



This document is an English translation of the Final Report on the fatal accident involving the Boeing 747-412F aircraft registered TC-MCL that occurred on January 16th, 2017 at Manas International Airport, Bishkek, Kyrgyz Republic.

The translation was done as accurate as a translation may be to facilitate the understanding of the Final Report for non-Russian-speaking people. The use of this translation for any purpose other than for the prevention of future accidents could lead to erroneous interpretations.

In case of any inconsistency or misunderstanding, the original text in Russian shall be used as the work of reference.

**INTERSTATE AVIATION COMMITTEE
AIR ACCIDENT INVESTIGATION COMMISSION**

**FINAL REPORT
ON RESULTS OF THE AIR ACCIDENT INVESTIGATION**

Type of occurrence	Fatal accident
Type of aircraft	Boeing 747-412F
Registration mark	TC-MCL
Owner	LCI Freighters One Limited (Ireland)
Operator	ACT Airlines
Aviation Authority	Directorate General of Civil Aviation of Turkey (Turkish DGCA)
Place of occurrence	Near Manas International Airport, Bishkek, Kyrgyz Republic, coordinates: N 43°03.248' E 074°2.271'
Date and time	16.01.2017, 07:17 local time (01:17 UTC), night time

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ABBREVIATIONS

AC	–	Advisory Circular
ACP	–	Audio Control Panel
AD	–	Airworthiness Directive
AFCS	–	Automatic Flight Control System
AFDS	–	Autopilot Flight Director System
AFM	–	Aircraft Flight Manual
AGL	–	Above Ground Level
AIP	–	Aeronautical Information Publication
ALT	–	Altitude
AMC	–	Aeronautical Meteorological Centre
A/P	–	Autopilot
APU	–	Auxiliary Power Unit
AS	–	Aerodrome Service
ARP	–	Aerodrome Reference Point
ASS	–	Aviation Security Service
ATC	–	Air Traffic Control
ATS	–	Air Traffic Service
CAS	–	Calibrated Airspeed
CAT	–	Category
CDU	–	Control Display Unit
CG	–	Center of Gravity
cd	–	Candela (unit for measuring light intensity)
cm	–	centimeter
CRM	–	Crew Resource Management
CVR	–	Cockpit Voice Recorder
DFCS	–	Digital Flight Control System
DA	–	Decision Altitude
DA(H)	–	Decision Altitude (Height)
DFDAC	–	Digital Flight Data Acquisition Card
DFDR	–	Digital Flight Data Recorder
DGCA	–	Directorate General of Civil Aviation (Turkey)

DH	–	Decision height
DME	–	Distance Measuring Equipment
DNA	–	<u>Desoxyribonucleic acid</u>
E	–	Eastern longitude
EFIS	–	Electronic Flight Instrument System
EGPWS	–	Enhanced Ground Proximity Warning System
EICAS	–	Engine Indication and Crew Alerting System
ELP	–	English Language Proficiency
ELT	–	Emergency Locator Transmitter
ERFSS	–	Emergency Rescue and Fire Protection Flight Support Service
FAA	–	Federal Aviation Administration, USA
FAF	–	Final Approach Fix
FCC	–	Flight Control Computer
FAP	–	Final Approach Point
FAR	–	Federal Aviation Regulations
FCT-747 (TM)	–	Boeing 747 Flight Crew Training Manual
FCOM	–	Flight Crew Operations Manual
FCTM	–	Flight Crew Training Manual
FD	–	Flight Director
FDR	–	Flight Data Recorder
FIR	–	Flight Information Region
FL	–	Flight Level
FLTA	–	Forward looking terrain alerting
FMA	–	Flight Mode Annunciator (on PFD)
FMC	–	Flight Management Computer
FO	–	First Officer
ft	–	feet
ft/min	–	feet per minute
GCU	–	Generator Control Unit
GS	–	Glideslope
h	–	hour

HAT	–	Height Above Terrain, Height Above Touchdown
HF	–	High frequency
HPC	–	High Pressure Compressor
Hz	–	Hertz
IAC	–	Interstate Aviation Committee
IAS	–	Indicated air speed
ICAO	–	International Civil Aviation Organization
IDG	–	Integrated Drive Generator
illeg	–	illegible
ILS	–	Instrument Landing System
IRS	–	Inertial Reference System
IST	–	Ataturk Airport, Istanbul (IATA Code)
JED	–	King Abdulaziz International Airport, Jeddah, Saudi Arabia (IATA Code)
KAIK	–	Accident Investigation Board, Turkey
kg	–	kilogram
km	–	kilometer
kt	–	knot
kVA	–	kilovolt-ampere
LH	–	Left-hand
LIM	–	Localizer Inner Marker
LOC	–	Localizer
LTD	–	Limited
LOM	–	Localizer Outer Marker
IATA	–	International Air Transport Association
ICAO	–	International Civil Aviation Organization
IFR	–	Instrument Flight Rules
ILS	–	Instrument Landing System
IOSA	–	IATA Operational Safety Audit
LPC	–	Line Proficiency Check or Low Pressure Compressor (by context)
LPT	–	Low Pressure Turbine

LTBA	–	Ataturk Airport, Istanbul (ICAO Code)
m	–	meter
MAP	–	Navigation display mode
MCP	–	Mode Control Panel
MDH	–	Minimum Decision Height
METAR	–	Meteorological Aerodrome Report
MFD	–	Multifunction Display
MHz	–	megahertz
min	–	minute
mps	–	meters per second
MSN	–	Manufacturer Serial Number
N	–	Northern latitude
N/A	–	Not applicable
ND	–	Navigation Display
nm	–	nautical mile
NOSIG	–	No significant changes
NTSB	–	National Transportation Safety Board, USA
OM	–	Operations Manual
OPC	–	Operational Proficiency Check
OPER	–	Operation
OVI-I	–	Level I High-Intensity Lighting System
OVI-II	–	Level II High-Intensity Lighting System
PAPI	–	Precision Approach Path Indicator
PF	–	Pre-flight
PFD	–	Primary Flight Display
PIC	–	Pilot-in-Command
PLC	–	Public Limited Liability Company
QFE	–	Atmospheric pressure at runway threshold
QNH	–	Mean sea level pressure
QRH	–	Quick Reference Handbook
RH	–	Right-hand
RVR	–	Runway Visual Range

RWY	–	Runway
SB	–	Service Bulletin
SOP	–	Standard Operating Procedures
SN	–	Serial Number
SSFDR	–	Solid State Flight Data Recorder
STAR	–	Standard Arrival Chart
TAF	–	Terminal Aerodrome Forecast
TCF	–	Terrain Clearance Floor
TDZ	–	Touchdown Zone
TEM	–	Threat and Error Management
TM	–	Training Manual
TOGA	–	Takeoff/Go-around
TOW	–	Takeoff Weight
TSO	–	Time Since Overhaul
TWY	–	Taxiway
UCFM	–	Manas Airport, Bishkek (ICAO Code)
US	–	United States
USA	–	United States of America
UTC	–	Universal Time Coordinated
V	–	volt
VHF	–	Very High Frequency
VHHH	–	Chek Lap Kok Airport, Hong Kong (ICAO Code)
VOR/DME	–	VHF Omnidirectional Range/Distance Measuring Equipment
WGS	–	World Geodetic System

Synopsis

On 16.01.2017, at 07:17 local time (01:17 UTC)¹, at night time, a fatal accident occurred to the cargo Boeing 747-412F aircraft, registration mark TC-MCL, operated by ACT Airlines, which was performing the THY6491 flight in order to transport the cargo from Chek Lap Kok Airport (VHHH, Hong Kong) via Manas Airport (UCFM, Bishkek) to Ataturk Airport (LTBA, Istanbul). During the landing at Manas International Airport (Bishkek city, the Kyrgyz Republic). There were 4 crew members (all being citizens of the Republic of Turkey) and 85618 kg of cargo on board the aircraft.

As a result of the accident and the post-crash ground fire, the aircraft was completely destroyed. The 4 persons on board and 35 local residents on the ground were killed. Other 36 residents on the ground received injuries of varying severity, 38 buildings were destroyed or damaged.

The information on the accident occurrence was received by the IAC at 07:00 on 16.01.2017.

The investigation was conducted by the Investigation team, appointed by Order No.1/814-r of the Chairman of Air Accident Investigation Commission, IAC, dated 16.01.2017.

In compliance with ICAO Annex 13, the notification on the accident was sent to the National Transportation Safety Board (NTSB), the accident investigation competent authority of the State of Aircraft Design and Manufacture (USA), as well as to Accident Investigation Board (KAİK), the accident investigation competent authority of the State of Registry and Operator (the Republic of Turkey)². The USA and Turkey appointed their Accredited Representatives to participate in the investigation.

The NTSB, US Federal Aviation Administration (FAA), aircraft design and manufacturing company (the Boeing Company, USA), KAİK, DGCA and ACT Airlines representatives participated in the investigation.

The investigation was launched on 16.01.2017.

The investigation was completed on February 17.02.2020

Initial actions at the accident site (securing the accident site, clearing the debris, evacuating the killed and injured) were performed by the Ministry of Internal Affairs and the Ministry of Emergency Response of the Kyrgyz Republic.

¹ Hereinafter, the UTC is used, the local time is UTC + 6 h.

² On 10.01.2019, KAİK was reorganized into the Transport Safety Investigation Board, UEİM.

When completing the Final Report, the investigation team took into account information provided by the Ministry of Internal Affairs and Ministry of Emergency Response of the Kyrgyz Republic.

The aircraft fragments were removed from the accident site and were handed over for custody to the administration of Manas Airport.

Preliminary judicial investigation was conducted by the Ministry of Internal Affairs of the Kyrgyz Republic.

Courtesy Translation

1. Factual Information

1.1. History of Flight

On 16.01.2017, the crew of the Boeing 747-412F TC-MCL aircraft was performing a THY6491 flight from Hong Kong via Bishkek (Manas Airport) to Istanbul (Ataturk Airport) in order to transport the commercial cargo (public consumer goods) of 85 618 kg. The cargo was planned to be offloaded in Istanbul (Ataturk Airport). Manas Airport was planned as a transit airport for crew change and refueling.

From 12.01.2017 to 15.01.2017, the crew had a rest period of 69 h in a hotel in Hong Kong.

The aircraft takeoff from the Hong Kong Airport was performed at 19:12 on 15.01.2017, with the delay of 2 h 02 min in respect to the planned takeoff time. During the takeoff, the climb and the on-route cruise flight, the aircraft systems operated normally.

At 00:41, on 16.01.2017, the aircraft entered the Bishkek ATC Area Control Center over the reference point of KAMUD at flight level of 10 400 m (according to the separation system, established in the People's Republic of China). At 00:51, the crew requested a descent and reached the FL 220 (according to the separation system, established in the Kyrgyz Republic). At 00:59, the crew received the weather information for Manas Airport: *"the RVR at the RWY threshold 400 m, the RWY midpoint and RWY end 300 m, the vertical visibility 130 ft"*³. At 01:01, the crew received the specified data: *"in the center of the runway RVR three zero zero meters, vertical visibility one five zero feet."*

At 01:03, the crew requested a descent, the controller cleared for the descent not below FL 180. At 01:05, the crew was handed over to the Approach Control. At 01:06, the crew was cleared for the descent to FL 60, TOKPA 1 ILS approach chart, RWY 26. At 01:10, the controller reported the weather: wind calm, visibility 50 m, RVR 300 m, freezing fog, vertical visibility 160 ft, and requested the crew if they would continue the approach. The crew reported that they would continue the approach.

The crew conducted the approach to RWY 26 in accordance with the standard approach chart. At 01:11, the controller informed the crew: *"... transition level six zero"* and cleared them for the ILS approach to RWY 26.

At 01:15, the crew contacted the Tower controller. The Tower controller cleared them for landing on RWY 26 and reported the weather: *"...wind calm... RVR in the beginning of the runway four hundred meters, in the middle point three hundred two five meters and at the end of the runway four hundred meters and vertical visibility one six zero... feet"*.

³ Hereinafter, if not indicated otherwise, the original author's edition is preserved in the quoted documents.

The aircraft approached the RWY 26 threshold at the height significantly higher than the planned height. Continuing to descend, the aircraft flew over the entire length of the RWY and touched the ground at the distance of 900 m away from the farthest end of the runway (in relation to the direction of the approach) (the RWY 08 threshold). After the touchdown and landing roll, the aircraft impacted the concrete aerodrome barrier and the buildings of the suburban settlement and started to disintegrate, the fuel spillage occurred. As a result of the impact with the ground surface and the obstacles, the aircraft was completely disintegrated, a significant part of the aircraft structure was destroyed by the post-crash ground fire.

At 01.17 UTC, the Tower controller requested the aircraft position, but the crew did not respond.

1.2. Injuries to Persons

Injuries to Persons	Crew	Passengers	Others ⁴
Fatal	4	0	35
Serious	0	0	36
Minor/None	0/0	0/0	0/0

1.3. Damage to Aircraft

The aircraft airframe disintegrated into multiple fragments, the largest of those were found at the accident site in the last third part of the aircraft's ground movement trajectory.

The ground fire bed is found in the central fuselage area on the line in-between the separated tail section and cockpit (Figure 1).

⁴ Injured and killed persons on the ground.



Figure 1. Main fire bed (indicated by yellow dashed line)

Fuselage

The aircraft fuselage is torn into several fragments, the largest fragments are: the cockpit, extending from Frame 1 to Frame 5; the tail section (the fin and the horizontal stabilizer with rudder and elevator); the APU compartment.

The cockpit is damaged. The pilots' and observer's seats have been torn off their standard positions.

Wing

The RH wing section and the LH wing section disintegrated (Figure 2 and Figure 3).



Figure 2. RH wing fragment



Figure 3. LH wing fragment

The structural elements, mounting the RH wing section to the fuselage, have been destroyed by the off-design stress loads, and the LH wing mounting elements have been destroyed by the thermal impact. The central wing section has been destroyed by the fire.

Fin and horizontal stabilizer

The fin and the horizontal stabilizer (Figure 4) have been found attached to the tail fuselage section, extending from the aft pressure bulkhead to the tail cone. The leading edges of the fin and the rudder show damage caused by the terrain impact. No traces of fire or soot have been found.



Figure 4. Tail fuselage section

The horizontal stabilizer fragment has remained in its standard position and has been found at the accident site in the turned-over position. The center box section, connecting the two parts of the stabilizer, the stabilizer trim drive mechanism and the jackscrew show no outer damage. The left part of the stabilizer and the elevator have been damaged as a result of the impact with the obstacles, part of the assembly is missing. The right part of the stabilizer has remained in its standard position and shows damage.

Landing gear

The main landing gear – the left wing gear, the left body gear, the right body gear and the right wing gear – separated from the airframe as a result of the impacts with the concrete aerodrome barriers and the obstacles at the area adjacent to the aerodrome.

Along the aircraft movement trajectory, the following landing gear fragments have been found:

- the right body gear has been torn off its mounting points and is found at the distance of approximately 100 m away from the point of the impact with the obstacles, further to the right, in the direction of the aircraft movement trajectory. The landing gear bogie (with the axle and the two rear wheels) has remained in its standard position attached to the gear extension/retraction cylinder rod. The front bogie axle still houses the brakes, the tyres have disintegrated. Nearby, the destroyed wheel tyres and the torn-off bogie fragment of the other landing gear have been found. At the various distances, to the right and to the left of it, the braking devices, the tyres and the wheels attached to the landing gear brakes as well as multiple fragments of the landing gear and of the wing flight control surfaces have been found. The condition of the gear extension/retraction hydraulic cylinder (the rod is in the extended position) shows that the gear was in the extended position, which is also confirmed by the position of the landing gear control lever in the cockpit (found in the "DOWN" position);

- the left body gear – the fragments of the gear, the wheels and discs have been found;
- the left wing landing gear assembly has been found, torn off its mounting points. The two rear wheels have remained attached to the bogie, the front axle with the wheels is missing.

- the right body landing gear assembly has been torn off its mounting points and disintegrated. The rear wheels have remained attached to the gear bogie axle, the axle with the two forward wheels has been torn off and disintegrated into separate fragments (Figure 5);



Figure 5. Right wing gear

- the nose gear has been torn off its mounting points as a result of the impact with the obstacles. The hydraulic cylinder, the rods, the stays and wheel axle are found assembled, showing the traces of the thermal impact. The wheel tyres have been destroyed by the fire. The position of the gear extension/retraction hydraulic cylinder rod (the rod is in the extended position) indicates that the landing gear was in the extended position. (Figure 6).



Figure 6. Nose landing gear

The landing gear extension/retraction control lever in the cockpit is found in the position, which corresponds to the extended gear position (Figure 7, indicated by the arrow)



Figure 7. Landing gear extension/retraction control lever

Wing flight control system

Leading and trailing edge flaps control system

At the time of the accident, the wing flight control surfaces were in the landing configuration, which is confirmed by the positions of ball-screw assemblies of the leading and trailing edge flaps (the surfaces have been found in the fully extended positions (in the mechanical stop positions)) (Figure 8), as well as by the position of the flap control lever (Figure 9).



Figure 8. Ball-screw assemblies' positions



Figure 9. Flap control lever

The leading and trailing edge flaps were among the first to be damaged as a result of the impact with the trees, concrete aerodrome barriers and various buildings. The wing flight control fragments are found scattered all over the vast area of the accident site. The found shafts and ball-screw assemblies of the leading and trailing edge flaps control show mechanical damage, they have disintegrated into separate fragments as a result of the impact with the obstacles.

The RH section of the flap transmission assembly, running along the aft wing spar, has disintegrated due to the thermal impact and off-design mechanical loads.

All the 8 ball-screw assemblies of the flap extension/retraction system (4 for each of the both outer wing sections) have been found. The shafts' positions in relation to the ball-screw nuts (thread turns) indicate that the flaps were at 30°.

The leading edge flaps disintegrated into separate fragments due to the terrain impact.

Some of the flap control transmission gearboxes have been found. The transmission shows no traces of twisting.

Spoilers

As for the spoiler control system, the actuators with the attached fragments of flight control surfaces have been found, their positions indicate that at the time of the accident, the spoilers were in the fully retracted positions (the ground spoiler actuator rods are in the retracted positions).

Flight control system

Longitudinal (pitch) control channel (elevators and horizontal stabilizer)

The pitch control is provided from the control columns, linked to the input rocking arms of the elevator actuators via the left and right control linkage branches.

During the cockpit inspection, no visual damage of the PIC's and FO's control columns has been found (Figure 10).



Figure 10. Pilots' control columns (indicated by arrows)

The control linkage has been found completely disintegrated into small fragments as a result of the aircraft impact with the obstacles and is no longer subject to proper identification.

Lateral control channel

The control linkage, running through the fuselage, has been found disintegrated into small separate fragments as a result of the aircraft impact with the obstacles and is no longer subject to proper identification. The control linkage, running through the aft spar of the LH wing shows traces of off-design mechanical impact and fire, the control linkage of the RH wing has been found disintegrated into fragments.

The LH wing ailerons are show skin disrupture. The RH wing ailerons have been found disintegrated into fragments.

Directional (rudder) control channel

The directional control is provided by the rudder pedals, linked to the main and standby rudder control actuators via the control cables.

The rudder pedals show no significant damage. The control cables running through the fuselage, disintegrated during the aircraft impact with the obstacles and are no longer subject to proper identification.

Hydraulic System

During the accident site inspection, the fragments of the hydraulic system have been found. The hydraulic system fragments are no longer subject to proper identification due to the traces of thermal and off-design load impact.

Fuel System

The fuel system components (the integral fuel tanks, units and fuel lines) were destroyed by the ground fire, the fire bed being found in the area of the aircraft's central fuselage and fuel tanks No.1 and No.2.

Avionics equipment

By design, the avionics units are located mainly in the forward fuselage under the cockpit (in the avionics bay). After the aircraft's impact with the terrain, a fire occurred and the avionics units were significantly damaged and burnt, many of them are no longer subject to proper identification. The found avionics units show no traces of the inflight fire, all the damage is found to be second-stage damage, caused by the aircraft impact with the terrain and the consequent ground fire.

Condition of the cockpit fragments

As a result of the aircraft disintegration, the cockpit separated from the main fuselage section and was significantly damaged due to the impact with the obstacles.

The cockpit fragments were found located very close to each other. No traces of thermal impact on the frontal parts of the remaining fragments of the instrument panels and the PIC's and the FO's panels confirm the fact that no fire occurred in the cockpit during the flight.

Left, Right and Central Main Instrument Panels

Left, Right and Central Main Instrument Panels show no significant damage. The following instruments have been found:

- the PIC's and FO's EFIS displays: the PFDs (Primary Flight Displays), NDs (Navigation Displays), the Primary EICAS (Engine Indication and Crew Alerting System) and Secondary EICAS display units,

- the standby instruments: Standby Airspeed Indicator, Standby Altimeter, Attitude Indicator;

- the autopilot control panel (Mode Control Panel, MCP).

The remaining frontal parts of the indicators shows no traces of thermal impact, which confirms the fact that there was no fire in the cockpit during the flight.

Forward Overhead Panel for the APU and engines start, electric power, air bleed, air conditioning and fuel supply controls

The following panels have been found:

- electrical power supply panel, generators control panel, APU and ground power control panels;
- the hydraulic pumps control panel;
- the powerplant fire protection system and the fire zone control panel;
- the engine start control panel;
- the fuel control panel;
- the windshield, air engine intake, wing leading edge, anti-ice system control panels for the Pitot tubes and static ports;
- the emergency transmitter control panel,
- the strobe, navigation, taxiing and landing lights control panels;
- the Inertial Reference System (IRS) control panel;
- the bleed air and air conditioning control panels.

The Control Stand for engines, flight control surfaces, navigation systems and radio communication controls

The Control Stand for engines and flight control surfaces control as well as the navigation systems and radio communication control panels show minor damage. The positions of the landing gear extension/retraction control lever (P2 panel), the flap control lever (at 30°) and the speed brakes control lever indicate that the aircraft was in the landing configuration.

The Communication and Passenger Address Systems

The Aft Electronics Control Panel has been found in full, including following components:

- the three Audio Control Panels (ACPs) for the radio communication devices for the PIC, the FO and the Instructor (located on the Aft Electronics Control Panel)
- the VHF control panel;
- the HF control unit (Antenna Coupler).

The other units have been found completely destroyed and are no longer subject to proper identification.

According to the statements of the ATC controllers and to the "crew-controller" radio communication recordings, during the flight from Hong Kong Airport to Manas Airport, there was no disappearance of the aircraft's transponder symbol.

Electrical Power System

The electrical wiring system of the aircraft has been completely destroyed. No traces of short circuit nor insulation discontinuity during the flight have been found. The wire looms of the aircraft electrical power system, located behind the circuit breakers panels have been found torn-off and scattered in the airframe disintegration spots.

The wire loom connectors, which have remained behind the cockpit panels, show no discontinuity. In the other remaining airframe fragments, no other discontinuity nor destructions of the electrical wiring, which would indicate that the electrical power system could have failed during the flight, have been found either.

The generator control units (GCUs) and the integrated drive generators (IDGs) have been found, the IDGs were found separated from the engines as a result of the impact and the consequent engines disintegration. The units show significant mechanical damage and traces of the ground fire.

The found fragments of the battery as well as one battery charger/controller unit and the APU charger/controller unit are destroyed.

No discrete signals on failures of the power supply units as well as of 115 V 400 Hz alternating current users or 28 V direct current users confirm that the aircraft electrical power system was operating normally from the engine start to the moment when the aircraft impacted the terrain.

Fire Protection System

The Fire Protection System includes two fire extinguishing bottles for each engine, one fire extinguishing bottle in the APU compartment, six fire extinguisher bottles for the cargo compartment, four M7326 control handles and the M7327 fire squib control panel, located on the P5 Overhead Panel in the cockpit.

The engines and APU fire extinguishing bottles have been found deformed and damaged as a result of the ground fire, their relation to the exact engines is no longer subject to the proper identification; the APU fire extinguishing bottle and the cargo compartments' fire extinguishing bottles have been also found.

Other components of the Fire Protection System are no longer subject to proper identification due to the acquired significant damage.

Flight Control System

The following items have been found:

- the three damaged Flight Control Computers (FCCs), electronic circuit boards have remained on one of the units (Figure 11);



Figure 11. FCC unit with remaining electronic circuit boards

Oxygen System

As for the Oxygen System, the two main fixed oxygen cylinders (one metallic and one made of composite materials) have been found; their standard onboard location is no longer subject to identification. The cylinders show significant damage caused by the fire. No oxygen has been found inside the cylinders. The character of the acquired damage indicates that the cylinders exploded when the post-crash ground fire occurred.

Lighting Systems

Taking into consideration the fact that the FDR contains no recordings on finding of the aircraft lighting systems, it can be concluded that the lighting equipment was operating normally.

The remaining items include the following:

- the tail navigation light which shows no mechanical damage;
- some other fragments of the lighting systems.

No findings related to the operational performance of the equipment indicates that the lighting equipment was operative.

Navigation and Piloting Equipment

The aircraft was equipped with two Flight Management Computers (FMCs). The right FMC unit has been found at the accident site near the cockpit fragment. The left FMC unit has not been found during the extensive search operation. The Inertial Reference System (IRS) unit and the Satellite Data unit have also been found. At a significant distance from the cockpit fragment, approximately 100-150 m away from the aircraft first touchdown spot, one of the Pitot tubes (the

left one) has been found. On the instrument panels P1, P2 and P3, the Control Display Units (CDUs) have been found.

Inboard flight data monitoring and recording equipment

The Digital Flight Data recorder (FDR) and cockpit voice recorder (CVR) have been found at the accident site near the aircraft tail empennage fragment (Figure 12).



Figure 12. Inboard flight data monitoring and recording equipment

The detailed information about the FDR and CVR is provided in Section 1.10 of the Report.

Power Plant

The PW4056-3 engines and the PW902A APU have been inspected and analyzed for their operational performance.

Engine No.1

Engine No.1 (Figure 13) has been found burnt-out due to the post-crash ground fire which occurred after the terrain impact.



Figure 13. Engine No.1

The inlet cowl, the [other] engine cowlings sections and the exhaust nozzle of Engine No.1 have been found torn-off and destroyed. The fan section of the cowling has been completely destroyed. The fan blades, the low pressure compressor (LPC) have been destroyed and show

traces of melting. The accessory gearbox casing has been destroyed: the engine-mounted units (the IDG, the starter) have been torn off, significantly damaged and burnt out. The high pressure compressor (HPC) and the combustion chamber have been damaged. The turbine section of the cowling, the turbine case cooling system and the related fittings have been deformed and melted. The low pressure turbine blades are melted. The engine shaft shows traces of twisting and has been torn off.

Engine No.2

Engine No.2 has been completely destroyed (Figure 14).



Figure 14. Engine No.2

The inlet cowl, the [other] engine cowling sections and the exhaust nozzle of Engine No.2 have been torn-off as a result of the aircraft impact with the concrete aerodrome barriers and other obstacles (trees and buildings) as well as due to the terrain impact. The fan cowling section has been completely destroyed. The fan blades have been destroyed and show traces of melting. The accessory gearbox casing has been destroyed due to the thermal impact. The HPC and the combustion chamber have been deformed. The turbine cowling section and the stator vanes have been significantly damaged. The units located on the fan cowling section as well as the engine manifolds, units and wiring have been burnt out.

Engine No.3

Engine No.3 has been completely destroyed due to the impact with the obstacles and the terrain (Figure 15).



Figure 15. Engine No.3

The inlet cowl and the [other] engine cowl sections of Engine No.3 have been torn-off and scattered over the accident site. The inlet cowl has disintegrated. The fan blades have been twisted and torn off, which confirms the fact that the turbines were driving the fan section during the impact with the obstacles. The LPC blades have also disintegrated. The combustion chamber has no visual damage. The units and fittings, mounted on the accessory gearbox, have been significantly damaged. Some of the LPT blades have disintegrated. The exhaust nozzle and sleeve have been torn off.

Engine No.4

Engine No.4 has been destroyed due to the aircraft impact with the obstacles. (Figure 16).



Figure 16. Engine No.4

The inlet cowl and the [other] engine cowl sections of the engine have been torn-off and scattered over the area of the accident site. The inlet cowl has disintegrated. The fan blades have been twisted and torn off, which confirms the fact that the turbines were driving the fan section at the time of the impact with the obstacles. The LPC blades have disintegrated. The combustion chamber has no visual damage. The units, mounted on the accessory gearbox, and the related fittings have been significantly damaged. Some of the LPT section casing and blades have disintegrated. The exhaust nozzle and sleeve have been torn off.

Auxiliary Power Unit

Within the separated tail fuselage section, the partially deformed APU as well as the APU casing have been found (Figure 17).



Figure 17. Dismantled APU with APU exhaust nozzle

The APU has been found in its standard mounting place. The fuel supply lines and the wiring, running to the APU, have been torn off and destroyed.

The APU fire extinguishing bottle has remained in its standard mounting place and shows no damage.

The main engines' and APU's controls in the cockpit have remained.

1.4. Other Damage

According to the information provided by the Ministry of Internal Affairs of the Kyrgyz Republic, 38 buildings in the settlement were destroyed (including 19 dwelling houses and 12 household outbuildings, which have been completely destroyed, and 7 partially destroyed dwelling houses).

1.5. Personnel Information

1.5.1. Crew Members Information

Position	Pilot-in-Command
Sex	Male
Age	59 years old
Pilot's license	TR-A-04060
Date of license issue, authority	27.05.2015, DGCA
Education	AIRFORCE ACADEMY, 30.08.1981
Weather minimum	Approved for CAT III A
Total flight hours	10808 h
Flight hours on B 747	820 h
Flight hours on B 747 as PIC	820 h
Flight hours over last month	39 h 36 min
Flight hours over last 3 days	None
Flight hours on accident day	06 h 29 min
Total duty time on accident day	11 h 47 min
Breaks in operations over last year	None
Date of last check on piloting skills	23.04.2016 (LPC), passed
Simulator training	28.09.2016
Pre-flight briefing	Conducted by PIC in Hong Kong Airport before departure
Crew rest	From 12.01.2017 to 15.01.2017 in Hong Kong hotel
Medical check before departure	Non-applicable
Previous accidents or incidents	01.03.2010, A300-B4 TC-ACB, run-off the Bagram Airport's RWY 03 after landing. Involved as First Officer. Main LH landing gear collapsed.
Emergency evacuation training (Land)	21.01.2016
Emergency evacuation training (Water)	24.04.2015

Recurrent qualification training	21.01.2016, JED
CRM Training	21.01.2016, JED
Medical examination	27.04.2016, Gazi Osman Pasa Hostital, Istanbul, valid for 1 year
English Language Proficiency (ELP) level	ICAO Level 5, valid till 28.10.2019

Position	First Officer
Sex	Male
Age	59 years old
Pilot's license	TR-A-07998
Date of issue, authority	27.10.2014, DGCA
Education	AIRFORCE ACADEMY, 30.08.1980
Total flight hours	5894 h
Flight hours on B 747	1758 h
Flight hours over last month	32 h 33 min
Flight hours over last 3 days	None
Flight hours on accident day	06 h 29 min
Total duty time on accident day	11 h 47 min
Breaks in operations over last year	None
Date of last check on piloting skills	06.12.2015 (LPC), passed ⁵ .
Simulator training	11.05.2016
Pre-flight briefing	Conducted by PIC in Hong Kong before departure
Crew rest	From 12.01.17 to 15.01.2017 in Hong Kong hotel
Medical check before departure	Non-applicable
Previous accidents or incidents	None
Emergency evacuation training (Land)	31.08.2016 31.05.2014

⁵ According to the aviation regulations of the Republic of Turkey and the airline's OM Part D, when the recurrent checking is undertaken within the last three months of the license validity period, the new validity period is counted from the original expiry date, not from the date of the actual check date. The expiry date of the previous check was 31.01.2016. Thus, the FO's check was still valid (the expiry date was 31.01.2017.)

Emergency evacuation training (Water)	
Recurrent training	31.08.2016, IST
CRM Training	31.08.2016, IST
Medical examination	18.08.2016, Dogan Hospital IST, valid for 1 year
ELP level	ICAO Level 6, lifetime validity

According to the information, available to the investigation team, no findings regarding the crew's training and qualification have been revealed.

1.5.2. ATC Personnel Information

Position	Shift supervisor (worked at shift supervisor's working station at time accident)
Sex	Male
Age	46 years old
Education	Riga Higher Aviation School of Civil Aviation, 1991
Air Traffic Controller's License	AC-00106, issued by Civil Aviation Agency of Kyrgyz Republic, valid till 06.04.2018
Experience as air traffic controller	Since 1991
Qualification class	Class 1, Civil Aviation Agency of Kyrgyz Republic, Order No.42/L dated 07.02.2000
Authorizations	Upper Airspace Area Control, Approach
Recurrent training	Institute of Air Navigation, Moscow, September 2013
Simulator training	29.12.2016
On-the-job practical skills qualification check	Upper Airspace Area Control, 17.10.2016, Approach Control, 18.10.2016
Annual medical examination	Medical examination board of Kyrgyzaeronavigatsiya, fit to work as air traffic controller, valid till 06.04.2018
ELP level	ICAO level 4, valid till 11.11.2019

Position	Senior Controller (worked at Approach Control working station at time of accident)
Sex	Male
Age	37 years old
Education	Kyrgyz Aviation College, 1999

Air Traffic Controller's License	AC-00167, issued by Civil Aviation Agency of Kyrgyz Republic, valid till 18.05.2017
Experience as air traffic controller	Since 2000
Qualification class	Class 1, Civil Aviation Agency of Kyrgyz Republic, Order No.313 dated 07.06.2007
Authorizations	Ground Control, Tower Control, Approach Control, Upper Airspace Area Control
Recurrent training	Institute of Air Navigation, Moscow, October 2013
Simulator training	12.10.2016
On-the-job practical skills qualification check	Approach Control, 17.10.2016 Ground Control and Tower Control 18.10.2016, Upper Airspace Area Control, 28.10.2016,
Annual medical examination	Medical examination board of Kyrgyzaeronavigatsiya, fit to work as air traffic controller, valid till 18.05.2017
ELP level	ICAO level 4, valid till 24.06.2018

Position	ATC Controller (worked at Tower Control working station at time of accident)
Sex	Male
Age	58 years old
Education	Riga Higher Aviation School of Civil Aviation, 1979; Aviation Training Center No.25, 1992
Air Traffic Controller's License	AC-00105, issued by Civil Aviation Agency of Kyrgyz Republic, valid till 22.12.2017
Experience as air traffic controller	Since 1992
Qualification class	Class 1, Civil Aviation Agency of Kyrgyz Republic, Order No.411 dated 12.10.2001
Authorizations	Ground Control and Tower Control
Recurrent training	Aviation Training Center of Kyrgyzaeronavigatsiya, 25.11.2016
Simulator training	29.11.2016
On-the-job practical skills qualification check	Ground Control and Tower Control, 28.11.2016,

Annual medical examination	Medical examination board of Kyrgyzaeronavigatsiya, fit to work as air traffic controller, valid till 22.12.2017
ELP level	ICAO level 4, valid till 06.05.2018

According to the information available to the investigation team, no findings regarding the ATC personnel's training and qualification have been revealed.

1.6. Aircraft Information



Figure 18. Boeing 747-412F TC-MCL before accident

Aircraft type	Boeing 747-412F
Manufacturer	The Boeing Company, USA
Date of manufacture	February 2003
MSN	32897
Registration mark	TC-MCL
Certificate of Registration	No.3151, issued by Turkish DGCA, 10.12.2015
Owner	LCI Freighters One Limited (Ireland)
Certificate of Airworthiness	No. 3151 issued by Turkish DGCA, 08.12.2017.
Service life	Not established, in service due to technical condition

Time Since New (TSN)	46820 h, 8308 cycles
Time Between Overhauls (TBO)	Not established, in service due to technical condition
Last overhaul	None
Last base maintenance	06.11.2015, C08-Check, performed in Singapore Airport
Last line maintenance	PF Check, 15.01.2017 at Astana Airport (Kazakhstan) by ACT Airlines maintenance personnel; Transit Check, performed at Hong Kong Airport prior to flight to Bishkek Airport on 15.01.2017 by ACT Airlines maintenance personnel

The aircraft is equipped with PW4056-3 engines and a PW901A APU, manufactured by Pratt & Whitney (USA).

Engines	Engine No.1	Engine No.2	Engine No.3	Engine No.4
Type	PW4056-3	PW4056-3	PW4056-3	PW4056-3
MSN	P724497CN	P729032	P727958	P724322CN
Date of manufacture	25.02.1993	15.09.2001	16.12.1999	30.01.1991
Service life	Depends on technical condition			
TSN, hours/cycles	87 317/13 962	56 378/9 769	47 974/7 170	90 286/15 306
Number of overhauls	2	2	1	3
Time since last overhaul (TSO), hours/cycles	4 857/870	13 407/2 631	32 149/4 986	7 323/1 359
Date and place of last overhaul	29.05.2012, Eagle Services Asia	26.06.2012, Eagle Services Asia	14.08.2006, Eagle Services Asia	14.03.2012, Eagle Services Asia

From February 2003 till December 2015, the aircraft was operated by Singapore Airlines (under the registration number of 9V-SFL).

Aircraft maintenance

ACT Airlines (Turkey) started the operation of the B747-412F aircraft (under the registration number of TC-MCL) on 10.12.2015.

During the period of the aircraft operation, the line and base maintenance was performed regularly and fully in accordance with the requirements of ACT Airlines Aircraft Maintenance Program, approved by the DGCA of Turkey on 10.01.2017.

The documentation analysis proved that the aircraft maintenance works were assigned in due time and were fully performed. From the start of the aircraft operation by ACT Airlines, the aircraft was never put into preservation.

The line maintenance works, the engineering support, the maintenance production planning and control works were performed by ACT Airlines specialists.

Last Line Maintenance Performed

- PF Check performed on 15.01.2017 at Astana Airport (in Kazakhstan) by the maintenance personnel of ACT Airlines;

- Transit Check performed on 15.01.2017 at Hong Kong Airport before departure to Bishkek Airport by the maintenance personnel of ACT Airlines.

Before the departure from Hong Kong Airport, the aircraft was refueled with 88 665 liters of Jet A-1 fuel (70 223 kg at the density of 0.792 kg/cm³). The total amount of fuel on board was 96 640 kg.

After the accident, the fuel sample of ≈ 1.0 liter have been taken from the LH wing tank for conducting the examination. The examination results have proved that the fuel quality was normal (see Section 1.16.1).

The aircraft logbook entries have been inspected for the period starting from 01.01.2017 for the correctness of the entries, evaluation of the findings made by the crew members and the defects, found during the aircraft maintenance, for the defects recurrences and the completeness of works performed. No findings have been revealed.

The procedure for opening deferred maintenance items (defects) has been checked. According to the aircraft logbook, there were four Category D deferred maintenance items at the time of the aircraft departure from Hong Kong Airport on 15.01.2017:

- the damage (insignificant dent) of the left side of the Engine No.2 thrust reverser cowling between Spars 147.14 – 177.5;

- the damage of the LH side fuselage skin near Frame 1;

- the damage of Dipsticks No.3, No.19, No.21, No.22 of LH Fuel Tank No.1;
- the damage of the fuselage near Frame No.1000.

On 02.12.2016, the deferred item entered on 30.11.2016 concerning paint delamination on the RH lower wing was rectified.

On 06.12.2016, the deferred item entered on 30.11.2016 concerning the damaged latch (missing pushbutton) of the fueling station access door was rectified.

The analysis for the completeness of the performed mandatory Service Bulletins (SBs) and Airworthiness Directives (ADs) concerning the aircraft airframe and powerplant has been performed. All the mandatory SBs and ADs, affecting the aircraft airframe and powerplant, were performed.

During the period of 23-25.11.2015, the last IATA audit of ACT Airlines was conducted, in accordance with the IOSA program⁶; as a result of which the airline company received the Certificate of Compliance with the IATA requirements. During the IATA audit, no findings on the maintenance or the technical documentation were revealed.

No findings on the operation of the aircraft, its systems, powerplant or avionics prior to the last flight were revealed.

Based on the analysis of the operational and maintenance documentation, of the assessed damage and the operational performance characteristics of the aircraft airframe, systems, powerplant, avionics and radio communication equipment, as well as of the data, recorded by the onboard recorders, the following has been found:

- the Boeing 747-412F TC-MCL was operated in accordance with the valid maintenance program of the ACT Airlines. During the analysis of the technical operational and maintenance documentation, no findings related to the technical operation of the aircraft has been revealed;
- at the time of the accident, the aircraft engines, APU and the components with the limited service life were well within their service limits;
- the aircraft had no individual characteristics, which might have contributed to the occurrence or further development of the abnormal situation during the landing at Manas International Airport (Bishkek) on 16.01.2017;
- the aircraft technical maintenance was conducted in the organizations which have the relevant certificates for conducting the associated works;
- the line and base maintenance works on the aircraft were conducted in full by the engineering and maintenance personnel who have passed the required theoretical and practical

⁶ The audit was conducted by Aviation Quality Services (AQS).

training and have been certified for performing maintenance works within their fully-approved competence privileges in accordance with the Aircraft Maintenance Program of the ACT Airlines, approved on 10.01.2017 by the DGCA;

- no indication of the aircraft equipment failures during the last and previous flights have been found during the analysis of the data, recorded by the onboard recorder;

- no indication of the aircraft equipment failure during the last flight have been found on during the inspection of the parts, assemblies and units of the aircraft airframe and its systems. All the damage was caused by the impact loads and the by burning fuel during the ground fire. Prior to the aircraft impact with the terrain, no fire was present in the cockpit, which is proved by the fact that neither traces of thermal impact nor soot on the frontal surfaces of the remaining instruments have been found;

- the character of the damage indicates that all the damage was caused by the aircraft impact with the terrain and the resulting ground fire. No airframe disintegration occurred during the flight;

- no traces of failures which might have caused the loss of the aircraft control have been found on during the inspection of the remaining parts of the control system, hydraulic system, fuel system, air conditioning system, APU and the furnishing;

- the disintegration of the control linkage of the aircraft control system as well as of the manifolds of the hydraulic, fuel and air conditioning systems was caused by the aircraft impact with the terrain and the resulting ground fire. The APU was off;

- during the last flight, the engines were serviceable and functionally operative until the moment of the aircraft impact with the terrain. The engine rotors' rpms, the exhaust gas temperature, the fuel consumption parameters were continuously in compliance with the standard requirements until the aircraft impact with the terrain and the resulting aircraft disintegration;

- the electrical system of the aircraft, the inertial reference system, the communication systems and other avionics systems show no traces of failure during the last flight until the time when the electrical system ceased to operate due to the aircraft structural disintegration. The avionics equipment show significant damage caused by the mechanical disintegration of the airframe structure caused by the aircraft impact with the terrain and the consequent ground fire.

1.7. Meteorological Information

On 15-16.01.2017, the weather at Chuya Lowland of the Kyrgyz Republic and at Manas Airport was affected by the cold front with waves, moving from the south-west to the north-east direction. The slow movement of the cold front with waves was contributing to the formation of a wide area of frontal fog for a long period at Chuya Lowland, which was proved by the actual weather with the "storm" index, received on 15.01.2017 from the meteorological stations, included

into the "storm circle" of Manas Airport: at Dzhany-Dzher Meteorological Station – at 02:25, fog 500 m, at Kara-Balta (located 64 km further to the south-west) – at 05:40, fog 200 m, at Talas Meteorological Station (located 190 km further to the south-west) – at 13:10, fog 200 m, and the Manas aerodrome actual weather.

Based on the synoptic situation, the weather forecast for the Manas aerodrome for 15.01.2017 starting from 12:00 and in all the consecutive weather forecasts were as follows: fog, visibility 200 m, vertical visibility 30 m.

On 15.01.2017, during the briefing at Hong Kong Airport, running from 13:30 to 13:55, the crew of the B747-400F TC-MCL aircraft were provided with the weather documentation package, including the weather forecast for the departure airport of Hong Kong for the period from 12:00 on 15.01.17 to 12:00 on 16.01.17, for the alternate airports of Astana, Karaganda for the period from 12:00 on 15.01.17 to 12:00 on 16.01.17, for the arrival airport of Bishkek (Manas) for the period from 12:00 on 15.01.2017 to 12:00 on 16.01.2017, the significant weather prognostic charts for FL 250-630 for 18:00 on 15.01.17, 00:00 on 16.01.17, the wind and temperature prognostic charts for FL 100, FL 180, FL 240, FL 300, FL 340 and FL 390 for 18:00 on 15.01.17 and for 00:00 on 16.01.17, the actual weather in the METAR format for Hong Kong Airport for 13:30 on 15.01.17, for Bishkek (Manas), Astana and Karaganda for 13:00 on 15.01.17, the SIGMET 2 information for Shanghai FIR, valid for the period from 13:30 to 17:30 on 15.01.2017.

The forecast correction for the arrival aerodrome of Manas in the TAF-format for 15.01.2017 was as follows:

TAF AMD UCFM 151154Z 1512/1612 24005MPS 0200 FZFG VV001 TEMPO 1512/1518 31003MPS 0800 FZFG FU VV003 TEMPO 1518/1524 0800 FZFG VV003 FM160600 32004MPS 1500 BR BKN005.

The weather correction was issued at 11:54 on 15.01.2017, valid for the period from 12:00 on 15.01.2017 to 12:00 on 16.01.2017: surface wind 240° at 05 mps, visibility 0200, freezing fog, vertical visibility 030 m, TEMPO from 12:00 on 15.01.2017 to 18:00 on 15.01.2017, surface wind 310° at 03 mps, visibility of 0800 m, freezing fog, smoke, vertical visibility 090, TEMPO from 18:00 on 15.01.2017 to 24:00 on 15.01.2017 visibility 0800 m, freezing fog, vertical visibility 090 m, from 06:00 on 16.01.2017 surface wind 320° at 04 mps, visibility 1500 m, mist, clouds broken at 150 m.

The actual weather for the arrival aerodrome of Manas in the METAR-format for 13:00 15.01.2017 was as follows:

METAR UCFM 151300Z 23003MPS 0150 R26/0550 FZFG VV001 M08/M09 Q1024 R26/19//60 NOSIG.

The weather at Manas aerodrome was as follows: surface wind 230° at 03 mps, visibility 0150 m, RWY 26 visibility range 0550 m, freezing fog, vertical visibility 100 ft (030 m), temperature minus 08°C, QNH 1024 hPa, RWY 26 wet, braking action 0.06, TREND NOSIG.

The forecast for the alternate aerodrome of Astana in the TAF-format for 15.01.2017 was as follows:

TAF UACC 151100Z 1512/1612 22004MPS 9999 SCT007 BKN100 TXM16/1609Z TNM23/1601Z TEMPO 1512/1606 VRB02MPS 3000 –SNBR BKN003 BECMG 1604/1606 04004MPS TEMPO 1606/1612 5000 –SN SCT005.

The weather forecast issued at 11:00 on 15.01.2017, valid for the period from 12:00 on 15.01.2017 to 12:00 on 16.01.2017 was as follows: surface wind 190° at 03 mps, visibility 10 km, clouds few at 210 m, clouds broken at 3000 m, maximum temperature minus 16°C at 09:00 on 16.01.17, minimum temperature minus 23°C at 01:00 on 16.01.17, TEMPO from 12:00 on 15.01.2017 to 06:00 on 16.01.2017 variable wind 02 mps, visibility 3000 m, light snow, mist, clouds broken at 090 m, becoming from 04:00 on 16.01.17 to 06:00 on 16.01.17 surface wind 040° at 04 mps, TEMPO from 06:00 on 16.01.17 to 12:00 on 16.01.17 visibility 5000, light snow, clouds few at 150 m.

The actual weather for the alternate aerodrome of Astana in the METAR-format for 13:00 15.01.2017 was as follows:

METAR UACC 151300Z 19003MPS 9999 –SG OVC010 M21/M24 Q1037 R22/4/0355 NOSIG RMK QFE745/0994.

The weather at Astana for 13:00 was as follows: surface wind 190° at 03 mps, visibility 10 km, light granular snow, overcast at 300 m, temperature minus 21°C, dew point minus 24°C, QNH 1037 hPa, RWY 22 dry snow, snow cover thickness 03 mm, braking action 0.55, TREND NOSIG, remark QFE745/0994.

The forecast for the alternate aerodrome of Karaganda in the TAF-format for 15.01.2017 was as follows:

TAF UAKK 151100Z 1512/1612 VRB02MPS 9999 SCT010 BKN100 TXM17/1609Z TNM25/1523Z TEMPO 1518/1604 3000 –SNBR SCT005 BECMG 1604/1606 08006MPS

The weather forecast issued at 11:00 on 15.01.2017, valid for the period from 12:00 on 15.01.2017 to 12:00 on 16.01.2017 was as follows: surface wind variable 02 mps, visibility 10 km, scattered clouds at 300, clouds broken at 3000 m, maximum temperature minus 17°C at 09:00 on 16.01.17, minimum temperature minus 25°C at 23:00 on 15.01.17, TEMPO from 18:00 on 15.01.2017 to 04:00 on 16.01.2017 visibility 3000 m, light snow, mist, clouds few at 150 m, becoming from 04:00 on 16.01.17 to 06:00 on 16.01.17 surface wind 080° at 06 mps.

The actual weather for the alternate aerodrome of Karaganda in the METAR-format for 13:00 on 15.01.2017 runs as follows:

METAR UAKK 151300Z 07003MPS CAVOK M24/M26 Q1035 R05/920555 NOSIG
RMK QFE728/0971.

The weather at Karaganda for 13:00 was as follows: surface wind 070° at 03 mps, ceiling and visibility OK, air temperature minus 24°C, dew point minus 26°C, QNH 1035 hPa, RWY 05 frozen snow with uneven surface of 20%, snow cover thickness 05 mm, braking action 0.55, TREND NOSIG, remark QFE 728/0971.

The forecasts and actual weather at the alternate aerodromes of Astana and Karaganda were in compliance with the requirements for the decision for departure with the forecast fog, visibility of 0200 m and vertical visibility of 30 m at the arrival aerodrome of Manas.

The Bishkek Aeronautical Meteorological Center provides the meteorological services for flights at Manas aerodrome and issues meteorological information for the operation of Bishkek Area Control (Ground Control, Tower Control, Approach Control, Upper Airspace Area Control, Control Tower briefing, FIC, ATC Main Center and Air Forces ATC), aircraft operators, flight crew members, search and rescue services and airport administration.

The following meteorological parameters are monitored at Manas aerodrome:

- wind direction and wind speed with WAA151 and WAV151 (main and backup) instruments;
- RWY visibility with LT-31 (main) and MITRAS (backup) instruments with the further calculation of RVR;
- weather phenomena occurrence, development, termination and intensity;
- quantity and forms of clouds visually, cloudbase altitude with CL31 (main and backup) instruments;
- air temperature and humidity with HMP45D (main) instrument and with TM-1-TM-4 (backup) set of thermometers;
- pressure with RTV220 (main) and BRS-1M (backup) barometers.

All the instrument pickups are linked to the main reference station and to the KRAMS-4 Aerodrome Navigational and Meteorological Complex and are in compliance with the requirements for the CAT II aerodrome (the aerodrome minimum is 30 m x 300 m). The parameters measurement data are stored by the KRAMS-4 Complex.

Both regular and special observations are conducted at Manas Airport. The regular observations at the aerodrome are conducted at 24/7 every 30 min. The METAR/SPECI reports are issued for the international OPMET databases and for other aerodromes.

The local weather reports are provided at 1-min intervals on the weather displays, installed at the ATC controllers' working stations and on the weather display of the forecaster-engineer.

On 16.01.2017, at 00:59, the controller of Bishkek Area Control informed the crew of B747-412F TC-MCL on the weather at Manas Airport: wind calm, RVR at RWY threshold 400 m, RWY midpoint and RWY end 300 m.

During the B747-412F TC-MCL aircraft approach, regular weather report for Manas Airport for 01:00 on 16.01.2017 was being broadcast via a VHF channel in Russian and English:

"Manas metreport 01:00 state of RWY26 damp braking action good wind calm visibility 50 meters RVR 300 meters freezing fog vertical visibility 100 feet temperature M09 dew point M10 QNH 1023 hPa NOSIG".

On contacting the Approach Control of Manas aerodrome at 01:10, the crew received new information on the actual weather for Manas Airport: *"wind calm visibility 50 meters RVR 300 meters freezing fog vertical visibility 160 feet."*

At 01:11, the Approach Control informed the crew on the aerodrome pressure: *"QNH 1023 hPa."*

At 01:15, the Tower Control provided the following information to the crew: *"RWY26: wind calm, RWY threshold 400 m, RWY midpoint 325 m, RWY end 400 m, vertical visibility 160 feet."*

At 01:17, the accident with the B747-412F TC-MCL aircraft occurred.

At the time of the accident weather forecast valid for the period from 00:00 on 16.01.2017 to 24:00 on 16.01.2017 was current for Manas aerodrome.

The weather forecast for Manas aerodrome in TAF-format for the period from 00:00 on 16.01.2017 to 24:00 on 16.01.2017 was as follows:

TAF UCFM 152244Z 1600/1624 24004MPS 0200 FZFG VV001 TEMPO 1600/1606 12005MPS 0800 FZFG FU VV003 FM 160600 32004MPS 1500 BR BKN005 TEMPO 1606/1612 0800 FZFG FEW003

Manas metreport issued on 16.01.2017, at 22:44, valid from 00:00 on 16.01.2017 to 24:00 on 16.01.2017: surface wind 240° at 4 mps, visibility 0200 freezing fog, vertical visibility 030 m, TEMPO from 00:00 on 16.01.2017 till 06:00 on 16.01.2017 wind 120° at 5 mps, visibility 0800 m, freezing fog, smoke, vertical visibility 090 m, from 06:00 on 16.01.2017 surface wind 320° at 04 mps, visibility 1500 m, mist, clouds broken at 150 m, TEMPO from 06:00 on 16.01.2017 to 12:00 on 16.01.2017 visibility 0800 m, freezing fog, clouds few at 090 m.

The actual weather at Manas aerodrome at 01:17: wind 60° at 01 mps, visibility: RWY threshold 100 m/RVR 400 m, runway midpoint 100 m/RVR 350 m, runway end 100 /RVR 400 m,

vertical visibility 050 m, temperature minus 09°C, dew point minus 10°C, QNH 1023,9 hPa, paved RWY 26 damp, braking action 0.6, TREND NOSIG.

As a result of the meteorological information analysis, the following was found:

- the TAF-forecasts for Manas aerodrome, valid from 12:00 on 15.01.2017 till 12:00 16.01.2017, from 00:00 till 24:00 on 16.01.2017, were in compliance with the actual aerodrome weather and came true in relation to all the meteorological parameters;
- the KRAMS 4 Complex meteorological pickups are provided with the valid certificates received on passing the meteorological audit and were operative at the time of the aircraft accident;
- the amount and the location of the meteorological equipment at Manas aerodrome are in compliance with the requirements of "Meteorological Flight Support Services" of the Aviation Regulations of the Kyrgyz Republic (APKR-3) concerning the meteorological support for CAT II landings and take-offs;
- the meteorological support for the flight of the B747-412F TC-MCL aircraft was in compliance with the requirements of APKR-3 "Meteorological Flight Support Services" and "Instructions for Meteorological Flight Support at Manas aerodrome".

1.8. Aids to Navigation, Landing and ATC

To cover air traffic control objectives, the following air traffic control units are provided:

- Bishkek Area Control;
- Approach Control;
- Tower Control.

The flight services director's work station is shown in Figure 19.



Figure 19. Flight services director's work station equipment:

1 – Baklan-RN radio station; 2- microphone; 3- BO-RP flight services director's unit of annunciation system; 4 –Alinko-DR135 MK III airport internal communication radio station (for 163.55 MHz frequency); EMS-57 microphone; 5 – "Polosa" runway occupancy light and audio annunciation system display unit; 6 – flight services director's display unit of "GORN-2" airport fire brigade annunciation system; 7 – individual work station display unit of "Alpha" ATC automation system; 8 – KRAMS meteorological information display unit; 9 – individual work station display unit of "Planeta" ATM automated planning system; 10 – switchboard microphone of voice communication system work station equipment; 11 – "Megaphone" voice communication system touch-screen display unit; 12 – "Megaphone" voice communication system loudspeaker; 13 – computer mouse; 14 – telephone unit; 15 – "Planeta" ATM automated planning system keyboard

The Approach controller's work stations is shown in Figure 20.



Figure 20. Approach controller's work station equipment:

1 – DF-2000 automatic radio-direction finder display unit; 2 – "Megaphone" loudspeaker; 3 – "Megaphone" touch-screen display unit; 4 – individual workstation's "Alpha" main display unit; 5 – individual workstation's of "Alpha" backup display unit; 6 – working documentation display panel of "Pult-A" air traffic controller work station; 7 – I-com F-110 standby-power radio station with microphone; 8 – "Pult-A" air traffic controller work station lighting system; 9 – individual workstation's "Megaphone" microphone; 10 – individual workstation's "Megaphone" push-to-talk switchboard; 11 – computer mouse; 12 – telephone unit; 13 – individual workstation's "Megaphone" headset unit; 14 – "Polosa" display unit; 15 – KRAMS display unit; 16 – individual workstation's keyboard of "Planeta"; 17 – RWY 08 ILS serviceability indication panel (for heading, glideslope, beacons); 18 – RWY 26 ILS serviceability indication panel (for heading, glideslope, beacons); 19 – VOR/DME serviceability indication panel

The Tower controller's work stations is shown in Figure 21.



Figure 21. Tower controller's work station equipment:

1 – KRAMS meteorological information display unit; 2 – individual workstation's "Megaphone" voice communication system push-to-talk switchboard; 3 – "Megaphone" voice communication system touch-screen display unit; 4 – "Megaphone" voice communication system loudspeaker; 5 – "Polosa" runway occupancy light and audio annunciation system display unit; 6 – "Polosa" runway occupancy light and audio annunciation system control panel; 7 – individual workstation's "Megaphone" voice communication system microphone; 8 – Alinko-DR135 MK III airport internal communication radio station (for 163.55 MHz frequency); EMS-57 microphone; 9 – computer mouse; 10 – "Alpha" ATC automation system display unit; 11 – lighting system control and monitoring panel; 12 – video system control switchboard

Physically, the flight services director's and the Approach controller's work stations are located in one room. The Area and Tower controllers' work stations are located in other separate rooms.

The flight services director's, Approach and Tower controller's work stations are equipped with "Alpha" ATC automation system display units (see Figure 19, Figure 20 and Figure 21).

Navigational Support

The ground navigational approach support equipment for RWY 26 includes the following:

- MVRL-SVK (Monopulse Secondary Surveillance Radar);
- ILS NM-7000 (111.7 MHz, IBK);
- VOR/DME (113.4 MHz, MNS);
- PAR-10C LIM beacon (481 kHz, "V");
- PAR-10C LOM beacon (975 kHz "VK").

The peculiarity of Manas International Airport is that the ILS systems on both RWY approach courses have the same frequency (111.7 MHz) while their letter-codes are different. According to the available information, the system is configured in such a way that when the ILS for one approach heading is engaged, the ILS for the other approach heading disengages automatically.

The STAR and approach charts are shown in Figure 22, Figure 23 and Figure 24.

Courtesy Translation

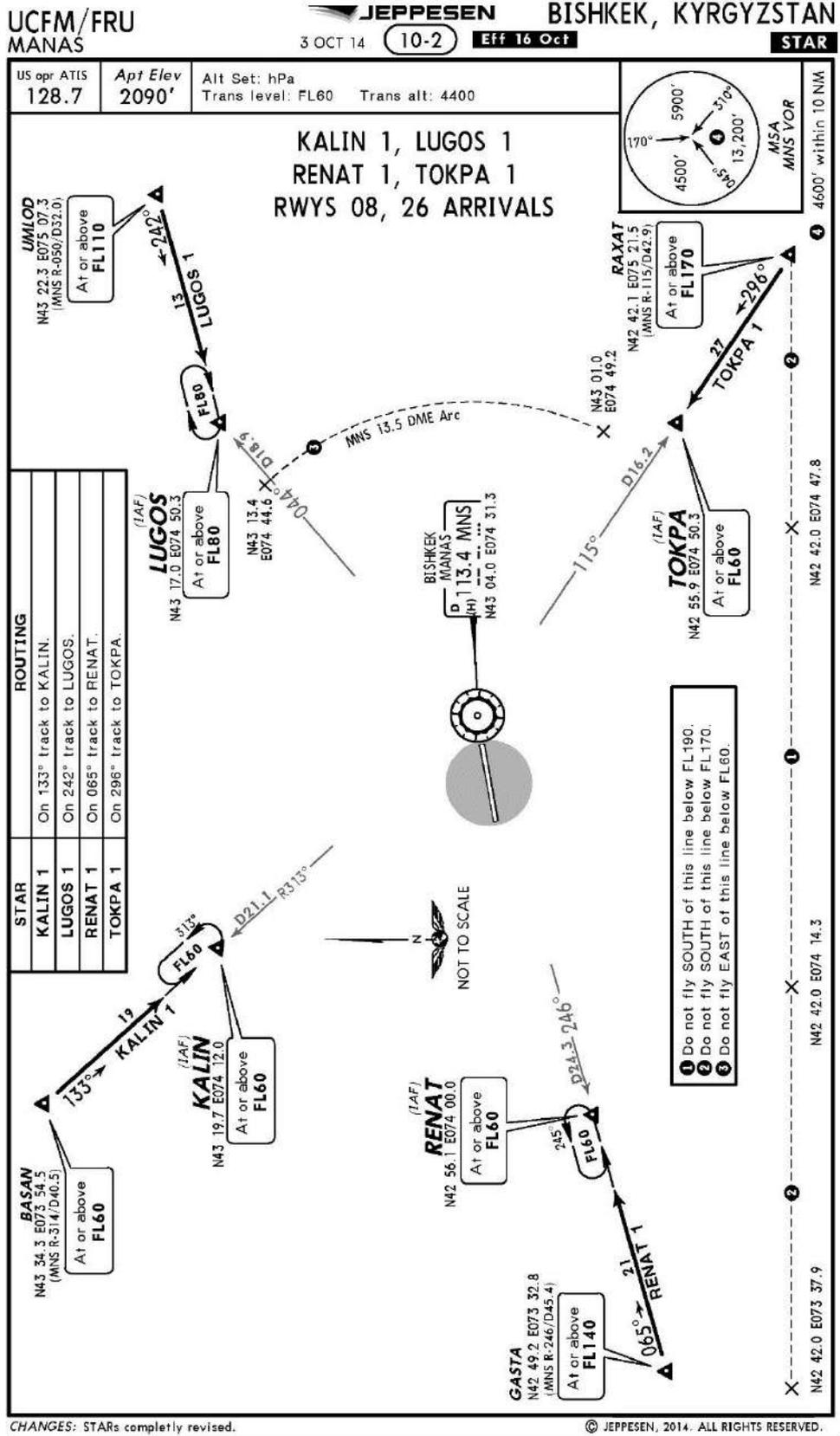


Figure 22. Standard Arrival Chart

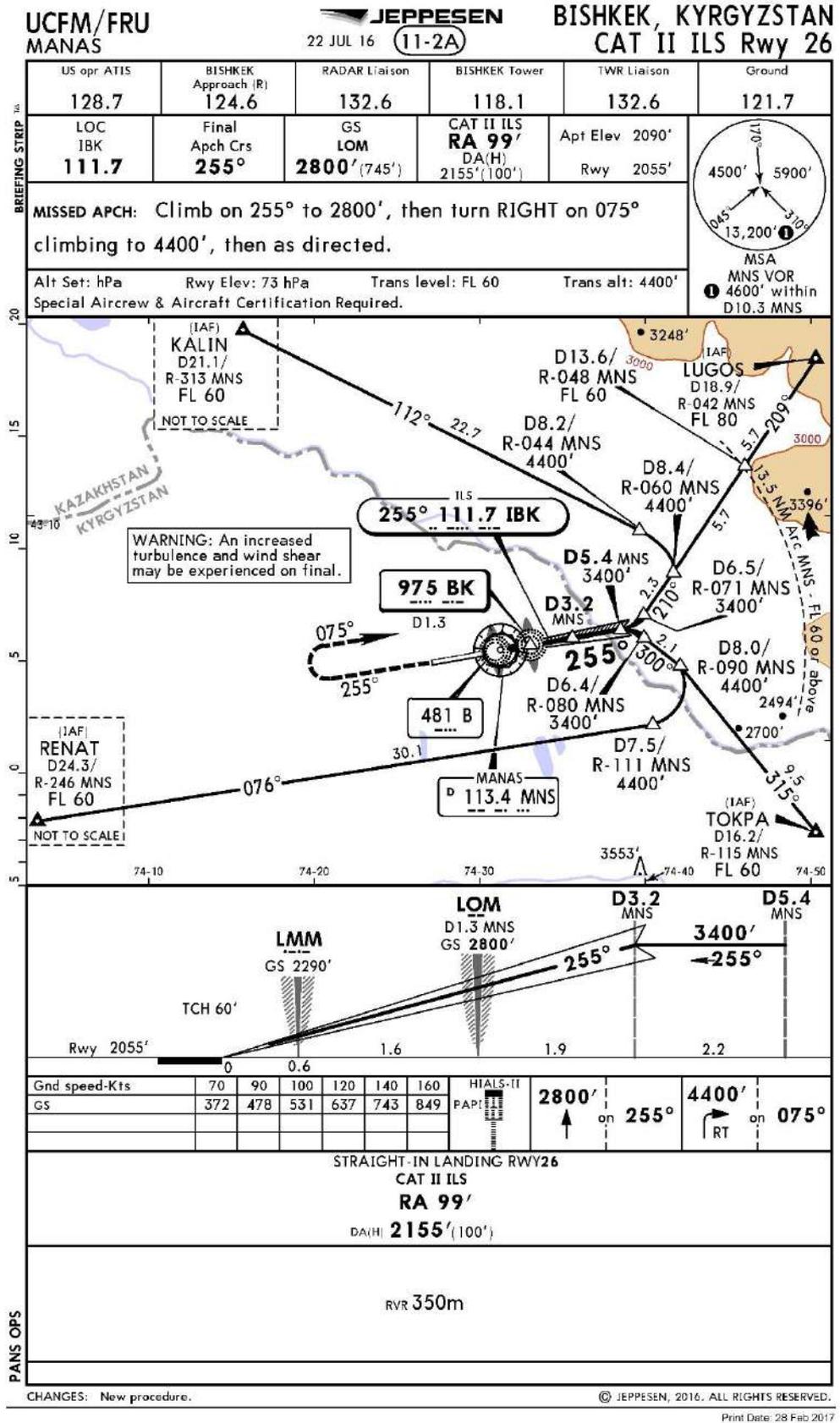


Figure 23. RWY 26 approach chart (Jeppesen)

AD 2.1 UCFM-98
16 OCT 14

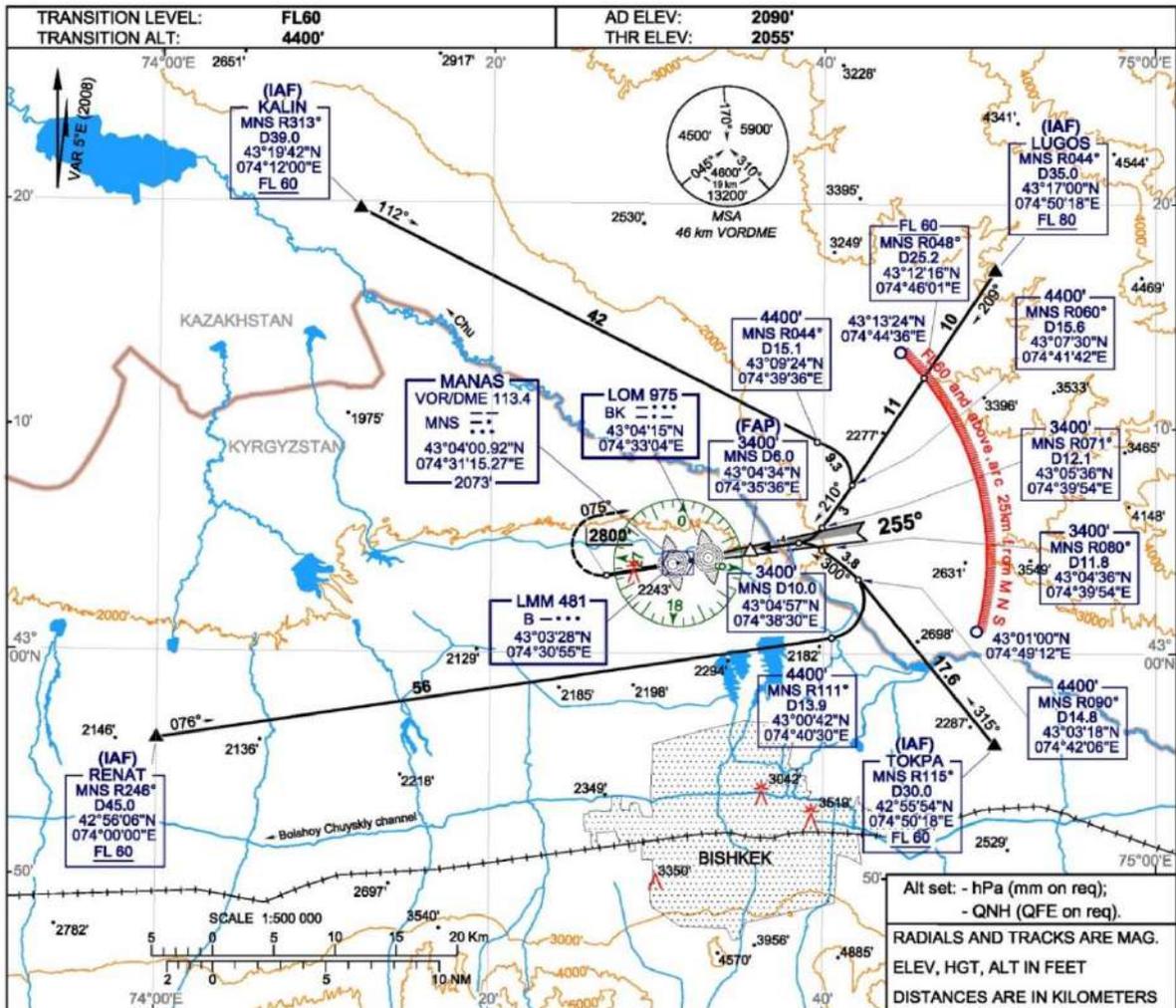
AIP
KYRGYZ REPUBLIC

**INSTRUMENT
APPROACH
CHART - ICAO**

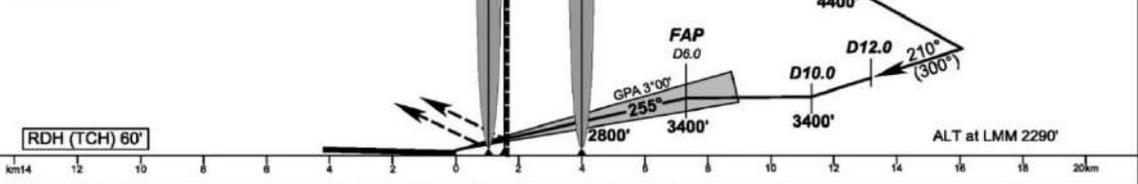
ILS/DME
255° 111.7 IBK
.....

APPROACH TOWER
124.6
118.1

**BISHKEK, KYRGYZSTAN
MANAS
ILS , 2 NDB RWY 26**



MISSED APPROACH
Climb on track 255° to 2800', then turn RIGHT on track 075° climbing to 4400', then by ATC instruction.



OCA/H		A	B	C	D							
Straight-in Approach	CAT II	2102' (49')	2116' (62')	2129' (75')	2142' (88')							
	CAT I	2194' (141')	2204' (150')	2214' (160')	2221' (170')							
	2 NDB	2391' (338')	2391' (338')	2391' (338')	2391' (338')							
GROUND SPEED	km/h	150	180	210	240	270	300	330	360	390	420	450
RATE OF DESCENT (Grad 5.2%)	m/s	1.9	2.3	2.7	3.1	3.5	3.9	4.2	4.6	5.0	5.4	5.8

WARNING
An increased turbulence and wind shear may be experienced on final.

AIRAC AMDT 05/14

Civil Aviation Authority

Figure 24. RWY 26 landing approach chart (AIP)

1.9. Communication Aids

Manas aerodrome is equipped with the following communication aids:

- (VHF) radio stations;
- loudspeaker communication;
- telephone communication;
- telegraph communication;
- aerodrome internal communication.

There is a direct loudspeaker communication system provided for the traffic control units in the airport. There is also loudspeaker operational (direct) communication in-between all of the ATC units, fully-automated telephone communication including access to the city telephone network, national and international telephone networks, the public network, as well as the aerodrome internal communication system provided on the airfield and the aprons.

1.10. Aerodrome Information

Manas aerodrome is located 23 km to the north of Bishkek. Manas airport with RWY 08/26 equipped for precise ICAO CAT II approaches holds the Certificate of Aerodrome Conformity issued by the Civil Aviation Agency of the Ministry of Transport and Roads of the Kyrgyz Republic, valid till 01.12.2017.

The aerodrome is equipped with one paved runway, 4204 m long and 55 m wide. The aerodrome designated code is "4 E". The runway has 4.5 m wide perimeter pavement along its entire length (concrete for 2.5 m, asphalt-concrete for 2 m) on each side of the runway.

Runway surface is 40 cm-thick fibercrete.

Runway longitudinal slope is 0.0026 (0.26%). There are no longitudinal slope deviations for more than 1.5%.

The coordinates of Manas Aerodrome as per WGS-84:

- ARP (Aerodrome Reference Point): 43°03'40.58"N, 074°28'39.03"E;
- RWY 08: 43°03'28.74"N, 074°27'07.55"E;
- RWY 26: 43°03'52.40"N, 074°30'10.53"E.

The ARP elevation is 2080 ft (634 m). The threshold elevation: for RWY 08 is 2090 ft (637 m) and for RWY 26 is 2055 ft (626 m).

The airstrip is 4324 m long and 300 m wide. The clearway measurements are as follows: RWY 08 – 400x300 m; RWY 26 – 250x300 m, the RWY surface type is unpaved ground.

There are unpaved ground runway end safety areas for RWYs 08/26 measured 240x110 m.

Along its entire perimeter, Manas aerodrome is surrounded by concrete and metal-net fencing barriers. Beyond the aerodrome, at a distance of about 1000 m from the threshold of

RWY 08, there are dwelling houses and outbuildings of Dacha-SU settlement, their heights not exceeding the pertinent limitations.

1.10.1. **Aerodrome Equipment**

The aerodrome service (AS) of Manas aerodrome provides the technical maintenance of the working aerodrome area and ensures whether it is serviceable for flights conduct.

At the time of the accident, the runways, the taxiways and the stands were serviceable, the RWY friction coefficient at 00:40 on 16.01.2017 was 06/06/06, the runway was wet (there is the associated entry in the Manas Aerodrome Working Aerodrome Area Condition Logbook, made by the shift engineer of the Manas Aerodrome Service). According to the working schedule of the aerodrome service, the runway surface inspection, including the friction coefficient measuring, is conducted whenever the runway surface condition is changed, the weather conditions are changed (in case of rain, snow, glazed frost, slash, rime icing) and/or on the flight services director's request, followed by recording the associated entry into the Manas Aerodrome Working Aerodrome Area Condition Logbook and by providing the actual information on the aerodrome condition to the ATC controller.

On request from the Head of Manas Aerodrome Service, at 02:40, the commission inspection of the aerodrome facilities' condition was performed and the associated Inspection Report was completed. According to the Inspection Report, the paved runway surface was wet, the friction coefficient was 06/06/06, no bird hazard was present, no findings related to the aerodrome equipment items were revealed.

The aerodrome is equipped with the necessary facilities for removal of obstacles and dirt from the runway surface. The chemical agents (both liquid and dry) for the winter runway maintenance are in stock.

The runway surface friction coefficient is measured by the aerodrome service personnel by means of ATT-2 aerodrome braking cars (two items) and by means of BV-11 skiddometers (two items). The measuring equipment is provided with the associated calibration certificates.

1.10.2. **Electrical and Airfield Lighting Support Equipment**

The aerodrome is equipped with the airfield lighting equipment, manufactured by IDMAN (Finland), positioned in compliance with the ICAO CAT I layout chart. In 2006, the aerodrome's airfield lighting system was additionally reinforced with the IDMAN OVI-II high-intensity lights subsystems in order to provide the possibility of the ICAO CAT II precision approach from the two magnetic landing bearings (RWY 08 and RWY 26). The performance

characteristics of the airfield lighting equipment are as follows: the layout chart, color and intensity of lights, the directions and angles of the airfield lights radiance are in compliance with the Aviation Legislation of the Kyrgyz Republic (the APKR-14) and with the ICAO Annex 14.

The operational and maintenance works on the electrical and airfield lighting equipment is provided by the Power and Airfield Lighting Flight Service, which is the structural division of the Bishkek office of the Manas International Airport OJSC.

The daily check of the airfield lighting equipment condition is performed by the shift engineer of the Airfield Lighting Flight Service station three times per day. There is a airfield lighting equipment operational database accessible from the backup control panel of the Electrical and Airfield Lighting Support Service work station, where the current information on the airfield lights operation is displayed.

According to the Instruction on operation and control of the airfield OVI-II high-intensity lighting system of Manas aerodrome, dated 05.12.2014, the operational control of the airfield lighting equipment on the aerodrome is provided by the Tower controller from the control panel located on the Tower controller's work station.

In case of the Tower controller's operational control of the airfield lighting equipment, the control of airfield lighting equipment from the Airfield Lighting Flight Service work station is automatically inhibited, and the Airfield Lighting Flight Service engineer is no longer able to interfere into the operation of the airfield lighting equipment.

The airport's airfield lighting equipment control panel has five levels of lights brightness. Each level of lights brightness provides the brightness values in accordance with the "Table of brightness levels and sets of engaged lights", available from the operation control panel of the OVI-I and OVI-II high-intensity lighting system. There is no possibility of simultaneous engagement of the approach lights sets of the both RWY landing headings, i.e. is the "RWY 08" pushbutton on the OVI-II lighting control panel, the RWY 26 lights are switched off (in case the RWY 26 lights are switched on, the RWY 08 lights are switched off).

The OVI-II aerodrome lighting system was switched on by the controller from the control panel, located at the Tower controller's work station, and on 15.01.2017 at 12:33, the system was set to RWY 26 with the Level 4 brightness pushbutton set to "ON". According to the "Table of brightness levels and sets of engaged lights" for the aerodrome OVI-I and OVI-II system control

panel, the Level 4 brightness of the OVI-II system control panel sets the following brightness parameters for the lighting subsystems:

- approach lights and runway crossbar lights – 30%;
- runway edge lights – 30%;
- runway threshold lights – 30%;
- runway edge lights – 30%;⁷
- touchdown zone lights – 10%;
- PAPI lights – 30%;
- taxiway edge lights and identifier lights – 100%;
- approach strobe lights (switched on with no brightness adjustment).

Note: *According to the guiding materials, provided in Attachment A p. 16.2 to Volume 1, Aerodrome Design and Operations of ICAO Annex 14, Aerodromes: "In fog the amount of light scattered is high. At night this scattered light increases the brightness of the fog over the approach area and runway to the extent that little increase in the visual range of the lights can be obtained by increasing their intensity beyond 2 000 or 3 000 cd. In an endeavour to increase the range at which lights would first be sighted at night, their intensity must not be raised to an extent that a pilot might find excessively dazzling at diminished range."*

According to Appendix 1 to the Instruction on use and control of the high-intensity Level II (OVI II) lighting system at Manas aerodrome, under night conditions, in the visibility of less than 1000 m, the lights shall be set to Level 4 brightness. Level 5 (maximum) brightness shall be used in the visibility of less than 1000 m under daylight conditions. The determination of the levels of brightness in relation to the day/night and meteorological conditions has been performed on the basis of the Table for determination (evaluation) of the runway visibility range (RVR) of Manas aerodrome, equipped with IDMAN aerodrome lighting system (Finland), approved by the Director of the Institute of Radar Meteorology (St. Petersburg, Russia).

⁷ 100% of brightness stand for 2500 cd for the runway centerline lights and 10000 cd for the runway edge (landing) lights

At 07:26 on 16.01.2017, on request of the shift engineer of the Power and Airfield Lighting Flight Service station, the full-scale functional inspection of the airfields lighting system, glideslope lights and the standby aerodrome electrical power sources (for RWY 08 and RWY 26) serviceability was conducted, including the system switching to "ON" from the Tower controller's work station. At 8:30 on 16.01.2017, after the lighting system check, the shift engineer of the Power and Airfield Lighting Flight Service station concluded that the airfield lighting system of the aerodrome was fully serviceable and functionally operative. No failures nor switching-offs of the airfield lighting system were recorded by the of the OVI-II airfield lighting failure-recording system during the period from 23:40 on 15.01.2017 to 08:30 on 16.01.2017, no interruptions in the aerodrome and airfield lighting system power supply were revealed during this period.

On 30.11.2016, onboard the flying laboratory Diamond DA-42, equipped with the AT-940 (ASU S/N 110, SPU S/N 110) flight monitoring equipment, the scheduled annual test flight of the OVI-II airfield lighting system (for RWY 08 and RWY 26) was performed. The Flight Test Reports on the flight test of the OVI II airfield lighting system, equipped with the PAPI visual glideslope indication system are available at the airport.

The electrical power supply of Manas aerodrome is provided by means of the two independent power sources through the two feeders. The aerodrome is equipped with the standby diesel-generator power source to supply power to the passenger terminal. In case one of the main power sources fails to supply electrical power, the switching to the alternate external power source by means of the automatic transfer switch will take 1 second. According to the requirements set for the first category special group of power users, the airfield lighting system is also powered by the two independent external power sources and by the two standby DGA-250 kVA diesel-generators, located OVI high-intensity lights technical stations No.2 and No.3.

OVI-II high-intensity airfield lighting system equipment

Approach lighting system for precision approach for RWY 08 and RWY 26

The approach lighting system for RWY 08 and RWY 26 consists of a row of lights, installed as an extension of the runway centerline outward from the runway ends for 900 m end. The white approach lights are supplemented with two edge rows of red approach lights running extending outward from the runway end for 270 m from and with two white runway cross bars, one of them positioned at a distance of 150 m and the other at a distance of 300 m from the RWY 08 and RWY 26 ends.

Longitudinally, the distance in-between the lights, constituting the centerline is 30 m, the nearest lights being installed at a distance of 30 m from the runway end.

The lights, constituting the runway approach edge light rows, are positioned along the centerline at both sides of it, with the same longitudinal distances in-between as the centerline lights. The nearest lights are installed at a distance of 30 m from the runway end.

The eleven lights of the cross bar are installed at a distance of 150 m from the runway end. The cross bar lights are installed at equal distances of no more than 2.7 m, except the lights, adjacent to the approach centerline light.

The 21 lights of the cross bar, installed at a distance of 300 m from the runway end with the in-between distances of 1.5 m.

The approach lighting system is installed in the horizontal plane, running through the runway end along the airport graded area.

The approach centerline lights are white floodlight bars, each constituting of 5 lights. The light bar length is 456 m with the lateral distances of 1.14 m in-between the two adjacent lights. The approach edge lights are floodlight bars, each constituting of 3 lights. Each light bar consists of 3 lights, positioned with the in-between lateral distances of 1.5 m. Additionally, the approach lighting system for RWY 08 and RWY 26 is supplemented with IDM 6290strobe lights with 21 xenon arc 30 js lamps with the pulsating frequency of up to 2 Hz.

Precision Approach Path Indicator (PAPI)

The PAPI system consists of wing bar of four IDM 6005 2-lamp lights with the abrupt color transition, positioned at equal distances from each heading course:

- 75° magnetic landing heading course at a distance of 381.64 m from the runway end;
- 255° magnetic landing heading course at a distance of 381 m from the runway end.

The system is installed at the left side of the active runway along the landing heading course in the way that:

- positioned on the glideslope with an angle of 3°00' or close to it ($\pm 10'$), the pilot can observe the two lights, located closer to the active runway as red lights, and the two lights, located further away from the active runway as white lights;

- positioned above the glideslope (13'), the pilot can see one light, located closer to the active runway as red lights, and the three lights, located further away from the active runway as

white lights; and positioned still higher above the glideslope (33'), the pilot observes all the four lights as white ones.

The lateral distance in-between the lights is 9 m. The distance from the active runway edge to the nearest light of the wing bar is 15 m.

The PAPI system is serviceable for flight operations both at daytime and at nighttime.

The color transition from red to white in the vertical plane can be observed from the distance of no less than 300 m within the range of the vertical angle of no less than 3'.

The light intensity distribution in-between the PAPI lights is in compliance with the APKR-14 and ICAO Annex 14 requirements.

The lights brilliance intensity adjustment is conducted from the operational lighting control panel within the range of 1%, 3%, 10%, 30%, 100% of brilliance in respect to the meteorological visible range of the active runway.

Each PAPI light can be adjusted in the vertical plane in order to ensure the lower limit of the white ray sector can be set at any required angle of elevation within the range of 1°30' to 4°30' over the horizon.

The tilting angle of the PAPI lights for the RWY 08 and RWY 26 is 3°00' and is the same as the ILS glideslope angle.

The elevation angle of the PAPI wing bars for the RWY 08 and RWY 26 is adjusted in the way that, during the approach, the aircraft pilot, observing one white light and three red lights, can proceed the flight over all the objects in the approach area with the sufficient clearance margin.

Runway landing (edge) lights

The runway edge lights are installed along the active runway edges throughout all its length in two parallel rows at the equal distances from the runway centerline. The distance in-between the rows is 58 m. The distance of the runway edge lights from the active runway edge is 1.25 m. The distance in-between every two lights in the row is 60 m.

At the places where the taxiway is connected to the active runway and at the turning zone of the runway with the magnetic landing heading course of 255°, the IDM 4052 landing inset lights with the white and white-and-yellow lamps are installed.

The runway landing lights are IDM 5848 omnidirectional lights with white lamps of steady radiance. Along the last 600 m of the both runway ends, looking from the approach direction, the yellow landing lights are installed.

Runway threshold and wing-bar crossing lights

The runway threshold and wing-bar crossing lights constitute a row which is perpendicular to the runway centerline and is positioned at the threshold end of the active runway at equal 2.88-meter intervals in-between the rows of landing lights. There are threshold and wing-bar crossing lights for each landing heading course. The wing-bar crossing lights constitute the same row as the landing lights and are installed at 2.88-meter in-between intervals in groups of four behind the rows of landing lights.

The active runway threshold lights and the wing-bar crossing lights are green IDM 2982/150W unidirectional floodlights with steady radiance in the direction of the approach to the active runway.

Runway end lights

The runway end lights (9 lights for each landing heading course) are installed perpendicular to the runway centerline and at equal intervals in-between the rows of runway landing lights. The runway end lights are red IDM 2982/150W unidirectional floodlights with steady radiance in the direction of the active runway.

Runway centerline lights

The touchdown zone lights are installed throughout the full distance of 900 m, starting from the runway threshold following the layouts, provided by the pairs of linear lights, the latter located symmetrically to the runway centerline. The longitudinal distance in-between the pairs of linear lights is 22 m. The linear light consists of three lamps, installed at 1.5-meter intervals in-between. The width of the linear light is 3 m. The touchdown zone lights are white IDM 4661 unidirectional floodlights with steady radiance.

1.11. Flight Recorders

The a/c was equipped with the following onboard flight data recorders:

- Honeywell SSFDR 980-4700-042 digital flight data recorder (DFDR);
- L3 FA2100 2100-1020-00 cockpit voice recorder (CVR).

The DFDR and the CVR were found at the accident site near the separated tail empennage fragment.

The recorders' readout was conducted at the IAC Laboratory with the participation of the experts from the Kyrgyz Republic, the Republic of Turkey and the United States of America.

Digital Flight Data Recorder

The 747-412F TC-MCL aircraft was equipped with Honeywell SSFDR 980-4700-042 digital flight data recorder (DFDR). The DFDR was found at the accident site near the tail fuselage section and was handed over to the IAC for performing the data readout.

During the DFDR examination, the following has been found:

- the DFDR casing and the protected memory unit show traces of thermal impact (Figure 12);
- the protected memory unit casing has no mechanical damage nor deformation;
- the front connector has been destroyed due to the thermal impact;
- the aft connector has some insignificant damage;
- the plate with the serial and part numbers has been destroyed due to the thermal impact.

To perform the data readout, the memory card was extracted out of the protected memory unit. When the amount of cable restoration works was completed, the memory card was connected to the laboratory-held FDR unit. As a result of the performed works, all the recorder flight data were read out.

The data readout was performed with the use of the Honeywell RPGSE hardware and software complex, the data processing and decoding was performed with the use of WinArm32 hardware and software complex.

The amount of the parameters and the coefficients, required for the flight data decoding were established in accordance with "Digital Flight Data Acquisition Card (DFDAC) Interface Control Document" (D243U316 REV N) developed by the Boeing Company.

As a result of the data decoding the following was found:

- the total length of the recording is 26 h 44 min;
- the quality of the recording is good;
- the recording contains the data on the Boeing 747-412F TC-MCL flight on 16.12.2017 which ended in an accident.

Cockpit Voice Recorder

The Boeing 747-412F TC-MCL aircraft was equipped with the L3 FA2100 2100-1020-00 cockpit voice recorder (CVR). The CVR was found at the accident site near the tail fuselage section and was handed over to the IAC for performing the data readout.

During the CVR examination, the following has been found:

- the CVR casing and the protected memory unit show traces of thermal impact (Figure 12);

- the CVR casing has been deformed;
- the protected memory unit casing has no mechanical damage or deformation;
- the plate with the serial and part number has been destroyed due to the thermal impact.

To perform the data readout, the memory card was extracted out of the protected memory unit. When the amount of works on the replacement of the end-fragment of the cable for the equivalent one out of the special set, manufactured by the L3 Communications Company, was completed, the memory card was connected to the laboratory-held CVR.

The data readout from the memory card was performed with the use of the L3 Communications hardware and software complex. As a result of the performed actions, all the recorded audio data have been read out and the 6 audio files have been read.

	Description	Duration
1	Channel 1	31 min
2	Channel 2	31 min
3	Channel 3	31 min
4	Open microphone	31 min
5	Channels 1...3 (mixed)	02 04 min
6	Open microphone	02 04 min

As a result of the recorded data analysis, the following has been found:

- the end of the audio recording corresponds to the time of the end of the SSFDR recording;
- the recording corresponds to the Boeing 747-412F TC-MCL flight on 16.01.2017 which ended in an accident;
- the quality of the recording is good.

The recorded voices identification has been performed by the ACT Airlines representative.

The ATS data

Within the framework of the investigation team activities, the crew-controller intercommunication script has been made. The investigation team also has been provided with the video recordings from the radio locator display as well as the data from the radio locator in the electronic format.

Synchronization of audio and parametric data

For the purpose of the synchronization, the Manas Airport ATC (Bishkek) time was chosen as reference time in the UTC format. Based on the made crew-controller intercommunication script, the synchronization of the L3 FA2100 2100-1020-00 CVR time with the time in the UTC format. The time of the intercommunication has been set in accordance with several reference points, corresponding to the aircraft's crew external radio communication contacts.

The synchronization with the Honeywell SSFDR 9809 4700 042 DFDR has been made in relation to the discrete signals associated with external radio communication, recorded by the

DFDR corresponding to the beginning time of the associated phrases, recorded by the L3 FA2100 2100-1020-00 CVR.

All the information below is provided with the reference to the time in the UTC-format.

Flight trajectory calculation

The aircraft flight trajectory calculation and plotting have been made based on the Honeywell SSFDR 980-4700-042 DFDR data.

The results of the flight data decoding has been used during the work on the Final Report.

1.12. Information on conditions of aircraft fragments and their location at the accident site

The aircraft accident occurred near Manas International Airport (Bishkek). The ground surface near the airport is flat, with a settlement of small private houses. Some parts of the area are covered with trees. The approach was conducted with the heading of 255°.

The accident site (Figure 25) is an area with the damaged or destroyed houses extending for the length of approximately 550 m and for the width of 40 – 60 m.



Figure 25. General accident site overview (photo made by drone, arrow indicates first touchdown point)

During the inspection of the paved RWY after the accident, neither aircraft marks nor fragments were found on the RWY surface. No other traces of the aircraft impact with the ground surface or obstacles were found on the area upstream the place where the aircraft main landing gear touched the ground, no other traces of the aircraft impact with the terrain were found.

Prior to the aircraft touchdown, the aircraft RH wing tip impacted the tops of the trees, which were located to the right of the aircraft trajectory and looking towards the direction of the trajectory (Figure 26).



Figure 26. Trees damaged by aircraft RH wing tip (indicated by arrow)

The aircraft first touchdown occurred at the distance of ≈ 900 m from the end of RWY at the cross track angle of ≈ 40 m to the right from the continued RWY coordinated axis.

The character of the first touchdown traces indicates that the first aircraft terrain touchdown occurred at an insignificant vertical speed and almost without any bank angle. The aircraft heading at the beginning was very close to the landing heading of 255° . At the area where the aircraft was moving on the ground surface, no marks of the nose landing gear wheels have been found, which indicates that the aircraft was having a positive pitch angle at the touchdown. The aircraft movement after the first touchdown was straightforward (Figure 27).



Figure 27. Main landing gear wheel traces at first touchdown place

After 20 m of movement along the ground surface, the aircraft impacted the concrete aerodrome barrier and destroyed it (Figure 28). Judging by the marks on the area, after the impact with the concrete barrier, the aircraft lifted off the ground surface for a short period of time.



**Figure 28. Trace of LH wing engine impact with aerodrome barriers (indicated by arrow),
view taken in direction opposite aircraft movement**

Judging by the aircraft fragments in this area, the impact was done by the main landing gear struts and wheels and by the engines. As a result of the impact, the RH wing flight control surfaces started to disintegrate.

At the distance of approximately 160 – 170 m from the first touchdown place, the second terrain touchdown occurred. The aircraft impacted the buildings with its RH wing and engines No.3 and No.4. The RH wing tip with the winglet as well as small RH wing fragments were found in this area (Figure 29).



Figure 29. RH wing tip with winglet

As the aircraft continued to move further, the RH wing disintegrated, and engines No.3 and No.4 were torn apart from it.

Then the aircraft started to turn to the right in respect to the direction of its movement, and at the same time, judging from the damage caused to the trees at a considerable height, by turning, the aircraft developed a significant bank to the right. The LH wing fuel tanks partially disintegrated. The RH main landing gear was also found in this area.

The aircraft movement along the ground surface still was of a straightforward character. The aircraft was moving forward with its LH side at the front, touching the ground with its lower fuselage. As a result, almost all the buildings, located in this area, were completely destroyed (Figure 30).



Figure 30. General overview of accident site

At a distance of ≈ 440 m from the place of the first touchdown, the aircraft cockpit impacted a brick house. The aircraft turned to the right to an angle of more than 90° , the aircraft fuselage was destroyed and the cockpit was torn off (Figure 31).



Figure 31. Main fragment of cockpit

The aircraft movement stopped completely ≈ 60 m away from the cockpit separation place. The tail section of the aircraft (Figure 32) and a big fragment of the LH wing with the traces of fire (Figure 33) have been found ≈ 470 m away from the place of the first terrain touchdown.



Figure 32. Tail fuselage section



Figure 33. LH wing at accident site

As a result of the fuel spillage, the fire occurred which destroyed most of the aircraft structure.

The largest aircraft fragments have been found at the accident site in the following sequence (following the flight trajectory):

- RH wing fragments with the flight control fragments;
- Engines No.3 and No.4, thrust reversers fragments of Engines No.3 and No.4;
- the main landing gear with the wheels;
- forward fuselage fragments (skin, structural frames, the cargo compartment entry door);

- the nose landing gear with the wheels;
- the tail section with the fin, the horizontal stabilizer, the pressure bulkhead and the APU;
- Engine No.2 with pylon fragments;
- Engine No.1, LH wing flight control fragments;
- the LH wing.

The main area of the aircraft wreckage is provided in Figure 34.

Courtesy Translation



Figure 34. Main wreckage-covered area

The list of aircraft fragments, found in the main wreckage-covered area of the accident site is provided in the table below:

1	Place of first aircraft touchdown
2	Place of aircraft impact of with concrete barrier
3	Engine nacelle fragment
4	Engine air inlet
5	Landing gear wheel disk fragment
6	Main landing gear wheel
7	Main landing gear wheel tyre
8	Engine air inlet, flap attachment assembly fairing
9	Landing gear door
10	Main landing gear strut with wheels
11	Main landing gear wheel
12	Engine air inlet
13	RH wing fragment with winglet
14	LH leading edge flap fragment
15	Thrust reverser fragment
16	RH engine
17	Main landing gear strut with wheels
18	Wing fragments with trailing edge screw-type mechanisms
20	RH wing trailing edge fragments
21	RH elevator fragment
23	RH engine
24	Engine pylon fragment
25	Main landing gear wheel tyre
26	Cockpit
27	Nose landing gear
28	Main landing gear with wheels
29	Cargo compartment door fragment
30	Aircraft tail section
31	Wing fragment
32	Main landing gear strut fragment
34	Engine No.2
35	Engine No.1
36	Last point of the aircraft disintegration area
37	LH wing

The ground fire bed has been found in the area of the central fuselage section, in-between the separated tail section and the cockpit.

No traces of fire or thermal impact on the fuselage, wing or engine fragments lying before the fire bed, on either the internal or the external sides of their skin, have been found.

Beyond the wreckage-covered area, no airframe fragments (of the fuselage, wing, empennage, or the like) have been found, which might have indicated that the aircraft disintegrated during the flight prior to the impact with the terrain.

1.13. Medical information and short summary of autopsy examination results

The 37 persons were brought to the medical institutions of the Ministry of Health Care Services of the Kyrgyz Republic, 36 of them have been dismissed after successful stationary treatment, one person has died.

39 persons have been stated killed (including the four crew members). According to the information, provided by the Ministry of Health Care Services of the Kyrgyz Republic, the causes of their death were the following factors: the thermal impact; the craniocerebral injuries; multiple rib, pelvis and limb fractures; the compression asphyxia; the carbon monoxide poisoning, vast blood loss (visceral injuries).

On 18.01.2017, the representative of the Turkish Embassy in the Kyrgyz Republic took the three bodies of the aircraft crew members from the Republic Forensic Expertize Center in order to identify the persons and to further bring them to the country of their origin. On 24.01.2017, a DNA-examination specialist from Turkey arrived at the Republic Forensic Expertize Center to conduct the identification of the fourth crew member. At the Republic Forensic Expertize Center's the Forensic Biological Department facilities, a blood sample was taken from one of the crew member's relative.

The Investigation team has no data related to the sample on the alcohol, drugs and DNA analysis results.

1.14. Survival Aspects

Due to the aircraft impact with the terrain and the resulting fire, the 4 crew members and the 35 local residents of the Dacha-Su settlement were killed. 36 local residents received injuries of varying severity.

It was found that the PIC and the First Officer were sitting at their work stations and had their seatbelts fastened. The two other crew members were found seated in the first and second observer's seats, also with their seatbelts fastened.

1.15. Search and Rescue Operations

After the first touch-down, the aircraft destroyed the perimeter barrier of Manas aerodrome as well as the inner marker of the magnetic heading 08, continued to disintegrate, moving on the ground surface, destroying the buildings of the settlement.

At the moment of the accident, the ELTs, installed onboard the aircraft, failed to operate. No emergency alert from the COSPAS-SARSAT Coordination Center was received in the point of contact of the search and rescue team either through the main or the backup channel.

The watchperson of the Aviation Security Service (ASS) of the Watch Point No.9, in the fog, noticed the lights of the aircraft on descent, which then crashed into the perimeter barrier of the controlled area of the aerodrome, overthrew this barrier and continued to move westwards. At about 01:21, following the duty instruction procedure, the watchperson of the ASS Watch Point No.9 reported the event to the ASS Shift Lead by means of the radio communication system.

When the radio contact with the aircraft flight crew was lost, the Flight Services Director reported this to the Bishkek Office of the Manas International Airport PLC, in compliance with the approved emergency alerting scheme, and, at 01:23, announced the alert by means of the "Gorn" annunciation system for all the emergency and rescue teams of the airport.

On receiving the alert message, at approximately 01:22, the ASS Shift Lead reported the accident to the duty Shift Supervisor of Manas Airport by means of the intercommunication system and headed to the accident site with the team of 9 persons under his supervision.

The search and rescue operation works were coordinated by the duty Shift Supervisor of Manas Airport in compliance with the Airport Emergency Actions Plan.

On receiving the "Gorn" alert, the search and rescue teams (summoned in accordance with the Airport Emergency Actions Plan) headed to the rally point at the Taxiway C.

The aircraft crash point was determined, in accordance with the area map, approximately in Grid 33/34 (Dacha-Su). All the emergency rescue teams headed to the accident site. The search and rescue operation works were conducted at nighttime and were complicated by the thick fog and smoke, caused by the aircraft fire.

The ASS specialists and the Emergency Rescue and Fire Protection Flight Support Service (ERFSS) fire brigades arrived first at the accident site at approximately 01:30. Before the Emergency Control Ministry of the Kyrgyz Republic arrived, the emergency rescue operations at the accident site were conducted by the ERFSS and the ASS forces.

The accident site area was cordoned off by the ASS forces.

The notification on the accident was provided to the Civil Aviation Agency of the Kyrgyz Republic and to the Emergency Control Ministry of the Kyrgyz Republic, in compliance with the

"Scheme of reporting to the executives and the organizations in case of air accident at the Bishkek Office of the Manas International Airport PLC".

At about 01:29, the two fire and rescue teams of Emergency Control Ministry of the Kyrgyz Republic and the task force of 6 persons, all located in the vicinity, headed to the accident site. At approximately 01:40, the fire and rescue teams of the Emergency Control Ministry of the Kyrgyz Republic arrived at the accident site and commenced the fire extinguishing activities.

At about 01:29, the 24 rescuers of the Bishkek Rescue Service of the Emergency Control Ministry of the Kyrgyz Republic headed to the accident site, they arrived at the accident site at approximately 02:06.

On arrival, the Emergency Control Ministry of the Kyrgyz Republic take over the responsibility for the conduct of the emergency and rescue operations. The ERFSS fire brigades and the ASS specialists continued to perform their work until the fire was completely isolated.

The 227 airport specialists were also engaged in the emergency and rescue operations, including 15 persons of Manas Airport Administration, 38 persons of the ERFSS personnel, 174 persons of the production services (including the emergency rescue teams). The 55 units of machinery were also engaged, 137 600 liters of water and 4800 liters of foaming agent were applied.

For the accident removal actions, 1081 persons and 67 machinery units of the Emergency Control Ministry of the Kyrgyz Republic and the Civil Defense Services were engaged.

About 20 persons of local residents took part in the search and rescue operations.

On the whole, 1308 persons and 121 machinery units were engaged in the accident removal actions.

1.16. Tests and examinations

1.16.1. Fuel samples examination

At the fuel and oils quality control laboratory of Manas aerodrome, the examination of the fuel samples, taken from the LH wing tank has been conducted (Report No.1-2 on fuel sampling, dated 16.01.2016).

The conducted examination proved that the fuel was of good quality and was in compliance with the technical requirements.

1.16.2. FCC examinations

In order to conduct special examination, the FCC unit (PN 822-1261-101 SN 144295), found at the accident site, was sent to the NTSB (Washington DC, USA). Further, the unit was forwarded to the manufacturing company (Rockwell Collins). The examination was conducted at

the unit manufacturer's facilities under the supervision of the NTSB representative. During the examination, the printed circuit board, containing the non-volatile memory unit, was extracted. The non-volatile memory unit data were successfully downloaded and used when preparing this Report.

1.16.3. Flight test of the ILS

On 18.03.2017, the flying laboratory (Diamond Da-42) has been used to perform the flight test of the ILS NM-7000 with the magnetic heading of 255°, installed at Manas aerodrome (in Bishkek). The flight test was conducted in accordance with the special program, coordinated among all the states, participating in the investigation. No parameters, which might have been beyond the established requirements, have been found during the conduct of standard approaches.

When performing the special part of the program, the false glideslope has been found. In accordance with the provided materials, the angle of the false glideslope is about 8.8°, the distance from the RWY 26 end for the height of 3400 ft is approximately 1.2 nm. The false glideslope signal at the above-mentioned height was found by means of the aircraft instrument equipment during the conduct of the flight test along the trajectory, corresponding to the trajectory of the accident flight of the Boeing 747-412F TC-MCL aircraft.

1.17. Information on accident-related organizations and administrative activities

The ACT Airlines operates in compliance with the regulations of the Republic of Turkey and with the governing documentation for the airline company, approved by the DGCA (DGCA SHT OPS 1, SHY-M) and in compliance with the ICAO Standards and Recommended Practices.

The official name of the airline company is "ACT Airlines". The company's address at the time of the accident was: Kurtköy Premium Residence Yenisehir Mh. Millet Cad. Sümbül Sk. No:8 K:7 Pendik, İstanbul, Turkey. The address at the time of the report preparation is: Yenisehir Mh. Mustafa Akyol Sokak No:7 A Blok Kat 3-4 Arwen – Merlin Ofis, 34912 Pendik, İstanbul, Turkey.

In compliance with the DGCA requirements, the airline company has an Air Operator Certificate AOC No: TR-16 for commercial air transportation, issued by the DGCA on 11.10.2016, which is valid till suspended or terminated by the respective civil aviation authority,.

The AOC No: TR-16 was issued on 11.10.2016 with the mandatory "Operations Specifications", issued on 17.10.2016. The first page of the "Operations Specifications" contains the information on the aircraft type (Boeing 747-400 (A2)) as well as the approved type of transportation ("Cargo"), and the list of geographical areas, where the company is authorized to

operate this type of aircraft ("Worldwide") with the note: "Covers the area specified in the insurance policy". The field "Special Limitations" states: "No special limitation".

1.18. Additional information

1.18.1. On amendments to training programs, procedures and related documentation of ACT Airlines

According to the information provided by ACT Airlines, after the issue of the Preliminary Report on the results of the investigation of the accident with the Boeing 747-412F TC MCL aircraft, the airline company has amended the training program, procedures and the related internal documentation.

The simulator training program ("B 744 Simulator Training (OPC Years 1, 2, 3 and LPC 1, 2, 3)") has been amended, including the following item: manual CAT II approach cancelled and replaced by autoland;

All flight crew members had additional training on the static simulator to replicate the scenario of this accident.

The ACT Airlines Operations Manual has been amended in respect to the flight crew training programs:

OM Part D Chapter 2:

- more detailed attention has been paid to such CRM aspects as efficient communication, coordination and delegation, surprise and startle effect, cultural differences, resilience development as well as CRM skills, relevant to the crew cooperation with other operational personnel and ground services.

OM Part A Chapter 8.4:

ILS CAT II Approach Procedure and the requirements for the flight crew members' training and flight hours, relevant to this flight conditions, are described in more details.

OM Part C, Chapter 0:

- the information on ACT Airlines' preferred use of Jeppesen Route Manual for determining the operating minima for departure, destination and alternate aerodromes has been added;

ACT Airlines' Standard Operating Procedures document has been amended:

- Decent and ILS Approach Procedures has been significantly extended and described in more detail;

- amendment has been made to the briefing procedure, conducted prior to performing the approach;

- warning information has been added in respect to the possible non-standard operation of the autopilot system during the localizer capturing.

1.19. New methods, used during investigation

No new methods have been used during the conduct of the investigation.

Courtesy Translation

2. Analysis

The flight of the Boeing 747-412F TC-MCL aircraft on 15-16.01.2017 was conducted on the route from Chek Lap Kok Airport (VHHH, Hong Kong) via Manas Airport (UCFM, Bishkek) to Ataturk Airport (LTBA, Istanbul). Manas Airport was planned as a transit airport for refueling and crew change. The aircraft takeoff weight on leaving Hong Kong was about 342 500 kg, the weight and balance was 23% which was within the limits, required by Boeing 747 FCOM.

According to the information, provided by ACT Airlines, prior to the day of the accident flight, the PIC performed flights to Manas aerodrome twice: in November of 2016 and in January of 2017; the January flight was conducted together with the First Officer (the FO's only flight to Manas aerodrome).

The departure from Hong Kong was conducted on 15.01.2017 at 17:10. During the preflight briefing from 13:30 to 13:55, the flight crew was provided with the meteorological documentation package, related to the planned flight route, with the weather forecasts for the aerodrome of departure, for the alternate aerodromes of Astana and Karaganda, for the arrival aerodrome of Bishkek, with the forecast charts for special weather phenomena, the wind and temperature forecast charts; METAR for Hong Kong aerodrome for 13:30 on 15.01.2017 and for Manas, Astana and Karaganda aerodromes for 13:00 on 15.01.2017; SIGMET 2 for the Shanghai FIR.

The forecast and actual weather for the aerodrome of Manas (Bishkek), for the alternate aerodromes of Astana and Karaganda were within the limits for the decision to depart, with the forecast fog and the visibility of 200 m and vertical visibility of 30 m at Manas aerodrome of arrival.

During the preflight briefing, the estimation of the intended flight was conducted, according to which the estimated time of the flight to Manas aerodrome was 06 h 03 min, the estimated fuel amount was 96 640 kg.

The takeoff weight and center of gravity were respectively 34 2487 kg and 23.0%, the values being within the limits, prescribed by the Boeing 747-412F FCOM for the given conditions.

The departure from Hong Kong was conducted with a delay of 02 h 02 min in respect to the planned time of departure, at 19:12 15.01.2017.

At 400 ft AGL (above ground level), the triggering of the right autopilot (AP-R) was recorded. The autothrottle was engaged before the takeoff.

At 19:37, the aircraft reached FL 320, later (from 20:43) it continued the flight at FL 340.

The level flight was conducted at the IAS of approximately 290 kt. The "VERTICAL NAVIGATION OPER" mode was engaged in the longitudinal control channel and the "LATERAL NAVIGATION OPER" mode was engaged in the lateral control channel.

Note: *Hereinafter, the names of the modes and discrete signals are provided in accordance with DIGITAL FLIGHT DATA ACQUISITION CARD (DFDAC) INTERFACE CONTROL DOCUMENT (D243U316 REV N) issued by Boeing.*

The analysis of the recorded information leads to the conclusion that the flight was being conducted normally, all the parameters (altitude and speed) set by the crew were being maintained.

On performing the level flight, the PIC conducted the Approach Briefing, during which the crew discussed the special approach characteristics of Manas aerodrome (Bishkek) in the low visibility conditions. The RWY 26 of Manas aerodrome (Bishkek) is certified for the ICAO CAT II landings, the RVR for the RWY 26 is 350 m, in accordance with the Jeppesen charts, used by the crew for performing the flight. In accordance with the airline's Operations Manual (Part A, p. 8.4.3), the required ICAO CAT II RVR minimum is 300 m.

The crew also discussed the actions in case of emergency on board the aircraft and the go-around procedure (if required). Particularly, the PIC described the situations requiring the conduct of the go-around procedure: "...If I see the runway lights I will call "landing", if I don't, I will call "go around". "And also, if any emergency occurs above or below one thousand feet (illeg), let's say, if we get autopilot no-land three, no autoland above one thousand feet, if we get autopilot no autoland, we will execute a go around, brother". "Yes, yes, if we get no land three, we will continue approach brother, OK?" "If the autopilot disconnects, eem, we will try to re-engage. Eem, if it happens below one thousand above touchdown zone, we will again execute a go-around". "If we get an ILS deviation above one thousand feet, sorry, below one thousand feet do a go-around in case of ILS deviation."

Note: *Hereinafter, on quoting the cockpit voice recorder, the phrases are provided in in English. Most of the time, the crew members were communicating in Turkish. The translation of such phrases has been made as close to the meaning of the transmitted information as possible. The parts of the communication, directly related to performing the operational procedures, as well as the external radio communication were conducted in English.*

In accordance with ACT Airlines SOP, 3.10.1, "Before Top of Descent Procedure", the Approach Briefing must be completed before the start of descent. Moreover, the content of the Approach Briefing is provided in ACT Airlines SOP, 3.11.2, Approach, and in accordance with the SOP, the approach phase starts at the transition flight level.

During the Approach Briefing, the following issues⁸ must be discussed:

- weather and NOTAMS at destination and alternate, as applicable;
- type of approach and the validity of the charts to be used;
- minimum safe sector altitudes for that airport;
- approach procedure including courses and heading;
- vertical profile including all minimum altitudes, crossing altitudes and approach minimums;
- determination of the Missed Approach Point (MAP) and the missed approach procedure;
- management of AFDS.

It does not seem possible to determine the completeness of the conducted Approach Briefing applying to the recorded information, as the cockpit voice recorder (CVR) did not record the beginning of the briefing due to the limits of the total recording time (the factual duration of the recording was approximately 02 h 04 min, with the designed minimum duration time of 2 h). It can be pointed out, that judging by the sequential order of the actions performed in accordance with the Approach Briefing, provided in the ACT Airlines SOP, and by the further development of the event, the crew did not complete the item related to the altitude limits on flying over the control points.

According to the recorded information, the approach was planned to be performed by means of the ILS in the automatic mode. At 00:37:17 on 16.01.2017, the crew completed the Descent Checklist. The checklist was performed in full.

Before the start of descent, the First officer (FO) reported the capture of the VOR beacon: "VOR is now locked on". At 00:51:43, the crew contacted the Bishkek ATC Tower: "Bishkek control, Turkish six four niner one, ready for descent". As a response, the ATC controller cleared the aircraft to descend to FL 220: "Turkish six four nine one, descend initially flight level two two zero". The crew confirmed receiving this information. The PIC was conducting the piloting during the descent and the approach phases, the FO was conducting the external radio communication. The allocation of duties was in compliance with the requirements of ACT Airlines SOP p. 4, "Low Visibility Operation".

Note: "ACT Airlines" SOP, p. 4 Low Visibility Operation.

The Captain shall always be Pilot Flying"

The descent was started at 00:52:05, with the aircraft located at a distance of approximately 131 nm from VOR/DME MANAS.

⁸ Only issues, related to the accident flight circumstances, are provided.

Note: On describing the flight, the distance values (if not stated otherwise) are provided from *VOR/DME MANAS*, which is located at a distance of 0.8 nm from the RWY 26 threshold.

At the start of descent, the AP "VERTICAL NAVIGATION OPER" mode was engaged in the longitudinal control channel and the "LATERAL NAVIGATION OPER" mode was engaged in the lateral control channel. The selected altitude⁹ was set to 22 000 ft. The average rate of descent was approximately 1450 ft/min, the IAS was 290 kt (Figure 35).

⁹ Hereinafter, if not stated otherwise, the values of the pressure altitude are provided in reference to the standard pressure of 1013.25 hPa.

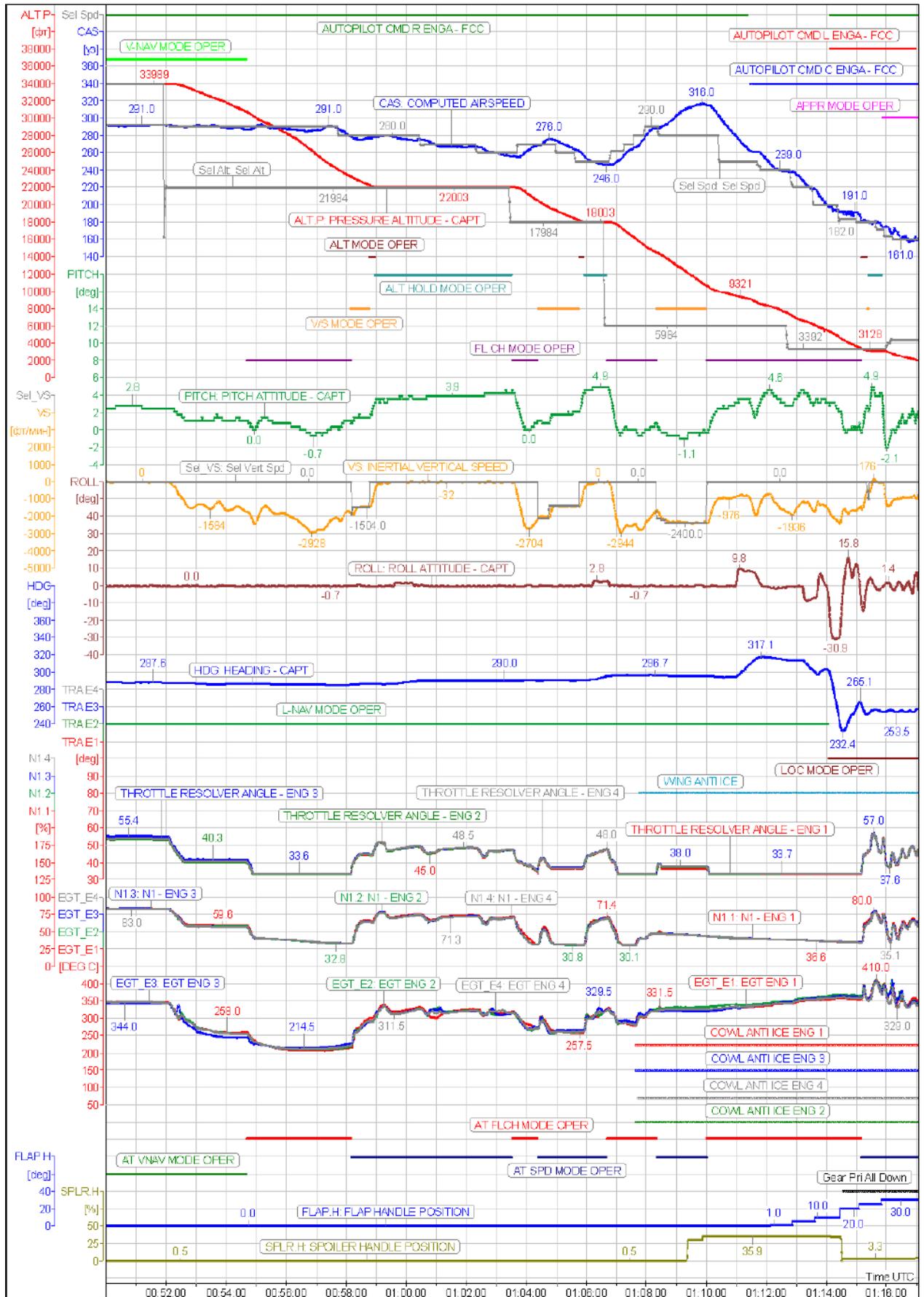


Figure 35. Aircraft flight parameters (descent and approach)

During the aircraft descent, on request from the crew, the ATC controller provided the information on the RWY in use and the RVR data: *"Turkish six four nine one, runway in use two six, RVR, in the beginning of the runway four hundred meters, in the center and at the end of... on the runway three two five meters, vertical visibility one three zero feet."* The visibility data, provided by the controller, allowed the crew to continue the approach. It was commented by the crew: *"Good, look now it is within limit."*

At 00:54:40, the "FLIGHT LEVEL CHANGE OPER" mode was engaged in the longitudinal channel. On approaching the selected altitude (of 22 000 ft), the "V/S MODE OPER" mode was engaged in the longitudinal channel. The selected vertical speed of descent was 1500 ft/min (which is in compliance with the airline's OM) and was the same as the true speed of descent; the IAS was \approx 275 kt. FL220 was reached at 00:58:58, the AP mode in the longitudinal channel was changed to the "ALT HOLD MODE OPER" mode, the "LATERAL NAVIGATION OPER" mode continued to be engaged in the lateral channel.

At 00:59:46, the controller instructed the crew to maintain the FL 220 and reported the RVR: *"Turkish six four niner one maintain flight level two two zero RVR in the beginning of the runway four zero zero meters, in the center and at the end three zero zero meters, vertical visibility one three zero feet."* The crew confirmed receiving this information, and almost immediately, on the command of the PIC, the FO requested further descent: *"Turkish six four niner one, request further descent."* In response, the controller repeated the previous instruction: *"Turkish six four niner one maintain flight level two two zero till further instructions."* The controller's refusal initiated the PIC's negative reaction: *"Don't leave me high, you (illeg.)..."* The controller's instruction on maintaining the current flight level was related to the fact that the flight was being performed over the mountainous area and the aircraft was still at a great distance from the RAXAT reporting point. This fact is confirmed by the recorded internal communication:

"I guess he is going to give it after passing over the mountains."

PIC: *"I will continue until sixty six miles, after sixty six miles, I need to descend again."*

PIC: *"That is a huge mountain!"*

FO: *"That is why the MSA is one thousand seven hundred....seventeen thousand eight hundred."*

PIC: *"Yes."*

FO: *"He is thinking if I give him the descent at that point it will fit the pattern perfectly."*

PIC: *"Yes, yes."*

The flight was continued at FL 220, the IAS was 265...275 kt. At 01:01:58, the controller provided the crew with the RVR data for the second time: *"Turkish six four niner one in the center*

of the runway RVR three zero zero meters, vertical visibility one five zero feet." The FO confirmed receiving the information.

At 01:03:02, the PIC again expressed his worry that the aircraft altitude was too high: "We are starting to be high." On command of the PIC, the FO repeatedly requested the controller's clearance for further descent. At 01:03:15, the controller cleared the crew to descend to FL 180 at RAXAT: "Turkish six four niner one, you are three two kilometers inbound point RAXAT, to point RAXAT descend flight level one eight zero, not lower."

According to the approach chart, published in the AIP of the Kyrgyz Republic and in the Jeppesen Route Manual (Figure 19), the flight over the RAXAT reporting point must be performed at FL 170 or above. Thus, the controller's instruction was in compliance with the approach chart, but it was 1000 ft above the minimum terrain clearance altitude, published on the chart. The crew confirmed receiving the instruction from the controller.

Note: *The Work Instruction for Senior Navigator of the Aeronautical Information Services Briefing Department, it is stated that he or she shall calculate safe flight altitudes along the flight route and at the area of the aerodrome. The safe altitudes' calculation is conducted on the day-to-day basis. By the moment the accident occurred, the navigator on duty had calculated the safe altitude. The safe altitude for this area was 17165 ft. This was the reason for the controller to issue the instruction to descent no lower than to FL 180. It should be pointed out that the calculated safety altitude values are higher in winter periods under the negative ambient air temperatures conditions; however, the aeronautical information documents available for the flight crews do not contain the information on this specific feature for performing the flights in the area of the Bishkek ATS center responsibility.*

At 01:03:31, the "FLIGHT LEVEL CHANGE OPER" mode was engaged in the longitudinal channel, and the aircraft started the descent with the vertical speed of up to 2700 ft/min. The "LATERAL NAVIGATION OPER" mode was still engaged in the lateral channel. The selected altitude was set to 18 000 ft. 50 seconds after the start of descent, the "V/S MODE OPER" mode was engaged in the longitudinal channel. The selected speed of descent was 2100...1400 ft/min and was the same as the true vertical speed of descent (Figure 35).

At 01:05:56, the aircraft reached the FL 180, and the AP "ALT HOLD MODE OPER" mode was automatically engaged in the longitudinal channel. At this time, the aircraft was at a distance of approximately 3 nm from the RAXAT reporting point, the IAS was approximately 260 kt. Before reaching FL 180, at 01:05:54, the aircraft was handed over to the Approach

controller: "*Turkish six four niner one, maintain flight level one eight zero, over point RAXAT... RAXAT, contact approach one two four decimal six, have a good day,* the FO: "*Maintain flight level one eight zero, ehm... contact one two four decimal six, bye-bye, Turkish six four niner one.*"

Despite the fact that the controller's instructions were in compliance with the established chart and the crew did not request the descent to FL 170 at RAXAT, the crew expressed the negative attitude to the controller's instructions on maintaining the flight level. Before contacting the Approach controller, the following internal communication was recorded:

PIC: "*Brother, switch to the frequency, eerr...ask for a descent right away.*"

FO: "*Sure, sure, this one wasn't very nice to us, that is why*¹⁰."

The crew contacted the Approach controller at 01:06:27: "*Bishkek good morning, Turkish six four niner one.*" In response, the controller cleared the aircraft for further descent for conducting the approach to the RWY 26 in accordance with the "TOKPA 1" chart: "*Turkish six four niner one, Approach, good morning, radar contact, descend flight level six zero TOKPA one arrival expect ILS approach for runway two six.*" In accordance with the approach chart, the TOKPA reporting point must be flown over at FL 60 or above. Although the controller's instruction was in compliance with the approach chart, the clearance for the descent to FL 60 again aroused the PIC's negative attitude: "*They left us high again.*"

At 01:06:30, when flying over RAXAT, the aircraft was positioned at FL 180. The descent from FL 180 was started at 01:06:40. At the beginning of the descent, the crew engaged the autopilot in the "FLIGHT LEVEL CHANGE OPER" mode in the longitudinal channel and the "LATERAL NAVIGATION OPER" mode in the lateral channel. The selected altitude was set to 6000 ft, the selected IAS on the MCP was set to 262 kt, the aircraft engines were operating in the mode close to the flight idle. At the beginning of the descent, the vertical speed was 2900...2700 ft/min. Judging by the phrase "*I will be six zero (illeg) at "TOPKA"*¹¹", the PIC was expecting to reach FL 60 by the time the aircraft reached the reporting point (Figure 36).

¹⁰ From the original internal communication, conducted in Turkish, it is evident that this phrase is about the controller.

¹¹ In this case that was how the PIC referred to the TOKPA reporting point.

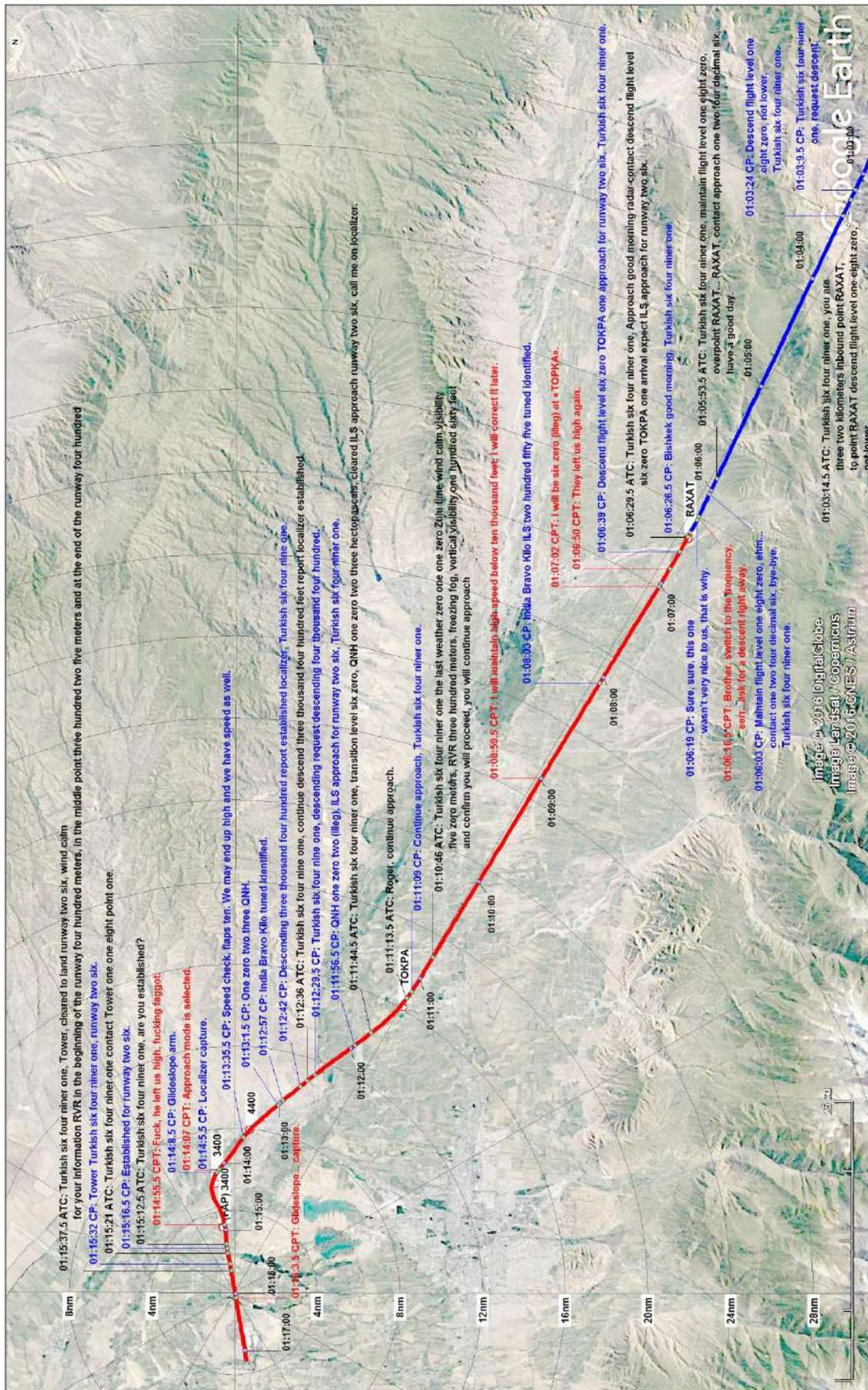


Figure 36. Aircraft flight trajectory during the approach and landing at Manas aerodrome (Bishkek)

For performing the standard descent, "Descent, Approach and Landing Procedure" (ACT Airlines SOP p. 3.11) runs as follows:

"The distance required for the descent is approximately 3 nm /1.000 feet altitude loss for no wind conditions using ECON speed. The rate of descent is dependent upon thrust, drag, airspeed schedule and gross weight. Normally, descend with idle thrust and in clean configuration (no speedbrakes). The speedbrake may be used to correct the descent profile if arriving too high or too fast."

The distance between the RAXAT and TOKPA reporting points is 27 nm. According to the approach chart and the controller's instruction, at this distance it was necessary to descend to 12 000 ft. Thus, the given distance was not enough for the standard descent procedure, required by ACT Airlines SOP (in this case the aircraft would descend approximately 9000 ft lower and would reach TOKPA at approximately 9000 ft instead of [the required] 6000 ft). Despite this, the initial descent was conducted without the use of the speedbrakes and with the increase of the IAS. After the initial descent, the MCP IAS was reset from 262 kt first to 270 kt and then to 280 kt (Figure 35).

During the descent, at 01:07:39, the engagement of the engine air intake anti-ice system and then, 7 seconds later, the engagement of the wing anti-ice system were recorded. At that moment, the aircraft was flying at 16 000 ft. The engagement of the anti-ice system indicates that weather conditions were deteriorating and that the aircraft was entering clouds. This is also confirmed by the crew's internal communication:

FO: *"It is nice until here, and from here on it starts to get cloudy."*

PIC: *"I am thinking it is patchy conditions."*

FO: *"I am slowly turning on the Anti-ice."*

After the anti-ice system engagement, the selected IAS was set to 290 kt.

At 01:08:03, the FO reported the setting to RWY 26 ILS: *"India Bravo Kilo ILS two hundred fifty five tuned identified"*. The PIC confirmed: *"Check."*

At 01:08:20 (1 minute 40 seconds after the start of the descent), the "V/S MODE OPER" mode was engaged in the longitudinal channel. By this time, the vertical speed of descent had been reduced to 1700 ft/min, the IAS increased to 290 kt. After the change of the autopilot mode, the vertical speed of descent was set to 2400 ft/min and the IAS was set to 280 kt. The autopilot maintained the vertical speed, set by the crew, while the IAS continued to increase (the maximum value of 317 kt was recorded at 01:09:53).

As it has been stated previously, there was a significant increase of the IAS during the descent. Judging by the report (at 01:09:00), the PIC was conducting the descent at the increased

speed on purpose: "*I will maintain high speed below ten thousand feet, I will correct it later.*" The PIC gave no explanation of his decision. According to ACT Airlines SOP, the maximum IAS below 10 000 ft is 250 kt.

At 01:09:20, at 12 200 ft, the manual deployment of the speedbrakes (spoilers) was recorded. The speedbrake control handle was initially set to 30°, and after 30 seconds it was set to 36°. The further descent was conducted with the deployed spoilers.

At 01:10:00, the engagement of the "FLIGHT LEVEL CHANGE OPER" A/P mode was recorded in the longitudinal channel. 26 seconds later, the IAS was set to 250 kt. The mode change caused the IAS to decrease simultaneously with the decrease of the vertical speed to 770 ft/min.

At 01:10:46, the controller provided the crew with the last weather report: "*Turkish six four niner one the last weather zero one one zero Zulu time wind calm visi... visibility five zero meters, RVR three hundred meters, freezing fog, vertical visibility one hundred sixty feet and confirm you will proceed, you will continue approach?*" The crew confirmed continuing the approach: "*Continue approach, Turkish six four niner one.*"

Note: *The crew's decision was in compliance with the airline's OM (OM Part A p. 8.4.5.7.2), which allows the pilots to continue the approach up to 1000 ft over the RWY threshold regardless to the provided RVR data.*

The flight past TOKPA was performed at 01:11:18, the aircraft reached 9200 ft in descent with the IAS of approximately 270 kt. According to the chart, the flight past TOKPA must be conducted at 6000 ft (FL 060) or above. Thus, the chart requirements were not formally violated, but the aircraft was too high for continuing the approach in accordance with the chart without additional maneuvering for decreasing the altitude (Figure 23 and Figure 24).

On request from the investigation team, the specialists of one airline company, operating Boeing 747 aircraft, have conducted the analysis of the aircraft's descent profile during the accident flight. According to the provided conclusion, taking into consideration the short distance available for the descent, the PIC's actions on maintaining the increased IAS and the absence of the speedbrakes application at the beginning of the descent were found incorrect. For the execution of the descent in accordance with the PIC's decision to reach FL 060 at TOKPA and the controller's instructions, the speedbrakes must have been applied at the beginning of the descent and the significant increase of the IAS must have been prevented. Even following this requirements, the deficiency of distance and the surplus of altitude are evident; thus, at a distance of 5...8 nm prior to the TOKPA reporting point, the landing gear must have been extended, the flaps must have been positioned at 5° (with the speedbrakes remaining in the deployed position), and the IAS must have been decreased to 210 kt. This would have provided a steeper descent profile.

It should be pointed out that ACT Airlines SOP does not stipulate for the application of the flaps for the increase of the speed of descent during the standard descent procedure (however, the flaps application is not forbidden, but AFM contains the IAS limitation of 280 kt for performing the flight with the flaps extended):

Note: *"ACT Airlines" SOP, p. 3.11 Descent, Approach and Landing Procedure:
The flaps are normally not used for increasing the descent rate. Normal descents are made in the clean configuration to pattern or instrument approach altitude.
The landing gear can be lowered to increase the rate of descent."*

At 01:10:58, the triggering of the "AP CAUTION" was recorded. The flight was performed in the automatic mode, with the "FLIGHT LEVEL CHANGE OPER" mode engaged in the longitudinal channel and the "LATERAL NAVIGATION OPER" mode was engaged in the lateral channel. According to the explanations made by the Boeing and Rockwell Collins specialists (the FCC design and manufacturing company), the triggering of the AP CAUTION was caused by a fault in the trim system, sensed by either the right or center FCC's, most probably, due to the stabilizer trim was not responding fast enough to the FCC commands for trim. As the analysis of the recorded information has shown, on providing the command for the stabilizer trimming (which is confirmed by the triggering of the "AUTO TRIM UP ARM" and "AUTO TRIM UP CONT" discrete signals), there was a delay of ≈ 23 seconds, during which the stabilizer position remained unchanged. In the previous cases, the time period between the triggering of the command for stabilized trimming and the start of the stabilizer trimming had never been more than 3...4 seconds. 17 seconds after the triggering of the command for stabilized trimming, as no stabilizer trimming movement followed, the "AP CAUTION" annunciation was triggered, which was "ON" for 7 seconds. The "AP CAUTION" annunciation disappeared when the stabilizer started to move. It should be pointed out that during the further flight, the stabilizer trimming was done without any delay and the above-mentioned fault did not affect the flight performance. The crew provided neither comment nor report on the triggering of the caution.

After flying past the TOKPA reporting point, the AP R disengagement, followed by almost immediate AP C engagement were recorded. The crew's actions on autopilots' switching may have been related to the triggering of the "AP CAUTION" annunciation. The autopilots' switching occurred 17 seconds after the "AP CAUTION" annunciation disappeared. The flight was continued in the automatic mode.

At 01:11:45, the controller informed the crew on the transition flight level (FL 060), the QNH (1023 hPa) and cleared for the ILS-approach to RWY 26: *"Turkish six four niner one, transition level six zero, QNH one zero two three hectopascals, cleared ILS approach runway two*

six, call me on localizer". The crew confirmed receiving the information. At 01:12:00, at 8300 ft (which was higher than the transition flight level), the crew set the QNH¹². At 01:12:07, at the speed of 250 kt and the distance of 12.5 nm, the flap control handle was set to 1°.

At 01:12:36, on request from the crew, the controller cleared for further descent to 3400 ft: *"Turkish six four nine one, continue descend three thousand four hundred feet report localizer established"*.

Note: *The altitude of 3400 ft in reference to the QNH corresponds to the glideslope capture altitude. The RWY threshold elevation is 2055 ft.*

At this moment, the aircraft was passing the altitude of 7900 ft in descent with the IAS of 240 kt. On receiving the controller's clearance for further descent, the crew set the selected altitude to 3400 ft.

At 01:12:51, with the speed of 240 kt and at the distance of 9.8 nm, the crew started to extend the flaps to 5°, after which the performance of the Approach Checklist was recorded. The crew identified the three-letter code of RWY 26 ILS (India Bravo Kilo), checked the selected QNH and performed the check of the altimeters' indications. The Approach Checklist was performed in full, no crew findings related to the operation of the aircraft equipment were recorded.

Note: *At Manas aerodrome (Bishkek), the same ILS frequency (111.7 MHz) is set for the both approach headings. However, the letter call signs are different. There is also an automatic system, preventing the simultaneous operation of the ILS beacons, which provide the opposite approach headings.*

The flight past the D 8.0/R-090 MNS 4400 guidepoint was performed at 01:13:28 at 6500 ft with the IAS of 220 kt (Figure 37). Thus, the aircraft was 2100 ft higher than the approach chart requires. (Figure 23 and Figure 24).

Note: *Hereinafter, the names of the navigation guidepoints are provided in accordance with the RWY 26 approach chart for Manas aerodrome (Bishkek).*

¹² Further, the pressure altitude is provided in reference to the QNH.

The approach controller's work station is equipped with the radar, so he could have observed the aircraft height at the TOKPA reporting point. The controller also did not inform the crew about the deviation in height from the chart requirements, as the aircraft position was no lower than the established height limits.

Note: *The working procedure and the job instruction for the Tower controller, p 4.2.7:*

...

- to monitor the aircraft movement to be in compliance with the issued clearance and, in case of any deviation to issue the instruction for the aircraft to reach the prescribed track and to prevent the aircraft from flying below the safe/prescribed altitude.

At 01:13:36, at the speed of 220 kt and the distance of 7.2 nm, the flap control handle was set to 10°. When extending the flaps, the FO expressed his worries about the possibility of performing the approach: "*Speed check, flaps ten. We may end up high and we have speed as well.*" There was no response from the PIC, and the FO did not raise this issue again. The aircraft continued the descent to the D 6.4/R-080 MNS 3400' guidepoint of the approach chart.

After the flaps were extended to 10°, the descent continued with the deployed spoilers (the spoiler control handle remained in the position of 36°). According to ACT Airlines SOP, to prevent buffeting, the spoilers should not be applied with the flaps extended to more than 5°.

Note: *ACT Airlines SOP p. 3.1, "Descent, Approach and Landing Procedure".*
"The speedbrakes should not be used with flaps greater than 5, to prevent buffets, speedbrakes should be retracted before reaching 1000 feet AGL."

At 01:13:55, the "LOC MODE ARM" mode was engaged, and at 01:14:05 the localizer capture and the start of the automatic positioning for approach were recorded. At that time, the aircraft was positioned at the distance of approximately 6.1 nm in the descent mode, the flight altitude was approximately 5700 ft and the IAS was 200 kt (Figure 38).

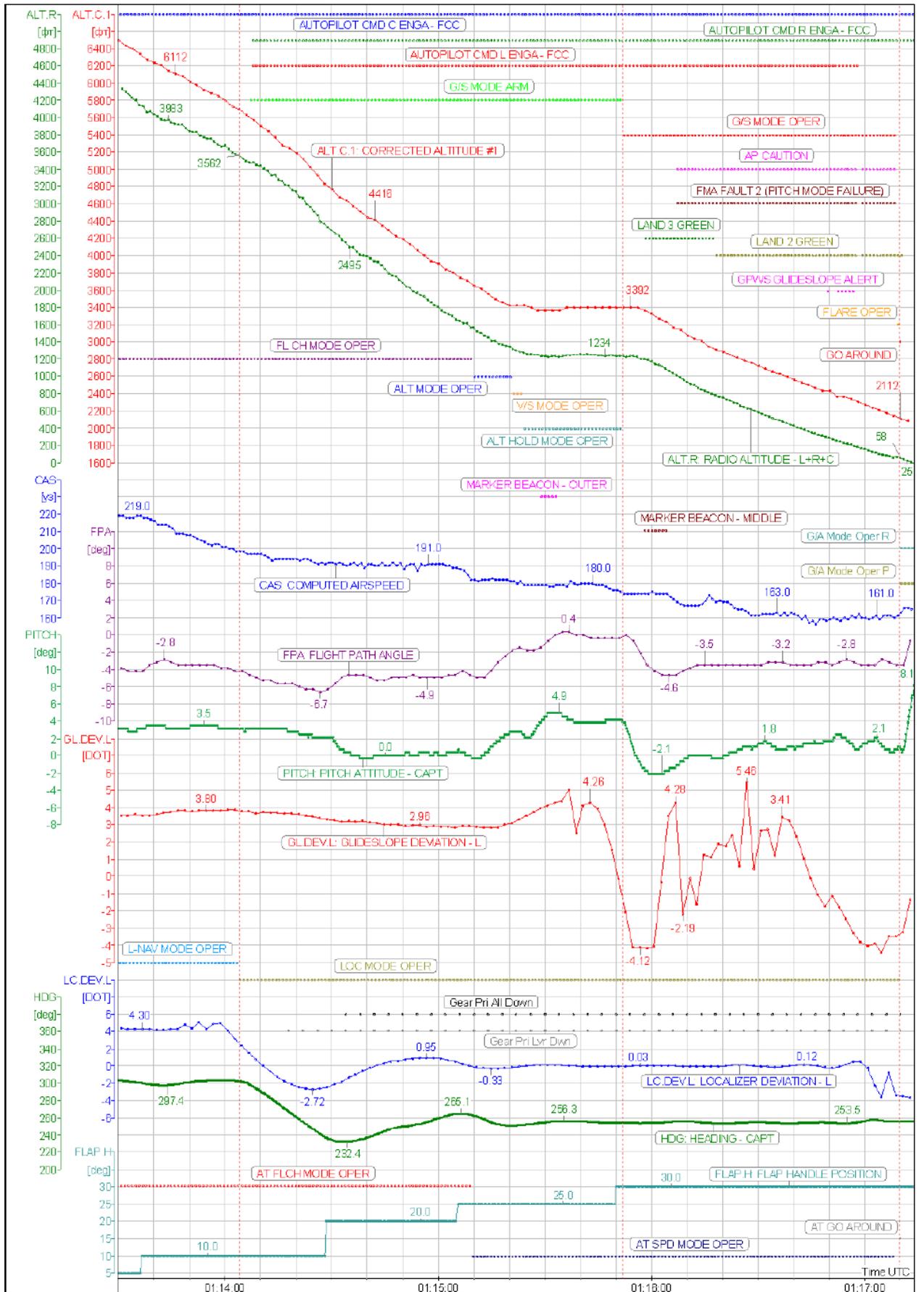


Figure 38. Aircraft flight parameters (approach)

The localizer capture was monitored by the crew. (FO: "*Localizer capture.*" PIC: "*Approach mode is selected.*" FO: "*Glideslope arm.*") These actions of the crew were in compliance with the Boeing 747 FCOM and ACT Airlines SOP requirements. The crew did not report to the controller about the localizer capture.

After the localizer capture, the "G/S MODE ARM" mode was engaged, and at 01:14:08 the three autopilots were engaged. The flight continued in the automatic mode: the "LOC MODE OPER" was engaged in the lateral channel, and the "FLIGHT LEVEL CHANGE OPER" mode was engaged in the longitudinal channel. The selected altitude was set to 3400 ft (which corresponds to the altitude of the glideslope capture). According to the approach chart, this altitude must be reached at the distance of 5.4 nm and must be maintained until the distance of 3.2 n (the point of glideslope capture)¹³.

At 01:14:18, on the PIC's command, the FO started to extend the landing gear. At that time, the aircraft was positioned at the altitude of 5300 ft near the D 5.4 MNS 3400' guidepoint. Thus, the crew failed to perform the descent in compliance with the approach chart: the aircraft was positioned 1900 ft higher than required by the approach chart.

At 01:14:29, at the speed of 190 kt and the distance of 4.8 nm, the flap control handle was set to 20°. During the process of the flaps extension to 20°, the spoilers were retracted.

At 01:14:36, the audio annunciation about the reached height of 2500 ft AGL was recorded. The FO checked the reached height: "*Checked*". No report from the PIC followed. In accordance with the ACT Airlines SOP p. 4 "Low Visibility Operation" requirements, in case of this annunciation triggering, the aircraft control must be provided by the both pilots.

On flying to the glideslope capture point, the PIC commanded the FO to concentrate his attention on the environment outside the cockpit:

PIC: "*Look, actually you can see the (runway/dirt) down there.*"

FO: "*I'm monitoring the instruments.*"

PIC: "*Instruments, I monitor the instruments, you look outside.*"

FO: "*He, he.*" (*expressing agreement*).

The PIC's command was in violation of the ACT Airlines SOP p. 4 "Low Visibility Operation" requirements and made the FO stop the continuous monitoring over the instrument flight performance, while the actual weather conditions did not allow to establish the visual contact with the RWY or with the ground references at this stage of the flight.

Note: 1. ACT Airlines SOP p. 4 "Low Visibility Operation":

¹³ Hereinafter, if not stated otherwise, the distance values are provided in reference to VOR/DMEMANAS, which is installed at the distance of 0.8 nm from the RWY 26 end (in the direction, opposite to the direction of the approach).

"During the final approach phase, the F/O shall remain head down until the landing is completed and call out the required FMA annunciations and any deviation from the normal flight profile."

2. The actual weather conditions at Manas aerodrome at the time of the aircraft approach was as follows: for 01:16: wind 60° 01 m/second, visibility: RW threshold 100/RVR400 m, RWY midpoint 100/RVR350 m, RWY end 100/RVR400 m, vertical visibility 050, temperature minus 09°C, dew point temperature minus 10°C, QNH 1023,9 hPa, runway wet, runway friction 0,6, TREND for landing no change.

At it has been mentioned above, the glideslope capture point is at the distance of 3.2 nm and at the height of 3400 ft. At the above-mentioned distance, the aircraft was crossing the altitude of approximately 4000 ft, the IAS was 190 kt, with the flaps positioned at 20° and the landing gear extended. No automatic glideslope capture occurred, probably, because the aircraft was positioned significantly higher than required.

Note: *In the frame of conducting the accident investigation, the approaches of other aircraft to Manas aerodrome (Bishkek), conducted on 15 - 16.01.2017, were analyzed. According to the explanatory reports, provided by the crew members, the performed approaches were standard, no findings related to the operation of the ground equipment were reported. Additionally, the data from the onboard flight data recorders from some of the aircraft were analyzed. The analyzed approaches had been performed in the automatic mode at the heights, close to the required by the approach chart, the approaches had been performed with the stable localizer and glideslope capture and the subsequent landing along the glideslope path till touchdown. No findings related to the operation of the ILS beacons of Manas aerodrome (Bishkek) were revealed by the conducted analysis.*

According to the Boeing 747 FCOM and ACT Airlines SOP, at the point of Final Approach Fix (FAF), the crew must check the flight altitude. The onboard recorder contains no data confirming that the crew performed this procedure. For Manas aerodrome (Bishkek), this point corresponds to the Final Approach Point (FAP D 6.0 ¹⁴3400' and is provided in the RWY 26 approach chart of AIP of the Kyrgyz Republic (Figure 24)). In Jeppesen Route Manual, which was used by the crew (Figure 23), the FAP/FAF is not shown.

Note: *1. FCOM Boeing 747, "Landing Procedure – ILS".*

¹⁴ The distance is provided in kilometers, 6 km is approximately 3.2 nm.

At final approach fix (LOM, MKR, DME) verify the crossing altitude.

Monitor the approach.

ACT Airlines SOP p. 3.11.4, "Landing Procedure – ILS.

2. At final approach fix (OM, MKR, DME) verify the crossing altitude.

Call out any deviations.

Monitor the approach progress.

3. ACT Airlines SOP p. 4, "Low Visibility Operation".

<i>Condition</i>	<i>CM 1</i>	<i>CM 2</i>
<i>OM or FAF</i>	<i>"Check"</i>	<i>"OM/FAF/___FT"</i>

No report on the height of flying past the reporting point was recorded. However, judging by the internal communication, at that stage the crew members were aware that the aircraft was higher than the required glidepath: (PIC: *"Fuck, he left us high, fucking faggot"¹⁵*." The FO made an attempt to calm down the PIC: *"Come on, nothing happened."*) This communication took place after the aircraft flew past the FAF at the distance of approximately 3 nm. Despite the evident deviation from the approach pattern, again, no corrective actions were performed by the crew.

During the standard approach, the glideslope capture occurs during the horizontal flight with the aircraft positioned below the glidepath. According to the Boeing 747 FCTM, the glideslope capture from above (in a descent mode) should be applied only in some cases and requires the crew to exercise higher level of attention and control.

Note: *747 Flight Crew Training Manual, Approach and Missed Approach, Intercepting Glide Slope from Above:*

"Normally the ILS profile is depicted with the airplane intercepting the glide slope from below in a level flight attitude. However, there are occasions when flight crews are cleared for an ILS approach when they are above the G/S. In this case, there should be an attempt to capture the G/S prior to the FAF. The map display can be used to maintain awareness of distance to go to the final approach fix. The use of autopilot is also recommended."

In fact, the Boeing 747 FCTM recommendations were not followed by the crew during the accident flight. The aircraft had already passed the FAF.

At 01:15:06, at the speed of 190 kt and the distance of 2.7 nm, the flap control handle was set to 25°.

¹⁵ Hereinafter the Investigation team quotes the crew communication retaining the explicit language, as in this case it shows the psychoemotional state they were experiencing.

As it has been mentioned above, the crew did not report to the controller about the localizer capture. At 01:15:13, the controller himself requested the crew: "*Turkish six four niner one, are you established¹⁶?*" and after the received confirmation of the localizer capture, the aircraft was handed over to the Tower controller: "*Turkish six four niner one contact Tower one one eight point one.*"

According to working procedure and the job instruction of the Approach controller, the Approach-to-Tower control transfer point is defined as follows: "*when the aircraft is on final at the distance of less than 20 km from the ARP (Aerodrome Reference Point)*". The control over the aircraft flight altitude at the time of the control transfer is not described in the Approach controller's working instruction. Thus, the Approach controller was performing his duties in compliance with the required working instruction.

Note: *By this moment, the FAP had already been passed, that is the aircraft must have captured not only the localizer signal, but the glideslope signal as well ("fully established"). During the discussion of the Draft Final Report, the State of Registry expressed their position stating that in low visibility conditions, to mitigate the possible risks, it should have been useful for the controller to ensure this by requesting the crew. The Investigation team points out that in this exact case, such a request, if stated in the controller's working instruction, could have prevented the further development of the negative sequence of events. On the other hand, if this request is put into the controller's working instruction for the use on regular basis, it may lead to the considerably increased amount of radio communication in large airports and to the crew's distraction from piloting the aircraft during one of the maximum workload flight stages.*

At 01:15:25, the aircraft performed the descent to the altitude of 3400 ft, the autopilot "ALT HOLD OPER" mode was engaged in the longitudinal channel. Thus, the altitude of glideslope capture was reached only at the distance of ≈ 1.7 nm (while the FAP is located at the distance of 3.2 nm). The further flight was performed at the constant altitude almost along the RWY 26 centerline. The aircraft was positioned considerably higher than the glidepath; according to the recorded information, the value of the "deviation from the equisignal glidepath zone" was +4...+5 dots, (the digit "+" corresponds to the position of the aircraft above the glidepath). The "G/S MODE ARM" was engaged; however, no glideslope capture occurred (Figure 38).

¹⁶ The remark of the investigation team: the localizer capture is meant.

At 01:15:31, the aircraft's crossing of the outer marker (OM) in cruise flight at 3400 ft was recorded (according to the approach chart, the altitude for the OM crossing is 2008 ft). Neither audio annunciation nor comments from the crew on flying past the OM were recorded on the CVR. The crew can disengage the audio annunciation; however, in any case, the crossing of the marker beacon is indicated on the PFD. The disengagement of the audio annunciation on crossing the OM violated ACT Airlines SOP and contributed to the fact that the crew did not monitor the aircraft altitude on flying past the OM.

Note: ACT Airlines SOP p. 4, "Low Visibility Operations, 4.4 Flight Procedures".
"– Markers audio set."

At 01:15:32, the crew contacted the Tower controller: "*Tower Turkish six four niner one, runway two six.*"

At 01:15:38, the controller cleared for landing on RWY 26 and provided the latest meteorological data: "*Turkish six four niner one, Tower, cleared to land runway two six, wind calm, for your information RVR in the beginning of the runway four hundred meters, in the middle point three hundred two five meters and at the end of the runway four hundred meters and vertical visibility one six zero... feet.*" The provided RVR data allowed the crew to continue the approach.

According to the Tower controller's working procedure and job instruction, on the aircraft ILS approach, the controller must

- report the actual wind speed and wind direction to the crew;
- in case of the visibility of 1500 or less and/or in case of the cloudbase/vertical visibility of 500 ft or less, request the specified data about the weather conditions from the Aeronautical Meteorological Centre (AMC) and transfer this information to the aircraft performing the approach before the aircraft flies past the OM.

The Tower controller followed the above-mentioned requirements of his working procedure. The necessary information (on the wind, the RVR and the vertical visibility) was provided to the crew in due time and in full. As the information on the RVR was provided for the three RWY points (the RWY threshold, the RWY mid-point and the RWY end), the total time of the controllers report was 23 seconds.

For the Approach controller, monitoring the aircraft position in relation to the approach pattern by means of the data provided by the radar surveillance system, which can be displayed on the screen of the controller's working station, is not required by the Tower controller's working procedure. According to the working procedure, the controller must perform only the visual monitoring within his visibility range. In this case, the controller could not visually monitor the aircraft. Moreover, according to the controller's explanatory report, he had not been trained and

authorized for the operations with the data provided by the radar surveillance system. According to his statement, at the time of the aircraft approach, the data on the current flight plans and of the aircraft parking areas were displayed on the screen, no data from the radar surveillance system were displayed. The investigation team points out that, as the on contacting the controller, the aircraft had already passed the LOM, but had not start the descent along the glidepath. The presence and use of the radar surveillance system data and the presence of the corresponding requirements in the controller's working instructions could have provided the Tower controller with the opportunity to reveal the non-landing position of the of the aircraft and to inform the crew about this issue.

At 01:15:50, at the speed of 175 kt and the distance of approximately 0.4 nm, the flap control handle was set to 30°. At the time of the flaps were extending to 30°, the FO was conducting the radio communication with the Tower controller. Probably, the flaps had been extended by the PIC himself (PIC: "Thirty", with no response from the FO) or by the FO, but without the appropriate callout.

The flap extension into the landing configuration was started after the pointer of the glidepath deviation indicator started to move from its end position, but before the actual capture of the signal from the glideslope beacon. According to ACT Airlines SOP p. 3.11, "Descent, Approach and Landing Procedure" and Boeing 747 FCOM, "Landing Procedure – ILS", the flap extension to the landing configuration must be performed after the glideslope capture.

The capture of the signal from the glideslope beacon occurred at 01:15:52, at that time the aircraft was positioned at the distance of approximately 1.15 nm form the RWY 26 threshold, the angle of the caught glideslope beacon signal was $\approx 9^\circ$, the flight altitude was 3400 ft (Figure 39). The nominal glidepath angle, required by the approach chart is 3° . Thus, in the accident flight, the capture of the "true" glideslope signal could have been performed only "from above", that is the aircraft must have been in the descent mode. In fact, the glideslope signal capture was performed in the aircraft in cruise flight; however, the crew did not pay proper attention to this fact.

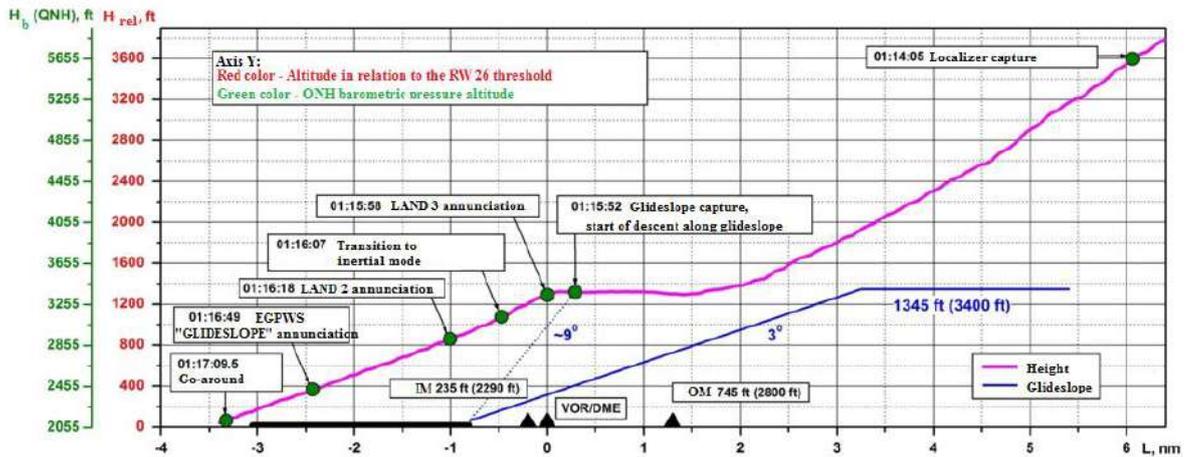


Figure 39. Aircraft flight trajectory during approach and landing at Manas aerodrome (Bishkek)

The analysis of the disposed information may lead to a conclusion that the onboard system of the aircraft captured the "false" glideslope signal with the angle of $\approx 9^\circ$. Besides, the aircraft design company confirmed that the glideslope signal capture was conducted in a "standard" way, as all the conditions, under which the on board equipment determines that the aircraft is approaching the equisignal zone, were fulfilled. The feature of monitoring the aircraft position in relation to the RWY is not provided in the glideslope capture algorithm by design.

The glideslope beacon (GSB) aerials vertically provide the radar directional envelope in the shape of the intersecting lobes which are formed with the help of the ground surface. As these GSB aerials are located at a certain height above the ground, both the direct radio wave and the radio wave reflected by the ground surface come to the reception point. Thus, the resulting radar directional envelope contains several lobes, and "false" glideslope lobes are formed.

Note: *In the frame of the investigation on the accident with Boeing 747-412F TC MCL, flight tests on the ILS NM-7000 system with the MK 255° localizer installed at Manas Airport (Bishkek) were performed. During the conducted standard approaches, no out-of-limit parameters were found. During the conduct of the special part of the testing program, a "false" glideslope was found. According to the documented information, the angle of the "false" glideslope is approximately 8.8° , its distance from the RWY 26 threshold for the altitude of 3400 ft is approximately 1.2 nm.*

The occurrence of the "false" glideslope signal at the above-mentioned altitude and distance was also recorded by the instruments of the Da-42 aircraft (which was used for the flight testing) on performing the flight along the track, which was the same as the track of the accident flight of the Boeing 747-412F TC-MCL on 16.01.2017.

The PIC's and the FO's navigation displays (NDs) were operating in the "MAP" mode with the scaling of 10 nm. The aircraft was in the landing configuration: the landing gear was extended, the flaps were positioned at 30°. The recorded internal communication confirm that at the glideslope signal capture and the start of descent, the crew did not monitor the distance to the RWY threshold and the distance from the VOR/DME beacon. Moreover, it must be pointed out that the Boeing 747 FCOM and ACT Airlines SOP do not require any monitoring of altitudes or distances (the altitude check is required only during the FAF crossing). The crosscheck of the altitude and distance is required only by 747 FCTM in case the crew suspect they are descending along the "false" glideslope:

Note: *747 Flight Crew Training Manual p. 5.15, "Approach and Missed Approach".*
"There have been incidents where airplanes have captured false glide slope signals and maintained continuous on glide slope indications as a result of an ILS ground transmitter erroneously left in the test mode. False glide slope signals can be detected by crosschecking the final approach fix crossing altitude and VNAV path information before glide slope capture. A normal pitch attitude and descent rate should also be indicated on final approach after glide slope capture. Further, if a glide slope anomaly is suspected, an abnormal altitude range-distance relationship may exist. This can be identified by crosschecking distance to the runway with altitude or crosschecking the airplane position with waypoints indicated on the navigation display. The altitude should be approximately 300 feet HAT per nm of distance to the runway for a 3° glide slope.
"If a false glide slope capture is suspected, perform a missed approach if visual conditions cannot be maintained."

After the glideslope signal capture, despite the fact that the "false" glideslope has the "reversed polarity"¹⁷, the aircraft was automatically set to the descent mode with the vertical speed of up to 1425 ft/min.

At 01:16:01, at the altitude of 3300 ft, the inner marker (LIM) beacon crossing was recorded (the altitude of the LIM crossing in accordance with the approach chart is 2290 ft). Neither the audio annunciation nor the crew's report on the LOM crossing was recorded by the CVR, while the LIM crossing (as the LOM crossing earlier) is indicated for the crew on the PFDs. The crew did not check the LIM crossing altitude.

¹⁷ See also the work entitled "Pitch-up Upsets due to ILS False Glide Slope", published by the Dutch Safety Board.
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Six seconds after the glideslope capture, the triggering of the "LAND 3" annunciation was recorded, which indicates that the autoland system was engaged in a triple redundant fail-operative configuration, suitable for use during the landing approach in the ICAO CAT III conditions.

The crew checked the capture of the glideslope beacon signal; the PIC's callout: "*Glideslope... capture.*" and the FO's response: "*Check. Four thousand four hundred*" are recorded. The altitude of 4400 ft was selected on the MCP in accordance with the operational procedure and was in compliance with the go-around altitude, required by the approach chart. The PIC also checked the annunciation on the armed automatic landing mode: "*Land three.*"

At this stage of flight, ACT Airlines SOP p. 3.11.4, "Landing Procedure – ILS" and the Boeing 747 FCOM, "Landing Procedure – ILS" require the performance of Landing Checklist. This checklist was not performed by the crew.

During the time period of 01:15:56...01:15:59, the aircraft crossed the glideslope beacon, which, however, did not cause the loss of the stable signal receiving on board the aircraft (which is confirmed by the "GLIDESLOPE DEVIATION VALIDITY" discrete signal, recorded on the FDR), thought the signal itself was changing within the range of -4 to +4 dots (Figure 35). In fact, during the entire subsequent flight, the values of the glideslope deviation were considerably higher than one dot. The similar situation (the fluctuating trend of the changes in glideslope deviation up to the maximum values) was observed during this flight phase on the instruments onboard the Da-42 aircraft, which performed the flight tests in accordance with the special program in the frame of accident investigation.

The recorded internal communication confirm that the crew did not monitor the values of the glideslope deviation. According to ACT Airlines SOP, one of the requirements for performing the ICAO CAT II approach is the glideslope deviation of no more than one dot.

Note: 1. ACT Airlines SOP p. 4 "*Low Visibility Operations*".

"– Both Pilots shall monitor the autopilot operation by cross-checking ILS raw data on the PFD."

2. ACT Airlines SOP p. 4 "*Low Visibility Operations*".

"– Glide slope deviation shall not exceed 1 dot."

At 01:16:07, 15 seconds after the glideslope signal capture at the altitude of 3150 ft (the radio height was approximately 1000 ft), the FDR recorded triggering of the "AP CAUTION" (the autopilot caution annunciation) and "FMA FAULT 2" discrete. This discrete signal corresponds to "AUTOPILOT" caution-level EICAS message and glideslope mode fail indication (amber line drawn through the glideslope mode annunciation on the FMA) respectively. The triggering of these discrete signals was accompanied by the corresponding audio alerts (4 'beeps' in a row). The

recordings of these discrete signals lasted almost up to the end of the flight (up to the time the "FLARE" mode of the autopilot was engaged).

No reports from the FO related to the triggering of the above-mentioned annunciations were recorded, which was in violation of the ACT Airlines SOP requirements. As it has been mentioned above, the constant instruments and annunciations monitoring could have been prevented by the PIC's direct command to the FO to concentrate mainly on the environment outside the cockpit: *"Instruments, I monitor the instruments, you look outside"*.

Note: 1. ACT Airlines SOP p. 4 "Low Visibility Operation":

"During the final approach phase, the F/O shall remain head down until the landing is completed and call out the required FMA annunciations and any deviation from the normal flight profile."

2. ACT Airlines SOP p. 4 "Low Visibility Operation":

"The Pilot Monitoring shall make all the callouts, backup the Auto Calls by making the same calls."

According to the explanation, provided by the Boeing Company, the "FMA FAULT 2" discrete signal recording indicates that the automatic system has determined the "PITCH MODE FAILURE" occurrence, that is the failure to maintain the capture of the glideslope beacon signal.

In this case, the following annunciation is provided:

- the Flight Director pitch bars are removed from the PFDs;
- the "G/S" indication (about maintaining the glideslope) on the PFDs (FMA) are crossed with an amber line;
- the two "MASTER CAUTION" lights come on;
- the "MASTER CAUTION" audio alert is triggered;
- the amber "AUTOPILOT" caution annunciation is triggered on the EICAS display.

It should be pointed out that the Boeing 747 FCOM and FTSM do not provide a complex and complete description of the "PITCH MODE FAILURE" annunciation triggering situation; the data about the light and audio annunciations are generalized and are provided in different sections (for example, in the "Automatic Flight – Controls and Indicators, PFD Flight Mode Annunciations (FMAs)" of FCOM. No direct instructions for the pilots' actions in case of this situation are provided either.

At the same time, the autopilot continues to operate. In the pitch control channel, irrespectively to the factual glideslope angle at the exact aerodrome, the autopilot will maintain the descent track with an inertially derived approximate angle of 3° ("INERTIAL PATH"), its calculation starting from the point at which the incapability of following the glideslope signal had

been detected for the first time. The flight with this constant angle of descent will continue until either the glideslope beacon signal, which the autopilot may follow, appears or the crew override the autopilot control either by the autopilot disengagement or by the go-around actions (by pressing the "TO/GA" pushbutton). With no crew's overriding actions, the aircraft will follow the inertial path until the "FLARE" mode is engaged. The armed "LAND 3" (or "LAND 2") automatic landing mode will also continue to be displayed. According to the designer's information, the above-mentioned feature which allows the autopilot to continue the approach in case of the loss of the valid signal of the glideslope or localizer beacon is common for the following Boeing aircraft types: 737 (CAT IIIb Fail Operational aircraft only), 747-400/-8, 757, 767, 777 and 787.

The analysis of the recorded data confirm that almost immediately after the glideslope signal capture, the onboard system of the aircraft determined the incapability to follow this signal. Besides, according to the information, provided by the Boeing Company specialists, the 15-second delay in triggering of the caution annunciation is purposely designed. The behavior of the alert is described in the FCTM, including the fact that anomaly detection is not annunciated to the crew if it is of short duration. However, the information about the exact the length of the delay (which differs depending on whether the airplane is above or below Alert Height), is found missing in any documents available for the crew or the airline (for further information refer to the note below).

According to the Boeing 747 FCTM recommendations, in this case (the loss of the glideslope signal while descending along the glidepath), no immediate action are required from the crew, except for the situations of the autopilot abnormal operation. In the accident flight, the aircraft was following a stable descent track at the angle of approximately 3° with the maintained annunciation on the armed automatic landing mode. Besides, the Boeing 747 FCTM sets the following limit: no continued approach below the weather minimums unless the adequate visual reference with the runway environment is established.

Note: *747 Flight Crew Training Manual, "Approach and Missed Approach":*

"5.15. If an autoland annunciation changes or system fault occurs above AH that requires higher weather minimums (reversion to LAND 2 or NO AUTOLAND), do not continue the approach below these higher minimums unless suitable visual reference with the runway environment is established.

"5.19. The AFDS includes a monitor to detect significant ILS signal interference. If localizer or glide slope signal interference is detected by the monitor, the autopilot disregards erroneous ILS signals and remains engaged in an attitude stabilizing mode based on inertial data. Most ILS signal interferences last only a

short time, in which case there is no annunciation to the flight crew other than erratic movement of the ILS raw data during the time the interference is present. No immediate crew action is required unless erratic or inappropriate autopilot activity is observed.

"5.20. If the condition persists, it is annunciated on the PFD. If the autopilot is engaged, annunciations alert the flight crew that the autopilot is operating in a degraded mode and the airplane may no longer be tracking the localizer or glide slope. When the condition is no longer detected, the annunciations clear and the autopilot resumes using the ILS for guidance."

According to the "Limitations" of the Boeing 747 FCOM, the automatic landing is allowed within the glideslope angle ranging from of 2.5° to 3.25°. In case of the factual glideslope angle deviation from the standard value (of 3°), the aircraft can go higher or lower the glidepath to a certain value before the alert, signaling the switching to the mode of flying along the inertial path, is triggered. The value of the glideslope deviation will depend on the current ground speed. As no immediate actions are required from the crew on the alert triggering, the aircraft can continue to deviate off the glidepath after the glideslope annunciation triggering (in case the crew performs no overriding actions); besides, the control over the aircraft position with the help of the pointers¹⁸ will be impossible, as the glideslope signal is unstable.

At the same time, the recommendations, provided in the "Full Flight Simulator CAT II/III Familiarization" section of the Boeing 747 Training Manual, in case of the "AUTOPILOT" caution triggering, require the pilot to perform the go-around procedure if there is no visual reference with the runway environment. Thus, the 747 FCTM and 747 TM requirements are significantly different, and there is a note, according to which the 747 TM is based on the FAA requirements, while the requirements of other aviation authorities may be different.

Note: *747 Training Manual, "Full Flight Simulator CAT II/III Familiarization":*

"PILOT RESPONSE TO APPROACH, LANDING, AND GO-AROUND ALERTS

<i>Alert</i>	<i>Above 200 ft. AGL</i>	<i>Below 200 ft. AGL</i>
<i>Master Warning/Caution Lights with EICAS Messages (see note)</i>		
<i>AUTOPILOT (Caution)</i>	<i>*Execute go-around</i>	<i>**Execute go-around</i>

** If suitable visual reference is not established.*

*** If suitable visual reference is established, land.*

NOTE: *All other EICAS messages are dealt with according to QRH procedures.*

¹⁸ The pointers indicating the glideslope position in relation to the aircraft position.

NOTE: Information in this table is based on FAA regulations and utilized for training purposes only. Individual operators should ensure procedural compliance with applicable regulatory requirements and AFM/company limitations."

Thus, the investigation team points out to some logical contradiction between the aim (to reduce the quantity of go-around events in case of temporary loss of the ILS signal) for which the aircraft designer (the Boeing Company) has developed the algorithm of transition to the flight along the inertial path, and the pilots' CAT II and CAT III landing training program, authored by the Boeing Company.

The investigation team considers that it is necessary for the aviation authorities and the operators to reassess the risks related to the onboard equipment's option of continuing the approach along the inertial path and to take the necessary measures to manage these risks.

ACT Airlines SOP also contains the requirement for performing the go-around procedure in case of the "AUTOPILOT" caution triggering at the height below 1000 ft in relation to the touchdown zone (TDZ); however, the used term of "FAILURE/WARNING" does not reflect the actual status of the alert – the "CAUTION" annunciation. Nevertheless, the requirement to perform the go-around procedure refers the EICAS annunciation system.

Note: ACT Airlines SOP p 4.8 "Procedures after Failures/Warnings in CAT II/IIIA Approach":

Failure/Warning	Phase	Procedure	
		CAT II	CAT IIIA
">AUTOPILOT"	Below 1.000 ft above TDZ	Execute Go Around	



Procedures After Failures/Warnings in CAT II / III Approach

Failure/Warning	Phase	Procedure	
		CAT II	CAT IIIA
EICAS MESSAGE:			
">AUTOPILOT"	Below 1,000 ft above TDZ	Execute Go Around	Execute Go Around

The crew did not respond to the above-mentioned annunciations. The crew neither performed nor discussed the go-around procedure.

The further descent was performed at the IAS of ≈ 160 kt (at the V_{ref} of 151 kt defined by the crew). The landing weight of the aircraft was approximately 274 800 kg, which was within the limits, set by the Boeing 747 FCOM. The aircraft balance was also within the limits.

At 01:16:18, the armed automatic landing mode was changed from "LAND 3" to "LAND 2", and the crew confirmed the above-mentioned mode change: PIC: "*Land two.*" FO: "*Check.*"

According to ACT Airlines SOP, the change from "LAND 3" to "LAND 2" allowed the crew to continue the approach.

Note: ACT Airlines SOP P. 4 "*Low Visibility Operations:*"

<i>Failure/Warning</i>	<i>Phase</i>	<i>Procedure CAT II</i>
<i>">NO LAND 3"</i>	<i>Below 1,000 ft above TDZ</i>	<i>Continue approach</i>

During the further descent, the crew was monitoring the flight altitude. The aircraft position in relation to the RWY was not monitored:

PIC: "*What is the altitude?*"

FO: "*Eight hundred.*"

PIC: "*Look, it is six hundred sixty now.*"

FO: "*Yes, radio six hundred sixty.*"

FO: "*Five hundred.*"

VA(voice alert): "*Five hundred.*"

PIC: "*Continue.*"

During the time period of 01:16:49...57, starting from the height of 300 ft, the EGPWS Mode 5 "GLIDESLOPE" annunciation was triggered five times.

According to the EGPWS Pilot Guide, at the AGL height of less than 1000 ft at the deviation from the glideslope beam of 1.3 dots or more, a "soft" alert is generated, which consists of the light caution indication and the aural "GLIDESLOPE" caution message, heard at 20% of the maximum volume. If the aircraft is positioned at the height of less than 300 ft and the deviation from the glideslope beam is 2 dots or more, a "hard" alert is generated, which will be repeated at the full (100%) volume. Besides, as in the case with the glideslope capture algorithm, the aircraft position in relation to the RWY is not assessed. In fact, at the moment of the alert generation, the aircraft was positioned above the RWY closer to the RWY end.

The analysis has revealed, that the alert was triggered in accordance to the designed algorithm. As the glideslope deviation increase was registered by the onboard equipment, the crew was receiving both "soft" and "hard" alerts (five aural alerts totally).

Despite the constant receiving of the significant deviation from the glideslope beam, the "GLIDESLOPE" caution annunciation was aborted at the AGL height of approximately 200 ft,

which is higher than the lower threshold of the annunciation triggering. The alert generation was aborted because the onboard system detected that the signal about the glideslope deviation was no longer valid (this is confirmed by the fact that the "GLIDESLOPE DEVIATION VALIDITY" discrete signals, recorded by the FDR, were aborted). Until this moment, the signal received by the onboard equipment was considered valid. The direct indication on the signal validity/invalidity is not provided for the crew. On the other hand, in the FCOM section entitled "Flight Instruments, Displays – Control and Indicators ", p. 10.10.25, it is stated that the glideslope pointers (indicating the aircraft position relative to the glideslope) are in view only when the glideslope signal is received. Thus, the FCOM contains information only on receiving the glideslope signal, not on the signal validity/invalidity.

The crew did not respond to the "GLIDESLOPE" caution annunciation. It should be pointed out that, during the Approach Briefing, the PIC made a briefing on the necessary actions in case of the ILS signal deviation: *"If we get an ILS deviation above one thousand feet, sorry, below one thousand feet do a go-around in case of ILS deviation."*

Despite this, the crew performed no go-around procedure. Later on, the EGPWS provided the information only about reaching the specified altitudes and minimums.

According to ACT Airlines SOP, in case of the glideslope deviation alert triggering, the crew must abort the approach and perform the go-around procedure. The 747 TM also requires the execution of the go-around procedure in case of the glideslope deviation alert triggering.

Note: 1. ACT Airlines SOP p. 4 "Low Visibility Operations."

<i>Failure/Warning</i>	<i>Phase</i>	<i>Procedure CAT II</i>
<i>ILS deviation</i>	<i>Below 1,000 ft above TDZ</i>	<i>Go around</i>

2. 747 Training Manual, "Full Flight Simulator CAT II/III Familiarization":

"PILOT RESPONSE TO APPROACH, LANDING, AND GO-AROUND ALERTS

<i>Alert</i>	<i>Above 200 ft. AGL</i>	<i>Below 200 ft. AGL</i>
<i>Master Warning/Caution Lights with EICAS Messages (see note)</i>		
<i>ILS Deviation Alert</i>	<i>*Execute go-around</i>	<i>**Execute go-around</i>

** If suitable visual reference is not established.*

*** If suitable visual reference is established, land.*

NOTE: All other EICAS messages are dealt with according to QRH procedures.

NOTE: Information in this table is based on FAA regulations and utilized for training purposes only. Individual operators should ensure procedural

compliance with applicable regulatory requirements and AFM/company limitations."

In fact, the aircraft, maintaining the final heading in a fully automated mode, was performing a landing beyond the RWY. At the height of 150 ft, the FO reported: "*Approaching minimums.*" and the PIC responded with the command to the FO to monitor the environment outside the aircraft: "*Look outside.*"

At 01:17:04, the aircraft passed over the RWY 26 end at the AGL height of approximately 110 ft. During the descent, the EGPWS terrain awareness alerting (including the "PULL UP" alert) was missing.

According to the data, provided by Honeywell (the EGPWS design company), in case the aircraft is configured for landing (the flaps and landing gear are extended), the Modes 1-4 alerts will not be generated:

Mode 1 Excessive Decent Rate.

Mode 2 Excessive Closure to Terrain.

Mode 3 Altitude Loss after Takeoff.

Mode 4 Unsafe Terrain Clearance.

The EGPWS system has two more functions of alerting in case of excessive ground proximity:

- Forward looking terrain alerting (FLTA);
- Terrain Clearance Floor (TCF).

For the FLTA function, the message inhibition is provided by design in case the aircraft is positioned in the RWY vicinity (≈ 0.5 nm (926 m) from the threshold or the end of the RWY). As the aircraft was performing a descent in the close vicinity of the RWY, no alerting messages were generated.

The TCF function is designed for preventing the air accidents related to premature aircraft descent. The alert is generated depending on the AGL altitude and the distance from the RWY threshold. The operation is also designed to use the onboard aerodrome RWY database. For Manas aerodrome, the TCF function is active for the distance of no less than 0.25 nm beyond the RWY end. The lower limit for the alert triggering is 10 ft AGL (radio) height (no alert messages are generated below this height). Moreover, the system is designed to generate the alert if the conditions, required for the alert triggering last for more than 1 second (this delay is necessary to confirm the validity of the information and to prevent the false triggering). The analysis of the recorded FDR data shows that the aircraft was positioned at the TCF triggering zone for less than 1 second and then descended below the radio height of 10 ft. The alert was not generated.

Thus, during the accident flight on 16.01.2017, the Boeing 747-412F TC-MCL EGPWS was serviceable and was operating normally, in accordance with the designed algorithm.

At 01:17:04.6, the EGPWS aural alert on reaching the radio height of 100 ft was triggered, at this time the decision height was 99 ft. 2 seconds later, the FO reported: "*Minimums.*"

At 01:17:07.7, the PIC reported negative visual reference with the RWY environment and commanded to perform the go-around: "*Negative, go around.*"

At 01:17:09, at the height of approximately 60 ft, the autopilot "FLARE" mode was engaged, and half a second later, at the height of 58 ft, the pressing of the go-around pushbutton was recorded (Figure 35).

The engagement of the go-around mode caused the engine thrust increase, which, together with the control column pitch-up input, resulted in the vertical load factor of 1.4...1.5 g and almost inhibited the aircraft descent rate. However, 3...3.5 seconds after the go-around pushbutton pressing aircraft touched down past the runway end (the FDR discrete signals for the landing gear compression were recorded). At the moment of the touchdown, the aircraft ground speed was approximately 165 kt.

The first touchdown occurred with the insignificant vertical speed and almost without a banking angle at the distance of ≈930 m from the RWY 26 end. Directly prior to the aircraft touchdown, the right wing tip impacted trees. As a result of the aircraft impact with the trees, the RH wing flight control devices started to disintegrate. After moving 20 m further on the ground surface, the aircraft main landing gear and engines impacted the aerodrome concrete barrier. At the distance of approximately 160...170 m from the place of the first touchdown, the second aircraft touchdown occurred, during which the aircraft right wing and engines impacted the buildings. As a result of the impacts with the obstacles, the aircraft disintegrated, a significant part of the aircraft structure was destroyed by the occurred ground fire.

Thus, one of the main causes of the accident was the lack of monitoring from the part of the crew over the aircraft position with regard to the RWY during the automated approach and landing, conducted at night in the weather conditions corresponding to ICAO CAT II. Based on the data available, the investigation team has not been able to determine unambiguously why the crew neither took the available measures to recover the aircraft attitude required by the approach chart nor performed the go-around procedure. The experience, gained during the previous accidents investigation, suggests that possible causes may be of psycho-emotional character.

Below, the selection of the crew members' comments, related to the ATC service specialists' instructions (clearances) and to the flight altitude, is provided:

1. The FL 220 flight (before descending to the RAXAT reporting point) under the control of the Bishkek ATC after the controller's instruction to maintain the flight level:

PIC: "Don't leave me high, you (illeg)..."

PIC: "We are starting to be high." "Ask for it"¹⁹, brother."

(Further, the translation of the above-mentioned excerpt into Russian is provided.)

2. During the RAXAT reporting point crossing at FL 180:

PIC: "Brother, switch to the frequency, eerr...ask for a descent right away."

FO: "Sure, sure, this one wasn't very nice to us, that is why."

3. After the RAXAT reporting point crossing and receiving the Bishkek Approach controller's clearance for the descent to FL 060 in accordance with the approach chart:

PIC: "They left us high again", "I will be six zero (illeg) at TOPKA."

4. At the distance of 7.2 nm and at the altitude of 6350 ft during the flaps extension to 10°:

FO: "We may end up high and we have speed as well."

5. When the aircraft was positioned in the FAF vicinity:

PIC: "Fuck, he left us high, fucking faggot."

The information, provided above, confirms that during the descent and approach, the crew members were constantly monitoring the altitude and were aware that the aircraft was positioned higher than required by the charts (the arrival and approach charts). The fact that the crew, during the long period of time available, failed to position the aircraft as required by the approach chart, undoubtedly, was increasing the psycho-emotional stress of the crew members.

It should also be pointed out, that the discontent expressed repeatedly (first of all, by the PIC) with the controller's instructions (besides, this discontent was ungrounded, as the controller's instructions were correct, while the crew themselves failed to maintain the required descent profile) could have contributed to increase of their psycho-emotional stress. This psychological phenomenon (when, being aware that the actual flight parameters do not meet the requirements, the crew, instead of conducting the objective analysis and taking the decision on changing the flight plan, start "blaming somebody else") has been seen by the IAC specialists many times during the conduct of the investigations on other aircraft accidents.

The phrases, provided above, prove that with the course of time the crew's discontent was increasing and was contributing to their psycho-emotional stress increase. While the height deviation had grown critical, as was reported by the FO, the PIC did not respond to this warning at all, but in a while, he cursed the controller (in regards to the altitude).

¹⁹ "It" is referred to the descent.

At this stage of flight, the possible solution on the part of the crew would have been to request the controller for some maneuvering (an orbit flight, for example) in order to decrease the altitude or for aborting the approach procedure. The crew made no decision either on aborting the approach procedure nor on maneuvering to decrease the altitude. As a result, the further crew actions were conducted in a hurry, which, under the condition of the increased psycho-emotional stress, was contributing to the probability of making errors.

Note: *Performance of orbit in the aerodrome area is non-normal maneuvering. The experience gained while conducting the investigations of events (for example, the accident involving the Boeing 737-200 EX-009 aircraft, which occurred on 24.08.2008 in the area of Manas International Airport²⁰) proves that such maneuvering may create additional flight safety risks, which shall be assessed for reasonability in each exact case individually. Therefore, the optimal solution for the crew would have been conducting the published missed approach procedure and second approach.*

The investigation team points out, that in general, the crew were well-trained in relation to the operational procedures and were also very disciplined; in other words, at the optimal psycho-physiological efficiency state, the crew members performed their working instructions properly. At the start of the descent, the crew members reported the selected autopilot modes and the flight parameters, the check list were performed in due time and in full. However, past the TOKPA reporting point, and especially at the final stage of the flight, the crew members started to deviate from the required operational instructions, they missed out some of the procedure actions (for example, the Landing Checklist), the awareness of the flight process was becoming more and regard to the approach chart.

The investigation team did not reveal any violations of the crew members' work and rest schedule. However, at the moment of the accident, the flight duration was more than 6 h, and their work time was more than 11 h. The flight was performed at night with the intersection of several time zones, the flight was delayed for more than two hours, and after the landing at Manas aerodrome, the crew was planned to be changed. Before the start of the descent, the crew members expressed their worries about the fact that the weather conditions could possibly be lower than the required minimums, and they might not be able to perform the landing; and when they received the information that the weather conditions were within the limits, they expressed their relief. Thus, most probably, the crew members were willing to perform the landing as soon as possible and

²⁰ The Final Report: https://mak-iac.org/upload/iblock/ef7/report_boeing-737-200_EX-009.pdf

were not psychologically prepared to abort the approach procedure. In other word, instead of the logic of "I am prepared for the go-around in case I find any deviation from the conditions required for performing the landing, and I will continue the approach procedure only if I find that all the parameters are standard" ("go-around prepared and go-around minded"), they used the logic of "I will try to perform the landing, and only if there is an evident incompliance with the requirements (for example, in case of no visual reference with the RWY at the DH (decision height)), I will conduct the go-around procedure".

In the situation of having the dominating aim and the non-optimal psycho-emotional state, the information (if it is not evident and unambiguous) which may prevent the fulfilling of the desired (in this case – performing the landing), is not perceived and is not taken into consideration (is subconsciously expelled). In the situation of the fragmented flight process awareness, the crew are unable to monitor all the required parameters, but focus their attention only on the parameters (down to one or two) which, from their viewpoint, currently are of prior importance. Judging from the crew's communication and actions, it is evident that during the accident flight such parameters were the aircraft altitude and the readiness of the system to execute an automated landing.

The above-mentioned assumption is repeatedly confirmed by the crew's communication and actions. Thus, the crew was monitoring and timely reacting to the status change of the systems, involved into the landing procedure:

- the localizer capture;
- the engagement of the armed glideslope mode;
- the glideslope capture;
- the engagement of the armed "LAND 3" and "LAND 2" automated landing modes.

At the same time, the crew did not respond to the events which, in case of their "correct" interpretation, must have led to the abortion of the approach procedure:

- their own comments about the aircraft's excessive altitude;
- the "fear" of the First Officer concerning the possibility of performing the approach;
- the significantly excessive aircraft altitude at the FAF, LOM, LIM and VOR/DME crossings and at the glideslope capture;
- the factual glideslope signal capture in horizontal flight, not in descent, while the aircraft was positioned over the glideslope;
- the altitude deviation during the flight over the RWY 26 end, indicated on the ND in the MAP mode;
- the appearance of the amber line through the G/S pitch annunciation (mode fail annunciation) on the FMA;

- the disappearance of the flight director command bars;
- the "AUTOPILOT" (caution) annunciation, accompanied by the "MASTER CAUTION" annunciation;
- the wide travel range of glideslope deviation indication;
- the "GLIDESLOPE" annunciation (this fact is especially important, as during the Approach Briefing, the crew discussed the preparedness to perform a go-around procedure in case this annunciation was triggered).

It should be pointed out, that the crew noticed and responded to all the changes in the PFD indications, related to the "desired" parameters. At the same time, they did not react on the "undesired" changes, even if these changes were accompanied by the audio annunciations.

Thus, most probably, at the final stage of the accident flight, the crew members, being in their non-optimal psycho-emotional state and having the dominating aim, experienced the "tunnel effect". It is well-known, that the "way out" of this state and the regaining of the full-amount awareness of the flight process is possible either in case some signal occurs which may be interpreted by the crew clearly and unambiguously or in case of the "outside assistance". In the accident flight, the signal was the reaching of the decision height, when the PIC, on failing to establish the visual reference with the RWY environment, decided to perform a go-around procedure. At the same time it should be pointed out, that the crew initiated the go-around procedure not in due time, but was trying to prolong the time by descending below the decision height (DH).

Note: **ICAO Annex 6**
Decision altitude (DA) or decision height (DH).

A specified altitude or height in a 3D instrument approach operation at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.

At the "outside assistance", which could have drawn the crew members out of the "tunnel effect" state and could have made the crew to take measures on aborting the go-around procedure in due time, could have been the actions of the ATC specialists or the aircraft systems annunciations.

As it has been mentioned above, the ATC specialists were operating in compliance with the established job instructions. However, the function of monitoring the aircraft flight altitude was not included into the Tower controller's job instruction. The technical equipment for performing this function was available, but it was not certified (approved) for fulfilling these tasks.

Note: *ICAO Doc 4444 Air Traffic Management*

8.9.7.1.2. A surveillance radar approach shall only be performed with equipment suitably sited and a situation display specifically marked to provide information on position relative to the extended centre line of the runway to be used and distance from touchdown, and which is specifically approved for the purpose by the appropriate ATS authority.

In ICAO Circular 314, "Threat and Error Management (TEM) in Air Traffic Control (CIR 314), it is pointed out that the threats in ATC are defined as events and error, occurring beyond the ATC controller's sphere of influence, which make the operational conditions more difficult to manage and which must be monitored in order to maintain the threshold level of the flight safety. On performing standard ATC operations, in order to meet the control objectives, the ATC controllers have to take into consideration various specific difficulties. Such difficulties include, for example, errors, made by flight crew members.

Threats, related to the crew's errors, are sudden, that is a controller cannot predict them. However, according to CIR 314, independent of the kind of threat (expected or sudden), one of the criteria of the ATC controller's readiness to control the threat factors efficiently is the ability to determine threats well in advance and to respond to these threats by means of taking the corresponding countermeasures. The control over the threat factors is the most preventive approach to maintaining the threshold levels of the flight safety during the ATC by means of eliminating the situations threatening flight safety.

Failure to efficiently monitor the threat factors may lead to the unwanted condition (when the unpredicted flight environment may lead to the decrease of the threshold level of flight safety) and, consequently, to the air accident or incident.

In the accident flight, the errors of the crew members in relation to maintaining the flight altitude and to monitoring the aircraft position, in the situation when no threat monitoring requirements was present in the ATC specialists' job instructions led to the unwanted conditions which the aircraft experienced: the untimely reaching of the glideslope capture altitude, which caused the false glideslope capture and the inertial path descent to the area beyond the RWY. The IAC investigation teams, involved in certain air accident investigations, have previously issued multiple recommendations on the necessity of improving some sections of the ATC specialists' job instructions related to the provision of more efficient assistance to the aircraft crews (if the technical facilities are available) in case of finding considerable deviations from the established routes and charts at different flight stages (for example, see Recommendations 5.2.29 and 5.2.30 of the Final Report on the investigation of the accident with Boeing 737-500 VQ BBN on

17.11.2013 (https://mak-iac.org/upload/iblock/30a/report_vq-bbn.pdf) or Recommendation 5.5.1 of the Final Report on the investigation of the accident with Tu-154M RA-85744 on 04.12.2010 (https://mak-iac.org/upload/iblock/7c8/report_ra-85744.pdf)).

Particularly, it is necessary to analyze the aircraft systems operations logic. The recorded information proves that the descent and the approach were conducted in the automatic mode with maintaining the flight parameters, set by the crew. No discrete signals, analog parameters or audio signals indicating the failures or anomalies in the aircraft equipment were recorded until the very end of the onboard recorders' operation. The analysis, conducted by the investigation team together with the aircraft and its systems' design company specialists, confirmed the normal operation of the onboard equipment (in accordance with the designed logic) until the time of the accident occurrence.

On the other hand, the circumstances of the accident indicate that the aircraft was maintaining the inertial path with an angle of approximately 3° in the fully automatic mode and, being armed for the automatic landing (first LAND 3 and then LAND 2 modes annunciation was displayed for the crew, no "NO AUTOLAND" annunciation was displayed), was descending to the area far beyond the RWY. Moreover, directly prior to the moment when the crew engaged the automatic go-around mode, the "FLARE" mode was automatically activated; in other words, the aircraft started to perform the automatic landing, being positioned beyond the RWY touchdown zone.

The investigation team requested the US FAA, which had issued the primary Type Certificate for this aircraft, on the applied certification requirements and on the evaluation of the compliance with these certification requirements. The provided response stated that, according to FAA representatives' opinion, the certification procedure (including the test flights) confirmed the aircraft compliance with all the applied requirements (see the text below). At present, the FAA representatives do not envisage any reasons for changing the logic of the automatic flight system (the associated recommendation is provided in the Preliminary Report: https://mak-iac.org/upload/iblock/21e/report_boeing-747-412F_TC-MCL_pro.pdf).

During the accident flight, the system operated in accordance with the designed logic, (including degrading of the landing category²¹, the indication of the changed landing category, the indication of the loss of the glideslope signal (glideslope mode fail annunciation), visual signals and multiple "CAUTION" alerts, including the audio annunciations).

²¹ Note done by the investigation team: from LAND 3 to LAND 2.

According to the information, provided by US FAA, the aircraft was certified, including the certification for the compliance with FAR 25.1322 ("Warning, Caution and Advisory Lights"), including the Amendment 38. According to this paragraph, the green annunciation light (in the context of the accident flight, it was the "LAND 3" and "LAND 2" on the PFDs) is used for advisory annunciation and for informing the crew on safe operational condition. The amber light is used for caution messages (in the context of the accident flight: the "AUTOPILOT" and "EICAS" messages). This annunciation indicates the possible need for future corrective action.

The investigation team points out that during the accident flight, the aircraft descent in the IFR ICAO II weather conditions far beyond the RWY end with the green indication of the armed automatic landing cannot be considered a "safe" situation. The conducted analysis of the accident flight circumstances shows that, most probably, the crew "relied on" the above-mentioned indication and, being in the non-optimal psycho-emotional state, subconsciously "excluded" the amber annunciation, which did not require immediate actions, but at the same time might have prevented reaching the crew's target to perform a landing.

The investigation team requested Sukhoi Civil Aircraft Company LTD, the RRJ-95 aircraft design company, on the automatic system operation of this aircraft type in the circumstances, similar to the ones of the accident flight. According to the provided information, on loss of the glideslope signal, the red warning "APPROACH LOST" annunciation will illuminate on the PFD, accompanied by the aural and light alerts, which require immediate actions of the crew on the aircraft control. Besides, according to the RRJ-95 FCOM, the above-mentioned annunciation the condition for the disengagement of either by the automatic go-around or by the autopilot disengagement, conducted by the crew.

The investigation team points out, that in the context of the accident flight, the red warning annunciation could have been the "trigger" which possibly might have forced the crew out of their "tunnel effect" state.

According to the information, provided by US FAA, on the aircraft certification, its compliance with FAR 25.1329 ("Automatic Pilot System"), including Amendment 46, had been demonstrated. Item "f)" of the above-mentioned paragraph states, that the system must be designed and adjusted so that, within range of adjustments available to the human pilot it cannot create hazardous deviations in the flight path, under any condition of flight appropriate to its use either during normal operation, or in the event of a malfunction (assuming that corrective action begins within a reasonable period of time).

Note: *The investigation team requested the aircraft manufacturing company on their interpretation of the "reasonable period of time" regarding the considered circumstances. In the provided response states that this term is a loose definition which should be understood in regard to the exact situation and is dependent on a wide number of factors. For the considered circumstances (flight in the automatic mode along the inertial path), Boeing is currently unable to provide the exact value which was considered.*

At the time of the Boeing 747-400F type certification in 1993, FAA AC 120-28C, "CRITERIA FOR APPROVAL OF CATEGORY III LANDING WEATHER MINIMA", was in effect. In this document (p. 6), it is stated that the automatic flight systems shall be in compliance with the requirements of FAA AC 20-57A, "AUTOMATIC LANDING SYSTEM". Paragraph 5.b.(4) of this advisory circular states, that the automatic landing system should ensure that the aircraft touchdowns performance outside the prescribed dispersion area (of between a point of 200 ft (60 m) beyond the threshold and that point down the runway at which the pilot is in position to see at least 4 bars (set at the in-between intervals of 100 ft/30 m) of the 3000 ft (915 m) touchdown zone lights)) is no less than improbable. In the more recent revision of this advisory circular (AC 120-28D which came in effect in July of 1999), it is specified that the probability of touchdown beyond the area in between the point on the runway 200 ft (60 m) and the point of 2700 ft (823 m) from the threshold shall be to a probability of 1×10^{-6} (Appendix 3, p. 6.3.1).

Note: *According to the explanations, provided by the State of Design, for the time period under consideration, the term "improbable" had both quantitative (for the assessment of the statistically measurable factors) and qualitative equivalents. The quantitative value was characterized by the probabilities ranging from 10^{-5} or less to no greater than 1×10^{-7} per flight hour. Besides, the qualitative characteristics implied that the event was not anticipated to occur during the entire operational life of a single random aircraft; however, the event may occasionally occur during the entire operational life of the all aircraft of one type.*

FAA AC 120-29, "CRITERIA FOR APPROVING CATEGORY I AND CATEGORY II LANDING MINIMA FOR FAR 121 OPERATORS", which was also in effect at the time of the Boeing 747-400F type certification, Appendix 1 p. 9.c.(4), in its turn, states that the automatic systems should demonstrate the capability of stabilizing the aircraft on the glide slope before an altitude of 700 ft (215 m) above the RWY level, and during the further descent to the decision

altitude, the allowable deviations from the glide slope should be within the range of ± 35 microamperes or ± 12 ft (4 m), whichever is larger. In the subsequent revision of this advisory circular (AC 120-29A, which came in effect in August, 2002), requires the aircraft to demonstrate the acceptability of the aircraft positioning and flight parameters at 200 ft HAT (Height Above Touchdown), 100 ft HAT or at DA(H) (Decision Altitude (Height)), and the capability of landing within the touchdown zone (p. 5.19.3.2.c).

The above-mentioned information suggests that the false glideslope capture which took place during the accident flight, and the followed inertial path flight with the presence of only amber annunciation and the missing red warning annunciation for the crew is not in full compliance with the established requirements.

3. Conclusion

The cause²² of the Boeing 747-412F TC-MCL aircraft accident was the missing control of the crew over the aircraft position in relation to the glideslope during the automatic approach, conducted at night in the weather conditions, suitable for ICAO CAT II landing, and as a result, the measures to perform a go-around, not taken in due time with the aircraft, having a significant deviation from the established approach chart, which led to the controlled flight impact with terrain (CFIT) at the distance of ≈ 930 m beyond the end of the active RWY.

The contributing factors were²³, most probably, the following:

- the insufficient pre-flight briefing of the flight crew members for the flight to Manas aerodrome (Bishkek), regarding the approach charts, as well as the non-optimal decisions taken by the crew when choosing the aircraft descent parameters, which led to the arrival at the established approach chart reference point at a considerably higher flight altitude;
- the lack of the crew's effective measures to decrease the aircraft vertical position and its arrival at the established approach chart reference point while the crew members were aware of the actual aircraft position being higher than required by the established chart;
- the lack of the requirements in the Tower controllers' job instructions to monitor for considerable aircraft position deviations from the established charts while the pertinent technical equipment for such monitoring was available;
- the excessive psycho-emotional stress of the crew members caused by the complicated approach conditions (night time, CAT II landing, long-lasting working hours) and their failure to eliminate the flight altitude deviations during a long time period. Additionally, the stress level could have been increased due to the crew's (especially the PIC's) highly emotional discussion of the ATC controllers' instructions and actions. Moreover, the ATC controllers' instructions and actions were in compliance with the established operational procedures and charts;
- the lack of the crew members' monitoring for crossing the established navigational reference points (the glideslope capture point, the LOM and LIM reporting points);
- the crew's failure to conduct the standard operational procedure which calls for altitude verification at the FAF/FAP, which is stated in the FCOM and the airline's OM. On the other hand, the Jeppesen Route Manual, used by the crew, contains no FAF/FAP in the RWY 26 approach chart;

²² In accordance with Annex 13 to the Convention on International Civil Aviation, ("Aircraft Accident and Incident Investigation", the identification of causes does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

²³ In accordance with ICAO Doc 9756 AN/965, "Manual of Aircraft Accident and Incident Investigation", the contributing factors are provided in the chronological order regardless of their priority.

- the onboard systems' "capture" of the false glideslope beam with the angle of $\approx 9^\circ$;
- the design features of the Boeing 747-400 aircraft type regarding the continuation of the aircraft approach descent in the automatic mode with the constant descent angle of 3° (the inertial path) with the maintained green indication of the armed automatic landing mode (regardless of the actual aircraft position in relation to the RWY) while the aircraft systems detected that the glideslope signal was missing (after the glideslope signal "capture"). With that, the crew received the designed annunciation, including the aural and visual caution alerts;

- the absence of the red warning alert for the flight crew in case of a "false" glideslope capture and the transition to the inertial mode trajectory, which would require immediate control actions from the part of the crew;

- the lack of monitoring from the part of the crew over the aircraft position in regard to the approach chart, including the monitoring by means of the Navigation Display (ND), engaged in the MAP mode;

- the crew's failure to conduct the Airline's Standard Operational Procedures (SOPs), regarding the performance of the go-around procedure in case the "AUTOPILOT" (the AP switching to the inertial mode) and "GLIDESLOPE" (the EGPWS annunciation of the significant glideslope deviation) alerts during the automatic CAT II landing at true heights below 1000 ft (with no visual reference established with either the runway environment or with the lighting system);

- the delayed actions for initiating the go-around procedure with no visual reference established with the runway environment at the decision height (DH). In fact, the actions were initiated at the true height of 58 ft with the established minimum of 99 ft.

4. Shortcomings, revealed during the investigation

The shortcomings, revealed during the investigation, have been provided in the text in the respective sections of the present Report.

Courtesy Translation

5. Safety Recommendations

For the top management of airline companies

- 5.1. To draw the attention of the flight crews to the necessity of fulfillment of the requirements, established in the approach charts, of the criteria for the stabilized approach and landing and of monitoring distance and altitude during the crossing of the reference points (FAF, LOM, LIM) when conducting ILS approaches, especially ICAO CAT II and CAT III approaches.
- 5.2. To provide the flight crew training, during which to clarify additionally that in case of absence of the visual reference with the runway environment, the go-around procedure must be initiated no lower than the established decision height/altitude.
- 5.3. To conduct additional training on the CRM and the interaction in case of one pilot's "fear" of the impossibility to continue the approach (or other stage of flight) and the absence of the other crew member's due reaction to this as well as the additional training on the actions required when the "minimums" message comes on.
- 5.4. To conduct the theoretical and practical (if required) training for the flight crews, operating the aircraft, manufactured by the Boeing Company (all models) for the recognition, order and specific features of conducting the flights in case of the autopilot switching to the inertial mode during the descent along the glideslope. To consider the applicability of this recommendation to the aircraft, manufactured by other companies.

For the ATC service personnel

- 5.5. In case of the pertinent equipment availability, to inform flight crews on significant altitude deviations from value, established by the approach charts, especially for ICAO CAT II and CAT III approaches and in case of conditions, requiring actions in compliance with the Low Visibility Procedures, and for this purpose, to consider the issue of making the corresponding amendments to the job instructions of air traffic controllers.
- 5.6. To finish the provision of the metreport to the crews before the aircraft reaches the LIM. The repetitive provision of the already-provided metreport should be avoided, especially if the flight crew is in the process of conducting the ICAO CAT II and CAT III approach and landing.
- 5.7. To consider the practicability of including additional requirement into the ATC specialists' job instructions, in case of flights in low visibility conditions, to request the flight crew for confirm capturing both the localizer signal and the glideslope signal ("fully established" status) after crossing the FAP.

For the Boeing Company and the FAA²⁴

- 5.8. To consider the practicability of improving the algorithm of glideslope capture and of the implementation of the warning type alert in case of the "false" glideslope capture.
- 5.9. To consider the practicability of changing the A/P logic in order to prevent occurrences of continuous inertial glideslope descent (in LAND 3 or LAND 2 modes) in cases when approach path does not allow landing in the appropriate zone of the runway.

For the Boeing Company

- 5.10. To consider the practicability of amending the operational documentation (FCOM, FCTM) in order to provide more detailed description of the inertial path flight mode.
- 5.11. To consider the practicability of amending the operational documentation (FCTM and the B-747 TM) in order to eliminate the discrepancies in the provided actions recommended for the crew in case of "AUTOPILOT CAUTION" annunciation triggering.

For the Aviation Administrations and the Aerodromes' Administrations

- 5.12. To analyze the acceptability of constructions in the immediate vicinity of aerodromes and, in case of findings, take appropriate decisions in cooperation with pertinent authorities.

For the Aviation Administration of the Kyrgyz Republic

- 5.13. To consider the practicability of amending the provided aeronautical information regarding the publishing of the note on the possibility of increasing the safe altitude following the associated instruction from the ATS unit.

²⁴ For other certifying authorities and aircraft design companies: to consider the applicability of these recommendations taking into account the actually applied algorithms.