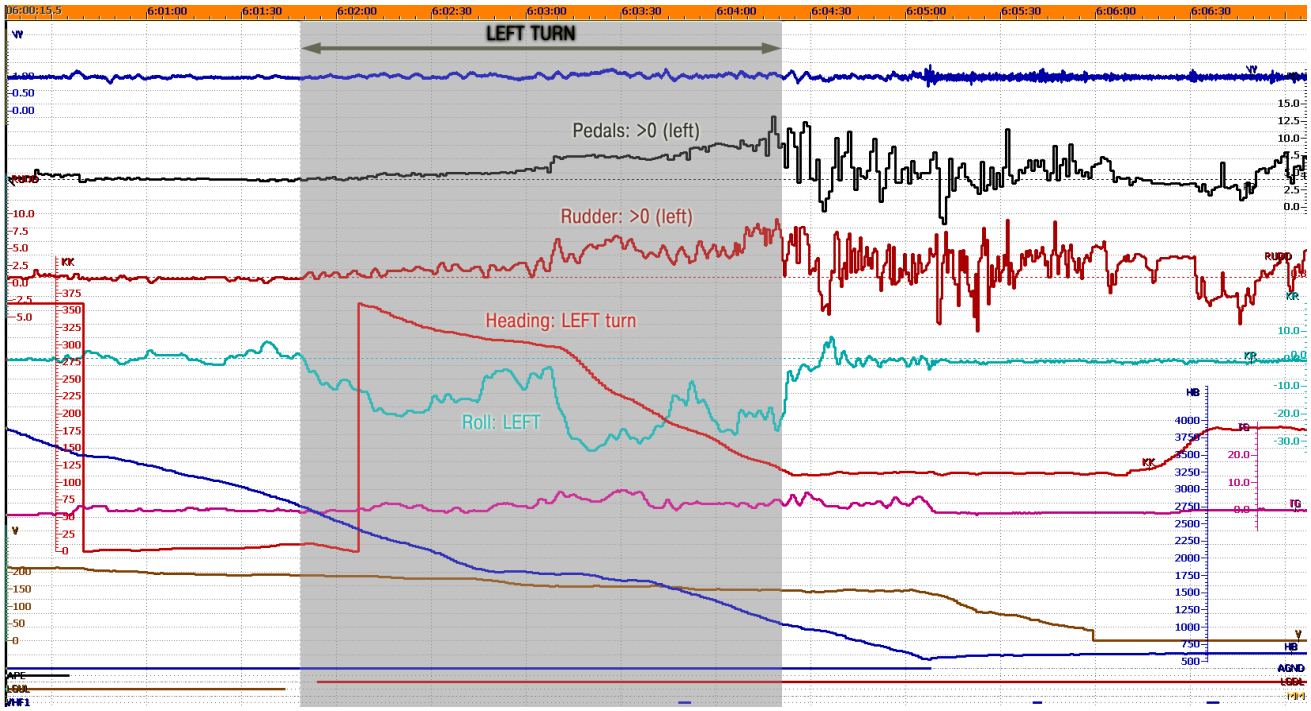

Figure 3.

Left turn in flight

Flight Operation

During the engine start-up, take-off, climb, level flight and descent, no any deviations were detected in piloting and operation of the equipment. The further investigation and recorder analysis were conducted as regards the final approach, landing and aircraft run on the runway.

The charts of basic flight parameters at approach, touchdown and run are in the investigation materials.

Runway Threshold Fly-Over Time Determination

At approach, no binary signal "Marker Beacon Fly-Over" was recorded that makes it impossible to construct with sufficient accuracy, based only on the FDR data and tire footprints, the aircraft path on the final, determine the time point of the runway threshold fly-over and distance from the runway threshold to the touchdown point.

To determine the time point of the runway threshold fly-over, the synchronization was performed of FDR and CVR data with the video (view from the left side window in the center wing section area) taken by the passenger's mobile phone during approach and landing run.

The phrase *"Cabin crew take your seats and be ready for landing"* is heard at the 29th second of the video. The same phrase is present on the CVR record (00:27:55 from the beginning) and corresponds to the synchronized flight time of 05:37:21.

The video clearly shows and defines the time of the runway threshold fly-over (Photo 12).

Photo 12.

Runway threshold fly-over on video

According to the flight synchronized with video, the runway threshold fly-over time point was determined by the FDR data (Figure 4.)

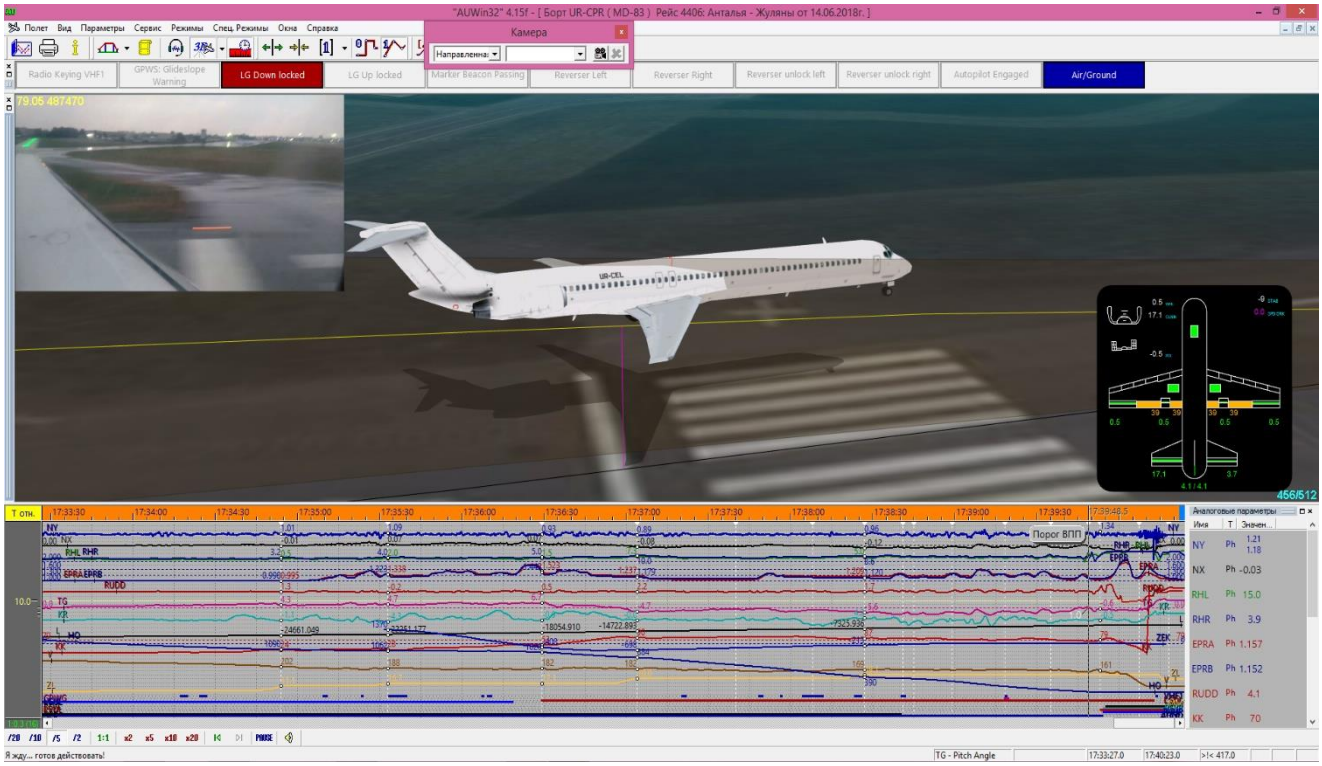

Figure 4.

Runway threshold fly-over according to FDR data

Flight Path and Touchdown Point Calculation

The runway threshold fly-over point (time) was assumed as a benchmark. As an end reference point for the aircraft path calculation, there was assumed the point (distance and lateral deviation from the runway center line) corresponding to the location of the first side row light, with which the aircraft collided. The distance from the runway threshold of the first damaged side light is 1260 m, the lateral deviation from the runway center line is 24 m.

The longitudinal distance to/from the runway threshold was calculated by the method of integrating the recorded instrument speed, taking into account the aircraft heading and environmental parameters.

In order to improve the accuracy of the calculation of the lateral deviation from the runway center line during the runway run (compared to the instrument speed integration), the calculation was made on the basis of the recorded heading deviation from the equisignal section. However, at long distances from the runway, due to the impact on the heading deviation readings of terrain, electromagnetic radiation, etc., the accuracy of determination of the lateral deviation over long distances is low, which does not affect the overall picture of approach, near-runway movement and runway run.

The touchdown time point was determined by the maximum value of n_y - "Vertical Overload" (normal acceleration.) At that, the calculated distance from the runway threshold was 350 m.

After calculating the path and drawing it on a map of the earth's surface, the conformity of the calculation results with the video was verified (Figures 5, 6, 7.)

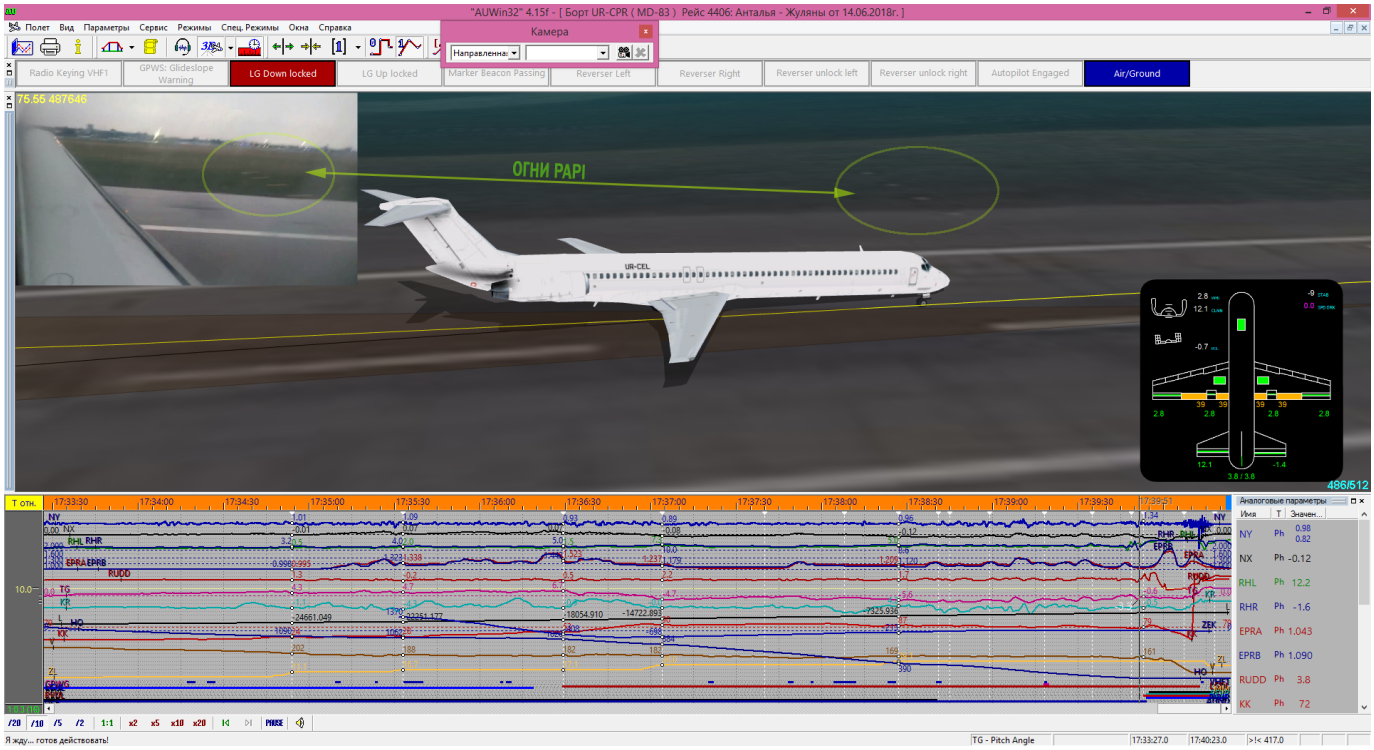

Figure 5. *PAPI lights*

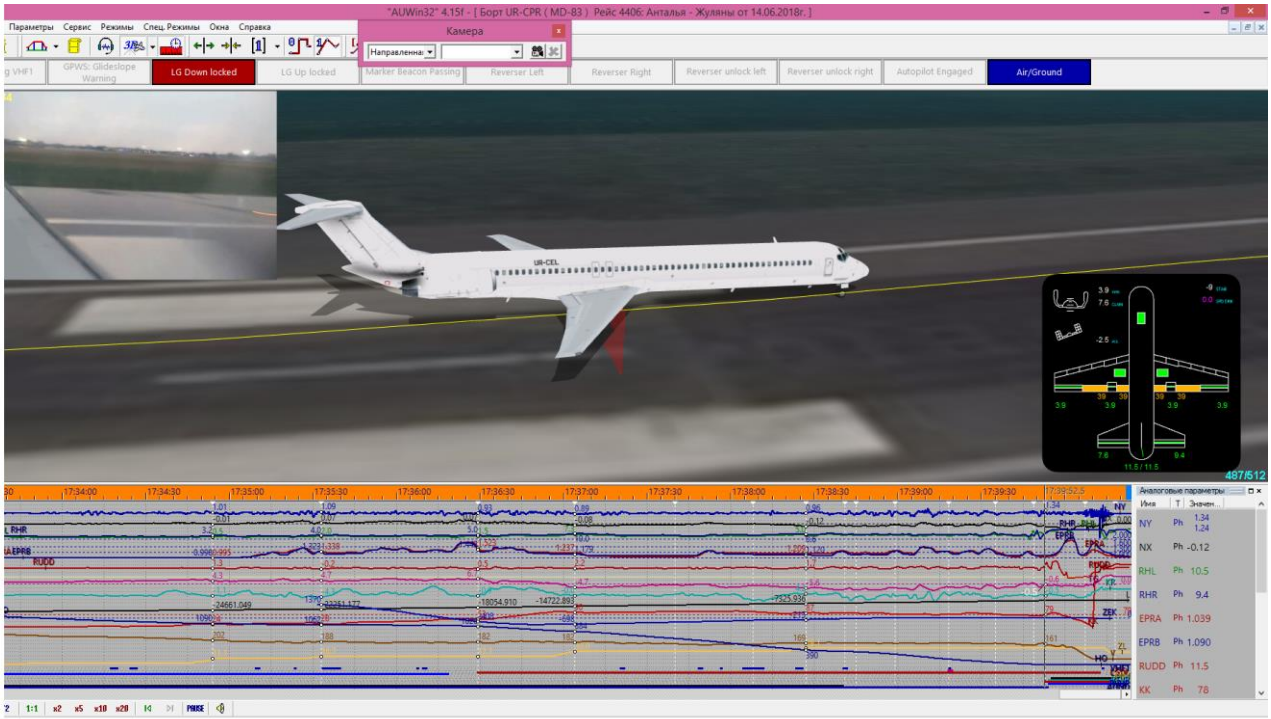

Figure 6. *1/24 sec (from video) till touchdown*

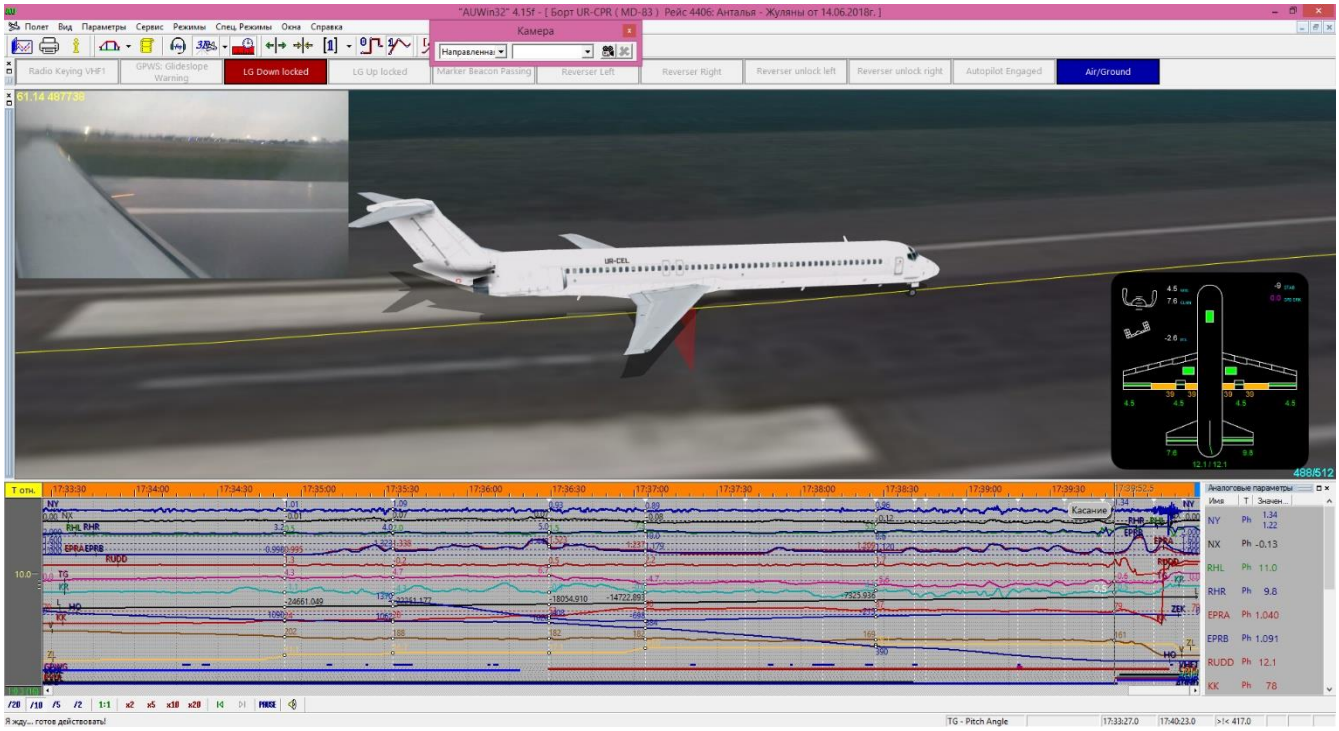

Figure 6.

Touchdown point

Approach and Landing

The landing approach was performed to Runway 08 of the Kyiv (Zhulyany) Aerodrome. Magnetic heading (landing) was 79°. Total runway length – 2310 m (the actual one – 2160 m plus offset threshold – 150 m.) Width – 45 m. Runway threshold safety area length – 90 m.

In the process of approach, the flaps were deployed to 11-15-28-40 degrees, landing gear was extended. The landing gear was extended at the distance of 18 km. The flaps were fully deployed to 40 degrees at the distance of 7.4 km from the runway threshold.

The Investigation Team found that the flaps were in 28º position. In connection with this, the Investigation Team analyzed by the FDR data the stages of flaps deployment from 0º to 40º during approach and determined that the aircraft landing was indeed performed with flaps deployed to the angle of 40º, as explained by PIC in his Statement to the Investigation Team. According to PIC, after the runway excursion, he reduced the flap deployment angle to 28º for easy evacuation of passengers.

Till the turn on final, the aircraft approached deviated to the right from the runway centerline. In the process of turning to final, the aircraft crossed the landing heading and deviated to the left. The maximum deviation was 730-740 m at the distance of 16 km from the runway threshold. Further, as it approached to the

runway threshold, the aircraft was approaching the landing heading, all the while remaining to the left of the runway center line. At the time of the runway threshold fly-over, the lateral deviation was 1 m to the left of the runway center line.

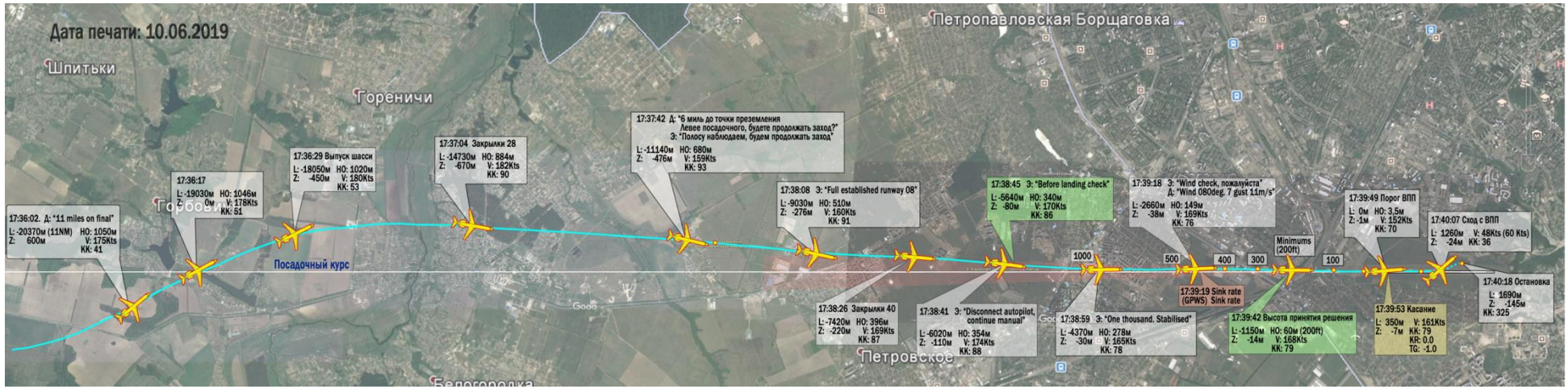

Fig. 8. *Aircraft approach path mapped on earth's surface*

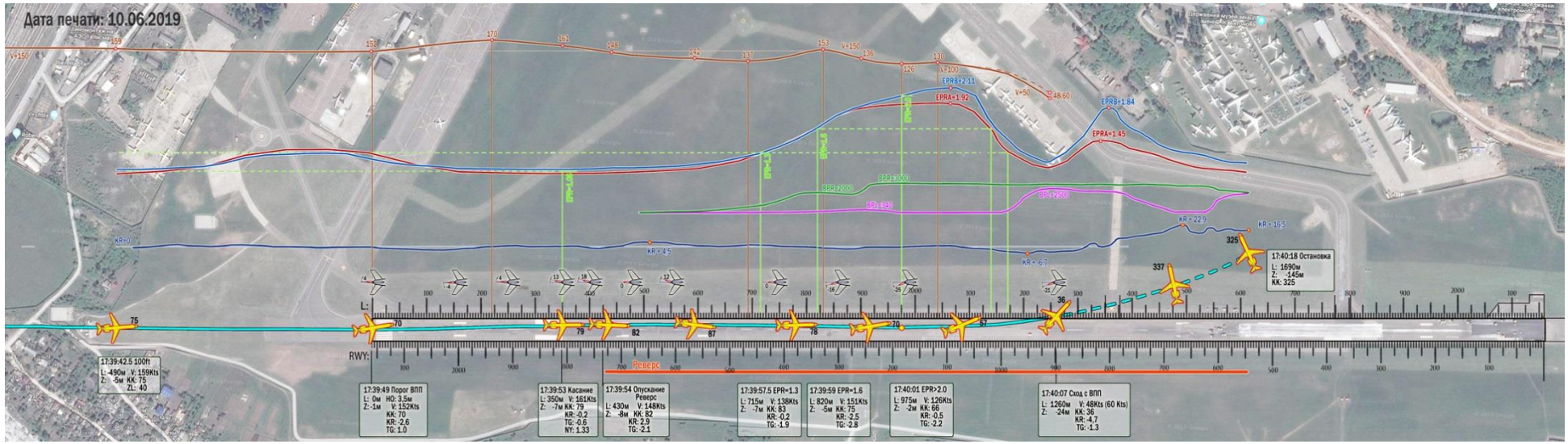

Fig.9. *Aircraft path on runway with indicated values of flight parameters, distances from runway threshold and rudder position*

Table 1. Parameter Values at Landing Approach Points

Time Point, pm	Point	H, m	Vy, ft/min	V, knots	KK, degr	KR, degr	TG, degr	EK, points	EG, points	L, km	Z, m	Note
05:34:54	Flaps 11	1090	-220	204	24	0	4.0	-2.1	1.7	24.6	–	Vmax=280
05:35:33	Flaps 15	1062	-10	188	28	-3	4.5	-3.2	1.4	22.2	1370	Vmax=240
05:36:29	Landing gear extension	1020	-583	180	53	0	6.9	1.1	0.0	18.1	-410	
05:36:50	Max Z	932	-790	182	82	17	1.8	2.3	-0.2	16.0	-737	
05:37:04	Flaps 28	880	-730	182	90	0	-4.5	2.4	-0.7	14.7	-700	Vmax=205
05:37:48	E: "See runway, will continue approach"	650	-1200	154	95	0	-0.4	1.9	-0.8	10.6	-440	To the controller's question: "6 miles to touchdown point. Left of the final course. Will you continue approach? "
05:37:59	Glide path intercept point	578	-1360	160	94	1	-4.5	1.7	-0.5	9.8	-365	Not shown
05:38:08	E: "...Full established RWY08"	510	-1360	160	91	-14	-2.2	1.4	-0.1	9.0	-280	Communicating Tower controller
05:38:27	Flaps 40	390	-910	169	87	4	-5.0	1.3	0.1	7.4	-210	Vmax=190
05:38:41	Autopilot disconnected	355	-610	175	88	-7	-7.0	0.8	-0.6	6.0	-110	E: "Disconnect autopilot, continue manual"
05:38:45	Before-landing check	340	-670	170	86	-5	-8.2	0.6	-0.8	5.6	-80	CVR: "Before landing check"
From the height of 1000 feet, the aircraft should be stabilized for approach by the instrument speed and descent speed												
05:38:55	H=300 m (1000 ft)	300	**-1020**	**168**	84	0	-7.0	0.3	-0.9	4.7	-29	
05:38:59	E: "One thousand. Stabilized"	278	**-1150**	**165**	78	-2	-4.9	0.3	-0.7	4.4	-30	
05:39:10	H=200 m	202	**-1290**	165	80	3	-4.8	0.2	0.3	3.4	-23	
05:39:18	H=(500 ft)150 m Request: «Wind check»	150	**-1200**	169	79	1	-4.0	0.4	0.9	2.6	-38	Operation of GPWS warning "Sink rate";
05:39:27	H=100 m	100	**-1010**	167	86	6	-5.4	0.5	**1.2**	1.6	-33	
05:39:35	Decision height (H=200ft)	61	-860	**168**	79	-8	-4.5	0.2	**2.0**	1.1	-14	MI: "Minimums"
05:39:49	Threshold	3.5	-380	152	70	-3	0.9	0.0	–	0	-1	Vref = 133
05:39:53	Landing	–	–	**161**	79	0	-0.6	0.2	–	0.350	-7	NYmax = 1.34 at 05:39:53.5 pm NZmax = -0.04, UA = -21.9° (Averaged UA for landing run: 21-22°)
05:39:54	Lowering	–	–	159	82	0	-2.1	–	–	0.430	-8	
05:39:58	EPR 1.3			137	86	0	-1.8	–	–	0.740	-6	
05:39:59	Brake right 2000psi	–	–	139	81	-2	-2.2	–	–	0.810	-5	
05:39:40	EPR 1.6			153	75	-1	-1.8	–	–	0.880	-3	
05:40:01	Brake right 3000psi	–	–	135	72	0	-2.2	–	–	0.950	-2	

05:40:03	Max reverse thrust	–	–	130	62	0	-2.7	–	–	1.085	-4	EPR (left / right) = 1.9 / 2.1
05:40:07	Runway excursion	–	–	48(60)	36	-5	-1.4	–	–	1.260	-24	
05:40:18	Stop	–	–	–	325	16	9.8	–	–	1.690	-145	

Abbreviations in Table:

Parameter	**Unit**	**Description**	**Note**
HO	m	Height (relative)	Design parameter
Vh	ft/min	Vertical speed	<0 – descent
V	knots	Instrument speed	
Vmax	knots	Instrument speed	Max permitted by Operation Manual
KK	°	Magnetic heading	
KR	°	Roll	
TG	°	Pitch	
UA	°	Angle of attack	
NY	units	Normal acceleration (Vertical G)	
NX	units	Longitudinal G	
EK	point	Heading equisignal zone deviation	<0 – Aircraft is to the right of heading equisignal zone;
EG	point	Glide path equisignal zone deviation	<0 – Aircraft is higher than glidepath;
L	km	Distance to/from runway threshold	
Z	m	Runway heading deviation	
MI		Voice alert system	
E		Crew	

05:38:45 pm: Autopilot Switching Off: at the height of 350 m and 6 km distance from the runway threshold, the autopilot was switched off and piloting was conducted manually.

05:38:46 - 05:39:14 pm: "Before Landing Check" was executed immediately after the autopilot was switched off. The checklist was read in full, but the answers to the checklist questions on the CVR record are indistinct.

During the aircraft descent, PIC should bring into operation the spoiler system, as this aircraft has an automatic system of spoiler deployment.

According to Section D of the MD-80 Maintenance and Repair Manual, an automatic spoiler system is a hydraulically operated, hydraulically actuated system used to reduce the lift of the wing and increase the pressure on the brake wheels for more effective braking during run on landing. At the spoiler control lever set to the ARM position (armed), the spoilers are deployed automatically at main gear wheel spin-up after touchdown, or at the front landing gear compression. The spoilers can be operated with levers manually.

According to the CVR, the checklist reading by the crew about bringing the spoiler deployment system to the armed state is recorded, but there is no confirmation that the lever was set to the ARM position. At the same time, the PIC reports in his Statement that this spoiler deployment lever was timely switched into ARM position.

Note: *According to the data obtained from the organization that conducted testing of the spoiler deployment system,* ***the system was operable. Therefore, the Investigation Team concluded that arming at the stage of descent was not performed and, after runway touchdown, the crew did not manually deploy the spoilers as prescribed by the Manual. Non-deployment of spoilers had a significant impact in the process of deceleration during the aircraft landing run****.*

The Investigation Team found that the cockpit spoiler control lever was not set to ARM.

05:38:59 pm: On the CVR record, after the voice alert system signal (05:38:57 pm) "One thousand", sounds a report of the co-pilot of the aircraft stabilized position. The flight parameters (stabilized position criteria) at this time are as follows:

	Reference Parameter	**Design/Target Value and Tolerance**	**Actual Value**	**Note**
1	Position of flaps, º	40	40	
2	Gear position	Extended	Extended	
3	Instrument speed, knots	133(+20)	168	**NOT STABILIZED**
4	Deviation from the heading equisignal zone, points	≤ 1	0.25↓ (to the left of equisignal zone and falling)	30 m
5	Deviation from the glide path equisignal zone, points	≤ 1	-0.8 (higher than equisignal zone and falling)	
6	Vertical descent rate, ft/min	≤ 1000	1150 ↑ (rising)	**NOT STABILIZED**

7	N2 (left/right) engine operation mode	≥ 80%	86/85	
8	Altitude, m (feet)	300 (1000)	278 (912)	
9	Distance from the runway threshold, km	–	4.4	
10	Magnetic heading, °	79 ± (wind) correction	79	

- autopilot switched off (05:38:45 pm);

- checklist read (05:39:14 pm);

The aircraft was in a non-stabilized state by the forward speed (165 knots) and vertical speed (1150 ft/min.)

At this stage, the PIC had to make a decision on go around (paragraph 8.1.3.18, "Criteria for Stabilized Approach" of the Bravo Airways Operating Manual.)

Having crossed the height of 1,000 feet, the aircraft gradually deviates below the glide path and continues to approach (from the left) the runway center line. At 05:39:19 pm, the GPWS "Sink Rate" alarm was triggered due to the exceedance of Vy sink rate (Vy = 1200 ft/min.)

At the height of 500 feet, the aircraft was also in a non-stabilized position by the forward and vertical speed.

05:39:17 pm: Wind check. At the distance of 2.7 km, the PIC requested Wind Check and received information from the controller: *"Wind 080 degrees, 7, gust 11m/s."*

05:39:42 pm: Decision height.

The values of the stabilized position criteria are shown in the table:

	Reference Parameter	**Design Value and Tolerance**	**Actual Value**	**Note**
1	Position of flaps, º	40	40	
2	Landing gear position	Extended	Extended	
3	Instrument speed, knots	133 (+20)	168	**NOT STABILIZED**
4	Deviation from heading equisignal zone, points	≤ 1	0.2↓ (to the left of equisignal zone and falling)	14 m
5	Deviation from the glide path equisignal zone, points	≤ 1	2.0↑ (below equisignal zone and rising)	**NOT STABILIZED**

6	Vertical descent rate, ft/min	≤ 1000	860↓ (falling)	
7	N2 (left/right) engine operation mode	≥ 80%	86/85	
8	Height, m (feet)	61 (200)	61 (200)	
9	Distance from the runway threshold, km	–	1.1	
10	Magnetic Heading, °	79 ± (wind) correction	80	

Height 200 feet, ***speed 168 knots, heading 79 degrees***, distance from the runway threshold 1150 m, deviation to the left from the runway center line 14 m. On the CVR record, the voice alert system gives the Minimums signal. From height 200 to 100 feet, the pitch gradually increases from -5 to -3, and the instrument speed drops ***from 168 to 160 knots***. Upon crossing the height of 100 feet, the engine mode increases from 1.1 to 1.3-1.35 EPR. The instrument speed stabilizes at a value of **151 knots**.

The PIC's report on continuation of the landing approach was not found in CVR recordings. There was no action also on the part of the co-pilot to perform go-around.

Note: According to paragraph 1.5.1 (Duties and Responsibilities of Co-Pilot) of the Operation Manual of Bravo Airlines LLC, Part A, the co-pilot should perform go-around according to FCOM from the decision altitude, if till that moment the PIC failed to take a decision and failed to notify the crew of landing or go-around.

05:39:49 pm Runway Threshold Approach.

The aircraft approached the runway from the left side of the runway center line, constantly approaching (from left to right) to the center line and moving below the glide path. The recorded median magnetic heading from the height of 100 feet is 75 degrees, and it is still decreasing before the runway threshold. Before the threshold fly-over, the aircraft turns to the left by heading, while continuing to shift to the right (approaching the center line.) 1.5-2 seconds before the runway threshold fly-over, the engine thrust falling begins, which reaches idle by the touchdown time. The displaced runway threshold fly-over was ***at the height of 11 feet (3.5 m), speed of 151-152 knots, lateral deviation of 1m to the left of the runway center line, and magnetic heading of 70-71 degrees***.

That is, at the time of the runway threshold fly-over, the aircraft had a deviation of:

	Reference Parameter	Design Value	Actual Value	Note
1	**Height, m (feet)**	15 (50)	3.5 (11)	**Lower by 11.5 m (39ft)**

2	**Instrument Speed, knots**	133	151-152	**Higher by 18-19**

After the threshold fly-over, the aircraft shifts to the left of the runway center line. The recorded values of the magnetic heading (to the left of the direction of the runway center line) and the aircraft position relative to the runway center line in the process of approaching the threshold (the shift was from left to right) indirectly indicate the presence of a side wind component from the left.

Also, from the runway threshold fly-over to the touchdown time and further, at the initial stage of braking, there was recorded increase with a further decrease of the instrument speed, at that, the values of longitudinal acceleration, which characterize speeding-up (positive values) or braking (negative values), remain negative. Such values of the recorded parameters indirectly indicate that the aircraft was affected by a variable front wind component (gusts.)

Figure 10 shows the basic parameters of the position of the aircraft, controls and engine operation modes from the final till the runway excursion and stop outside the runway.

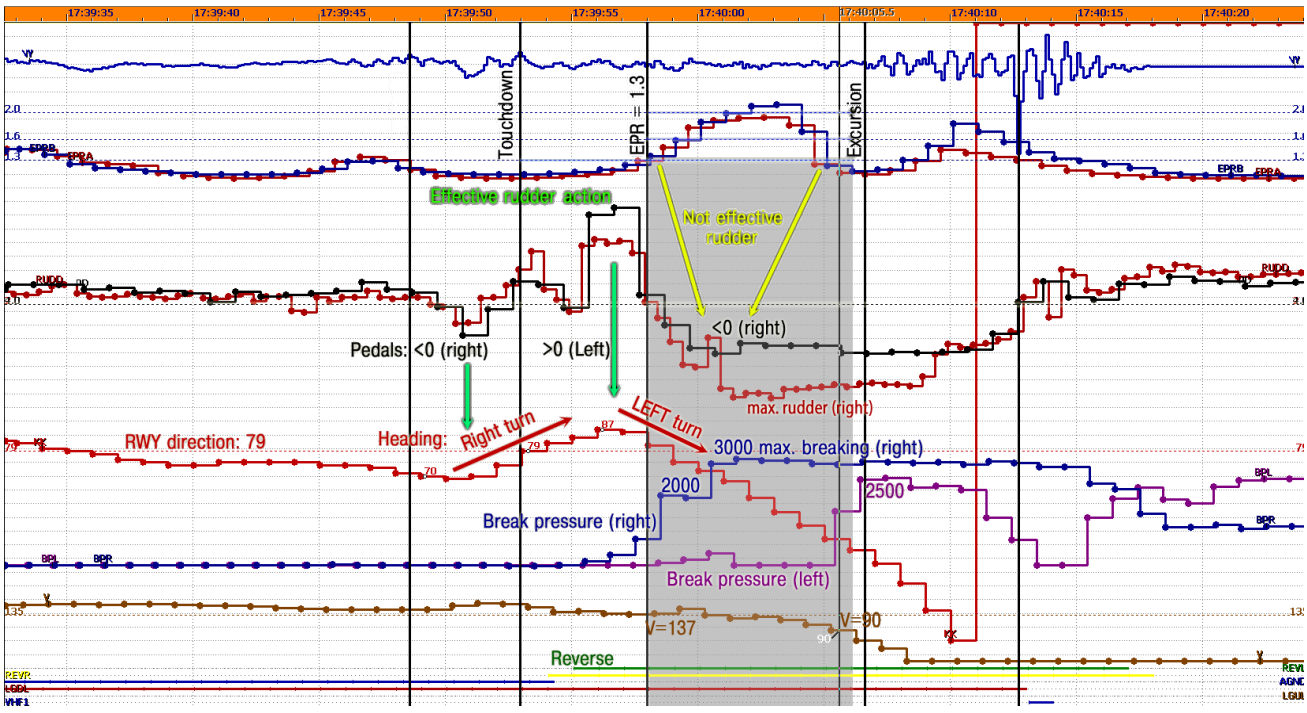

Figure 10.

Movement parameters at touchdown

05:39:53 pm: Touchdown. After the runway threshold fly-over, the rudder deviation to the right (minus), the aircraft starts turning to the right by heading in order to turn to the landing heading (shown in Figure 10 by the first green arrow between the "Threshold" and "Touchdown" markers.) The main landing gear touchdown took place at **05:39:53.5 pm** at the distance of 350 m from the displaced runway threshold, 7 m to

the left of the center line, heading 78-79 degrees (strictly in the landing direction) at the speed of ***161 knots***. The maximum normal acceleration (vertical overload) at landing was ***1.34g.***

For compensation of the created right-of-heading turning moment for the purpose of landing in the runway heading, **the rudder was twice deviated to the left by 17-21 degrees (80-90% of the rudder movement)** – shown in Figure 10 by the second green arrow between the "Touchdown" and "EPR = 1.3" markers.) The rotation to the right stops (the maximum fixed course was 87 degrees.) As a result of these actions, in 3-3.5 seconds after touchdown, **the aircraft left-of-heading turn begins**.

After touchdown, the crew deploys a thrust reverser and begins to increase the engine thrust level. **Spoilers were not deployed in the automatic mode after touchdown, and the crew did not deploy them in the manual mode.**

Note: *FDR does not record the spoiler arming data or spoiler deployment handle position, and according to the CVR decoding data, a report is indistinct as regards the spoilers arming during checklist reading before landing.*

Lowering of the nose landing gear took place for one second after touchdown.

During the run, the PIC must immediately apply the brake system according to the manuals. The PIC's braking actions were correct.

After the main gear touchdown and after start of the nose gear lowering, the thrust reversers must be switched to the throttle reverse idle gate system. After the nose wheel is compressed, and ENG REVERSE UNLOCK and ENG REVERSE THRUST lights are on, the reverse thrust should be increased as needed. The Pilot Non-flying must monitor the engine's operating limits and report of any approaching or exceeding engine operation limits, any thrust reverse failures or other deviations. It is necessary to apply the required value of the reverse thrust up to the maximum – to reach the speed of 80 knots, but, at the actual runway condition – no more than 1.3 EPR, as recommended in the Flight Operations Bulletin and Letter to All MD-80 Aircraft Operators.

However, the crew actions to use the reverse were incorrect. The engine operation mode on the reverse thrust was increased to 1.9-2.1 EPR.

05:39:57.5 pm: EPR = 1.3 In 4 seconds after the runway touchdown by the main landing gear, at 715 m from the runway threshold (365 m from the touchdown point), the engine reverse thrust reaches 1.3 EPR and continues to increase. Simultaneously with achievement of EPR = 1.3 in the reverse thrust mode, the aircraft had a tendency to turn by heading and deviate to the left due to the previous deviation of the rudder to the left (Figure 10.) Differential braking of the right landing gear wheels up to the pressure of 2000 psi and then – to the maximum pressure of 3000 psi was applied to compensate the turning moment to the left and maintain the aircraft heading along the

runway center line. The rudder was deflected to the right to the maximum values. However, the differential braking by the right wheels and handwheel control deflection (simultaneously with the rudder) to maintain the movement direction parallel to the runway center line during the aircraft run were ineffective due to spoilers non-deployment, and the rudder deflection control at the expense of aerodynamic forces "was ineffective" due to shadowing of the rudder. "The aircraft continues to turn to the left of the heading and continues to move uncontrollably with drift to the left along the runway center line.

In order to correct the aircraft back to the center line, the brakes must be released, and the reverse thrust should be reduced to idle. The brakes release increases the tire rotation and contributes to maintaining or restoring the directional control. Switching the reverse thrust to idle reduces the lateral component of the thrust force with no need to go through a complete reverse cycle. Pedal steering and differential braking must be used to prevent an excessive correction with crossing the runway centerline. When heading control is restored and the aircraft is aligned along the runway center line, the maximum braking and symmetrical reverse thrust should be applied to fully stop the aircraft.

Note: *Using this method increases the operational (required) landing distance.*

During the investigation, the Investigation Team used the information materials of the Working Group for reduction of the number of aviation runway excursion accidents under the Flight Safety Foundation.

Two Delta Airline's Newsletters on MD-88/90 fleet, the Flight Operations Bulletin and Letter to All MD-80 Aircraft Operators define 1.3 EPR (Engine Pressure Rise) as the target value, not the maximum value, on non-dry runways. In particular, a newsletter, which was published in November 2014, reminded MD-88 pilots that "for a dry runway, the MINIMUM EPR = 1.3 EPR and the TARGET EPR = 1.6 EPR. On a non-dry runway, the TARGET EPR = 1.3 EPR." This newsletter also states that "Linear inspection data shows that many pilots use the reverse thrust much lower than the TARGET value." In addition, the February 2015 newsletter provided the same reminders on TARGET EPR values.

Failure to maintain the specified parameters for using the reverse thrust during the landing run, namely, maintaining the value of the degree of increase in engine pressure above 1.3 EPR, has led to the loss of the aircraft controllability due to a rudder shading and did not allow the crew keeping the aircraft within the runway, and caused its runway excursion to the left.

05:40:07 pm: Runway Excursion. In 13.5-14 seconds after touchdown, at the distance of 1260 m from the threshold, the aircraft is suffering the runway excursion. The recorded instrument speed was 48 knots (taking into account the drift angle and air

pressure probe shading, it was approximately 60 knots). The aircraft continued its movement on the soil beyond the runway and stopped at the distance of 1690 m from the runway threshold, 145 m to the left of the runway center line (counting to the aircraft center-of-gravity position.)

2 to 3 seconds prior to the runway excursion, the engines were slowed down, and the left wheel brakes were applied (up to 2000 psi.) The right and left wheels braking continued to be applied until the aircraft came to rest.

The further movement of the aircraft is marked with the tire footprints.

After the runway excursion, the PIC re-increased the power rating in the reverse thrust mode.

In the process of movement outside the runway, the right main landing gear retracted to the undercarriage bay, and the left main landing gear was broken, which damaged the left wing and spoiler mechanism on the left side (Figure 11), resulting in deflection of the left spoilers, which was recorded by the FDR.

Figure 11.

Spoilers damage

2 to 3 seconds before the aircraft came to rest, the flaps were retracted to 28 degrees. According to the PIC, the flaps were retracted for convenience of passenger evacuation.

The FDR did not contain a record of engine shut down (probably, according to the instructions, the recorders were turned off after the aircraft stop with circuit breakers pulling.)

The aircraft suffered damage, which is depicted in section 1.3 of this report, as a result of movement on the soil.

As a result of the accident, none of the crew and passengers sustained serious injuries.

The aircraft was recovered from the aerodrome in a week after the accident, following which, the airport operation was restored with no limitations.

3. Conclusions:

1. The PIC and co-pilot have valid transport pilot certificates and Class I Medical Certificate in accordance with the acting requirements.

2. The aircraft is registered with the State Aircraft Register of Ukraine and has the Certificate of Airworthiness in accordance with the acting requirements of the State Aviation Administration of Ukraine.

3. The aircraft operator is Bravo Airways.

4. The crew of the Bravo Airways performed a charter flight en-route Antalya (Turkey) – Kyiv (Zhulyany.)

5. The flight crew rest duration met the requirements of the normative regulations.

6. The Investigation Team did not receive from the airline the flight preparation materials and documents confirming the State Aviation Administration's approval of use of the Electronic Flight Bag.

7. During the flight preparation, the crew used the weather data (METAR for 09:00) for the Kyiv (Zhulyany) Aerodrome, which was not updated at the time of taking decision to departure.

8. According to the crew statements, during the flight preparation, he used a 12-hour TAF forecast for the Kyiv (Zhulyany) Aerodrome, which is not made by the Kyiv Aviation Meteorological Station Civilian.

9. For the time of arrival at the Kyiv (Zhulyany) Aerodrome, the thunderstorm activity was forecasted, of which the crew was not aware at the time of departure.

10. The Bravo Airways Operations Manual contains various readings of definitions of runway statuses and calculations of the required landing distances.

11. The flight was performed with delay of 6 hours. The flight delay was caused by non-arrival of the aircraft.

12. The BV-1 sector controller did not provide the crew with the weather information at the Kyiv (Zhulyany) Aerodrome.

13. The information on the weather conditions at the Kyiv (Zhulyany) Aerodrome was given by ATIS channel in full volume.

14. During the flight, at the landing stage, the crew informed the BV-5 sector controller about the readiness to perform landing in the thunderstorm conditions.

15. TREND forecast for landing in METAR for 3:30 pm, 4:00 pm, 4:30 pm, 5:00 pm did not mention deterioration of meteorological conditions and occurrence of dangerous weather phenomena, but the forecast did not come true. At the same

time, according to the meteorological radar, there was a thunderstorm moving in the aerodrome direction.

16. The crew failed to comply with ATIS instruction to notify the BV-1 sector controller about receiving the BRAVO's information.

17. Landing at the Kyiv (Zhulyany) Aerodrome was performed with the ILS system.

18. The control service is not fully compliant with the requirements of subparagraph d) of paragraph 4.1 of the Regulations on Aircraft Flights and Air Traffic Management in Classified Airspace of Ukraine, approved by the Order of the Ministry of Transport of Ukraine dated April 16, 2003 No. 293, in part of providing consultations and information to ensure the safe and effective performance of flights.

19. At landing, the PIC was a pilot flying, the co-pilot was a pilot monitoring. The level of PIC and co-pilot training conformed to the flight task performance.

20. The technical operation of the aircraft was conducted in accordance with the Bravo Airways Maintenance Program and other guidance documents of the aircraft manufacturer and State Aviation Administration of Ukraine.

21. At the height of 1000 ft, the aircraft was non-stabilized by the instrument speed and vertical descent speed, which required from the crew to go around.

22. Despite the fact that the aircraft was non-stabilized at the decision height, the PIC decided to continue the approach for landing.

23. Just before and at the time of landing, the aircraft was under the wind variable in strength and direction.

24. The landing was performed in the touchdown zone, 7m to the left of the runway centerline with the final heading.

25. During the descent, the crew did not move the spoilers to ARM mode (armed position.) After landing, the spoilers were not deployed and continued to operate in aileron mode, and the crew did not deploy the spoilers manually as required by the Operation Manual.

26. At braking on the wet runway, the thrust reversing was applied up to the maximum thrust values (>1.3 EPR.)

27. Application of the main wheel brakes because of spoiler non-deployment and rudder application because of the reverse thrust operation mode for the purpose of the aircraft directional control were ineffective.

28. The aircraft remained controllable until reaching the engines reverse thrust 1.3 EPR mode, and after exceeding the reverse thrust mode of 1.3 EPR, the aircraft did not respond to the rudder steering action and moved by inertia under influence of external forces.

29. As a result of the runway excursion, the aircraft suffered significant damage.

30. The aircraft CVR does not meet the requirements of the Operational Directive of the State Aviation Administration of Ukraine dated 29.12.2015 ED-05k-15 in part of the record keeping time. The FDR meets the regulatory requirements.

31. Upon onset of precipitation, an aerodrome service engineer conducted the runway inspection with violation of the procedures for measuring the friction Mu-factor and precipitation layer thickness.

32. The information on the measured friction Mu-factor value, which is indicated in the Airfield Status Log for 06:05 pm, 07:14 pm and 08:05 pm, does not correspond to the measurement results set out in ATT-2 measurement protocols for the respective time points.

33. On the accident day, fire trucks were filled with a foaming agent, the storage period of which expired on 12.06.2018 (the storage period is 36 months.)

34. No recording of the communication through radio exchange channels during rescue operations by land-based recorders was conducted, which contradicts the requirements of the Regulations on Emergency Rescue and Fire Protection Support.

35. The rescue team did not use a foam-producing agent to fill the place of fuel leakage, which does not meet the requirements of the Emergency Plan.

36. System failures during aerodrome flight support were found, which were observed also during previous investigations.

37. The aircraft recovery from the accident site was carried out by the Bravo Airways with participation of the aerodrome operator. No coordinator of the recovery works at the ME Kyiv (Zhulyany) International Airport was appointed, and there was no agreement (in the form of official contractual relations) between the aerodrome operator and Bravo Airways.

3.1. Causes

The cause of the accident, i.e. runway excursion of MD-83 UR-CPR aircraft operated by Bravo Airways, which took place on June 14, 2018 at the Kyiv (Zhulyany) Aerodrome at performance of flight BAY 4406 en-route Antalya-Kyiv (Zhulyany) – was the PIC's decision to continue the landing at the Kyiv (Zhulyany) Aerodrome in the thunderstorm conditions with the following main factors:

- non-stabilized approach for landing, starting from the height of 1,000 feet;

- spoiler non-deployment by the crew;

- incorrect crew actions in application of the reverse thrust on a wet runway (EPR>1.3).

Factor: human, crew.

Occurrence Category: RE.

3.2. Contributing Factors:

- Air traffic control service in the classified airspace of Ukraine, which is required by the Order of the Ministry of Transport of Ukraine dated April 16, 2003, No. 293, was not provided to the crew in full;

- Wind variable in strength and direction;

- Probably, the crew's failure to listen to the latest ATIS reports for the Kyiv (Zhulyany) Aerodrome;

- Bravo Airways Operator's Manual does not contain landing approach procedures;

- Low-quality pre-flight preparation, pre-landing preparation, checklist reading and completion at all flight stages.

4. Safety Recommendations:

To State Aviation Administration of Ukraine:

1. Initiate before the Ministry of Infrastructure of Ukraine bringing the Order of the Ministry of Transport of Ukraine of 16.04.2003 No. 293 into conformity with subparagraphs 3.2, 3.3, 3.4 Doc 8168 ICAO Aircraft Flight Operations, volume III, first edition, 2018 as regards the stabilized landing approach parameters, stabilized landing approach elements and go-around principles.

2. Carry out an unscheduled inspection of the activities of the Aircraft Rescue and Fire Fighting Service at the Kyiv (Zhulyany) Aerodrome.

3. Take actions aimed at elimination of deficiencies in the aerodrome flight support at the Kyiv (Zhulyany) Aerodrome.

4. Ensure compliance with the requirements of the operational directives on FDR and CVR. Organize an inspection of recorders, including CVR, on all aircraft for compliance of the information recorded on them for at least 2 hours.

5. Draw up and enter amendments into Section II (Observance of Flight Regulations) of Regulations of Flights of Civil Aircraft in Airspace of Ukraine approved by the Order of the Ministry of Infrastructure of Ukraine dated 20.10.2011 No. 478 and registered with the Ministry of Justice on 21.11.2011 under No.1327/20065 in the part concerning the obligatory listening by aircraft crews arriving at aerodromes of ATIS radio broadcasts, taking into account periods of their updating and reporting, having contacted ATS units, which shall provide, respectively, the approach control service or aerodrome control service in reception of the radio information.

6. Oblige operators of the civil aviation aerodromes, where ATIS radio broadcasts are provided, to enter the appropriate amendments into the Flight Operation Instructions (use of airspace) in the part concerning the procedure for aircraft crews' listening to ATIS information and reporting to ATS units for further publication in the Aeronautical Information Publication of Ukraine.

To Igor Sikorsky Kyiv International Airport (Zhulyany):

1. Take actions to ensure at the aerodrome preparation to operation that the airport aerodrome service personnel comply with regulatory documents requirements to the procedures for measurement of the friction Mu-factor and thickness of the runway deposits layer.

2. Pay attention to the quality of the runway preparation and reporting for compilation of consultations and information to be transmitted to crews.

3. Assess the possibility of MD-83 aircraft operation at Kyiv (Zhulyany) aerodrome in terms of presence of the traffic intensity restrictions and weight restrictions.

To Bravo Airways:

1. Bring the pre-flight preparation, pre-landing preparation of crews and briefings into conformity with the procedures.

2. Approve with the State Aviation Administration of Ukraine the use of the Electronic Flight Bags for calculations.

3. Eliminate inconsistencies regarding runway status determination and improve the methods for calculating the operational landing distances in the Bravo Airways Operation Manual.

4. Ensure equipping the aircraft with the recorders, which comply with the operational directives.

5. Carry out the simulator-based training of crews in the reverse thrust use on dry and wet runways.

6. Demand from the flight personnel to comply with the instructions transmitted by ATIS and confirm to ATS receiving of the relevant information.

7. Conduct the crew training in taking a decision on go-around in case of a non-stabilized aircraft position.

To Ukrainian State Air Traffic Services Enterprise:

1. Take actions on observing by the ATS personnel of requirements of the operating instructions during reporting the aerodrome weather information.

Investigator-in-Charge _____

(Signature)