Islamic Republic of Iran

Civil Aviation Organization

Aircraft Accident

Investigation Board

Aircraft Accident Investigation Final Report

file number:	**A13930519EPGPA**
Type of occurrence:	**ACCIDENT**
Date of occurrence:	**10.AUG, 2014**
Place of occurrence:	**Near Mehrabad International Airport/ Tehran- IR of IRAN**
Aircraft type:	**AN.140-100**
Registration:	**EP-GPA**
Operator:	**Sepahan Airline**

Date of Issue: August 9, 2017

In the name of GOD

Crash Near Airfield Following Aircraft One Engine Failure Just Upon Lift-Off

Sepahan Airlines Flight 5915
Antonov 140-100, MSN 90-05
Tehran, Mehrabad International Airport
August 10, 2014

File Number: A13930519EPGPA

Issued by
Aircraft Accident
Investigation Board
"AAIB"

Introduction and Synopsis:

This report discusses the August 10,2014, about 04:52 UTC, accident involving an AN-140-100, Iranian registration EP-GPA (MSN 90-05), operated by Sepahan Airlines flight # 5915, which was on lift-off from runway 29L when the aircraft experienced engine number one failure and crashed shortly after take-off near Mehrabad International Airport (THR), TEHRAN –IRAN ;

The airplane was completely destroyed. Fatality incorporates 34 of the 40 passengers, 4 of the 4 flight attendants, and 2 of the 2 flight crew members. The 11 passengers received serious injuries which finally 40 fatalities and 8 passengers survived.

CAO.IRI AAIB sent notification forward to ICAO, the IAC (Interstate Aviation Committee which was established in December 1991 on the basis of the interstate Agreement on Civil Aviation and Use of Airspace between CIS countries.) The IAC introduces Mr. Yachmenov as an accredited representation.

CAO.IRI AAIB also notified the Ukrainian Investigation Authority, but nobody was introduced by this State as an Accredited Representative.

CAO.IRI AAIB conducting the investigation and releasing the final reports on August 7, 2017

All ***times*** in this report are UTC daylight time (unless otherwise noted) and based on a 24-hour clock. The differential between local time and Coordinated Universal Time (UTC) at date of accident was 04 hour +30 minutes.

As a result of investigation, the accident investigation team issues safety recommendations to all related parties including, aircraft state of design, IAC , CAO.IRI and Sepahan Airlines , HESA manufacturing company, ANTONOV Co. , the Aircraft Rescue and Firefighting Working Group, and the Iranian Airport Company (i.e. : ATS services) in order to improve the safety level among the operation .

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Note: All ***times*** in this report are UTC daylight time (unless otherwise noted) and based on a 24-hour clock.

Abbreviations:

AAIB: Aircraft Accident Investigation Board
A/C: Aircraft
ACC: Area control center
ACS: Air Conditioning System
AFCS: Aircraft Flight Control Systems
AFM: Aircraft Flight Manual
APP: Approach Control
APU: Axillary Power Unit
ARFF: Aircraft Rescue & Fire Fighting
AMM: Aircraft Maintenance Manual
AMP: Aircraft Maintenance Program
AGL: Above Ground Level
AIG: Aircraft Accident and Incident Investigation
A/P: Auto Pilot
ASL: Above Sea Level
ATIS: Automatic Terminal Information System
ATS: Air Traffic Service
CD: Clearance Delivery (ATS)
CAO.IRI: Civil Aviation Organization of Islamic Republic of Iran
CRS: Certificate of Release to Service
CVR: Cockpit Voice Recorder
CSN: Cycle Since New
CBO: Cycle Between Overhaul
DNA: Deoxyribo Nucleic Acid (Aviation Medicine)
EEC: Electric Engine Control
GND: Aerodrome Ground Controller (ATS)
FAR: Federal Aviation Administration
FS: Flight Simulator
FCOM: Flight Crew Operating Manual
FCU: Fuel Control Unit
IAC: Interstate Aviation Committee
IAC-AR : Interstate Aviation Committee the Aviation Register
IAS: Indicated Air Speed
IFR: Instrument Flight Rules
OEI: One Engine Inoperative
MATS: Manual of Air Traffic Service

MTOM: Maximum Take-off Mass
NBAAI: National Bureau of Air Accidents Investigation (of Ukraine)
NOTAM: Notices to Airmen
PF: Pilot Flying
PIC: Pilot in Command
PNF: Pilot Non Flying
RWY: Run Way
QRH: Quick Reference Handbook
SID: Standard Instrument Departure
SMS: Safety Management System
SOP: Standard Operation Procedure
SSDFR: Solid State Digital Flight Recorder
SPN: Sepahan Airline (ICAO 3 letter indicator)
TWR: ATS Aerodrome Control Tower
THR: Tehran –Mehrabad International Airport
TBO: Time Between Overhaul
TSN: Time Since New
VMC: Visual Metrological Condition
VIGV: Variable Guide Vane
W&B: Weight and Balance

* ***Note: CAO.IRI Safety & AIG department has been changed to Aircraft Accident Investigation Board (AAIB) since 2016.***

1. Factual Information

1.1 History of Flight

On August 10,2014, at 04:52 UTC daylight time, an AN-140-100 aircraft , Iranian registration EP-GPA (MSN 90-05), operated by Sepahan Airlines flight # 5915, experienced engine number 2 shutdown just about 2 seconds before lift-off and crashed shortly after take-off nearby Mehrabad International Airport (THR), TEHRAN; IR. Of IRAN; the aircraft was on lift off from runway 29L. The airplane was completely destroyed by impact forces and post-crash fire. Fatality incorporates 34 of the 40 passengers; 4 of the 4 flight attendants, and 2 of the 2 flight crewmembers. The 11 passengers received serious injuries, which finally as a result of that accident there are 40 fatalities and 8 passengers recovered from injury.

Sepahan Airline was operating under the provisions of CAO.IRI operational requirement for commercial air transport. Before the accident flight the airplane dispatch from Isfahan and arrived at Tehran about 03:30. The dispatcher and PIC perform the load calculation using the aircraft FM performance charts. Because of load limitation for 15° flap position, load sheet change and re-write with 10° flap position and re-calculated MTOM. The aircraft was enrouted to Airport Tabbas Visual meteorological conditions (VMC) prevailed, and an instrument flight rules (IFR) flight plan was filed. Figure 1 below is a map showing the location of the accident and the aircraft flight path. Figure 2 shows THR runway 29L SID and figure 3 show timeline of event in the flight path. According to overview of flight crew performance, it is indicated that the crewmembers were provided with the flight release paperwork, which included weather information, notices to airmen (NOTAM), and the flight plan.

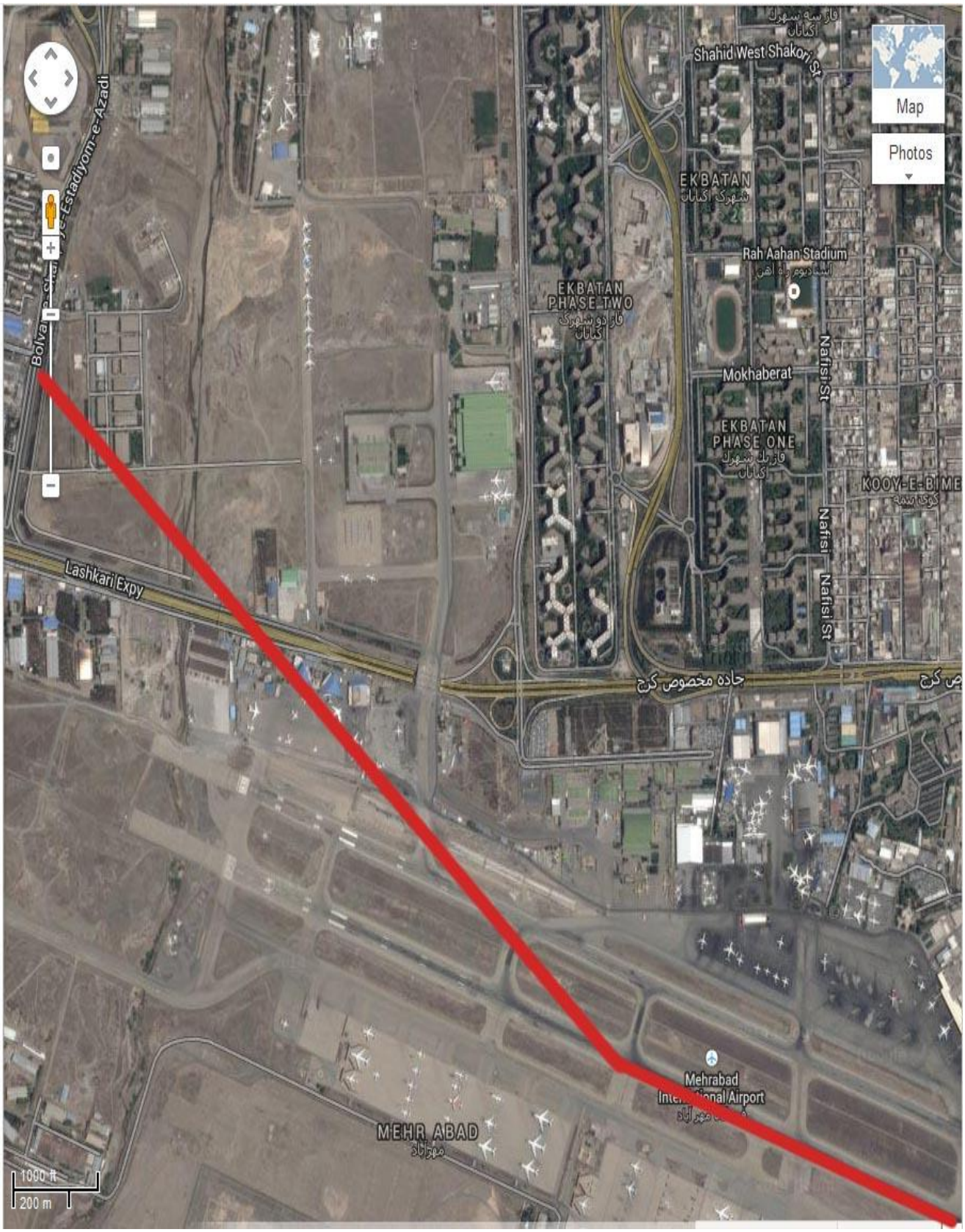


Figure 1. Map of the accident location and flight path.

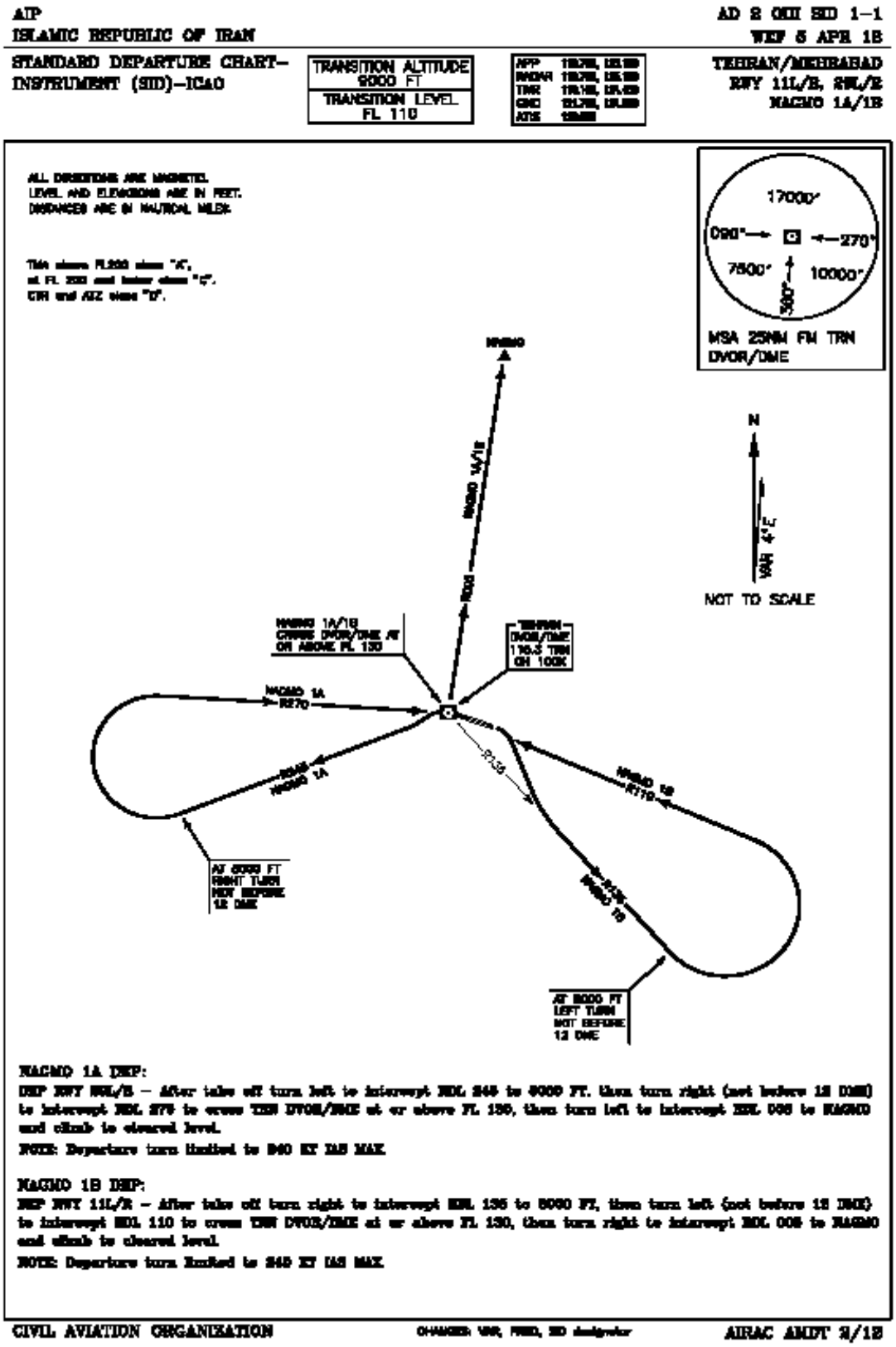


Figure 2. SID chart for the THR runway 29L procedure.

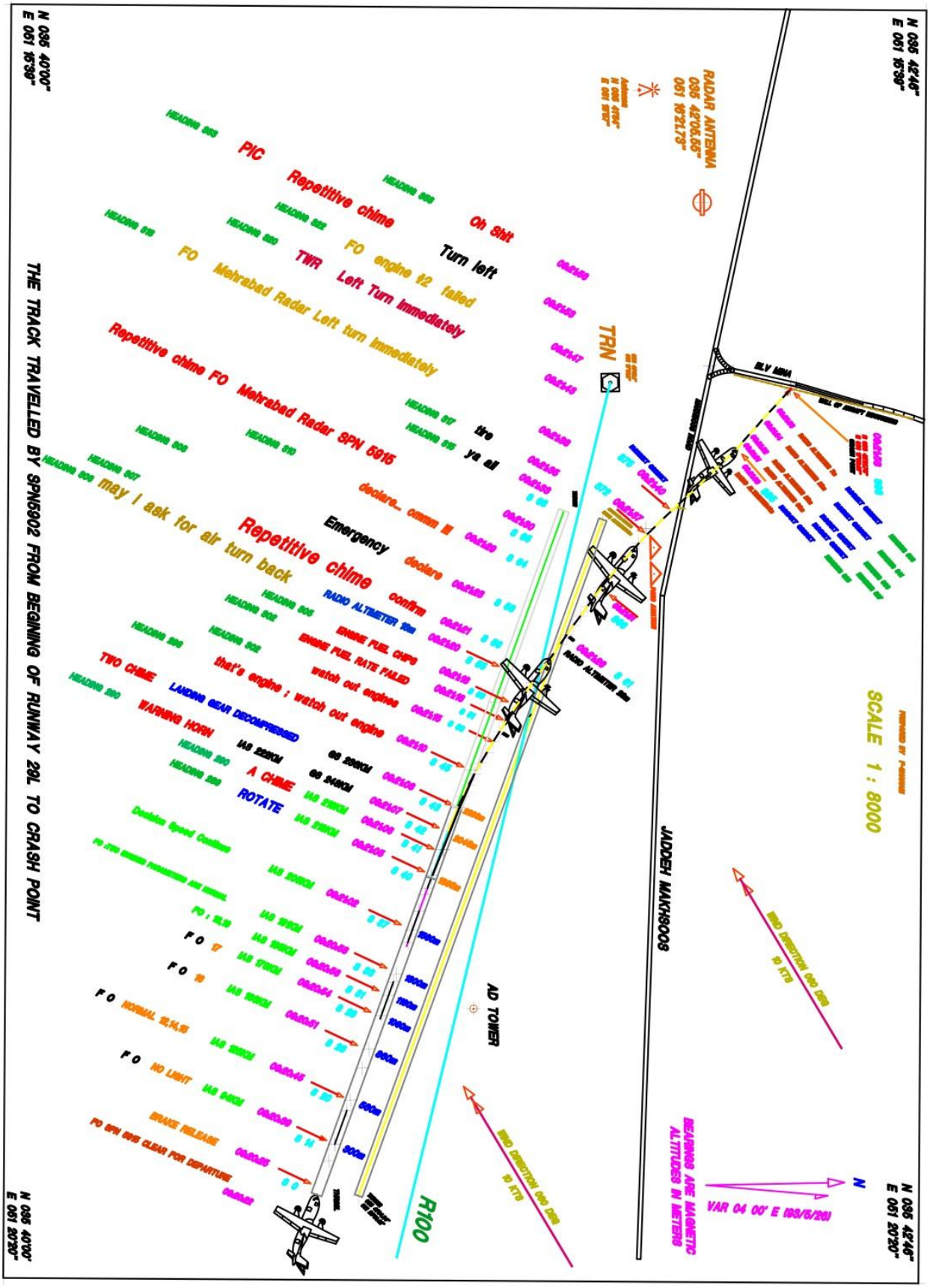


Figure 3. Timeline of selected events during departure and Profile view of the last 2 minutes of flight # 5915.

1.2 Injuries to Persons:

Injuries	Cockpit Crew	Cabin Crew	Passengers	Others	Total in aircraft
Fatal	2	4	34	.	40
Serious	.	.	8	.	8
Minor	.	.	.	.	.
None	.	.	.	.	.
Total	2	4	42 *	.	48

***** *2 of them were Sepahan Airline on duty flight mechanics*

Table 1. Injury chart.

37 Victims were found at the accident site. One passenger during transfer to the hospital and two passengers were lost vital characters in the hospital, a few days after the accident. Eventually, as a result of this accident, there were 40 fatalities and 8 passengers recovered from injury.

1.3 Damage to Airplane

The airplane was completely destroyed by the impact forces and post-crash fire.

1.4 Other Damages

A Portion of "SAMT INDUSTRIAL COMPLEX" wall at the impact point demolished and some trees also were damaged by impact forces and the post-crash fire and during the accident rescue and firefighting operation at the impact point.

1.5 Personnel Information

1.5.1 The Pilot Flying

The PIC was the pilot flying. He has age 63, held an Airline Transport Pilot Certificate issued by CAO.IRI. With a multiengine land airplane rating and type ratings in the AN-140-100 aircraft, his most recent CAO.IRI medical certificate was issued on July 26 , 2014, with no limitations and an expiration

date of January 27, 2015. He completed ground training, full flight simulator training, and also simulator check. His proficiency check on AN-140 simulator carried out on May 5, 2014 with expiration date of December 8, 2014. The Sepahan Airlines records did not indicate any previous accidents, incidents, violations, or company disciplinary actions against him. The PIC had ATPL No. 1670; accumulated 9,478 total flight hours, including 2000 hours as pilot on AN-140. He had 33 hours of AN-140-100 flight time and 24 hours of AN-140 simulator time in the 90 days before the accident. Within 30 days, and 7 days before the accident, the PIC accumulated about 33 flight hours, and 5 flight hours, respectively.

1.5.2 The Pilot Non Flying (Copilot)

The copilot, age 32, held a Commercial Transport Pilot Certificate (CPL) No.3215 issued by CAO.IRI. He began transition training to AN-140 captain on September 18, 2005 and his line-oriented flight training check.

He completed ground training, full flight simulator training, and also simulator check. His proficiency check on AN-140 simulator carried out on May 11, 2014 with expiration date of December 16, 2014 He accumulated 572 flight hours flying which about 400 flight hours on AN-140 aircraft. He had 72 hours rest before accomplishing his last flight.

1.5.3 The Pilot flying's previous flight

On 10 August, 2014, the pilots have served as PIC from Isfahan to Tehran round-trip. Departing IFN at 02:30, and arriving to THR at 03:30. Arriving at THR early morning, and then preparing for the next flight from THR to Tabbas airport.

1.6 Aircraft Information

1.6.1 General

The AN-140-100 airplane is a transport category, twin-engine turboprop airplane that required two pilots by type certification. The aircraft is a high-wing cantilever monoplane with two turboprop engines mounted in the

underwing nacelles and a tricycle single-strut landing gear with a nose gear and two main landing gear. The fuselage is a pressurized, round cross-section, semi-monocoque structure. It accommodates a flight compartment, a transport compartment including a passenger compartment, a vestibule, and a rear baggage/cargo compartment. The baggage/cargo and accessory compartments, nose and main landing gear wells are under the floor.

Two TB3-117BMA-C6M-1 turboprop engines with AB-140 propellers are mounted on the aircraft.

The following type certificate issued for AN-140 Aircraft:

- Certificate No. CT 184-AH-140 is issued by Interstate Aviation Committee Aviation Register (IAC AR).
- Certificate No. Тл 0010 is issued by the State Aviation Administration of Ukraine (Ukraviacia).

The airplane was manufactured in 2008 and his final assembly was completed by HESA industrial company in Isfahan –IRAN (serial number 90-05).

The airplane was registered for the HESA Airlines on 21 November, 2010. The airline name was changed to Sepahan Airlines on 09 October, 2013. It had been operated as scheduled air transportation for the time being.

At the time of the accident, the airplane had accumulated about 1370+35 total flight hours and 1058 total flight cycles.

Sepahan Airlines maintained the airplane in accordance with the manufacturer's recommended continuing maintenance program, and the most recent scheduled maintenance was performed on August 02, 2014,

The aircraft was operated according to the AN-140-100 aircraft Flight Manual (AFM) and Sepahan Airline operations manual.

The accident flight was performed with flaps 10°. In departure the weight limits was calculated by the dispatcher and accepted and endorsed in W&B sheet by the PIC.

This aircraft was equipped with ВУК-140М S/N 64561031 - installed on 08 August, 2009; and on 05 August, 2009 it undergone re-programming to software version 804.8И.0010-07-01;

The engine No. 1 (left): engine ТВ3-117ВМА-СБМ1 S/N 3873171000031 manufactured on 30 June, 2007, operating time: 1559 hours / 1311 cycles. The engine was equipped with the following accessories:

- RED-2000 S/N 54310652074 with software version 2000.05.08 installed on 02 June,2013, including adjustment of assembly settings on 02 June, 2013 in compliance with Directive No. 44, including deactivation on 03 August, 2013 of the functional fuel flow control loop algorithm in accordance with Directive No. 22/2013;
- HP-2000 series 54 S/N 07706254092
- PT-2000 S/N 18108653062
- PCB-34M S/N 0407-89

The engine No. 2 (right): engine ТВ3-117ВМА-СБМ1 S/N 3873171200034, manufactured on 29 November, 2004, operating time: 1555 hours / 1329 full cycles. The engine was equipped with the following assemblies:

- RED-2000 S/N 54308752080 with software version 2000.05.08 installed on 02 June,2013, including adjustment of the assembly settings on 02 June,2013 in compliance with Directive No. 44, including deactivation on 03 August, 2013 of the functional fuel flow control loop algorithm in accordance with Directive No. 22/2013;
- HP-2000 series 68 S/N 07704368302 (with gear-type pumping unit) installed in compliance with Decision No. 2000-10092013
- PT-2000 S/N 18109653064
- PCB-34M S/N 0307-87

Auxiliary power unit (АИ9-ЗБ) S/N 2253092700067, manufactured on 25 April, 2009, with operating time: 558 hours /1352 cycles.

Information about aircraft malfunctions and important event during last 3 months are as following:

On 12 April, 2014 - there was performed a status check for HP-2000 S/N 07704368302 (with gear- type pumping unit) of the right engine after 100 hours operating time in compliance with "Decision No. 2000-10092013" - no foreign particles or debrises were detected on the F-2 filter and magnetic trap, engine run was performed, ПИ-140 and FDR records were submitted to STAR JSC;

On 23 April, 2014 - failure of RED-2000 of the right engine at cruising power during flight on route Isfahan-Bandar Abbas, САУ-2000 switched to hydro-mechanical flight control system; activities taken after landing: washing

of connectors, engine running and false starting failure signal was removed, FDR did not contain records about failure causes;

On 24 April, 2014 - failure of RED-2000 of the right engine at cruising power during flight on route Bandar Abbas - HESA, САУ-2000 switched to hydro-mechanical control system. During the engine run the failure did not repeat, according to HESA assumption the HP-2000 S/N07704368302 was the cause of a defect, it was replaced with HP-2000 S/N...083 (with gear-type pumping unit), FDR and ПИ-140 records didn't have signals about failure cause;

On 28 April, 2014 -failure warning of RED-2000 of right engine appeared for a short-time, the "ДАВ" sensor was replaced, and the aircraft continued flights;

On 29 April, 2014 - corrosion revealed on compressor blades of the left engine during bore scope inspection of compressor blades of both engines, the blade leading edge shape of the left engine compressor turbine was changed. In accordance with IVCHENKO-PROGRESS SE letter No.35/3370-30 dated 30 April, 2014 the engines continued operation with the existing defects;

On 12 May, 2014 - aircraft flew to HESA for B maintenance check, no complains revealed;

On 19 May, 2014 - during measurement of plays (gap) between plunger and step-bearing of HP-2000 of left engine increase of plays within tolerance was revealed. STAR JSC provided a letter to continue the operation of the mentioned HP-2000;

On 28 May, 2014 - MOTOR SICH JSC representative performed adjustment of right engine assemblies for elimination of "scissors" effect of torque of right and left engines (pilots reported 2 pixel difference by indicator);

On 02 June, 2014 - STAR JSC performed measurement of plays between plunger and step-bearing of HP-2000 of the left engine and inspected the condition of Ф-2 filter and magnetic trap of HP-2000 of the right engine, no remarks revealed; HP-2000 of the right engine S/N ….083 was replaced with HP-2000 S/N….302;

On 10 June, 2014 - MOTOR SICH JSC representative again performed adjustment of right engine assemblies for elimination of "scissors" effect of torque of right and the left engines with subsequent test flight. The one pixel difference remained. It was decided to continue operation in the existing condition;

On 24 June, 2014 - the «ENG PROP ERG-FAIL» signal was recorded during flight, replaced PCB-34M and the defect was eliminated;

On 14 July, 2014 - the aircraft transfer to HESA facilities for periodical maintenance;

On 03 August, 2014 - ferry flight to base airport in Shahid-Beheshti (Isfahan) for continued operation after maintenance;

On 07 August, 2014 –in flight from Tabriz to Isfahan (1 landing); Right hand engine vibration reported by the crew and FDR recorded this vibration ; (the previous flight prior to the accident) in which reportedly noticed a high vibration level of the right engine with warning alarm in flight, as it was recorded by aircraft PIC in the logbook. Elimination of the defect was carried out by vibration sensor replacement. After sensor replacement, indications of the right engine vibration level were not reliable in comparison with the vibration of the left engine that could be the result of improper installation of the sensor or defect of replacing sensor.

On 10 August, 2014 - flight from Isfahan to Tehran (1 landing),

On 10 August, 2014 - the flight accident happened during departure from Tehran to Tabas.

1.6.2 Instrument Panel Displays

The AN-140-100 instrument panel provides indication and warning information to the flight crew as shown in figure 5.
Figure 4 shows some indicators of the AN-140-100(EP-GPA) after the accident.

Figure 4. AN-140-100 control panel after accident.

Figure 5. AN-140-100 instrument panel.

1.6.3 Engines and propellers

The AN-140-100 airplane was powered by two TV3-117BMA-CBM1 turboprop engines**.**

Basic specification of the engine is as follows:

Maximum emergency power condition: (SLS, ISA +22°C)	
Propeller shaft horse-power, shp (kW)	2800 (2059)
Emergency power condition: (H=5170 m, H_{fl}=0.3, ISA +10°C)	
Propeller shaft horse-power, shp(kW)	2130 (1567)
Take-off power condition: (SLS, ISA +15°C)	
Propeller shaft horse-power, shp (kW)	2500 (1838)
Specific fuel consumption, kg/ehp.•h (kg/eqkW•h)	0.199 (0.270)
Maximum cruise power condition: (H=6000 m; M_{fl}=0,5; ISA)	
Propeller shaft horse-power, shp (kW)	1750 (1287)
Specific fuel consumption, kg/ehp•h (kg/eqkW•h)	0.188 (0.256)

Table 2: AN-140-100 Basic specification

Figure 6 and 7 show the ТВ3-117ВМА-СБМ engine and related electronic control diagram. The SAY-2000 engine electronic control system used in these engines which control engine operation through the RED-2000 unit.
Engines and propeller information are as follows:
Engine No.2 S/N: 3873171200034,
Date of manufacture: 29 October, 2004
TSN: 1555 flight hours
CSN: 1221 cycle
TBO: 3000 hours
CBO: 2550 cycle
Engine No.1 S/N3873171000031
Date of manufacture: 30 June, 2008
TSN: 1559 flight hours
CSN: 1311 cycle
TBO: 3000 hours
CBO: 2550 cycle
Propeller Type: AB-140
APU S/N: 2253092700067

RED-2000

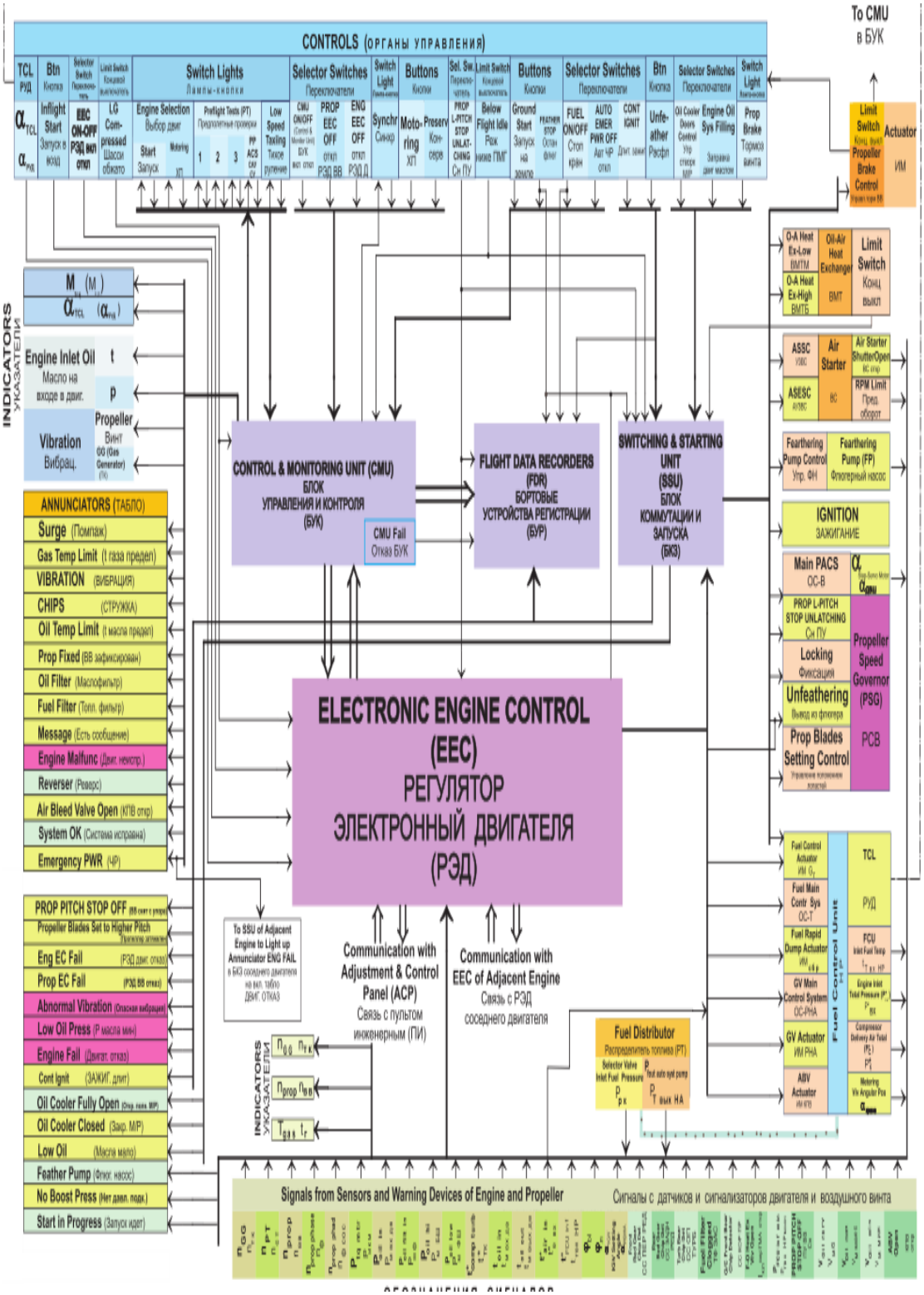
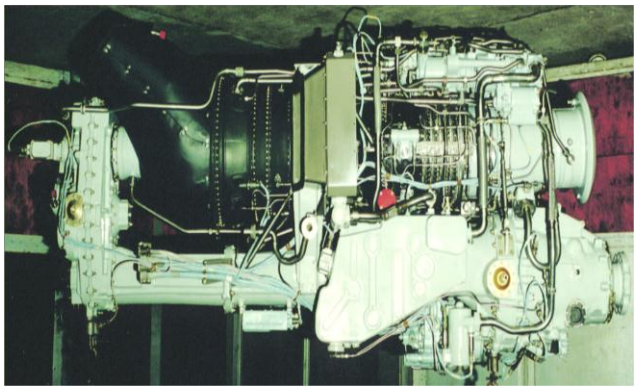


Figure 6: ТВ3-117ВМА-СБМ engine and related electronic control diagram.



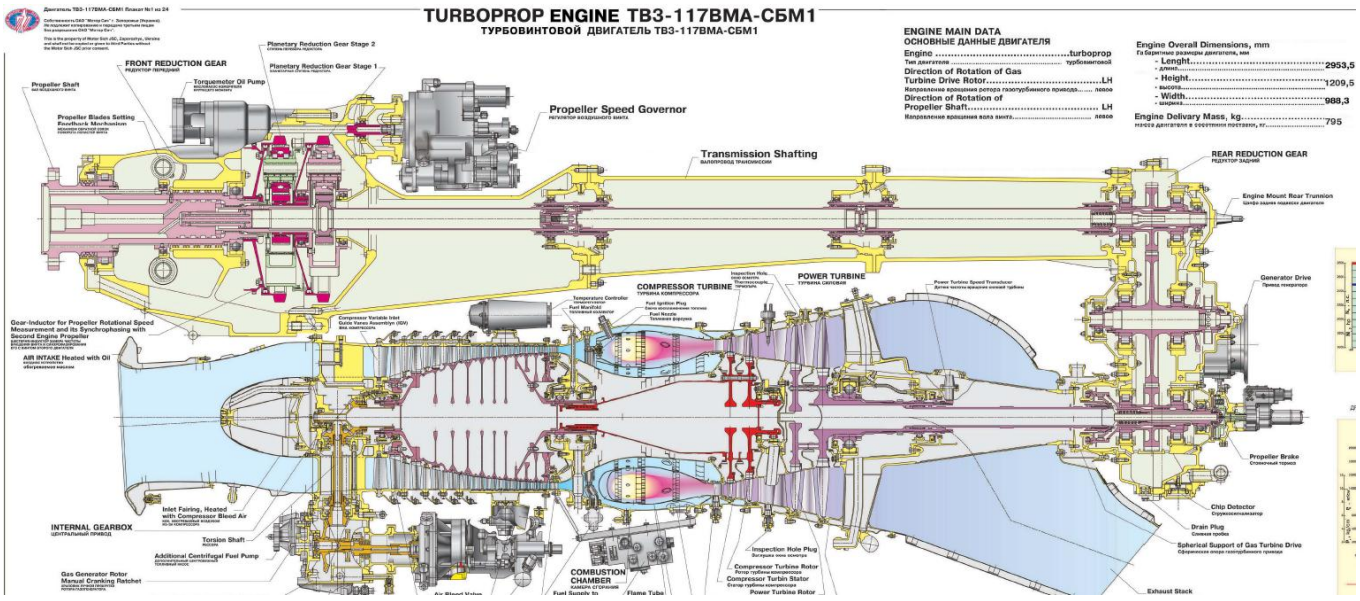


Figure 7: TB3-117BMA-CБM engine diagram.

1.7 Meteorological Information

Meteorological Information form this flight is as follows:
METAR (OIII) – 10 August, 2014. UTC 04:00. Surface wind direction 070º; wind speed 6 knots, CAVOK conditions (visibility over 10km, clouds over 1500m, no hazardous weather formations), temperature +34ºC, dew point -3ºC, pressure QNH 1013 HPa (pressure QNH 29.92 inches).

METAR (OIII) – 10 August, 2014. UTC 04:30. Surface wind direction 060º; wind speed 10 knots, CAVOK conditions (visibility over 10km, clouds over 1500m, no hazardous weather formations), temperature +35ºC, dew point -2ºC, pressure QNH 1013 HPa (pressure QNH 29.92 inches).

METAR (OIII) – 10 August, 2014. UTC 05:00. Surface wind direction 070º; wind speed 8 knots, visibility 10 km or more , few clouds 1200m, scattered cloud 3000 m, temperature +36ºC, dew point -2ºC, pressure QNH 1013 HPa (pressure QNH 29.92 inches).

1.8 Aids to Navigation

There were no problems with any navigational aids at the time of departure from runway 29L.

1.9 Communications

Communication with ATS service was conducted by the copilot by means of the aircraft Орлан-85СТ VHF-radio stations. All radio communication facilities at the moment of the aircraft accident 10.08.2014 were functional and provided stable two-way communication between the pilots and the aerodrome control tower of the Mehrabad International Airport, Teheran.
There were no failures of radio communications equipment at the time period preceding the accident. There was no any known difficulty with communications.

1.10 Aerodrome Information

The Mehrabad International Airport (THR) is located just few miles west of Tehran city and operated by the Iran Airport Company. THR is served by 2 paved runways and the airport elevation is 1208 m (ASL). Two parallel runways are oriented east/west. At the time of the accident, runway in use was 29L and runway 29R was not operational which was used for taxi and back track.

The Mehrabad International Airport has not yet obtained Aerodrome Certificate from the CAO.IRI. The Airport also has not yet completely established and implements a Safety Management System (SMS).

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder:

The AN-140-100 airplane is equipped with the Опал-Б-type aircraft voice recorder (CVR) mounted in the airplane's tail section. The general characteristics of the CVR are as follows:

Name	Type	Manufacturer	Part No.	Serial No.	Recording duration
Cockpit Voice Recorder (CVR)	Magnetic tape	NIIEMP	OPAL-B	39	120 minutes

The Опал-Б aircraft voice recorder records into five independent channels the following data:

1) Transmittable and receivable by both pilots through intercom and exterior communication lines;
2) From microphones of the PIC and copilots with no " INT" or "RADIO" button pushed;
3) Transmitted by the cabin attendant through the interphone & public address communication channel (INT/PA);
4) From the cockpit open microphone;

5) Coded time for synchronization of the recorded voice information with the data flight parameters recorded by БУР-92А.

An examination of the CVR by the CAO.IRI showed evidence of minor structural and/or heat damage. The "Magnetic Tape Recorder" of the CVR was removed from the damaged CVR set and was installed on the related player. Finally audio information was extracted without difficulty. The extracted 2-hour, 5-minute, 33 seconds recording consisted of 5 channels of useable audio information.

A CVR transcript was prepared starting at 04:32:47 and is provided in Appendix B of this report.

1.11.2 Flight Data Recorder (FDR)

The AN-140-100 airplane is equipped with the БУР-92А-type flight data recorder (FDR). The БУР-92А FDR records 25 hours of 137 analog parameters (including 20 parameters that characterize the motion of the aircraft, 92 parameters for the power plant, 16 parameters for the aircraft control system and 9 parameters that characterize the condition of the aircraft systems); and 716 single commands (including 20 on engine and propeller operation, 280 discrete signal for left RED, 280 discrete signals for right RED and 183 on the various aircraft systems). This data covering the latest 25 hours of flight is recorded into an airborne protected solid-state storage device.

The AN-140-100, EP-GPA airplane S/N 90-05 was equipped with the ЗБНТ-24МТ-02 S/N 645321028 storage device. As it was established 13.08.2014, during disassembly of the FDR protected memory module by the experts of “PAO NTK Elektronprilad”, FDR experienced evidence of thermal damage but no data carriers were damaged. Using the БПИ-4Т (S/N 645191146) unit, data from the ЗБНТ storage was read and processed by means of the related software. The ЗБНТ-24МТ-02 storage unit data were read in full (last 25 hours) including the last flight information. For the БУР-92А records analysis the investigation team used several software (including Monster FDR Analysis program and AUwin32.)

For this investigation, parameters were verified. The values recorded for some Parameters were brought out and a table of events extracted from FDR, is provided in Appendix C of this report.

1.12 Wreckage and impact information

The aircraft wreckage was spread at "SAMT INDUSTRIAL COMPLEX" nearby Mehrabad International Airport (THR) at the crash site: 35°42’21’’ N latitude and 51°42’21’’ E longitude. The airplane was completely destroyed by the impact forces and post-crash fire. Tail section was detached from airplane structure and thrown off the" Boulevard-e-Sharaqi-e-Azadi." Figure 8-15 show wreckage of the airplane.

By the results of the crash site inspection, it was concluded that the initial collision with the ground was by the right wing with a significant right bank. Also the kind of damages of trees is indicating significant right bank. Right outer wing was not found on the crash site. At the crash site, due to the fuel spill was surface fire (there are burn marks on the ground). Left and right engines were detached from attaching points and located under the center wing. Crew cabin burnt. The central part of the fuselage burnt out as a result of ground fire. Aft fuselage as well as vertical and horizontal stabilizers were seriously damaged. Nose landing gear leg and main landing gears were in an extended condition (were not retracted). Flap position was about 10 degrees and an APU ramp in open position.

1.12.1 Wreckage of the engines

According to the inspection of the engines at the place of aircraft crash the following was revealed:

There are multiple damages on the engines from the collision with obstacles and the ground. There are traces of surface fire impact on the engine structure. The left engine propeller blades damage suggests that the engine was in operation until collision with the ground.

In order to provide for rescue operations and firefighting after aircraft crash, the engines with other structural members of the aircraft were shifted and were not set to their initial positions during visual inspection.

Concerning the left engine(S/N 3873171000031):

The gas generator, transmission and other main structural elements of the left engine had not been separated and remained in their places, but were damaged in many places due to the aircraft crash.

All the units and vendor items were in their designed places except for ВТС-СБМ1 air starter which had separated along turbine casing but remained attached to the pipeline;

Traces of extensive fire on the engine were not revealed, but casing of the ДЦН-104 pump which is provided with a flange for attachment of fuel supply pipe was burnt completely (is located on the accessory drive gearbox if looking forward).

Propeller blades were burnt, partially cut or broken; one blade was broken at the blade shank, located separately from the propeller and was not burnt.

The HP-2000 FCU control lever was set to position ≥ 105°, while the shutdown lever was set to the 'SHUTDOWN' position; tie rod of the shutdown lever was deformed during the crash, which probably resulted in shifting of the 'SHUTDOWN' position during a crash;

Concerning the right engine(S/N 3873171200034):

The left engine was damaged to a larger extent and has traces of extensive fire in the area of accessory drive gearbox and front support casing; almost all large sized vendor items are shifted from their mounting points;

The transmission and exhaust unit are separated from the gas generator along the rear joint of the free turbine casing and exhaust unit;

The shafting and front reduction gear are damaged to larger extent; in this case, there were not revealed the signs of deterioration of the shafts and gears with projection outwards through the transmission casings, the joint of shafting and rear reduction gear is deteriorated, the tie rods attaching the gas generator to the transmission held the front reduction gear in its attachment point relative to the suspension plane;

The air intake was damaged, but it was located in its attachment point;

burnt piece of the oil pump block was revealed, which testifies to the fact that the accessory drive gearbox was in the fire zone; the gears except for the gears of the HP-2000 FCU and oil pump block drives were not found;

The HP-2000, series 68, S/N 07704368302, FCU was separated from the accessory drive gearbox, its flange has attachment clamp, torsion shaft is bent but not shared, the HP-2000 FCU control lever is set to position ≥ 105°, while

the shutdown lever was set to the 'SHUTDOWN' position and both levers are broken;

The front support casing is extensively damaged during the fire. The suspension ring of the gas generator and VIGV control system with the DBCKT-650 unit is attached only to the mating parts of the engine design, which were not burnt during a fire;

The compressor is heavily damaged due to crash, the signs of deterioration of the rotating parts and their projection outwards the casing were not revealed; viewable rotor blades of stages 1, 7 and 8 are not damaged by the entry of foreign object during engine operation (stage 1 rotor blades are bent in the direction of the rotor sense of rotation, which is the result of an impact during a crash);

A portion of the combustion chamber casing is broken away with a flange used to bleed air for the ACS (is located on the aircraft mating pipe), external shape of the fracture is inherent to the static deterioration impact during a crash, pipes used to supply air for the engine needs are partially separated;

The signs of deterioration of the rotating parts and their projection outwards the casing on the compressor turbine and free turbine were not revealed, free turbine rotor blades are not damaged from the entry of foreign matter while the rotor partial seizure is evident;

The air-oil cooler attachment bracket and casings of the combustion chamber and turbines on the right side if looking forward have light brown trace, presumably from the products of burning of the casings in area of the accessory drive gearbox;

The air intake is damaged extensively during the crash and is located outside the engine; the oil tank is damaged extensively and is located at its attachment point on the shafting;

The propeller blades are burnt and partially broken; two blades are located outside the propeller and are not burnt. The propeller blades position recorded on the BUR-92A, also the propeller blades position, measure with a special tool directly on the propeller hub, which indicates the propeller blades were feathered at 84° to 85°. The engine was exposed to ground fire (the accessory gearbox and part of the compressor were burnt out).

Figure 8. AN-140-100 wreckage

Figure 9. AN-140-100 wreckage-engine

Figure 10. AN-140-100 Direction of impact

Figure 11. AN-140-100 Direction of Impact and rescue operation

Figure 12. AN-140-100 Impact point (rear view)

Figure 13. AN-140-100 Wreckage of tail section

Figure 14. AN-140-100 Wreckage–landing gear

Figure 15. AN-140-100 Wreckage –propeller

1.13 Medical and Pathological Information

1.13.1 Fatalities

The total fatalities of accident raised to 40 people.

1.13.2 Injuries and the cause of death

The medico-legal investigations were conducted by the team of the Tehran Legal Medicine Institute and following full autopsy of all bodies and human remains with deontological examination; tissue (muscle bone and fluids), sampling for DNA and toxicological investigations.

The medico-legal investigation described that the cause of death was determined to be multiple organ dysfunction due to severe burning and multiple traumatic injuries and the manner of death to be an accident and passengers were seriously injured and transferred to hospitals after the accident for treatment and survived.

Injuries included a skull fracture, multiple traumatic brain injuries, cervical, spine fracture and fractured ribs, upper and lower extremities. As a result of the investigation the causes of death for the 40 identified victims have been attributed to multiple injuries and mutilations.

1.13.3 Survivors

Overall 8 passengers, who suffered from serious injuries, and treated at a hospital in Tehran, survived.

1.13.4 Flight Crew Toxicological Testing

The toxicological analyses were restricted to the captain and copilot. Body fluids and tissues medical examination collected at the autopsy were negative for both drugs and alcohol.

1.14 Fire

No evidence or witness statement indicated an in-flight fire. The evidence indicated that all fire damage occurred after the airplane impacted the ground.

A fire erupted during post impact of the accident sequence and destroyed majority sections of the airplane before being suppressed by firefighting personnel.

Examination of the accident site and the airplane's fuel tanks showed no evidence of Pre-crash fire involving fuel. Skins were burned away, and the fire did penetrate internal insulation and mechanisms into the cabin. However, below the cabin floor in the cargo bay, severely burned.

The post-crash fire likely originated from the ignition of the fuel that was released or spilled from the aircraft fuel tanks when the aircraft impacted the ground.

Aircraft fuel was about 500 kg more than required fuel for the accident flight. After aircraft impact, remaining additional fuel aggravated the fire.

Figure 16: fire damage to the airplane.

Figure 17. Fire damage to the fuselage

Figure 18. Firefighting operation and Location where occupants were found.

1.15 Survival Aspects

The AN-140-100 was equipped with 2 pilot seats in cockpit, 52 passenger seats and 2 attendant seats.
The cabin has a single zone, which was incorporating service areas (galleys and Lavatories). Seat section contained 52 Economy-class seats in rows 1 to 13 were equipped with seat belts.

The airplane was equipped with 4 doors that also served as emergency exits. There were no other cabin exits. The 4 doors were paired along the airplane fuselage and numbered beginning at the front of the cabin and proceeding aft as 1 through 2 left (L) and 1 through 2 Right (R). A window in each door allowed observation outside the airplane.

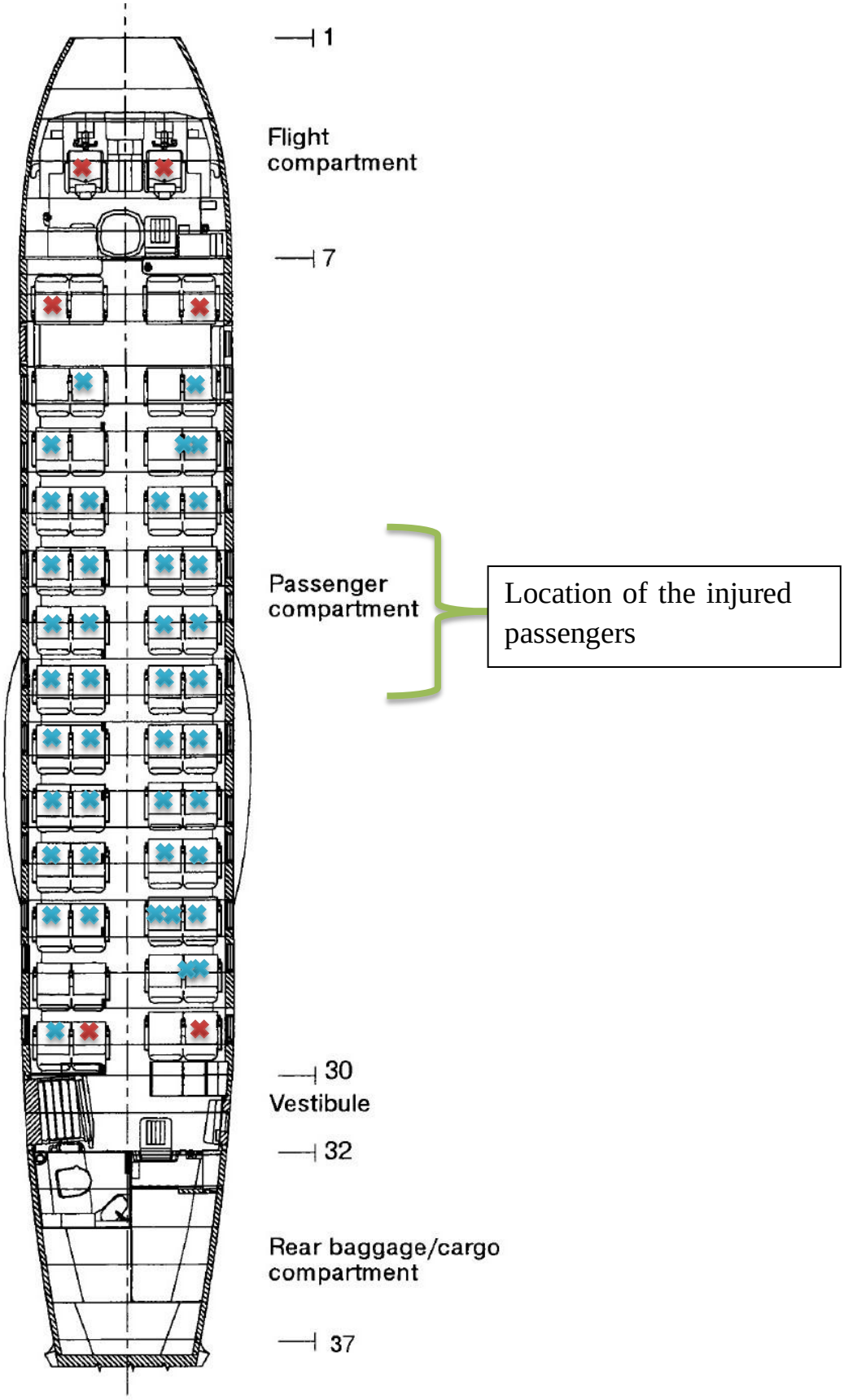


Figure 19: flight deck crew and passenger seats configuration

Passenger location Crew location

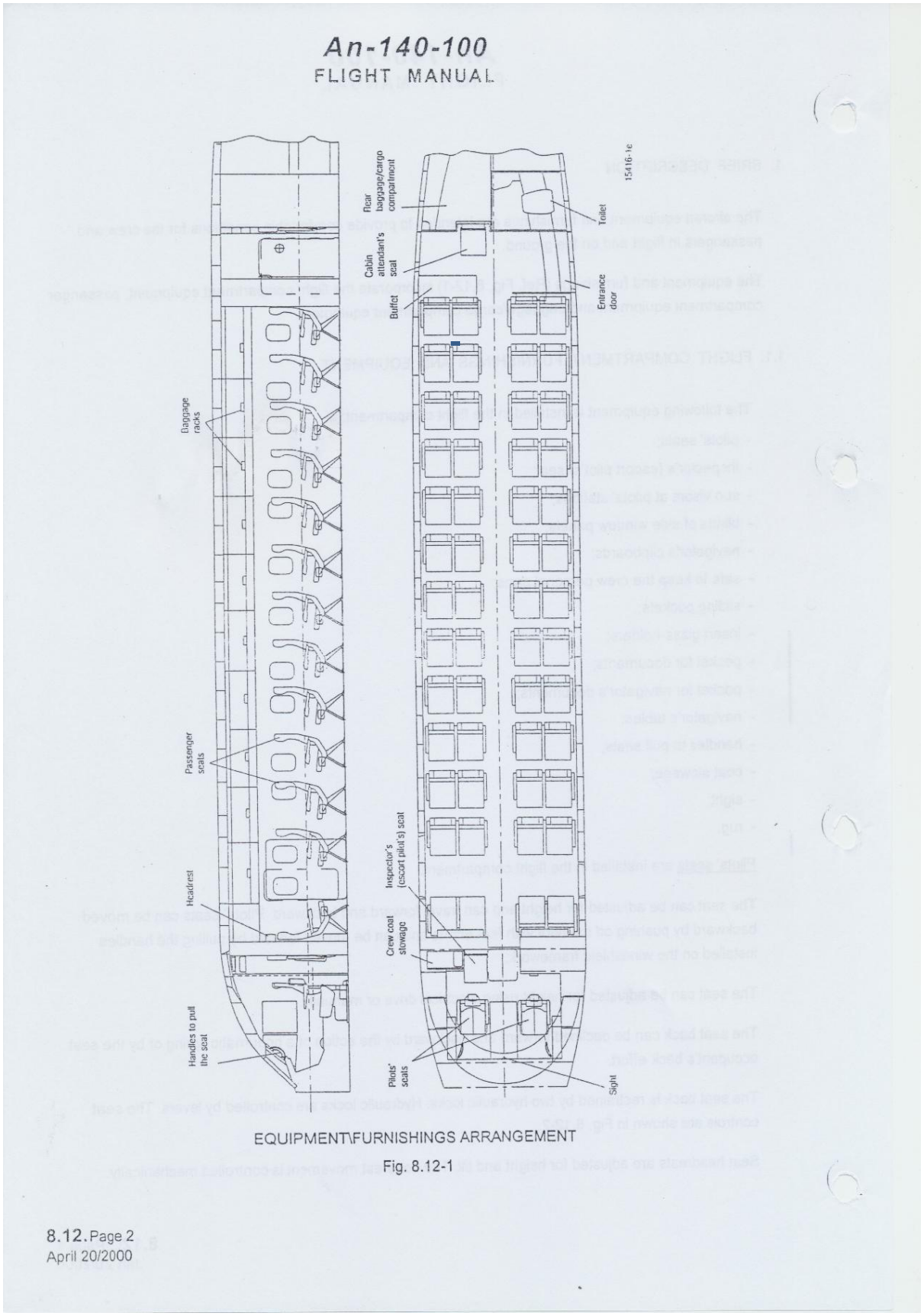


Figure 20. Diagram of cabin configuration.

1.15.1 Rescue activities

The rescue activities start at Mehrabad International Airport. ATS alarm was activated on time, but due to lack of enough coordination and wrong position reporting the airport rescue group reached on the accident site later than city firefighting.

The Mehrabad International Airport failed to timely, informed Tehran rescue organization regarding accident, according to airport emergency plan. City rescue and firefighting has begun at the base of voluntary reports and information by the people. The injuries rescued by themselves before firefighting man reach on the accident site.

1.15.2 Cabin Damage

The cabin was heavily damaged by the impact and post-crash fire. All of the seats were damaged and deteriorated by the impact and the post-crash fire. The fire appeared to be more severe on the left side than the forward right side of the area which received the severe fire damage.

1.16 Tests and Research

1.16.1 Engine Examinations:

After accident right hand engine baroscopic inspection carried out to identify any failure of internal parts. Then the engine disassembled completely. Turbine, compressor, combustion chamber and other engine module completely inspected for any internal or external defect which may cause engine failure before impact. Except for combustion chamber air-condition duct attachment there are not any other findings.

Disassembly of the R/H engine did not confirm the presence of foreign objects and fragments of destroying items in the air path of the engine compressor and turbine during its operation. Metallography examination at the IHSRC revealed that Particles and little metal pieces that were found in the engine air path are alluvial in nature and could get into the engine in consequence of collision with the ground firefighting and rescue operations and further transportation. There was no damage of the turbine blades in the form

of nicks. Compressor blades have damages caused by the compressor casing collapse in consequence of collision with the ground. Free turbine blades are not damaged. The bearings of the engine mounts are in normal condition. At the moment of collision with the ground the rotor was not run (there is no traces of the rotor turning at the moment of collision with the ground on the engine stator). However, at the outer diffuser of combustion chamber were detected tear of mounting flange of the aircraft air conditioning system bleed tube that required further research. The external shape of the fracture is inherent to the static deterioration impact during a crash. This portion of the Combustion chamber air-condition duct separates from combustion. This portion transferred to the KLIMOV Co. Laboratory in Russia for further test and investigation to identifying causes of the fracture. As a result of the necessary test some defect in welding joint appears," such as porous, poor penetration and alfinated layer," but investigation team revealed that the most probable cause of duct fracture was accident impact load and mention defect was not cause of duct fracture.

1.16.2 Component Examinations:

FCU and fuel distributor disassembled at AAIB department and completely inspected for any defect, no finding revealed.

1.16.3 Oil and Fuel Examination:

Oil and fuel sample laboratory examination carried out according to specification which no complaint revealed.

1.16.4 Airplane Performance Study:

The Accident investigation team also conducted performance study of An-140-100 aircraft for take-off climb performance after engine failure. In the study, FDR parameter, result of ANTONOV Co. calculations, and mathematical aircraft motion simulation used. The Study showed some safety issue regarding aircraft take-off, climb performance and also Aircraft Flight Manual weight and speed calculation ambiguity.

Sepahan Airline has not CAO.IRI approved SOP procedure for using flap 10°, but according to the decision of the PIC, take-off was performed with flaps set to 10°.

1.16.5 Simulator Evaluations:

The accident flight simulation carried out at HESA facility synthetic flight simulator in order to study the crew reaction after engine failure. In this study, time delay between engine failure and pilot reaction measured.
According to the study, which almost complies with the related airworthiness requirement identified that the PIC action time delay after engine failure was reasonable.

Also result of Mathematical modeling of aircraft motion and the related calculation performed by the aircraft designer (ANTONOV Co.) were used for aircraft take-off climb performance analysis.

1.16.6 Wake turbulence study:

The AAIB department investigation showed that AN-140-100 (EP-GPA) takes clear for take -off after one MD-88 aircraft. The AAIB department studied on weak turbulence probable effect of MD-88 aircraft on AN-140-100 aircraft in accident flight. Probable weak turbulence effect on engine flameout and aircraft take-off performance studied.

Time delays between two aircraft take-off and related FDR parameters as well as CVR transcribe were used. The study revealed that according to ICAO Doc 4444 there is not any requirement for take-off time delay between two non-heavy aircraft. Additionally, mathematically evaluation of the MD-88 aircraft weak turbulence carried out by the Russian Central Institute for Aerodynamics (which coordinated by IAC) revealed that weak turbulence of the preceding aircraft (MD-88) was damped and had no effect on AN-140-100 aircraft performance and engine operations.

1.17 Organizational and Management Information

1.17.1 Research on history of engine defect and malfunction :

Research on pervious AN-140 accident/incident carried out. This study revealed that SAY-2000 malfunction is the main cause of the several Accident/Incident. Aircraft reliability program as well as HESA and SAMT industrial complex; communication with engine designer and manufacturer showed that rate of engine failure is not bellow acceptable level. The study revealed that designer performed some modification and software

improvement to rectify the malfunction, especially for SAY-2000 malfunction, but the failure rate of these systems was not reduced to acceptable levels. At year of 2013 because of some engine defect (fuel pump plunger gap, compressor blade corrosion and erosion, turbine blade melting and….), the CAO.IRI start close monitoring of AN-140 operations and restricted AN-140 aircraft to fly to some specific climatic area (south of I.R IRAN).

Accident investigation team revealed some AMM section were not clear and there are some mistakes or ambiguity on its procedures. For example, chapter 073.00 page 20 charts was not correct (the SAY-2000 diagram) and procedure for engine vibration rectification was not complete (A process that did not exist at the time of the accident is referred). The mention diagram (SAY-2000 diagram) has been amended by the Antonov Co. after this accident.

1.17.2 Research on aircraft performance and aircraft loading procedure.

Study of aircraft performance and aircraft loading procedure showed that in pervious flight load calculations carried out by the Sepahan Airline without using the appropriate chart.

AFM confusing performance chart caused and resulted the pilots relying on performance calculation that, significantly overestimate the aircraft MTOM.

1.17.3 Mehrabad International Airport and rescue and firefighting operation.

The Mehrabad International Airport did not timely, informed Tehran rescue organization regarding accident, according to airport emergency plan. Research revealed that THR was not Performed his duty according to Emergency Response Plan. Rescue and firefighting activities were initiated on the base of voluntary information which was given by the witnesses. Firefighting & survival group started to rescue right after extinguishing the fire terminated.

2. Analysis

2.1 General

The flight crewmembers were properly certificated and qualified in accordance with CAO.IRI requirement.

The investigation team found no evidence that the flight crews' performance were affected by any behavioral or medical condition or by the use of alcohol or drugs.

The investigation found except right engine failure no evidence of any pre-impact structure, or system failures, including no indications of problems with the airplane's AFCS.

Aircraft Load was beyond weight limits and weather conditions at the time of the accident.

Air traffic controllers cleared flight # 5915 to the lineup area of runway 29L,and issued a clearance for the departure regarding succeeding MD80 aircraft which was take off about 2 minutes ahead of SPN5915 at a position and attitude that allowed for a normal departure from the runway.

The departure separation was applied in accordance with CAO.IRI procedures.

A NOTAM had been published indicating that the runway 29R was used as a parallel taxiway for airport traffic convenience , and the flight crew were aware of the outage and performed back track on RWY 29R to holding point RWY 29L.

The following analysis describes the accident sequence and examines the safety issues associated with the flight crew's performance and the operation of the airplane's systems during the departure.

2.2 Accident Sequence

The aircraft toke-off from The RWY 29L of Mehrabad Airport under normal weather conditions at the ambient air temperature ~+35°C with 10° flaps the airfield altitude 1208 m (ASL). Flight course was 286°, runway length – 4030 m. The aircraft was taking off with crosswind W=10 knot with wind heading ψ_W=60°.

The right engine of the aircraft failed during take-off run about 2 seconds before lift-off. After lift-off the aircraft deviated to the right from runway course, climbed around 40 m, stalled and crashed in the area of urban utility service communications (highway) at a distance of about 3000 m from runway threshold. The aircraft impact to the ground and broke into separate pieces. Impact and post-crash fire destroyed fuselage, the most part of the wing and passenger cabin.

2.3 Flight Crew Performance

2.3.1 Fatigue

The Accident Investigation team evaluated a number of criteria, including recent rest quality, circadian factors, and time awake to determine whether the flight crewmembers were experiencing fatigue at the time of the accident. There is no evidence that any of the pilots began their duty period without a pre-existing rest or fatigue.

2.3.2 Flight Crew Communication

The Pilot Flying (PF), and Pilot Non Flying (PNF), reported that they had normal crew interactions, call-outs, responses, and actions during the accident flight.

The CVR recordings also indicated that PIC about 4 second after right engine failure communicates to co-pilot regarding engine failure and 9 seconds after right engine failure emphasized co-pilot again. About 14 seconds after the engine failure copilot’s report to the ATS regarding engine failure.

2.3.3 Analysis of Crew Procedures

The following has been established based on the results of the analysis of the ОПАЛ-Б Cockpit Voice Recorder records and other related operational data:

1. No information about preflight preparation of the crew is available.
2. External information can be heard as the crew is briefed about take-off and landing conditions and meteorological conditions at the aerodrome of departure.

3. According to the analysis of data, the aircraft's actual take-off weight was 19866 kgf.
4. According to the decision of the pilot in command, take-off was performed with flaps set to 10°.
5. For the actual weight of 19866 kg according to table 4.2.3 of AFM, which generally used by the crew for calculation of V_R and V_2 the rotation speed will be 224 km/h, liftoff speed (V_{LOF}) will be 234 km/h, and V_2 will be 234 km/h.
6. Radio communications with ATS prior to engine starting and taxiing out was as per requirements.
7. In the course of preparation for departure, PIC corrects radio communications by the co-pilot.
8. Base on CVR communication between PIC and PNP, PIC's phrase uttered at 04:48:42 regarding the MD-88 aircraft which is taking off "(MD-88) just running now."It is so heavy same as ours. ""RUN RUN up to tomorrow". This utterance indirectly confirms that the crew knew that the take-off weight was excessive.(about 190 kgf)
   Nevertheless, the takeoff weight was exceeded the MTOW for flaps set to 10° by 2600 kgf (calculation was done by using the An-140-100 AFM charts, Section 7.1 and 7.2)
9. The right engine failure warning was not activated according to designer predetermined indication. (continuous Chime was not triggered) meanwhile PIC about 4 seconds after right engine failure communicated with co-pilot regarding engine failure and 9 seconds after right engine failure emphasized to co-pilot again.
10. After the right engine failure, the crew did not duplicate press on the right engine propeller feathering ENGINE OFF - FEATHER push button.
11. Co-pilot reported to the ATS regarding engine failure about 14 seconds after the engine failure.

2.4 Aircraft loading and weight limitations

Sepahan Airline used aircraft designer (ANTONOV Co.) procedures for calculation of weight, and C.G., and also completed the aircraft load sheet.

Weight and balance, manual completely describes the procedures. Aircraft empty weight extracted from the aircraft Log book. Investigation shows that empty weight has significantly more than original design weight. In this respect, empty weight approved by the designer. This gain empty weight led to the decreased aircraft performance capability, especially in hot and high condition and reduced performance margin.

The accident flight load sheet has some mistake and/or incorrect data, also there are difference between the weights of cargo in load sheet and computerized software of Sepahan airline (about 25 kgf). This mistake or incorrect data calculation has not significant effect on weight calculation.

Departure weight limits were selected by the dispatcher and accepted and endorsed in W&B sheet by the PIC. According to this calculation revealed that PIC knows overweight of about 190 kgf.

The calculation of V_{lof} as per the AFM charts for MTOW of 19.8 tons with $\delta_3=10°$ requires compliance with ground speed limitations of 250 kmph and using the operational envelope of the charts.

Considering these limitations the MTOW of the aircraft was 17200 kgf. Finally calculation shows 2600 kgf overweight.

2.5 Compliances with Aircraft design requirement

According to the "Type Certificate" which issued by the Interstate Aviation Committee Aviation Register (IAC AR) and Type Certificate which issued by the State Administration of Ukraine (Ukraviacia) the An-140 aircraft should meet the requirements of the certification basis (СБ-140) developed in accordance with Part-25 of Aviation Regulations (АЛ-25). According to AFM section 2.1 pages 1/2, Part-25 of Aviation Regulations (АЛ-25) is made according to USA Airworthiness requirement (FAR-25) including amendment 1 to 73.

During investigation some issues regarding compliance with Aircraft certification basis, especially АЛ-25 revealed as follows.

- According to АЛ-25 point 25.107(e)(1), V_R may not be less than the speed (determined in accordance with § 25.111(c)(2)) that allows reaching V2 before reaching a height of 10.7 m above the take-off surface;
- According to АЛ-25 point 25.111(c)(2) The airplane must reach V_2 before it is 10.7 m above the take-off surface and must continue at a speed

as close as practical to, but not less than V_2, until it is 120 m above the take-off surface;

- According to АЛ-25 point § 25.121(a) Take-off; landing gear extended. In the critical take-off configuration existing along the flight path (between the points at which the airplane reaches V_{LOF} and at which the landing gear is fully retracted) and in the configuration used in § 25.111 but without ground effect, the steady gradient of climb must be positive for two engine airplanes,
- According to АЛ-25 point § 25.121(b) Take-off; landing gear retracted. In the take-off configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in § 25.111 but without ground effect, the steady gradient of climb may not be less than 2.4 percent for two engine airplanes.

According to FDR data analyses crew rotate the aircraft at a speed of 219 km/h instead of 224 km/h which derived from AFM section 4 table 4.2.3. In the other words PIC rotate aircraft about 5km/h before reaching V_R.

Angle of attack of the aircraft after liftoff was more than AFM recommendations (4-7 degree). Aircraft speed after liftoff not only never reached V_2, it even also continually reduced.

To indicate the effect of aircraft high pitch angle after take-off and rotation of aircraft before reaching V_R, mathematical modeling of aircraft flight and related calculations result carried out by the Aircraft Designer (ANTONOV Co.) used.

The result of ANTONOV Co. calculation which also approved by the Ivchenko-Progress SE and MOTOR SICH JSC has written in technical report dated on October 25, 2015.(Appendix D) according to the report even if crew performs take-off as recommended in AFM, the mentioned airworthiness requirement of АЛ-25 never meet. Suppose that aircraft rotate at a speed of 224 km/h and pitch Angle selection and other action of crew comply with AFM, according to table 5.3 and Fig. 5.1 and 5.2 of mention Technical report, aircraft at a height of about 40 m above the take-off surface (instead of 10.7 m) ; reached V_2.

Some assumption which used for deriving such mathematical model and report also were less restrictive than the requirement of АЛ-25 and actual accident condition, especially for initiation of pilot first and consequent action time delay following recognition of engine failure. It is important that because of the SAY-2000 failure, related engine warning (warning light and continuous

chime) as actuated with about 14 seconds delay. Also field elevation considered 1150 m instead of 1208 m actual THR elevation.

2.6 MTOM calculation according to the Aircraft Flight Manual(AFM)

AFM section 4.2 describes procedure for take-off. According to this procedure, table 4.2.3 (take-off with flaps at 10°) must use for calculation of required take-off speeds (V_R, V2, V3 and V_4). By using table 4.2.3 of the AFM for the accident flight with a MTOM of the 19866 kgf VR and V_2 respectively, will be equal to 224 km/h and 234km/h. These speed values also confirmed by the ANTONOV Co technical reports dated on 25 October, 2015.

The maximum allowable take-off weight of the aircraft can be taken from AFM chapter 7. By using a chart of Fig. 7.2-11 of the AFM, maximum allowable take-off weight for the accident flight (ambient temperature of 35 degrees) will be about 19650 kgf. According to this chart, the accident flight has about 190 kgf over weight. After accident other An-140 pilot of Sepahan Airline and also aircraft designer (ANTONOV Co.) used this chart and derive the maximum allowable take-off weight. As mention before, at accident flight aircraft speeds never reached V_2. This means that something is wrong. Investigation in this mater revealed other AFM issues.

Using chart of the AFM Fig.7.2-1B as shown in Figure 21 and 22 below, revealed that V_R must be at least 231 km/h, but because of even weight of 19500 kgf which by designer considered allowable is outside of graph limits. According to section 7.1.1 of the AFM which state the parameters should not be determined outside the limits stated in the graphs. Therefore, this weight will not be allowable. By using this chart following Information derived:

- Maximum allowable take-off weight of aircraft must not be more than 18850 kgf
- For this weight (18850 kgf) V_R must be 224 km/h.

Additionally, if we used a chart of Fig. 7.2.1r of the AFM for accident flight the weight is outside of graph limits. By using this graph the maximum allowable weight and V_2 respectively, will be 18866 kgf and 226 km/h.

Furthermore, if we use the chart of Fig. 7.2.8 of the AFM for compliance with *ground speed limitations* of 250 kmph, the MTOW of the aircraft will be 17200 kgf. (Figure 23: MTOM versus ground speed Limitation) This calculation shows 2600 kgf aircraft overweight.

Therefore, the AFM confusing performance chart caused the pilots relying on performance calculation that, significantly overestimate the aircraft MTOM for the accident flight.

According to the agreement between the "SAMAN" ground handling, service provider and the "Sepahan" airline; the adjustment of load sheet was the responsibility of the Sepahan airline.

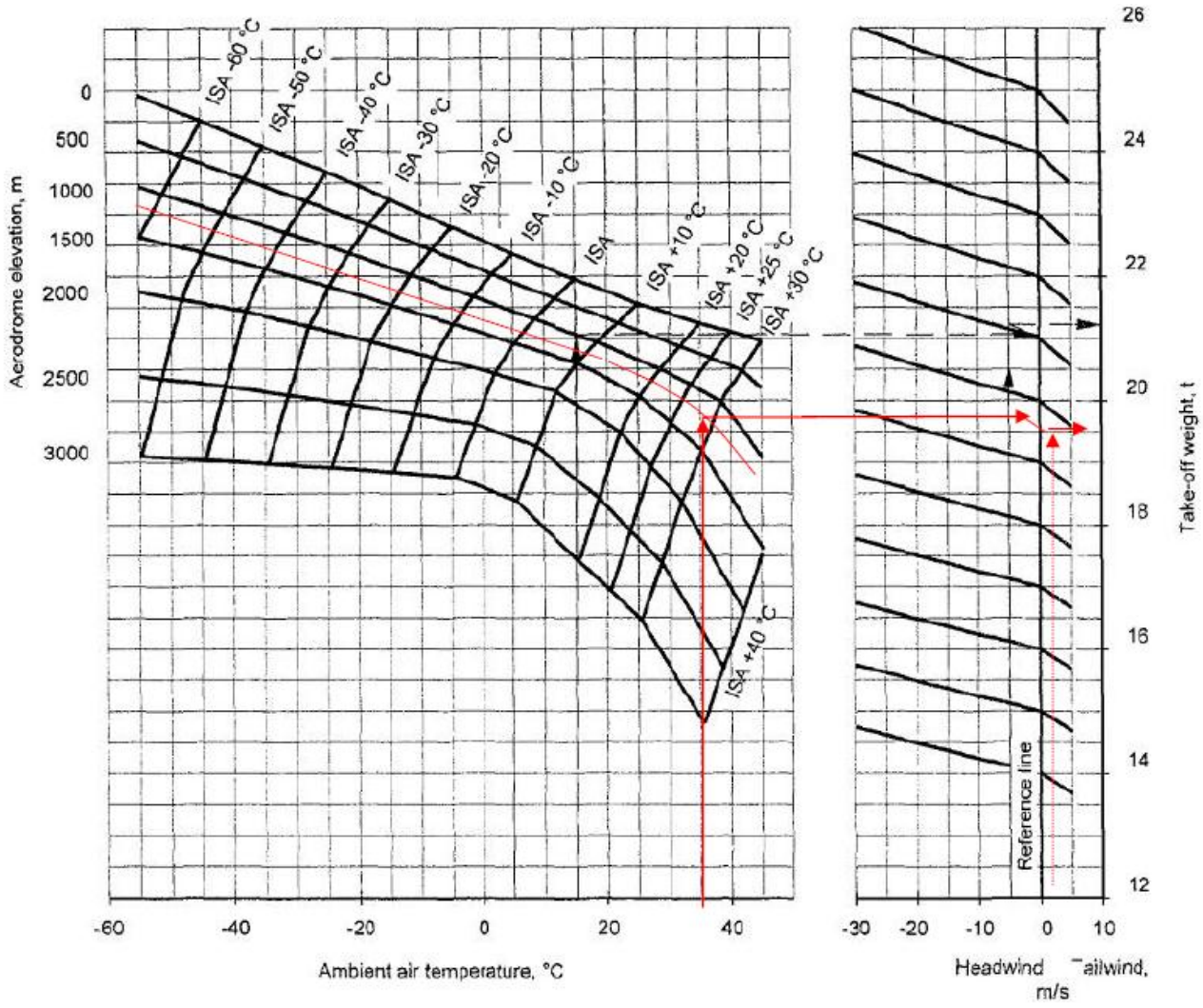
The accident flight load sheet had some mistakes and/or incorrect data. Also, there have been difference between the weights of cargo in load sheet and computerized software of Sepahan airline (about 25 kgf), but this mistake or incorrect data calculation did not significant effect on weight calculation.

Sepahan Airline used manufacturer weight and balance manual for completing the load sheet and calculating aircraft weight, which is not in compliance with CAO.IRI operational requirements for load sheet and passenger weight.

There are other findings regarding AFM charts as follow:

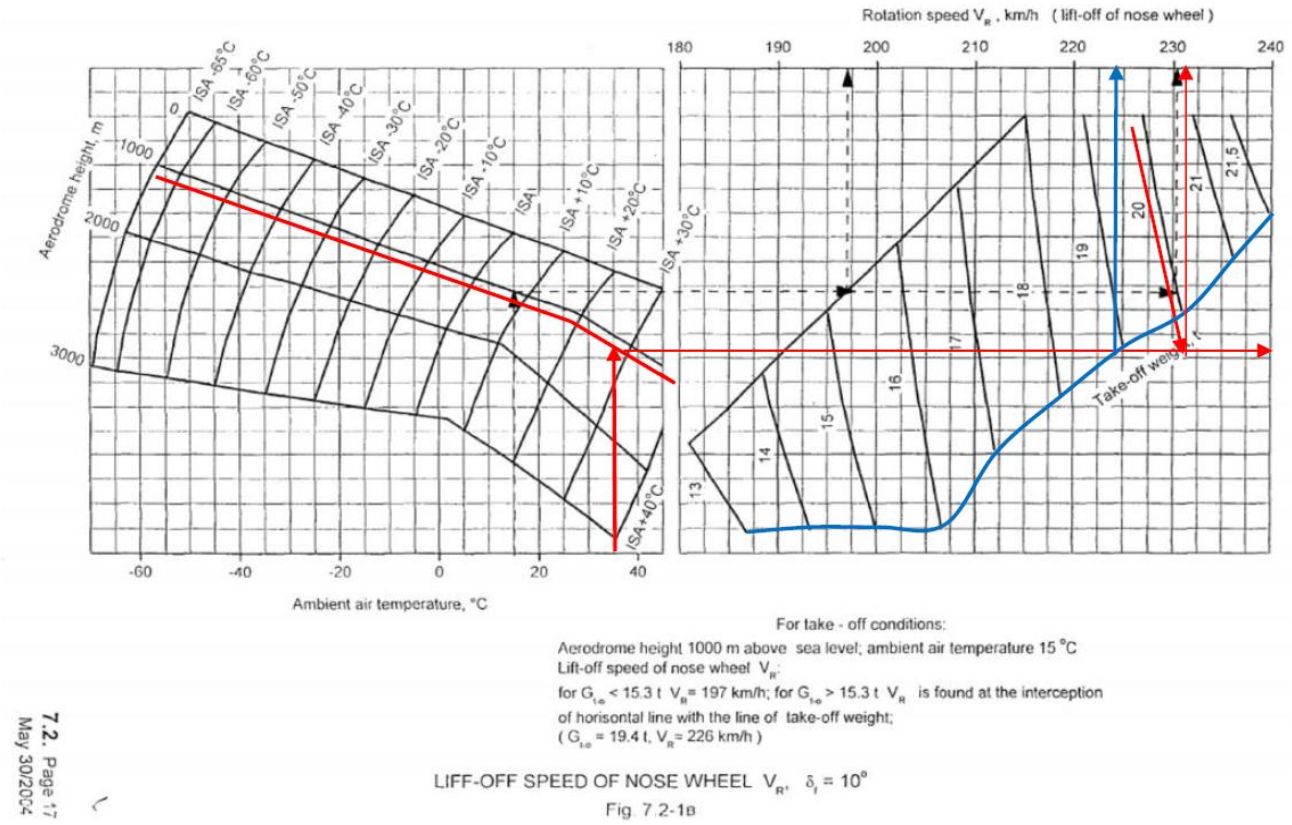
- There aren’t any charts or explanation regarding to maximum tire brake energy, limiting weight and tire speed limitation weight.
- The procedure of take-off with one engine inoperative is not clear, for retraction of landing gears after take-off. (V_2 speed achievement mentions before the retraction of landing gear which was not attainable at the accident flight)

One engine is operating at the contingency rating.
The propeller of the failed engine is feathered.
Take-off configuration of the aircraft, δ_f =10°.
Height over the lift-off point is 120 m.
Gross climb gradient is 2.4%
Flight speed - V_2 (ref. Fig. 7.2-1r).
Air bleeding from the engine to the air conditioning system is accounted for.
Air bleeding to the wing anti-icing system is cut-off.
The landing gear is retracted.



MAXIMUM ALLOWABLE TAKE-OFF WEIGHT AT THE THIRD SEGMENT OF TAKE-OFF PATH
Fig. 7.2-11

Figure 21: MTOM calculation chart



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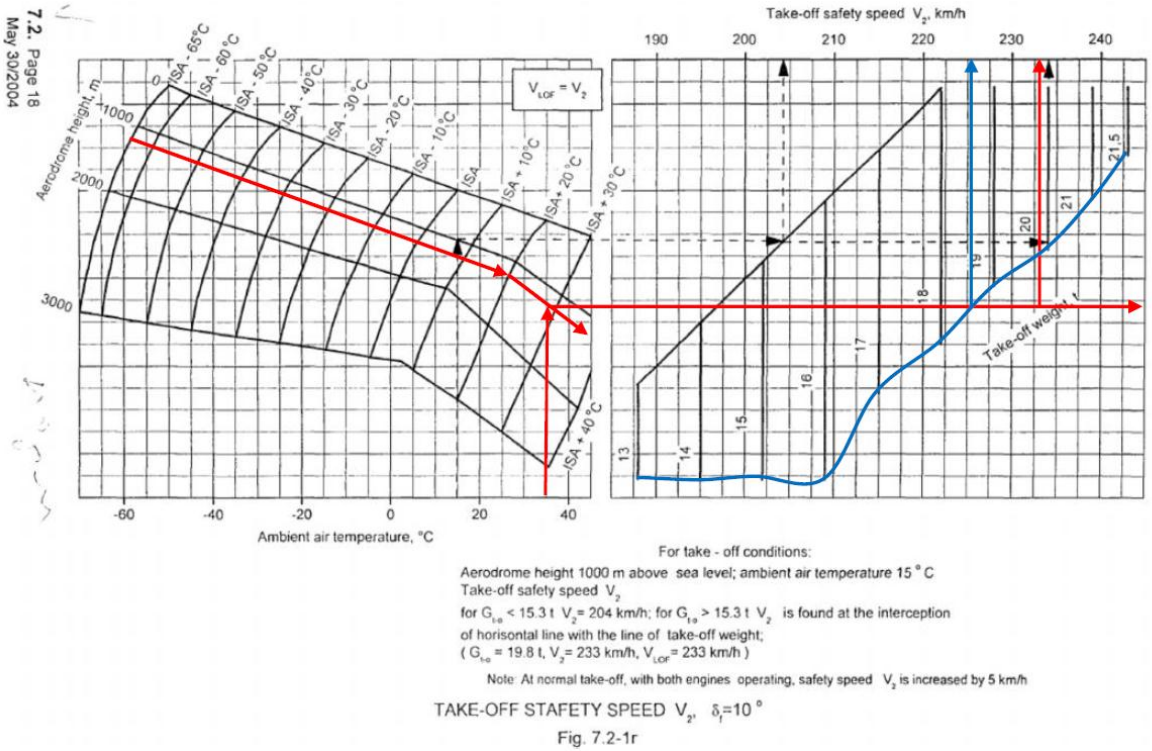

7.2. Page 18
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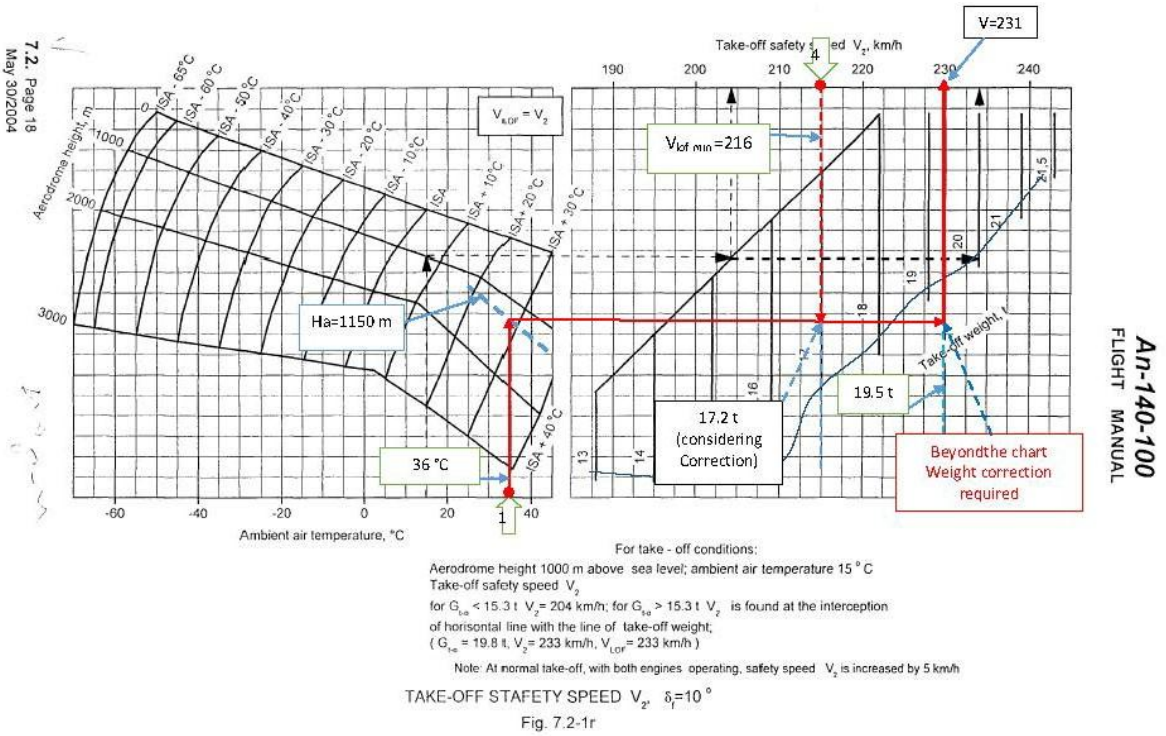
Figure 22: MTOM and V_R and V_2 Limitation

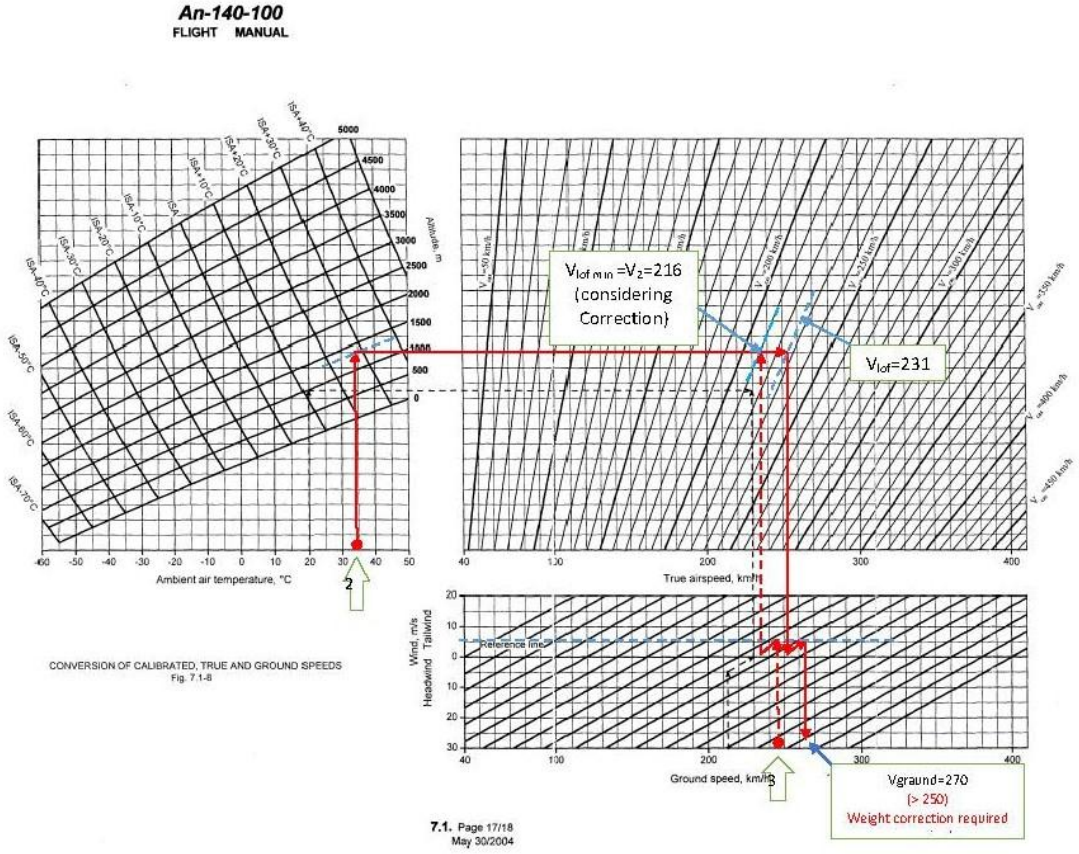


For take - off conditions:
Aerodrome height 1000 m above sea level; ambient air temperature 15 ° C
Take-off safety speed V_2
for $G_{t.o.} < 15.3$ t $V_2 = 204$ km/h; for $G_{t.o.} > 15.3$ t V_2 is found at the interception
of horisontal line with the line of take-off weight;
($G_{t.o.} = 19.8$ t, $V_2 = 233$ km/h, $V_{LOF} = 233$ km/h)

Note: At normal take-off, with both engines operating, safety speed V_2 is increased by 5 km/h

TAKE-OFF STAFETY SPEED V_2, δ_f=10 °

Fig. 7.2-1r



CONVERSION OF CALIBRATED, TRUE AND GROUND SPEEDS
Fig. 7.1-8

Figure 23: MTOM versus ground speed Limitation

2.7 Power plant Operability Analysis

2.7.1 Left Hand Engine (S/N 3873171000031)

There were no comments on the operation of the left hand engine at take-off till the end of the flight, except at 04:48:25 just after slow taxi switch off, which SPR1 did not increased to nominated speed(SPR1 =77). After throttle position change by the PIC, all engine parameters stabilized at normal value.

After the right engine power decreased (rotational speed of the engine compressor turbine rotor dropped by more than 7 %), the L/H engine was automatically set at contingency power, and its parameters increased accordingly. The left engine operated normally at contingency power till the end of the FDR record.

2.7.2 Auxiliary Power Unit (APU)

The APU operated at take-off till the end of the flight with no comments.

2.7.3 Right Hand Engine (Engine 2 S/N: 3873171200034)

There were no comments on operation of the right hand engine during starting, taxiing, acceleration to take-off power and aircraft run to speed of about 215 km/h.

The aircraft take-off run was performed with the engines operating at take-off power; hereafter, the following events occurred:

- At 4:51:06 R044, R046, R047 and R048 maintenance signals about engine life recorded in FDR. Further investigation showed that these signals were false and in this situation RED-2000 should not send such a signal to the FDR (related switch was not pressed on)
- At the same time, communication to BUK signal (R128), combustion chamber flame-out signal (R259) recorded and turbine exhaust gas temperature (TGZ2), compressor outlet temperature (GGP2), began to decrease.
- Simultaneously "Shutdown electromagnet control failure signal" that are characteristic in the case of the engine shutdown electromagnet activation in the HP-2000 unit recorded. Such signals are inadmissible on the running engine under normal operation of the RED-2000 unit.

- The "R/H engine data exchange channel - FAIL" signal indicating functioning failure of the ENGINE 2 RED-2000 data transfer system;
- At 4:51:07 gas generator rotational speed (NGG2), free turbine speed (NFT2), began to decrease.
- When the Engine No.2 operation parameters started to drop, increase of the propeller blade pitches has begun to a position of φblade = 46°, which is confirmed by the lack of free turbine rotor spin-up. The maximum value of the reached reversal thrust with partial wind milling as related to the feathered propeller made up to145 kgf. After About 17 seconds from the moment of the Engine No. 2 shutdown the propeller was fully feathered by a command of the RED-2000 unit.
- Within 4:51:08 to 4:51:23 the right engine control loop parameters are not recorded on the FDR.
- At 4:51:10 right engine RED-2000 failure recorded(FRT2)
- Detail of the engine recorded parameters on the FDR, are provided in the appendix C to this Report.
- During the time period from 4:51:08 to 4:51:23, there was not correct representation of some analog and binary parameters received from the RED-2000, in addition , various unstable signals were recorded;
- Performance of the RED-2000 unit from 4:51:06 to 4:51:23 did not comply with the main requirements of the САУ-2000 unit Requirements Specifications as follows:

    - Non-response of САУ-2000 unit with output of standard control commands;
    - Non-availability of timely information output about САУ-2000 unit failure;
    - Non-availability of timely information about engine failure;
    - Non-execution of changeover to redundant hydraulic-mechanical control system with the main electronic system failed or automatic engine shutdown with the propeller feathered;
    - Presence of signals being characteristic in case of the engine shutdown electromagnetic valve actuated.
    - Parameters of propeller zero position φblade and VGVs position recorded by the БУР–92А FDR at a time from 4:51:09 to 4:51:23 are unreliable (set to zero by RED-2000) since: the propeller could not be

at an angle below the intermediate stop (no "propeller unlatched" sign); zero position for φblade and VGV is intermediate and cannot be maintained physically for such long time.

- At 4:51:23 (after about 17 seconds from the moment of engine unprompted shutdown) registration of false signals outputted by the RED-2000 unit was stopped (see Figure 7.3), and "engine failure" signal was outputted; propeller feathering command was issued; and correct registration of engine operating parameters was continued.

– At 4:51:22 right engine failure signal recorded. It was available till the end of recording,

– No standard commands for the Engine No. 2 shutdown, either automatic from the САУ-2000 unit or compulsory from the cockpit, have been recorded until at 4:51:23 which commands for automatic engine shutdown with feathering of the propeller blades recorded.
– From 4:51:08 fuel temperature raised from 52° to 74.5° of centigrade.

Analysis of the aforementioned condition and related data revealed that:

– Engine shutdown occurred immediately in the period of time when the БУР 92А FDR began to register a non-standard signals and changes of parameters being inconsistent with the principles of physics, which is an evidence of the failure existence in the functioning of the RED-2000 unit systems.
– The reason for the engine No.2 shutdown was shutoff of fuel supply to the combustion chamber, which is confirmed by a drop of the engine operation parameters and by increase of the fuel temperature in the HP-2000 unit after the engine shutdown.
– Fuel supply from the aircraft fuel supply system to the HP-2000 unit was uninterrupted. (This is confirmed by absence of engine inlet minimum fuel pressure warning). The fuel supply cut-off, most likely, was caused by abnormal operation of the engine automatic control system. (SAY-2000)
– After engine shut down, the SAY-2000 system did not work according to design expectation for about 17 seconds.
– About 17 seconds after right engine failure, those probable failed sections of RED-2000 were restored. By that time, the RED-2000

detected that the engine was inoperative and shut it down with propeller feathering.

- The change of the engine inlet air pressure from 0.93 to 1.734 kgf/cm2 (for 1 second), then drop to 0.93 kgf/cm2 (for 1 second), and then again abrupt change to the same value of 1.734 kgf/cm2 (as recorded on the FDR) are, most probably, a result of RED-2000 unit failure.
- The reason of the RED-2000 unit failure could have been caused both by the hardware failure and abnormal operation of the primary electronic engine control system software.

2.8 AV-140 propellers

During the investigation, there was not revealed any AV-140 propeller (№4750962136) or propeller governor (PCB-34M №0307-87) failure. The right hand engine propeller full feathering delay (for about 17 seconds), could occur due to failure of the automatic engine control system (SAY-2000). After the free turbine speed drop, the propeller began feathering of the blades in accordance with PCB-34M signal. Feather pump was not involved in the functional operation at this stage. Propeller blades brought to angle of 46 degrees. After 17 seconds, feather pump was switched on and propeller blades were completely feathered. The position of propeller blades as recorded in FDR and by measuring with a special tool directly on the propeller hub indicates full feathering position of the propeller.

2.9 ATS action

The accident investigation team revealed that the ATS Manual of Air Traffic Services (MATS) neither updated nor implemented at date of accident. The TWR controller did not follow the track of the aircraft during take-off. So the TWR asked the crew to turn left, with delay. The ground controller informs firefighting on time.

2.10 Firefighting and survival

The accident investigation team revealed that:

1. The Mehrabad International Airport did not timely, informed Tehran rescue organization regarding accident, according to airport emergency plan.

2. Rescue and firefighting activities were initiated on the base of voluntary information which was given by the witnesses.

3. Firefighting & survival group started to rescue right after extinguishing the fire terminated.

3. Conclusions

3.1 Findings

1. The flight crew were properly certified and qualified in accordance with CAO.IRI regulations. Flight crew fatigue did not adverse effect in the accident.

2. Based on the autopsy, toxicology and medical reports, there was no evidence to indicate that the pilot's performance was degraded by physiological factors or incapacitation affected the flight crew performance.

3. Prior to engine starting and taxiing out radio communications with ATS was carried out as per requirements by the crew. In the course of preparation for departure, PIC corrects radio communications by the co-pilot.

4. Crew performed aircraft preparation, taxi and take-off almost according to requirement except for the following items:

- Before take-off, the crew did not set the elevator trim tab and the rudder trim tab to the positions complying with the requirements of the AFM. The elevator trim tab was set to -2° instead of 0° or +6° depending on the aircraft CG position. The rudder trim tab was not set to the neutral position, its angle before take-off was about -3°.
- PIC rotated the aircraft at the speed of about 219 km/h (whereas 224 km/h is the speed recommended by the AFM table 4.2.3)
- Having identified the right engine failure 5 seconds after it had failed, the crew did not manually feather the propeller by pressing the ENGINE OFF - FEATHER push button as it was required by the AFM.
- PIC accepted overweight of about 190 kgf and endorsed it in W&B sheet.
- PIC flied with aircraft flaps set to 10°, notwithstanding that there aren't CAO.IRI approved SOP procedure for using Flap 10°.

5. Although engine failure continuous warning chime and light activated by about 14 seconds delay, but the PIC noticed engine failure after about 5

seconds and communicated to co-pilot and emphasized again about 9 seconds after engine failure.

6. The aircraft was destroyed by impact forces and post-impact fire.

7. There was no evidence of airframe failure or system malfunction and /or fire prior to the accident. (except R/H engine failure) No failure or malfunction of the flight control system was revealed.

8. The accident investigation team revealed that crew generally used chapter 7 of AFM chart (Fig.7.2-10 and 7.2-11) for aircraft maximum allowable weight calculation. Aircraft designer and manufacturer also used this charts. According to this charts aircraft weight of accident flight was about 190 kgf over allowable weight. (ambient temperature of 35 degrees of centigrade)

9. The accident investigation team revealed that AFM procedure for weight calculation is not clear that confused the crew. So if for accident flight, charts of AFM section 7.2 page17 (Fig 7.2-1B) and Page 18 (Fig 7.2-1r) are used, the aircraft weight (19866 kgf) will be outside of graph limits.
   By using this graph the maximum allowable weight, V_R and V_2 respectively will be 18850 kgf, 223 km/h and 226 km/h. So gained results have significant difference with result taken from chart of AFM Fig.7.2-11 and table 4.2.3.
   By considering the ground speed limitations at take-off, in accordance with the An-140-100 AFM charts (Section 7.2.2) the calculated MTOW should have been 17200 kgf.

   Therefore according to aforementioned findings the AFM procedure for takeoff weight calculation was not clear and confused the crew.

10. Even though according to result taken from chart of AFM Fig.7.2-11 and table 4.2.3, the crew knows that aircraft weight is about 190 kgf, over maximum allowable aircraft weight, but according to charts of AFM Fig. 7.2-1B , Fig. 7.2-1r, and Fig. 7.2-8 actual aircraft over weight was about 2600 kgf. So AFM confusing performance charts caused the pilots relying on performance calculation that, significantly over estimate the aircraft MTOM for the flight.

11. Sepahan Airline used manufacturer weight and balance manual for completing load sheet and calculating aircraft weight, which is not in compliance with CAO.IRI operational requirements for load sheet and passenger weight.

12. Accident flight load sheet has some mistakes and/or incorrect data. Also there are difference between weights of cargo in load sheet and computerize software of Sepahan Airline (about 25 kgf). These mistakes or incorrect data calculation and difference have not significant effect on weight calculation.

13. By using the mathematical modeling of aircraft motion and related calculation performed by the aircraft designer(ANTONOV Co.) revealed that even if engine warning system was activated without any delay, crew fly according to AFM, and landing gear retracted, actual aircraft take off performance has not comply with airworthiness requirement of AP-25. The aircraft did not reach V_2 before it is 10.7 m above the take-off surface;

14. AFM chapter 7 defines section 1 through 4 for take-off, climb, but in the AFM performance charts segment 1, 2, 3 and 4 were used. In addition, the term of "segment" as used in these charts has not the same meaning as defined in design requirement. As matter of fact the AFM is not clear enough.

15. The post-crash fire likely originated from the ignition of the fuel that was released or spilled from the aircraft fuel tanks when the aircraft impacted the ground.

16. About 2 seconds before lift-off engine No.2 shutdown automatically. The reason of engine No.2 shutdown was shutoff of fuel supply to the combustion chamber, which is confirmed by drop of the engine operation parameters and by increase of the fuel temperature in the HP-2000 unit after the engine shutdown. Fuel supply from the aircraft fuel supply system to the HP-2000 unit was uninterrupted (which is confirmed by absence of engine inlet minimum fuel pressure warning.)

17. The fuel supply cut-off, most likely, was caused by abnormal operation of the engine automatic control system.(SAY-2000)

18. After engine No.2 shutdown, the SAY-2000 system was not acting according to their pre-defined function. So, propeller feathered by about 17 seconds delay and also engine shutdown warning in cockpit activated by about 14 seconds delay (continuous chime and light)

19. The accident investigation team revealed that high rate of engine failure especially RED-2000 failure did not comply with the current airworthiness requirement.

20. The accident investigation team revealed that maintenance actions carried out by the Sepahan Airline for rectifying vibration of the engine No.2, which reported by the crew at flight from Tabriz to Esfahan (2 flight before the accident) was not carried out according to AMM and logical process, but the engine manufacturer representative accepted this action later on.(taking into account the fact that actions for rectifying vibration of the engine No.2 were carried out in the transit airport without participation of the engine manufacturer Representative.)

21. The accident investigation team revealed some AMM section was not clear and there are some mistakes in it. For example, chapter 073.00 page 20 charts was not correct (the SAY-2000 diagram) and procedure for engine vibration rectification was not complete (A process that did not exist at the time of the accident is referred).

22. Sepahan Airline has not CAO.IRI approved SOP procedure for using flap 10°.

23. The Mehrabad International Airport did not timely informed Tehran rescue organization regarding accident according to airport emergency plan. Rescue and firefighting activities were initiated on the base of voluntary information which was given by the witnesses.

24. Due to lack of enough coordination and wrong position reporting the airport rescue group reached on the accident site later than city firefighting group.

25. Some of the injured passengers rescued by themselves before firefighting man reach on accident site.

26. The TWR controller did not watch-out the track of the aircraft.

27. The ATS Manual of Air Traffic Services (MATS) was neither updated nor implemented.

28. Aircraft fuel was about 500 kg more than required fuel for the accident flight. After impact additional fuel aggravated the fire.

3.2 Causes and Contributing factors

3.2.1 Causes

The accident investigation team determined that the main cause of this accident was combination of:

1. Electronic engine control (SAY-2000) failure simultaneously with engine No: 2 shutdown, just about 2 seconds before aircraft lift-off.
2. AFM Confusing performance chart resulted the pilots relying on performance calculation that, significantly over-estimate the aircraft MTOM.

3.2.2 Contributing Factors to the accident were:

1. Aircraft flight manual unclear procedure, including the procedure for calculating maximum allowable take-off weight, V_R and V_2 and ambiguity in the climb segment definition and applications.
2. Crew performance, including:
   - PIC rotated the aircraft at the speed of about 219 km/h (whereas 224 km/h is the speed recommended by the AFM table 4.2.3)
   - The crew failed to perform the manual propeller feathering procedure for the failed engine.
   - The PIC's decision to fly with the aircraft, notwithstanding, had about 190 kgf overweight.
   - Aircraft fuel was about 500 kg more than required fuel for the accident flight.
3. The appearance of negative thrust from the unfeathered propeller blades at takeoff were not considered during the aircraft

certification tests, as it was considered improbable. However, in the accident flight the negative thrust did appear and affected the flight performance.

4. Safety Recommendations

As the result of the investigation, the accident investigation team issues the following safety recommendations:

- **To the CAO.IRI:**
  1. Analyses, in conjunction with aircraft designer & manufacturers, the information obtained in this accident investigation and related finding to evaluate the adequacy of certification standards and test methods specified in CAO.IRI requirement and guidance materials especially for aircraft and engine type validation process. If appropriate, modify certification standards and re-evaluate compliance of AN-140-100 aircraft and its engine in compliance with CAO.IRI airworthiness requirement in accident findings related subject.
  2. To re-evaluated the maintenance procedure regarding engine vibration rectification in conjunction with aircraft/engine designer and manufacturer.
  3. To re-evaluate the CAO.IRI oversight regulation and take necessary action to improve their surveillance and monitoring when rate of failure grows.
  4. Take necessary action to ensure that the Manual of Air Traffic Services (MATS) review and revise according to ICAO, Doc4444.
  5. To take necessary action to establish and implement necessary requirements for Airdrome certification.
  6. To take necessary action to implement SMS in the Iranian Airport Company, related airports and Tehran Area Control Center.

- **To HESA and SEPAHAN Airlines:**
  1. Revise aircraft loading procedure and agreement with a ground handler service provider according to CAO.IRI requirements.
  2. Revise SEPAHAN SOP to add the procedure for flight with Flap 10°.
  3. Revise pilot training program and reinforce, pilot training programs,
  4. To fully implement CAO.IRI Maintenance and continuing airworthiness requirements.

- **To the State of design and State of manufacturer (related to the ANTONOV Co. and its subsidiary contractors or suppliers)**

  Review aircraft take-off climb performance, according to related airworthiness requirement and take necessary action to comply with the requirement. (Reduce empty weight, improve engine power and/or….)

  1. Review and revise the AN-140-100 AFM. Take into account performance charts, take-off climb segment, and OEI procedure and so on.
  2. Review and revise the AN-140-100 AMM and correct related charts and procedure.
  3. Take appropriate action to rectify SAY-2000 malfunctions and poor engine reliability.
  4. Take appropriate action to reduce aircraft empty weight to pre-determined design criteria.
  5. Take appropriate action in order to make automatic propeller feathering system comply with related airworthiness requirements. It should be modified in order to be capable of operating in its intended manner at the time of engine failure with no special operations necessary on the part of the crew in order to make the automatic feathering system operative.
  6. To develop required AN-140 training that will empower flight crew understanding of weight calculation, manual engine control modes and aircraft performance through improved documentation, courseware, and instructor training.
  7. Take appropriate action in order to, the Antonov Enterprise conduct special tests to draw recommendations for flight crews as to their actions if there appears negative thrust from the unfeathered propeller blades in case of engine failure at takeoff.

- **To the Iranian Airport Company, the Mehrabad International Airport and Aircraft Rescue and Firefighting Working Group:**

  1. Review and revise the Manual of Air Traffic Services (MATS) according to ICAO Doc4444.
  2. Take appropriate action, including necessary training for controllers to watch-out and watch-in the track of the aircraft exactly during landing and departure.
  3. Mehrabad International Airport emergency plan should be reviewed and task sharing between firefighting of airport and other parties should be clarified.

4. THR emergency plan should be communicated and related training and exercises should be done at least annually according to the approved time frame.
5. Mehrabad International Airport should use the baggage's weighting facilities at passenger check-in gates at departure terminal with the capability of weight recording.
6. The Iranian Airport Company should take the necessary action to obtain Aerodrome certificate for Mehrabad International Airport.
7. The Iranian Airport Company should develop, implement and maintain Safety Management System (SMS) within the company, including Mehrabad International Airport and Tehran Area Control Center (ACC).

AAIB Department

Adopted: 9 August, 2017;

IIC (INVESTIGATOR IN CHARGE)

Appendices

Appendix A: Investigation and Hearing

Investigation

The Accident Investigation Team was notified about the accident on AUG 10, 2014, arrived on scene about half an hour after the accident.

Then IAC (Interstate Aviation Committee) and National Bureau of Air Accidents Investigation were notified about the accident on 11August, 2014 according to Annex 13 to the Convention on International Civil Aviation Organization.

Parties to investigation were; IAC, Antonov Co., Motor-Sich, Ivchenko Progress SE, from state of design and aircraft, engine and related component designer and manufacturer.

The National Bureau of Air Accidents Investigation did not attend in the investigation due to evolving in another accident.

Public Hearing

In this regard, there were several session and announcement regarding how that accident took place and also how far investigation was going on.

Appendix B: Cockpit Voice Recorder Transcript

Transcript of AN-140-100, EP-GPA CVR

(The Red statements are translated from the Persian to the English)

time UTC	caller	Conversion text
04:32:47	FO	SPN5915 good morning
04:32:52	GND	GND, SPN5919 good morning to you
04:32:56	FO	AN-140-100 Destination to Tabas FL 190 stand 406 copied information 1012
04:30:48	PIC	۳۴ تا داریم اونم ۴۰ تا (we have 34 Adults and 40 PAX totally)
04:30:57	PIC	ببند درب را (please close the door)
04:36:27	FO	Good day SPN5915 request engine start
04:36:34	GND	Startup approved SPN5915
04:36:39	GND	SPN5915 destination to Tabbas flight plan…….
04:37:20	PIC	آخ ، بسم اله الرحمن الرحیم. اون ور Clear است؟ (In the name of GOD, is other side clear?)
04:37:26	FO	Right clear
04:38:42	FO	در حال خواندن Check list (reading check list)
04:39:48	FO	SPN 5915, good morning STBY on 406
04:39:57	GND	SPN 5915, good morning, confirm your position
04:40:00	FO	406 SPN5915
04:40:09	GND	406 ok Stand By
04:40:11	FO	Stand by SPN5915

04:42:26	GND	SPN 5915 take E6 A3…
04:42:32	FO	E6 back track 29L SPN 5915
04:42:35	GND	No, vice versa, back track 29R hold, short 29 L
04:42:38	PIC	عوضی همه را گفتی (you said all sentences wrong)
04:42:40	FO	Back track 29R hold short 29L SPN 5915
04:42:44	PIC	همه را عوضی گفتی، همه را (you said all sentences, wrong, all!!)
04:42:46	FO	E6 دسترسی به.... (E6 ACCESS TO ….)
04:44:06	FO	Sir بیا Take off Briefing را انجام بدهیم (Sir, Let's Do Take off Briefing)
04:44:08	PIC	Take off را من انجام میدهم با Flap 10 (I undertake Take-off with flap 10)
04:44:15	PIC	Failure اگر قبل از V_1 بود Abort وگرنه Take off. Radio call ها با شما و نگه داشتن Aircraft با من. (If failure occur before V_1 , we will abort, otherwise will continue take off , you do radio calls and I will control aircraft)
04:44:25	PIC	بعد از V_1 بود اگه پا شدیم و گردش به سمت چپ می کنیم و می رویم سمت KAZ و ۷۰۰۰ پاو توی Sequence قرار می گیریم برای نشستن. Otherwise برابر ۲۶۰ درجه میرویم و استاند بای می شویم تا ببینیم رادار چه Procedure ی به ما میدهد (If we take off after V_1, we will turn to the left direct to KAZ and enter in to traffic pattern for landing , otherwise proceed to 260 heading awiating ATS recommended procedure)
04:44:53	GND	SPN 5915 contact tower 118.1, good day
04:44:56	FO	SPN 5915 contact tower 118.1, good day
04:45:10	FO	Mehrabad tower, good morning SPN 5915
04:45:18	TWR	SPN 5915, good morning hold short 29 L….

04:45:23	FO	Hold short 29L SPN 5915
04:45:29	FO	اگر سبک و خالی بود می شد از همین جا برویم. (If the aircraft was light and empty, we could arrange departure from here (intersection Take off))
04:45:33	PIC	کاری که ما تو دوبی کردیم.لیکن اینقدر برای ما بار نبود .... (Yes, once we did that in Dubai airport but on that time we had not so much PAYLOAD)
04:46:44	FO	نکنه بار امام (فرودگاه) داشتید. yes sir (May its load alike "IKA" flight loading)
04:45:59	FO	در حال خواندن check list (check list read-out)
04:47:12	PIC	اینقدر ماند تا یک هواپیمای دیگر آمد و یارو چرا Take off نکرد؟ (The succeeding flight (MD-88) stand up to other aircraft came for landing)
04:47:19	FO	اون ارباس اول take off کرد. (that airbus toke-off first)
04:47:40	----	صدای زدن کلید (Knocking the key)
04:47:42	PIC	اه! چرا میره؟ (Wow, why it is going?)
04:48:13	PIC	جون مادرت Line up را بده (Please clear us for lineup)
04:48:18	FO	SPN 5915 stand by for 29L
04:48:21	TWR	On RWY SPN 5915
04:48:42	PIC	هنوز داره می دود. اون هم مثل ما سنگین است. حالا بدو تا فردا بدو. باند را داره تمام میکنه ها ! باند تمام شد. (MD-88 just running. It is so heavy, same as us. RUN, RUN till tomorrow)
04:48:58	FO	تازه هنوز Nose اش بلند شد.

		(just now its nose L/G is lift-off)
04:50:15	TWR	SPN 5915 clear for take-off wind…..
04:50:22	FO	SPN 5915 clear for departure …..
04:50:39	FO	No light
04:50:45	FO	Normal 12,14, 15
04:50:51	FO	16
04:50:54	FO	17
04:50:56	FO	18,19
04:50:58	FO	Two engines parameters are normal,
04:51:02	FO	Decision speed ,continue
04:51:07	----	Chime!
04:51:08	----	Warning horn
04:51:08	----	Two chimes
04:51:11	PIC	موتوره) موتورو نگاه کن (it is engine ,please watch out the engine)
04:51:16	PIC	موتورها را نگاه کن (watch the engine)
04:51:17	FO	Engine fuel rate failed
04:51:19	FO	Engine fuel chips
04:51:21	FO	درخواست کنم برگردیم؟ (May I request to air turn back?)
04:51:22	PIC	آره --- (yes) Repetitive chime
04:51:24	PIC	بگو Emergency (declare emergency) Repetitive chime

04:51:30	PIC	بگو ام (Tell "EM")
04:51:31	FO	Mehrabad Radar SPN 5915 Repetitive chime
04:51:33	PIC	یا علی ... (" ya alli") slang
04:51:35	PIC	چرخ (wheel)
04:51:39	FO	Mehrabad Radar left turn Immediately
04:51:44	TWR	Left Turn immediately
04:51:48	FO	Engine #2 failed
04:51:54	PIC	Turn left Repetitive chime
04:51:56	PIC	Oh, Shit Repetitive chime
04:51:59	-----	end of voice

*****PIC: Pilot in Command, * FO: First Officer,

*TWR: TOWER, * GND: Ground

Appendix C: Flight Data Recorder Transcript

UTC	Event	Explanation
04:37:28 04:37:58	ENS 0→1 SPR2 0 →70 HEA 15^0	The aircraft begun to start engine no. :2 at stand 406 in Mehrabad International Airport ramp
04:42:29	Parking Brake off TH2 28 →72	The aircraft begun to taxi out
04:46:00	LAIL 0→ 24.5 →-24	In accordance with aircraft flight manual the, ailerons shall be tested within) (-24 up to +24°) and the pilot action was right and there were no error event registered.
04:46:01	LELV 11.5 →-16.7 →12.4	In accordance with aircraft flight manual the elevator shall be tested within (-30 up to +16) and error event was registered in FDM software
04:47:34	RUD 0 →21.3 →-14.8 PD 0 →33.6 → -28.5	In accordance with aircraft flight manual the rudder shall be tested within (-33 up to +33) as well as related rudder pedals within (-100 up to +100) , nevertheless it is not registered any pilot error in FDM software
04:47:42	HEA 200 L,R LST off SPR1 93.4 GGP1 4.32 BLE1 7.3 SPR2 95.7 GGP2 3.97 BLE2 4.	The pilot has put power lever a little forward , and as a result of no braking action aircraft moves forward and then he applies the brakes
04:48:08 04:48:18	HEA 200 L,R LST on SPR1 88→78 GGP1 2.9 BLE1 -3.7 SPR2 88→74 GGP2 2.9 BLE2 -3.7	As a result of holding the aircraft at the runway holding point ,the pilot turned on Slow Taxi switch
04:48:25 04:48:30	HEA 200 L,R LST off SPR1 75→90 GGP1 2.64→4.16 BLE1 1.4→4.7 FC1 124→209 SPR2 72→75 GGP2 2.50→2.82 BLE2 1.2→1.7 FC2 124→144	The pilot has turn off Slow Taxi switch; as a result engine no.2 parameters varied in consistence with Engine. no. 1

04:49:06	4 HEA 200 →28 Parking Brake On TH 1,2 = 28^0 (ground Idle)	The aircraft is ready to be cleared for takeoff at the beginning of runway 29L
04:49:08 04:49:15 04:49:22	Parking Brake on TH1,2 28 →64 →110 TGZ1 488 →512 →666 SPR1 72 →93 →99 TGZ2 512 →532→668 SPR2 85→93→99	The pilot while holding the aircraft at runway threshold tried to test the engine performances (in the meanwhile at 09:19:16 Eng. No: 2 power become as much as Eng. No :1)
04:50:15 04:50:19	Parking brake On TH1,2 54→111 TGZ1 486→583 SPR1 72 →96 TGZ2 510 →591 SPR2 70→96	Both engines have reached to takeoff power simultaneously
04:50:25	Parking Brake Off TH1,2 111 TGZ1= 684 SPR1= 99.4 BLE1 19.7 TGZ2= 680 SPR2= 99.4 BLE2=18.8	The pilot tried to release parking brake with no braking action in order to initiate takeoff
04:50:51	HEA= 288 V=163 TGZ1= 704 SPR1= 100 BLE1 23.4 TGZ2= 696 SPR2= 100 BLE2=23.2	The aircraft departed at normal flight condition
04:51:05 04:51:06	HEA=289 V=219 TGZ1= 704 SPR1= 100 BLE1 =26.6 TGZ2= 692 SPR2= 100 BLE2=26 PWR1 =2083 GGP1=8.1 FC1=432 PWR2=1898 GGP2=7.98 FC2=432 CLM 92.2→15.4→-80.3	The Engine. no:2 malfunction began to intensify and engine power as well as compressor pressure decreased
04:51:06 04:51:07	HEA=290 V=221 TGZ1= 704 SPR1= 100 BLE1 =26.9 TGZ2= 648 SPR2= 100 BLE2=26.3 PWR1 =2017 GGP1=8.13 FC1=432 PWR2=1004 GGP2=3.86 FC2=432 NGG1=101.2 NGG2=82.4 LELV 5 →0 →-6.5 RBUK signal RDEC signal R259 Signal RUD -0.8 →-0.8 PD -4 CLM -50→-50	Eng. no:2 power decreased Disconnection between RED 2000 and BUK-140 Disconnection between RED2000 with engines Single chime appearance Eng. No.:2 flame out

04:51:07 04:51:08	HEA=290 V=221 TGZ1= 704 SPR1= 100 BLE1=27.1 TGZ2= 596 SPR2= 41.5 BLE2=45.9 PWR1 =2086 GGP1=8.13 FC1=438 PWR2=765 GGP2=2.64 FC2=? R265 Signal LMES Signal SLEX signal- on RUD -2.6 →-3 PD -13.7→-15 CLM -72.6→-73.6	Engine oil out signal (R265) Engine malfunction signalization Eng. No.:2 propeller moves toward feathering Spoiler (L/H) opening The pilot has begun to apply rudder pedal
04:51:08 04:51:09	HEA=293 V=217 TGZ1= 723 SPR1= 100 BLE1 =28.3 TGZ2= 550 SPR2=? BLE2=? PWR1 =2697 GGP1=9.13 FC1=554 PWR2=797 GGP2=1.8 FC2=? SLEX Signal LMEP Signal RUD -2.8 →-7.8 PD -14.2→-31 CLM -73.5→-60.4	non-reliable data RED2000 Eng. No:1 in contingency condition Spoiler (L/H) opening The pilot began to apply more rudder pedal
04:51:09 04:51:10	HEA=295 V=213 TGZ1= 752 SPR1= 100 BLE1 =28.7 TGZ2= 527 SPR2=? BLE2=? PWR1 =2757 GGP1=9.42 FC1=566 PWR2=784 GGP2=1.49 FC2=? LLGC Signal RLGC Signal RUD -7.8 →-10.4 PD -31→-36 CLM -60→-59.4	the aircraft had lift-off the runway
04:51:11 04:51:12	HEA=297 V=213 Hg=2M RUD -8.6 →-8 PD -26.9→-27.8 CLM -50→-50 BNK -2.5→-2.3 SLEX signal- off	Spoiler (L/H) closing
04:51:17 04:51:19	HEA=303→306 V=210 Hg=19→26 M RUD -12.8 →-12.5 PD -45.3→-45.7 CLM -45.6→-42.4 BNK -1.7→-0.8	The pilot tried to regain the aircraft control
04:51:23	HEA=308 V=205 R.Alt= 28 TGZ1= 780 SPR1= 100 BLE1 =28.3 TGZ2= 423 SPR2=8.7 BLE2=46 PWR1 =2700 GGP1=9.26 FC1=536 PWR2=240 GGP2=0.93 FC2=632 All failure Signal	RED2000 data regain normal condition

	RUD -12.5 PD= -46.9 CLM -37.9 BNK -2.6 PTC=13.3	
04:51:41	HEA=319 V=200 Hg=43 RUD= -14.7 PD= -51.1 CLM -47.7 BNK -6.7 PAA= 12.7 AOAL Signal	As a result of 12 degrees angle of attack (AOA) critical value ,there were error event signal registered
04:51:49 04:51:50	HEA=322→325 V=187-184 Hg=37→41 RUD -14.4 →-14 PD -50→-46.3 CLM -45.6→-20.9 BNK 0.4→2.4	
04:51:54	HEA=340 V=185 Hg=28 RUD -14 PD -47 CLM -45.6→-20.9 BNK 5.3 WHL 66.2 →31.4	As result of yoke movement (WHL) reduction, bank angle (BNK) shall be decreased. but flight control were out of control and the aircraft was forced to stall and crashed.
04:51:56 04:51:57	HEA=358 V=190 R.Alt= 9 TGZ1= 780 SPR1= 100 BLE1 =25.6 TGZ2= 312 SPR2=21 BLE2=79 PWR1 =2680 GGP1=9.17 FC1=528 PWR2=0 GGP2=0.87 FC2=632 BNK 7→32.5	Hitting the Grond
04:51:58	End of the Read out Data	End of the Data Read out

Appendix D: ANTONOV Co. Technical Report (selected)

Table 5.1. Actual rudder deflection angles vs. angles required for straight flight

							Actual		Required	
T, sec	V, km/h	H, m	η, %	γ, °	β, °	$\Delta C_x=f(\beta)$	δ_H, °	P_H, kgf	δ_H, °	P_H, kgf
9:21:07	222	0	0.0	-2.1	-4.4	0.0063	-1	-13	-10	-28
9:21:08	218	0	0.0	-3.1	-4.4	0.0063	-4	-18	-10	-28
9:21:09	214	0	0.0	-4.0	-4.4	0.0063	-8	-25	-10	-28
9:21:10	211	0	0.2	-2.5	-4.4	0.0063	-11	-29	-13	-33
9:21:11	215	0	0.3	1.7	-4.5	0.0067	-8	-24	-21	-46
9:21:12	219	1	1.0	2.9	-4.6	0.0070	-8	-25	-22	-48
9:21:13	219	2	1.6	1.4	-4.6	0.0070	-12	-32	-20	-44
9:21:14	218	3	2.1	0.9	-4.7	0.0073	-12	-32	-19	-42
9:21:15	217	5	2.5	0.7	-4.8	0.0076	-14	-34	-19	-42
9:21:16	217	7	2.6	0.3	-4.9	0.0079	-13	-32	-18	-41
9:21:17	215	9	2.8	-1.0	-5.0	0.0083	-13	-32	-16	-37
9:21:18	214	11	3.3	-1.6	-5.0	0.0083	-13	-32	-15	-36
9:21:19	212	13	3.6	-0.9	-5.1	0.0086	-13	-32	-16	-38
9:21:20	211	16	3.5	-0.7	-5.1	0.0086	-12	-32	-17	-39
9:21:21	209	18	3.5	-1.1	-5.2	0.0089	-13	-32	-17	-39
9:21:22	207	21	3.6	-1.4	-5.3	0.0092	-12	-32	-16	-38
9:21:23	206	23	3.5	-1.9	-5.4	0.0095	-13	-32	-16	-37
9:21:24	204	26	2.9	-2.9	-5.5	0.0099	-13	-33	-13	-33
9:21:25	203	27	2.3	-3.7	-5.7	0.0105	-13	-32	-12	-30
9:21:26	207	29	1.9	-3.7	-5.8	0.0108	-13	-32	-11	-29
9:21:27	206	30	1.6	-3.2	-5.9	0.0112	-13	-33	-12	-31
9:21:28	206	31	1.1	-3.5	-6.0	0.0115	-13	-33	-11	-30
9:21:29	205	32	0.9	-3.4	-6.1	0.0118	-13	-33	-12	-31
9:21:30	204	32	0.3	-3.0	-6.3	0.0124	-13	-33	-13	-33
9:21:31	204	32	0.0	-2.5	-6.4	0.0128	-13	-33	-14	-34
9:21:32	203	32	0.3	-2.7	-7.0	0.0147	-13	-32	-14	-34
9:21:33	203	32	0.9	-2.5	-7.7	0.0169	-13	-33	-14	-35
9:21:34	201	33	1.4	-1.2	-8.3	0.0196	-14	-34	-17	-40
9:21:35	200	34	1.4	-0.9	-8.8	0.0225	-14	-35	-18	-41
9:21:36	199	35	0.7	-2.2	-8.9	0.0231	-13	-33	-16	-37
9:21:37	199	35	-0.3	-3.1	-9.0	0.0237	-13	-33	-13	-33
9:21:38	200	34	-1.1	-3.0	-9.0	0.0237	-14	-35	-14	-34
9:21:39	201	34	-0.6	-3.0	-9.1	0.0242	-14	-35	-13	-34
9:21:40	201	34	0.2	-3.8	-9.2	0.0248	-14	-35	-12	-31
9:21:41	199	34	0.0	-5.3	-9.3	0.0254	-15	-36	-8	-25
9:21:42	198	34	0.1	-5.7	-9.5	0.0265	-14	-35	-8	-24
9:21:43	196	34	0.5	-6.2	-9.8	0.0283	-14	-35	-7	-23
9:21:44	194	34	0.6	-7.1	-10.1	0.0300	-14	-34	-5	-19
9:21:45	192	35	0.7	-6.0	-10.4	0.0317	-14	-35	-8	-24
9:21:46	189	35	1.0	-5.0	-10.6	0.0329	-15	-36	-10	-29
9:21:47	186	36	0.3	-5.9	-10.8	0.0340	-15	-36	-9	-26
9:21:48	183	36	-1.0	-5.1	-10.9	0.0346	-16	-37	-11	-30
9:21:49	181	35	-1.5	-0.5	-11.1	0.0357	-14	-35	-25	-51
Stalling										

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Table 5.2. Drag force components during aircraft accident.

T, sec	α, °	β_t °	V, km/h ПР	$R_x(\delta_в)$, kgf	$R_x(\alpha, B)$, kgf	$R_x(\beta)$, kgf	$R_x(\delta_в)$, kgf	$R_x(H)$, kgf	$R_x(\delta_н)$, kgf	$R_x(\delta_{вуз})$, kgf	R_x(Ш), kgf	$\sum R_x$, kgf	P1, kgf	P2, kgf	$\sum P$, kgf	$\sum P \cdot \cos\alpha_\phi$, kgf	Θ, °	$G \cdot \sin\Theta$, kgf	$\sum P - \sum R_x - G \cdot \sin\Theta$ kgf
9:20:58	0.4	1.7	194	7	626	10	75	-144	1	0	286	860	1940	1940	3880	3880	0.0	0	3020
9:20:59	0.4	1.6	198	8	638	10	71	-150	1	0	298	876	1920	1920	3840	3840	0.0	0	2964
9:20:00	0.3	1.5	202	9	660	9	68	-155	1	0	311	902	1890	1890	3780	3780	0.0	0	2878
9:21:01	0.3	1.2	206	10	669	8	71	-161	1	0	323	920	1870	1870	3740	3740	0.0	3	2816
9:21:02	0.3	1.0	210	7	694	7	74	-168	1	0	335	950	1850	1850	3700	3700	0.0	0	2749
9:21:03	0.2	0.8	214	8	715	6	73	-173	1	0	347	976	1820	1820	3640	3640	0.0	0	2664
9:21:04	0.2	0.6	217	10	721	4	72	-179	1	0	359	988	1800	1800	3600	3600	0.0	3	2608
9:21:05	0.3	0.5	221	8	751	4	48	-186	1	0	371	997	1780	1780	3560	3560	0.0	-3	2566
9:21:06	0.9	0.5	224	9	807	4	4	-196	3	0	383	1014	1760	1750	3510	3510	0.0	-10	2506
9:21:07	1.6	1.5	222	1	730	9	-2	-196	1	0	374	917	1780	-240	1540	1540	0.0	3	620
9:21:08	2.0	1.5	218	1	749	8	0	-192	4	70	362	1002	2230	825	3055	3055	0.0	7	2045
9:21:09	2.5	1.6	214	4	765	8	-10	-189	9	75	350	1011	2250	169	2419	2418	0.0	3	1404
9:21:10	8.0	1.5	211	3	1401	-1	-87	-260	13	72	338	1478	2270	27	2297	2280	0.1	45	757
9:21:11	10.2	-0.7	215	29	1876	-2	-144	-329	17	75	351	1874	2250	4	2254	2225	0.2	52	299
9:21:12	10.3	-2.6	219	50	1983	17	-162	-332	15	78	366	2015	2220	-20	2200	2171	0.6	204	-48
9:21:13	9.9	-3.8	219	47	1872	63	-153	-289	22	0	365	1925	2230	-40	2190	2164	0.9	325	-86
9:21:14	10.2	-4.1	218	25	1936	76	-149	-257	20	0	363	2013	2230	-58	2172	2144	1.2	404	-273
9:21:15	9.7	-3.7	217	28	1807	58	-124	-194	13	0	360	1948	2230	-58	2172	2147	1.5	504	-305
9:21:16	9.7	-3.8	217	29	1792	61	-117	-141	16	0	357	1997	2240	-58	2182	2157	1.5	511	-352
9:21:17	10.1	-4.1	215	36	1860	73	-115	-91	15	0	353	2132	2240	-58	2182	2154	1.6	546	-523
9:21:18	10.4	-4.4	214	31	1914	88	-104	-29	14	0	349	2264	2250	-58	2192	2162	1.9	646	-748
9:21:19	10.1	-4.4	212	27	1839	86	-99	0	12	0	343	2209	2260	-59	2201	2174	2.1	715	-750
9:21:20	10.3	-4.5	211	32	1864	90	-105	0	13	0	338	2233	2260	-59	2201	2172	2.0	701	-762
9:21:21	10.5	-4.8	209	35	1885	104	-108	0	15	0	333	2263	2270	-80	2190	2160	2.0	701	-805
9:21:22	10.8	-5.1	207	35	1928	119	-114	0	15	0	327	2310	2280	-102	2178	2146	2.1	708	-872

T, sec	α, °	β_t °	V, km/h ПР	$R_x(\delta_в)$, kgf	$R_x(\alpha, B)$, kgf	$R_x(\beta)$, kgf	$R_x(\delta_в)$, kgf	$R_x(H)$, kgf	$R_x(\delta_н)$, kgf	$R_x(\delta_{вуз})$, kgf	R_x(Ш), kgf	$\sum R_x$, kgf	P1, kgf	P2, kgf	$\sum P$, kgf	$\sum P \cdot \cos\alpha_\phi$, kgf	Θ, °	$G \cdot \sin\Theta$, kgf	$\sum P - \sum R_x - G \cdot \sin\Theta$ kgf
9:21:23	10.5	-5.4	206	40	1822	129	-99	0	16	0	322	2229	2290	-123	2167	2137	2.0	698	-790
9:21:24	10.4	-5.9	204	39	1791	150	-99	0	16	0	317	2214	2290	-145	2145	2116	1.7	570	-668
9:21:25	10.6	-6.4	203	41	1818	173	-102	0	16	0	313	2258	2300	-80	2220	2189	1.3	446	-515
9:21:26	10.5	-8.8	207	40	1851	306	-99	0	14	0	327	2437	2280	-80	2200	2170	1.1	380	-647
9:21:27	10.2	-9.1	206	39	1764	317	-96	0	12	0	324	2361	2280	-80	2200	2172	0.9	314	-504
9:21:28	10.6	-9.8	206	50	1853	364	-109	0	11	0	323	2492	2280	-80	2200	2169	0.6	211	-534
9:21:29	10.5	-10.8	205	46	1815	420	-100	0	14	0	320	2515	2280	-80	2200	2170	0.5	176	-522
9:21:30	10.4	-11.3	204	45	1779	446	-112	0	11	0	318	2487	2290	-80	2210	2180	0.2	59	-365
9:21:31	11.2	-11.9	204	51	1981	487	-123	0	11	0	316	2722	2290	-80	2210	2175	0.0	-7	-540
9:21:32	11.7	-12.9	203	63	2095	584	-136	0	12	0	315	2932	2290	-80	2210	2172	0.2	52	-813
9:21:33	12.0	-13.9	203	59	2149	679	-127	0	11	0	312	3083	2300	-80	2220	2179	0.5	183	-1087
9:21:34	11.7	-14.3	201	52	2052	706	-127	0	9	0	309	3001	2300	-80	2220	2181	0.8	283	-1103
9:21:35	11.3	-14.9	200	68	1934	751	-115	0	10	0	305	2953	2310	-80	2230	2194	0.8	270	-1029
9:21:36	10.8	-15.8	199	73	1794	821	-101	0	16	0	301	2903	2310	-80	2230	2197	0.4	138	-844
9:21:37	10.7	-15.8	199	59	1781	824	-100	0	12	0	303	2880	2310	-80	2230	2198	-0.2	-66	-616
9:21:38	11.6	-15.4	200	54	2006	802	-132	0	8	0	305	3042	2310	-80	2230	2192	-0.6	-211	-640
9:21:39	12.4	-15.4	201	69	2224	814	-153	0	11	0	307	3271	2310	-80	2230	2186	-0.3	-117	-968
9:21:40	11.6	-15.8	201	70	2016	844	-123	0	13	0	307	3128	2310	-80	2230	2192	0.1	38	-974
9:21:41	11.6	-16.0	199	71	1988	851	-129	0	12	0	302	3096	2310	-80	2230	2192	0.0	7	-911
9:21:42	12.2	-16.5	198	64	2104	910	-142	0	12	0	298	3246	2320	-80	2240	2197	0.1	28	-1076
9:21:43	12.4	-17.0	196	76	2140	960	-144	0	13	0	292	3337	2330	-80	2250	2206	0.3	104	-1235
9:21:44	12.4	-17.8	194	77	2095	1042	-142	0	15	0	286	3374	2340	-80	2260	2215	0.4	124	-1283
9:21:45	13.1	-18.2	192	59	2230	1073	-158	0	13	0	280	3496	2350	-80	2270	2220	0.4	142	-1418
9:21:46	13.0	-18.3	189	78	2169	1059	-144	0	14	0	273	3449	2360	-80	2280	2230	0.6	204	-1423
9:21:47	12.4	-18.5	186	89	1945	1040	-130	0	33	0	263	3240	2380	-80	2300	2255	0.2	66	-1051

T, sec	α, °	β_t °	V, km/h ПР	$R_x(\delta_в)$, kgf	$R_x(\alpha, B)$, kgf	$R_x(\beta)$, kgf	$R_x(\delta_в)$, kgf	$R_x(H)$, kgf	$R_x(\delta_н)$, kgf	$R_x(\delta_{вуз})$, kgf	R_x(Ш), kgf	$\sum R_x$, kgf	P1, kgf	P2, kgf	$\sum P$, kgf	$\sum P \cdot \cos\alpha_\phi$, kgf	Θ, °	$G \cdot \sin\Theta$, kgf	$\sum P - \sum R_x - G \cdot \sin\Theta$ kgf
9:21:48	13.2	-17.3	183	44	2095	879	-158	0	21	0	255	3136	2390	-80	2310	2258	-0.6	-204	-675
9:21:49	15.2	-15.2	181	38	2610	671	-222	0	3	0	250	3350	2400	-80	2320	2249	-0.9	-304	-797

Table 5.3. Drag force components induced by pilot's actions in accordance with Fig. 5.2.

T, sec	α_r, °	β_r, °	V, km/h ПР	$R_x(\delta_э)$, kgf	$R_x(\alpha, B)$, kgf	$R_x(\beta)$, kgf	$R_x(\delta_э)$, kgf	$R_x(H)$, kgf	$R_x(\delta_н)$, kgf	$R_x(\delta_{эк})$, kgf	R_x(Ш), kgf	$\sum R_x$, kgf	P1, kgf	P2, kgf	$\sum P$, kgf	$\sum P \cdot \cos\alpha_ч$, kgf	Θ, °	$G \cdot \sin\Theta$, kgf	$\sum P - \sum R_x - G \cdot \sin\Theta$, kgf
9:20:58	0.5	1.7	195	7	642	10	65	-147	1	0	290	868	1930	1930	3860	3860	0.0	0	2992
9:20:59	0.5	1.6	200	8	654	10	61	-153	1	0	303	883	1910	1910	3820	3820	0.0	0	2936
9:20:00	0.4	1.5	204	9	676	9	57	-159	1	0	316	910	1880	1880	3760	3760	0.0	0	2850
9:21:01	0.4	1.5	208	10	686	10	61	-165	1	0	328	931	1860	1860	3720	3720	0.0	3	2786
9:21:02	0.4	1.4	212	7	711	10	63	-171	1	0	341	962	1840	1840	3680	3680	0.0	0	2718
9:21:03	0.3	1.3	215	8	714	9	59	-176	1	0	353	968	1810	1810	3620	3620	0.0	3	2648
9:21:04	0.3	1.2	219	10	738	9	61	-182	1	0	365	1002	1790	1790	3580	3580	0.0	3	2574
9:21:05	0.3	1.2	223	8	763	9	37	-188	2	0	377	1008	1770	1770	3540	3540	0.0	0	2531
9:21:06	1	1.2	226	10	825	9	6	-200	6	0	389	1045	1750	1740	3490	3490	0.0	-10	2455
9:21:07	1.7	2.2	224	3	749	17	-1	-201	0	0	382	948	1760	-240	1520	1520	0.0	7	565
9:21:08	2.2	2.3	221	2	787	17	-2	-198	16	71	371	1064	2210	825	3035	3034	0.0	10	1960
9:21:09	3.9	3.4	218	25	910	41	75	-205	22	77	360	1307	2230	169	2399	2396	0.0	10	1079
9:21:10	8.4	4	214	0	1505	64	-105	-279	37	75	350	1648	2250	27	2277	2258	0.1	21	590
9:21:11	10.1	2.8	218	20	1908	25	-151	-337	37	78	362	1942	2230	4	2234	2205	0.2	55	208
9:21:12	10	2.4	223	36	1955	10	-161	-330	21	81	377	1990	2210	-20	2190	2163	0.7	238	-65
9:21:13	9.6	2.3	222	39	1867	7	89	-282	30	0	376	2125	2210	-40	2170	2146	1.2	404	-384
9:21:14	8.3	1.9	222	14	1597	-2	-104	-213	33	0	376	1700	2210	-58	2152	2135	0.9	294	141
9:21:15	8.6	1.7	223	11	1663	-2	-108	-197	24	0	376	1768	2210	-58	2152	2133	0.5	173	192
9:21:16	8.8	1.6	223	13	1682	-2	-109	-187	22	0	340	1760	2210	-58	2152	2132	0.3	117	255
9:21:17	8.9	1.3	223	15	1708	-2	-109	-178	22	0	304	1760	2200	-58	2142	2121	0.3	97	265
9:21:18	8.9	1.1	224	16	1715	-2	-107	-169	21	0	266	1739	2200	-58	2142	2121	0.3	93	289
9:21:19	8.9	0.9	224	16	1721	-1	-105	-160	20	0	229	1721	2200	-59	2141	2121	0.3	104	297
9:21:20	8.8	0.8	225	17	1708	-1	-101	-148	19	0	192	1685	2200	-59	2141	2121	0.3	117	319
9:21:21	8.8	0.6	225	17	1715	-1	-99	-136	18	0	154	1668	2190	-80	2110	2090	0.4	138	284
9:21:22	8.8	0.5	226	18	1722	-1	-97	-121	17	0	116	1655	2190	-102	2088	2069	0.5	156	258
9:21:23	8.7	0.4	226	18	1708	-1	-93	-103	16	0	78	1623	2190	-123	2067	2048	0.5	176	248
9:21:24	8.7	0.3	226	18	1715	0	-91	-83	15	0	39	1612	2190	-145	2045	2027	0.6	200	214
9:21:25	8.6	0.2	227	18	1702	0	-87	-61	14	0	0	1585	2180	-80	2100	2082	0.6	218	279
9:21:26	8.6	0.1	228	18	1712	0	-86	-38	13	0	0	1619	2180	-70	2110	2091	0.7	238	234
9:21:27	8.5	-0.1	228	18	1699	0	-83	-11	12	0	0	1635	2180	-70	2110	2092	0.7	256	201
9:21:28	8.5	-0.2	229	18	1706	0	-81	0	11	0	0	1655	2170	-70	2100	2082	0.8	270	158
9:21:29	8.5	-0.3	229	18	1713	0	-81	0	11	0	0	1660	2170	-70	2100	2082	0.8	283	139
9:21:30	8.4	-0.4	230	18	1698	0	-80	0	10	0	0	1645	2170	-70	2100	2083	0.9	301	137
9:21:31	8.4	-0.5	230	18	1704	-1	-80	0	9	0	0	1651	2170	-70	2100	2083	0.9	314	117
9:21:32	8.3	-0.6	230	18	1687	-1	-78	0	9	0	0	1635	2170	-70	2100	2083	0.9	325	123
9:21:33	8.3	-0.7	231	18	1693	-1	-78	0	8	0	0	1640	2160	-70	2090	2073	1.0	339	94
9:21:34	8.3	-0.7	231	18	1698	-1	-78	0	8	0	0	1645	2160	-70	2090	2073	1.0	349	79
9:21:35	8.2	-0.8	231	18	1680	-1	-77	0	8	0	0	1628	2160	-70	2090	2074	1.0	359	86
9:21:36	8.2	-0.9	232	18	1685	-1	-77	0	7	0	0	1632	2160	-70	2090	2074	1.1	370	71
9:21:37	8.2	-0.9	232	18	1689	-1	-77	0	7	0	0	1636	2160	-70	2090	2074	1.1	377	61
9:21:38	8.2	-1	232	18	1693	-1	-77	0	6	0	0	1639	2160	-70	2090	2074	1.1	387	47
9:21:39	8.1	-1	232	18	1675	-1	-76	0	6	0	0	1622	2150	-70	2080	2064	1.2	397	44
9:21:40	8.1	-1.1	233	18	1679	-1	-75	0	6	0	0	1626	2150	-70	2080	2064	1.2	404	33
9:21:41	8.1	-1.1	233	18	1683	-1	-75	0	5	0	0	1630	2150	-70	2080	2064	1.2	415	20
9:21:42	8	-1.2	233	18	1665	-1	-74	0	5	0	0	1612	2150	-70	2080	2064	1.2	422	31
9:21:43	8	-1.2	234	18	1668	-1	-74	0	4	0	0	1615	2150	-70	2080	2064	1.2	428	21
9:21:44	8	-1.3	234	18	1645	-1	-74	0	4	0	0	1592	2150	-70	2080	2064	1.3	435	37
9:21:45	8	-1.3	234	18	1648	-1	-74	0	4	0	0	1595	2140	-70	2070	2055	1.3	446	13
9:21:46	8	-1.3	234	17	1651	-1	-74	0	4	0	0	1598	2140	-70	2070	2055	1.3	449	8
9:21:47	7.9	-1.4	234	17	1637	-1	-73	0	4	0	0	1584	2140	-70	2070	2055	1.3	456	14
9:21:48	7.9	-1.4	235	17	1639	-1	-73	0	4	0	0	1587	2140	-70	2070	2055	1.3	463	5
9:21:49	7.9	-1.4	235	17	1641	-1	-73	0	4	0	0	1589	2140	-70	2070	2055	1.4	466	-1

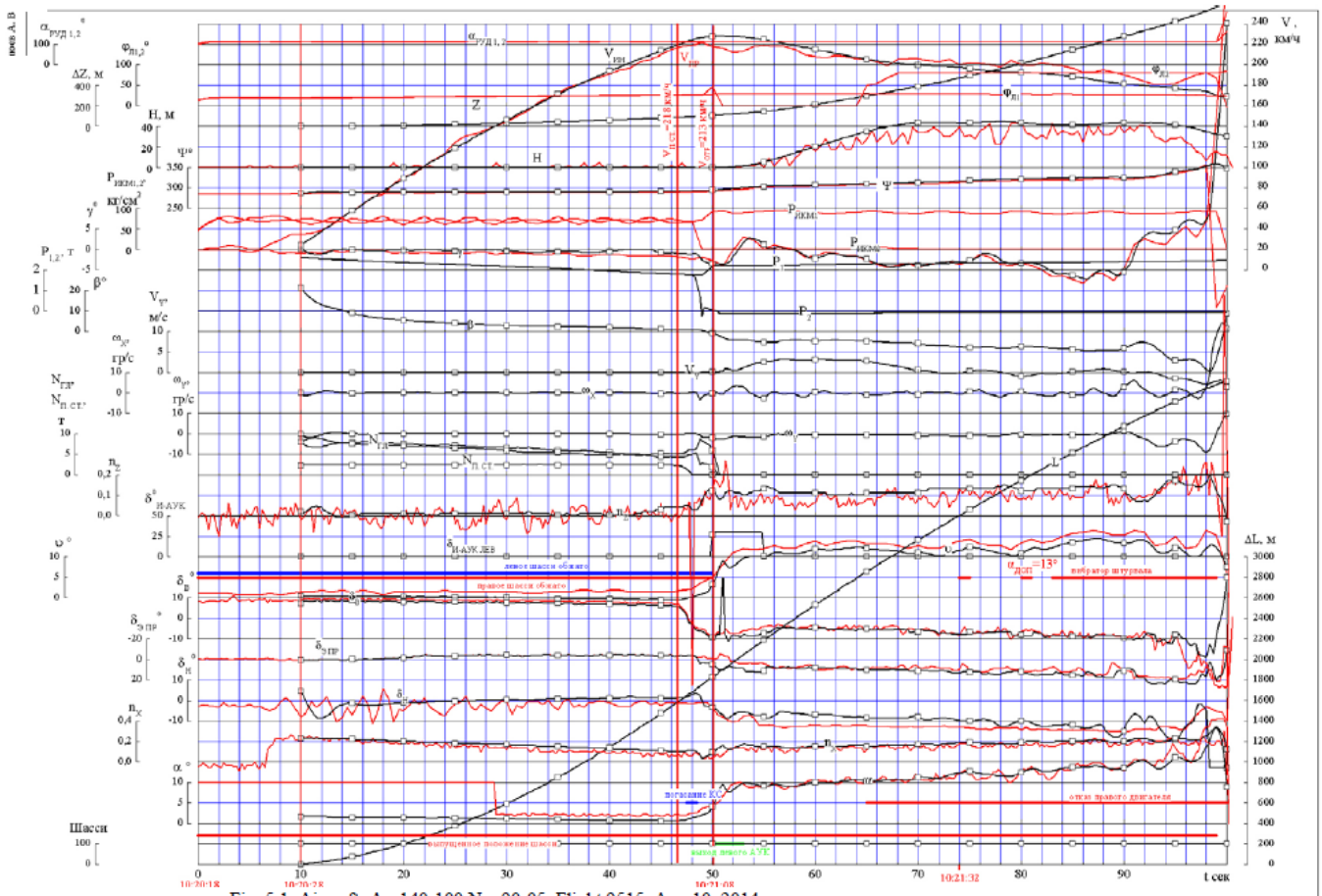

Fig. 5.1. Aircraft: An-140-100 No. 90-05. Flight 9515. Aug.10, 2014.
Parameters of motion at continued takeoff: W=4m/s, AMH=286°; AW=60°; δFL = 10°; G=19.866t; Δt=30°; HA/D. = 1150m; μ≥0.6; XT~ 0.265; PH=662mmHg
—— Motion during takeoff at Mehrabad airport. An-140-100 Aircraft No. 09005. Flight 9515. Aug.10, 2014.
—◦— Calculation for same conditions.

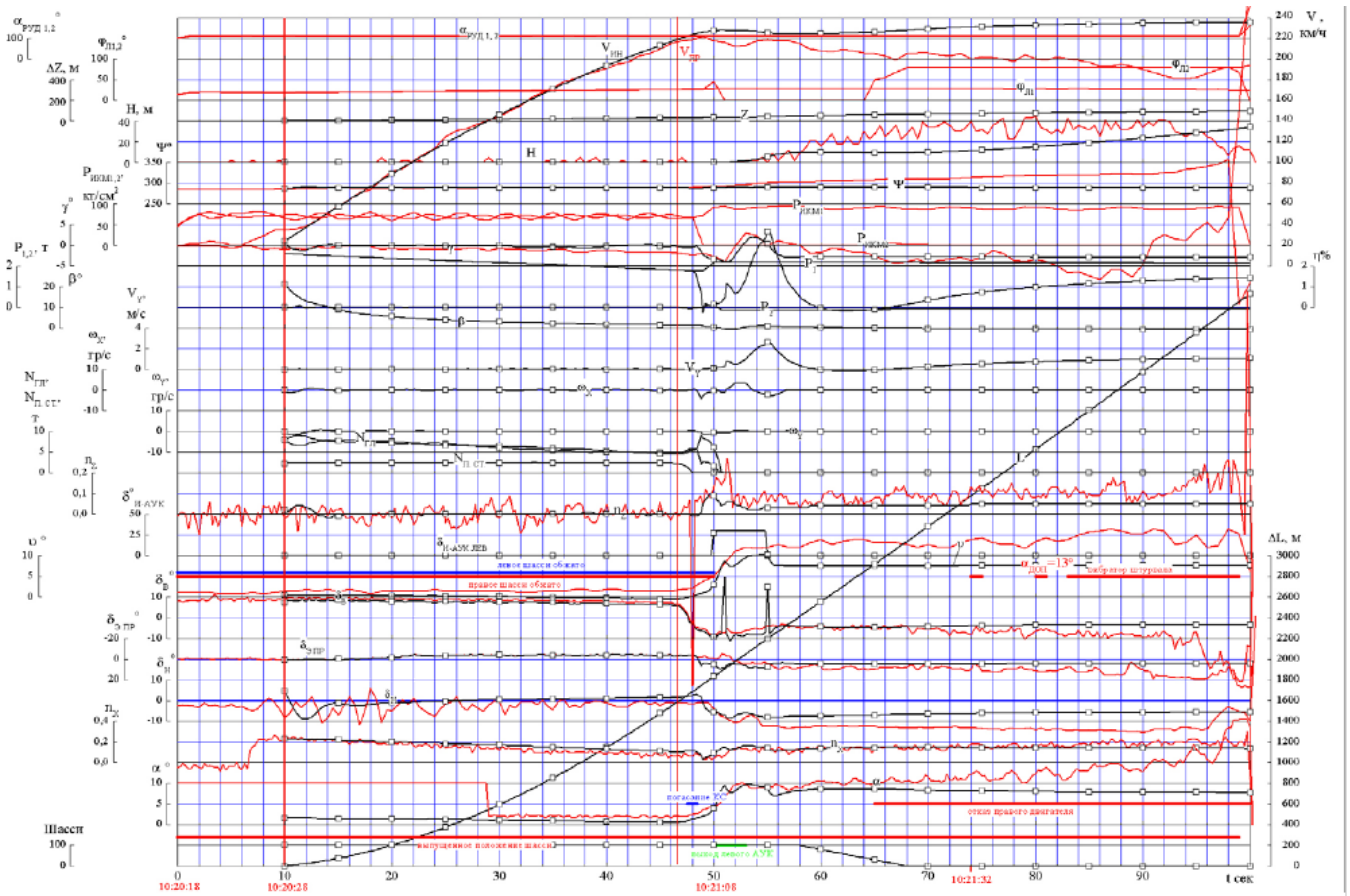

Fig. 5.2. Aircraft: An-140-100 No. 09005. Flight 9515. Aug.10, 2014.
Parameters of motion at continued takeoff: W=4m/s, AMH=286°; AW=60°; δFL = 10°; G=19.866t; Δt=30°; HA/D. = 1150m; μ≥0.6; XT~ 0.265; PH=662mmHg
—— Motion during takeoff at Mehrabad airport. An-140-100 Aircraft No. 09005. Flight 9515. Aug.10, 2014.
—◦— Calculation for same conditions.

Appendix E: Comments from the other States

The IAC (Interstate Aviation Committee) and National Bureau of Air Accidents Investigation were notified about this accident on 11August, 2014.

The National Bureau of Air Accidents Investigation did not attend in the investigation due to evolving in another accident. The IAC introduce Mr. Yachmenov as an Accredited Representation.

The CAO.IRI AAIB also forwarded the draft of final report to the IAC and National Bureau of Air Accidents Investigation (NBAAI).

Their Comments to Draft of final report are as follows:

Note1: The National Bureau of Air Accidents Investigation endorsed the Antonov Co., Motor-Sich, and Ivchenko Progress SE, comments. Nevertheless, their next correspondences had some differences with initial comments and superseded them.

Note2: In the following table, at remark box The Accident Investigation Team has written down which comment was agreed by the Accident Investigation Team (and included in the final report) as well as which one was disagreed upon ,

1. **The IAC comments:**

Item	IAC comments	Remark
1	**Item 1, Page 2** The probable cause of the engine failure has been described in our Report on participation in the accident investigation. The right engine failure at takeoff did not have anything to do with the electronic engine control unit (RED-2000) failure.	Comment was not agreed by the CAO.IR AAIB.
2	**Page 14, line 6 top down** The Type Certificate issued by IAC AR does not cover the An-140-100 EP- GPA aircraft, as HESA is not included into the list of aircraft manufacturers in the data sheet appended to the Type Certificate. There has been no certification request from HESA to IAC AR.	Comment was not agreed by the CAO.IR AAIB.
3	**Page 17, paragraph 2 top down**	Comment partially agreed by the CAO.IR AAIB and draft of

	The improper rectification of the "Hazardous engine vibration" defect has been confirmed by the investigation team. The vibration was not eliminated and might have caused the separation of the air bleed flange	the Accident Final Report amended.
4	**Pages 26-27** ***Concerning the right engine*** The description of the right engine does not contain the fact that the propeller blades were feathered at 84° to 85°. The engine was exposed to ground fire (the accessory gearbox and part of the compressor were burnt out). The aft reduction gear unit was not found during the accident site inspection.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
5	**Page 42, Fig. 19** There are no indications of the location of the killed and injured passengers on the aircraft compartment layout drawing.	Comment partially agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
6	**Para 1.16.1, Page 45, Lines 13-15 top down** The data in the mentioned lines are not consistent with the conclusion made by JSC Klimov during the metallographic examination of the combustion chamber destruction causes.	Comment partially agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
7	**Conclusions of the metallographic examinations of the combustion chamber elements (Page 25):** **Para 2.** the examination revealed welding defects non-compliant with the requirements of metallurgical documentation. The examinations confirmed the presence of defects in the welding joints such as pores, poor penetration and alfinated layer. The improper welding quality might have affected the nature of the flange destruction. **Para 3.** the fractographic examinations revealed a step-by-step static nature of the destruction. Localized areas of fatigue crack development were found in the fracture. The pertinent request from IAC AAIC was made to the manufacturer of the ТВ3117СБМ engine, JSC Klimov who confirmed that the defect in question might have resulted in engine shutdown.	Comment partially agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
8	**Para 1.17.1, Pages 46-47** It is stated that rate of engine failure is not bellow acceptable level. It is necessary to specify the acceptable level of the engine failure rate that is applied by the Operator and CAO IRI and who it was established by. It appears from this section that there were a number	Comment was not agreed by the CAO.IR AAIB.

	of right engine malfunctions in operation right before the accident, but no engine failures. The engine continued operation on hydromechanical control. The FDR did not record any indications of engine systems failures. The defects rectification was mostly by replacement of sensors. Based on the brief analysis of this section, the root causes of the right engine malfunctions were not thoroughly or timely examined. A number of malfunction indications determined by the hazardous vibration signals in previous flights recorded by the FDR were eliminated by replacing the sensor, that later stopped indicating the vibration level at all due to unknown reasons. The analysis of the vibration level recorded by the FDR revealed that it was increasing. Lack of relevant actions resulted in the air duct uncontained damage and might have caused the engine failure.	
9	**Para 2.3.2, Page 49,** Flight Crew Communication It should be mentioned that the crew, having identified the engine failure, did not follow the AFM requirements as to feathering the propeller of the failed right engine, which resulted in negative thrust formation and affected the flight performance. Besides, the landing gear was not retracted after the liftoff.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
10	**Para 2.3.3, Pages 49-50** Analysis of Crew Procedures Item 8 The takeoff weight exceeded the MTOW for δ_3 10° by 2600 kgf)calculation done using the An-140-100 AFM charts, Section 7.1 and 7.2.(Item 9 Having determined the right engine failure the crew did not duplicate the right engine propeller feathering by pressing the ENGINE OFF - FEATHER pushbutton.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
11	**Page 51, upper paragraph** The calculation of Vlof as per the AFM charts for TOW of 19.8 tons with δ_3 =10° requires compliance with ground speed limitations of 250 kmph and using the operational envelope of the charts. Considering these limitations the MTOW of the aircraft was 17.2 tons.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
12	**Page 51, Para 2.5, upper paragraph** The Type Certificate issued by IAC AR does not cover the An-140-100 EP- GPA aircraft s/n 90-05 manufactured by HESA (IRI), as HESA is not included into the list of aircraft manufacturers in the data sheet appended to the Type Certificate. There has	Comment was not agreed by the CAO.IR AAIB.

	been no certification request from HESA to IAC AR.	
13	**Para 2.7.3, Page 56, Right Hand Engine** It should be mentioned that the first recorded signals were the decrease in air pressure behind the compressor, decrease in gas temperature and decay of the combustion chamber which was reacted accordingly by the RED 2000. These signals are typical of air duct uncontained damage due to the separation of air bleed flange. It can be assumed that the external conditions appearing after the air duct damage might have affected the RED 2000 operation, but its operation resumed after 17 seconds. The propeller blades were feathered.	Comment was not agreed by the CAO.IR AAIB.
14	**Page 59, Para 2.8** The 17-second delay of complete right engine propeller feathering might have resulted from the RED 2000 malfunction, as the conditions appearing after the air duct damage were not consistent with the expected operational conditions considered during the certification.	
15	**Conclusions , Para 3.1 Findings Item 4.3, Page 60** Having identified the right engine failure 5 seconds after it had failed, the crew did not manually feather the propeller by pressing the ENGINE OFF - FEATHER pushbutton as required by the AFM. Item 8 In accordance with the An-140-100 AFM charts (Section 7.2.2) the MTOW should have been 17.2 tons considering the ground speed limitations at takeoff. Item 9 We confirm that AFM procedure for takeoff weight calculation was not clear. Item 16 The engine failure was caused by the decrease in air pressure behind the compressor and decay of the combustion chamber due to the air bleed flange being ripped off. Item 19 It is necessary to specify the acceptable rate of engine failures in accordance with your current airworthiness requirements, that was exceeded during operation of the An-140-100 EP-GPA passenger aircraft.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
15	**3.2.1 Causes, Item 1, Page 63** Item 1 RED 2000 had nothing to do with the engine failure. Based on the jointly conducted examinations it can be concluded that the probable cause of the right engine was the uncontained damage of engine	Comment was not agreed by the CAO.IR AAIB.

	air duct due to the separation of the air bleed flange. This is confirmed by the FDR recorded signals: first were the decrease in air pressure behind the compressor, decrease in gas temperature and decay of the combustion chamber which was reacted accordingly by the RED 2000. The changed external conditions that were not consistent with the expected operational conditions for RED 2000 operations resulted in its malfunction and it resumed operation after 17 seconds, which is confirmed by the recorded signals and complete propeller feathering.	
17	**Para 3.2.3, Page 64** To be extended. The appearance of negative thrust from the unfeathered propeller blades at takeoff were not considered during the certification tests, as it was considered improbable. However, in the accident flight the negative thrust did appear and affected the flight performance. Antonov Enterprise should conduct special tests to address this issue and draw recommendations for flight crews.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
18	**Safety Recommendations, Page 65** Antonov Enterprise should conduct special tests to draw recommendations for flight crews as to their actions if there appears negative thrust from the unfeathered propeller blades in case of engine failure at takeoff.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.

2. The National Bureau of Air Accidents Investigation of Ukrainian comments:

Item	National Bureau of Air Accidents Investigation of Ukrainian comments	Remark
1	The *Introduction and Synopsis* section of the CAO IRI AIG Department Final Report requires an amendment in the designation of engine, which experienced failure: engine No. 2. Information in this section is marked *3.2.2.* and repeats the information of sub-sections 3.2.1 *Causes* and 3.2.3. *Contributing Factors to the Accident* of the *Conclusions* section. Considering the	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.

	recommendations of Supplement to the ICAO Annex 13 to the Convention on International Civil Aviation and the Aircraft Accident and Incident Investigation Manual (Doc. 9756), we suggest that the information about accident causes and factors contributing to the accident be deleted from the *Introduction and Synopsis* section and included in the *Conclusions* section only.	
2	Paragraph 2 of the *Introduction and Synopsis* section, paragraph 2.6 of the *Analysis* section, paragraphs 9 and 10 of section 3.1. *Conclusions*, paragraph 2 of sub• section 3.2.1. and paragraph 1 of sub-sections 3.2.2. and 3.2.3, sub-section 1.16.4 (1st paragraph) of the CAO IRI AIG Department Report mention ambiguous and confusing performance charts. The charts contained in the AFM in Fig. 7.2-10 and Fig. 7.2-11 make it possible for the pilots to do an unambiguous and error-free calculation of the maximum take-off weight (MTOW), based on the consideration of assuring the required climb gradient of 2.4% at the height of 120 min take-off configuration with one engine inoperative. Reference speed tables 4.2.2 and 4.2.3, and also charts given in Figures 7.2-1a, 7.2-1b, 7.2-1B and 7.2-1r make it possible to determine, using the maximum take-off weight value and meteorological conditions, the rotation speed V_R and the take• off safety speed V_2 • The above-mentioned charts do not have a limit line for the weight isolines bottom limit, and this allows to extend the isoline for a specific takeoff weight to intersection with the horizontal line corresponding to the outside air temperature and aerodrome altitude conditions of the take-off. We wish to direct your attention to the limiting lines drawn below the V_R and V_2 charts in page 55 of the AIG CAO IRI Report: these lines do not correspond to those of the AFM charts. Maximum allowable take-off weight of the aircraft determined from Fig.7 .2-11 of the AFM should not have exceeded the value of 19500 kgf. According to the CAO IRI AIG Department Report, this weight should not be higher than 19650 kgf (page 52).The actual take-off weight of the aircraft at starting point was 19800 kgf. All weight values mentioned above lie within the weight envelope shown in the charts given in the AFM Figures 7.2-la, 7.2-1b, 7.2-lB and 7.2-lr with the minimum weight of 13000 kgf, and	Comment was not accepted by CAO.IR AAIB.

	maximum weight of 21500 kgf. The requirements of paragraph 7.1.1 *"Terms of Performance Application"* of the AFM are met. Figur 1 of the Appendix shows example for determination of the takeoff reference speed V_2 with the maximum allowable take• off weight of 19500 kgf. Flying crews piloting the An-140-100 aircraft undergo a training cycle to study the AFM and acquire flying skills. Over the years of long-term An-140-100 aircraft service with airlines of Ukraine, Russia and Iran there have been no complaints as to ambiguities or confusion in the performance charts.	
3	The *Introduction and Synopsis* section and sub-section 3.2.1 of section 3 *Conclusions* of the CAO IRI AIG Department report state principal causes of the flight accident and particularly specify as main cause, out of the combination of factors, - Electronic engine control (CAY-2000) failure simultaneously with engine No: 2 shutdown. The results of the An-140-100 aircraft flight tests and also the certification activities performed by the State Aviation Administration of Ukraine (SAAU) and IAC AR on the basis of the flight tests, as well as calculations shown in Figures 6.1 and 6.2 of the *Technical Report of working group of specialists of ANTONOV Company, IVCHENKO-PROGRESS SE and MOTOR-SICH JSC on results of analysis of flight accident with An-140-100 aircraft No. 90-05 on 10.08.2014* (hereinafter referred to as the *Technical Report …)* as well as checks of taking off on the An-140 aircraft simulator carried out with the participation of CAO IRI experts demonstrate safety of taking off under the conditions of this engine failure provided flying is performed in accordance with AFM requirements. Therefore, the main cause of this accident was, in our opinion, the sum-total of factors including: • failure of engine No. 2 with failure of its CAY-2000 electronic engine control system and non-indication of the crew about the engine failure; • erroneous crew actions, which directly affected development of the situation of engine failure from major to catastrophic, and resulted in the generation of considerable drag leading to the aircraft	Comment was not agreed by the CAO.IR AAIB.

	deceleration to stalling speed, stalling, loss of altitude, and collision with the ground.	
4	Indicated on page 13 is the erroneous date when the co-pilot completed his AN 140 simulator proficiency check - 18 May, 2013. 18 May, 2014 should be indicated. Page 14 shows erroneous date of the most recent scheduled maintenance - 02 August 2013. 02 August 2014 should be indicated.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
5	The number of engine No. 2 cycles indicated on page 20 of the CAO IRI AIG Department Report is - CSN:1221. The actual value that should be indicated is 1329, as shown on page 15 of the Report. Besides, life between overhauls of both engines should be amended: the value is 4000 hours, 3400 cycles.	Comment was not agreed by the CAO.IR AAIB.
6	The CAY-2000 engine electronic control diagram given on page 21 in sub-section 1.6.3 of the CAO IRI AIG Department Report does not correspond to the diagram in chapter 073.00 (page 20) of the effective Engine Maintenance Manual, therefore we consider it necessary to cancel the text of the second paragraph of sub-section 1.17.1 in the Report.	Comment was not agreed by the CAO.IR AAIB.
7	The name of the OIIAJI-E CVR manufacturer should be corrected on page 24: the manufacturer is NIIEMP, Kiev.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
8	The descriptions of damage to the left and right engines on pages 27-28 of the CAO IRI AIG Department Report have been mixed up: the left engine was assigned the damage detected on the right engine and vice versa.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
9	As regards the selection of the take-off configuration (see sub-sections 1.16.4 on page 45 and 3.1. on page 60 of the AIG Department Report), it should be noted that the operating procedure for take-off with flaps set to 10° has been foreseen and described in the An-140-100 Aircraft Flight Manual, therefore, the crew had a right to use this configuration of the wing high-lift devices for take-off. The crew selects the flap settings for take-off at the stage of performing the aircraft pre-flight procedure (see AFM section 3 .1). As far as we know, SEPAHAN AIRLINES had a copy of the	Comment was not agreed by the CAO.IR AAIB.

	AFM approved by CAO IRI on the yearly basis.	
10	Actual take-off weight of the aircraft is determined in accordance with WBM and the calculation has been performed by the flying crew properly, and this is acknowledged in paragraph 3 of the CAO IRI AIG Department Report sub-section 2.3.3. indicating the aircraft's actual take-off weight on the ramp of 19866 kgf. The maximum allowable take-off weight is determined using the chart given in Fig. 7 .2-11 of the AFM, and according to this chart the maximum allowable weight of the aircraft should not exceed 19500 kgf. The crew was aware that the weight had been exceeded, which is indirectly confirmed by the conversation between the captain and co-pilot.	Comment was not agreed by the CAO.IR AAIB.
11	When identifying the conditions of the aircraft take-off in sub-sections 1. 7 and 2.2. of your Report, it is necessary to take into consideration the correction of the airfield elevation of 1208 m indicated in your Report for the actual barometric pressure at the time of the take-off. According to the FDR records, the aerodrome pressure altitude at the time of the take-off was H_{aer}=1150 m. According to METAR (OIII) routine weather report, the actual outside air temperature at the aircraft starting point (Time: 04:50:24 UTC) was 36°C. The values of t=37°C and Haer=l 150 m were adopted (upon agreement with the members of the flight accident investigation commission) for computational analysis of the aircraft motion paths.	Comment was not agreed by the CAO.IR AAIB.
12	With reference to sub-section 2.4, page 50, of the AIG CAO IRI Department Report. When performing pre-flight calculation of the take-off, en-route (gross) and landing weights (for preparation of the center-of-gravity diagram), the values of the empty aircraft weight and CG positions are to be taken from the Log-Book. The empty aircraft weight and CG position data shown in the Log-Book are determined by the results of weighing of the particular aircraft (the one under consideration). In the process, it is necessary to ensure that the take-off, en-route and landing CG positions fall within the range designated by the diagram of operational weights and CG positions, and also assure that principal weight limitations specified in 2.1.1 of the Weight and Balance	

	Manual are complied with. The calculated values must not exceed: - maximum takeoff weight - maximum landing weight - maximum zero fuel weight - maximum payload weight (with due account for the equipment installed in the aircraft with payload penalty)	
13	Section 2.5. Compliances with Aircraft Design Requirement of the AIG Department Report and paragraph 13 of sub-section 3.1. Conclusions contain remarks regarding non-compliance of the An-140-100 aircraft performance with certain AP-25 Aviation Regulations requirements. These remarks are not correct. In the course of the An-140-100 aircraft certification testing performed jointly with SAAU and IAC AR, full flight test cycle has been covered and the tests have demonstrated compliance of the aircraft's flight performance and takeoff/landing performance characteristics with all requirements of Subpart B, Flight, of the CB-140 Certification Basis. In accordance with Contract No. 141/3/1011-140-74-l dated 03.12.1995 and Protocol No. 140H-24-2001 dated 31.07.2001, CAO IRI together with ANTONOV have examined all essential documentation requested by CAO IRI and prepared by ANTONOV based on the results of the accomplished certification procedure, which has confirmed in full compliance of the Aircraft Type Certificate (including compliance of the operating and maintenance publications, the AFM inclusive) with the requirements the Certification Basis elaborated based on the AP-25 Aviation Regulations. Moreover, at the CAO IRI and HESA request, two flights was performed on 14.03.2002 with the participation of the HESA pilot and with the flight profile as proposed by CAO IRI. The results of the flights demonstrated compliance of the aircraft performance with the performance declared in the AFM. Based on the results of the HESA and CAO IRI expert team activities, the specialists of the Parties signed the Protocol No. 140A-33-2002 dated. 14.03.02, which established the fact that all certification materials were evaluated by the HESA and CAO IRI experts as sufficient for validation of the Type Certificate No.CT 184-AN-140 issued by	Comment was not agreed by the CAO.IR AAIB.

	IAC AR for the An-140 and An-140-100 aircraft, and for submission of the Type Acceptance Certificate for the An-140 and An-140-100 aircraft from CAO IRI to ANTONOV Company. in accordance with the CAO IRI procedure and based on the results of examination of documents submitted by ANTONOV, the organization confirmed acceptance of the An- 140/ An-140-100 aircraft by the Type Approval Certificate number Al-530/1/7/1 in October 2002. As regards the comment made in the CAO IRI AIG Department Report in sub-section 2.5., on page 52, it should be noted that during the flight under examination the aircraft indeed failed to attain the V_2 speed since improper crew actions as specified in paragraph 3 above) created considerable drag, which prevented the aircraft from accelerating to the required speed. When performing the procedures prescribed by the AFM, the crew could have accelerated the aircraft to the V_2 speed. This has been demonstrated by mathematical modelling. Additional modeling was performed with lesser control column pull to pitch up so as to demonstrate feasibility of accelerating the aircraft with simultaneous climb when, upon reaching the height of 10.7 m, the aircraft accelerated to the speed of V_2=234km/h. the results of this computation are shown in Fig. 2 of the appendix. With the maximum take-off weight determined using chart given in Fig. 7.2-11 of the AFM (G_{TO}=19500 kgf), according to the tested and proven mathematical model, with the aircraft compliance with AFM the speed of V_2 = 232 km/h is reached at the height of 10.7 m (see Fig. 4 of the Appendix), i.e., the requirement of the AP-25 paragraph 25.107 (e)(1)(iii) is complied with. Thus, the results of the take-off path computation shown in Figures 2, 3 and 4 of the Appendix allow us to make a conclusion that, if the AFM requirement of accelerating the aircraft after lift-off up to the take-off safety speed V_2 had been strictly complied with, it would have been possible for the crew to continue take-off safely with the actual weight of 19800 kgf and in the situation of early lift-off. In determining the continued take-off path of the aircraft the rotation speed V_R was determined so that the take-off safety speed V_2 is attained at the	

	height of H=l0.7 m above takeoff runway surface and continued take-off is assured at the V2 speed until the height of H=l20 m is reached in climb with climb gradient of at least 2.4% with the landing gear up. The requirement of the AP-25 Aviation Regulations§ 25.107(e)(l) and § 25.121(b) is thus complied with. With the take-off configuration existing along the flight path (between the point at which the airplane reaches VLOF and the point at which the landing gear is fully retracted) and without ground effect, the steady gradient of climb is positive (AFM Fig. 7.2-2 and Fig. 7.2-3), and this is in compliance with the requirements of AP-25 § 25.121(a).	
14	Sub-paragraph 2.6 of the Analysis section of CAO IRI Report - p. 53, sub paragraph 3.1 of the Conclusion section, paragraph 4, 8. According to the AFM chart 7 .2-11, the maximum take-off weight of the aircraft at start should be 19500kgf, maximum, for the take-off conditions corresponding to the accident, the OAT temperature 37°C, aerodrome altitude 1150m, and the tailwind component 3 mis. The aircraft overweight was 300kgf, not 190kgf. If, for calculation of the maximum take-off weight, we assume the OAT value of35°C, aerodrome altitude of 1208 m, and the tailwind component of 3 .9 mis, the AFM chart 7 .2-11 shows the 19500 kg value of the aircraft maximum allowable take-off weight, the aircraft overweight being the same 300kgf. The Technical Report by the Team of ANTONOV, IVCHENKO-PROGRESS and MOTOR-SICH Specialists on the Results of Analysis of the Circumstances of Aviation Accident with An-140-100 Aircraft No. 90-05 on 10.08.2014, and besides, Fig.2 and Fig.3 of the Appendix hereto contain the results of analysis and mathematical modeling of the aircraft takeoff with a 19800kgf take-off weight exceeding the maximum allowable takeoff weight by 300kgf. It is shown that in case the crew actions comply with AFM recommendations, the aircraft with such weight may be accelerated to V2, climb, and continue its flight safely. Paragraph 4, dash 5 contradicts the AFM materials. AFM section 4.2 gives recommendations for the An-140-100 takeoff with the flaps set to 10°	Comment was not agreed by the CAO.IR AAIB.

	sufficiently for performance of take-off. The selected flap position at take-off is determined by the crew at the stage of aircraft preparation for flight (AFM, section 3 .1). The procedure of landing gear retraction at take-off in case of one engine inoperative is described in AFM Para. 5.1.2 "Engine Failure During Takeoff"' Following the dash which recommends to gradually turn the aircraft to climb with simultaneous acceleration up to a takeoff safety speed V2, there is another dash prescribing to start retraction of landing gear at an altitude of lOm, that is, definitely lower than 10.7m. Concerning the remark about the absence of any diagrams in AFM or lack of explanations concerning the maximum energy of wheel braking, it should be said that the aircraft mass and speed of motion limitations are illustrated in AFM with a diagram Fig.7.4-3 onpage.11/12 of section 7.4. This diagram contains limitations for the maximum speed of brake application at landing which are determinable on the basis of effective limitations for the wheels brake kinetic energy absorption capacity in expected operation conditions. No limitations of the brake application speed at aborted take-off are specified. As for the limitations concerning the wheel tire, Para. 5 of the AFM Section 7 .2.2 entitled "Determination of Maximum Allowable Take-Off Weight of the Aircraft and Decision Speed" describes the procedure of limiting the aircraft take-off weight depending on the ground speed (IIYT) of the tire on runway. This limitation corresponds to the maximum value of 250 km/h IIYT. In case of 19800kgf take-off weight of the aircraft with tailwind of 3 m/s at takeoff, OAT+37°C, airfield elevation of 1150m, the indicated lift-off speed, as per AFM, V_{LoF}=234km/h corresponds to the ground speed of-271km/h ITYT, which exceeds the established limitation of 250km/h ITYT. However, in case of an upwind take-off with the same take-off weight the aircraft ground lift-off speed V_{LoF} would be 250 km/h IIYT, therefore not exceeding the	

	established limitation. This allows to conclude that the crew did not take into account the wind effect on the aircraft ground lift-off speed.	
15	The list of crew's erroneous actions given in para.4 section 3.1., page 60 of the Report does not mention any violations of the aircraft operating procedure requirements that occurred, namely: take-off with a considerable excess of angles of attack and pitch, failure to retract the landing gear after take-off, non-performance of actions for the aircraft acceleration after lift-off.	Comment was not agreed by the CAO.IR AAIB.
16	As to Para.11 section 3.1., please be informed that the Weight and Balance Manual (WBM) and the Center-of-Gravity Diagram (CGD) of the Designer (ANTONOV Company) approved by IAC AR, SAAU, and CAO IRI allow making accurate calculations of aircraft weight and balance data for the passenger and luggage weights different from the values assumed in CGD. However attention should be paid to the requirement so that the aircraft total weight with the actual payload does nor exceed the maximum allowable weight determinable with AFM charts, and the CG position lies within the limits prescribed by the AFM "Limitations" section 2 .. Airlines use of the procedure referred to in the aircraft WBM for airplane weight & balance calculation can not contradict the requirements of CAO IRI since WBM is a directive document for the Operator, and as far as we know, it was approved by CAO IRI.	Comment was not agreed by the CAO.IR AAIB.
17	Concerning Para.14 section 3.1, p. 62. Unambiguous definition of climb segments presented in AFM Para.7.1.3, and the requirements for definition of climb gradients in AFM charts figures 7 .2.1.2 through 7.2.1 is ensured by the fact that full gradients are provided for the final altitudes of take-off segments 3 and 4 (120m and 450m) as the most critical requirements of thrust/weight/ratio for flight performance. Unambiguous definition of the segment 2 (between the point in which the aircraft reaches 10.7m altitude. the point in which its landing gear is completely retracted, and the requirements for definition of climb gradients in charts of Fig. 7.2-2 and Fig.7.2-3 is ensured by the fact that full gradient is reduced to the altitude of 10.7m, because in case of the maximum take-off weight determined by	Comment was not agreed by the CAO.IR AAIB. *

	the chart 7.2.-11, variation of altitude before full retraction of landing gear is –3m which basically has no influence on thrust performances of the aircraft powerplant, while the aircraft resistance is decreased by the quantity of the landing gear resistance. In this connection, AFM contains charts for determination of takeoff climb gradients for 10.7m altitude with extended landing gear as a critical provision for the takeoff path. segment two.	
18	As regards the wording of paragraph 20, section 3.1., page 62 of the CAO IRI AIG Department Report, we suggest taking into account the fact that actions for rectifying vibration of the engine No.2 were carried out in the transit airport without participation of the engine manufacturer Representative.	Comment agreed by the CAO.IR AAIB and draft of the Accident Final Report amended.
19	Considering the above-mentioned and taking into account the fact that the shortcomings listed in paragraph 4, section 3.1 of the CAO IRI AIG Department Report directly caused change in the situation from major to catastrophic failure conditions, we suggest that section 3.2. should be revised and set forth as follows: « 3.2. Causes and Contributing Factors 3 .2.1. Causes The AIG Investigation Team determined that the cause of aircraft accident was combination of the following events and factors: • Engine No.2 shutdown and its electronic engine control system (CAY-2000) along with non-indication of the crew about the engine failure caused major failure conditions during the aircraft takeoff; • Crew actions which directly caused change in the situation from major to catastrophic failure conditions, including: - performing take-off with the allowable maximum takeoff weight of the aircraft exceeded by 300 kgf for the given conditions; - co-pilot prematurely reporting about attainment of the decision speed, which should be followed, according to AFM, by the continued take-off after one engine failure; - failure by the pilot flying the aircraft to perform the required procedures to accelerate	Comment was not agreed by the CAO.IR AAIB.

	the aircraft to takeoff safety speed V_2 = 234 km/h; - the crew's failure to retract landing gear upon attaining the height of 10 m above runway surface; - insufficient deflection of rudder by the pilot flying to counteract the turning moment due to the engine failure, which, according to the calculations presented in Table 5.1, were within the limits of pilot's physical abilities. As a result, after the aircraft lift-off, its flight proceeded with the increasing lateral acceleration and growing left sideslip which caused an extra aircraft drag; - failure by the crew to perform manual propeller feathering procedure for the failed engme; The above-mentioned factors led to a substantial growth of the aircraft drag, and its braking to the stalling speed; having attained which the process of stalling commenced, the aircraft lost altitude and collided with the ground.	
20	Safety Recommendations for the State of design and manufacturer (related to the ANTONOV Co. and its subsidiary contractors or suppliers) stated in the part 4 items 1, 2, 3, 4 on the page 65 should be revised and set forth as follows: 1. Render assistance to airlines in training that will empower flight crew understanding of weight calculation, manual engine control modes and aircraft performance through improved documentation, courseware, and instructor training. 2. Take appropriate action in order to make automatic engine control system (CAY-2000). It should be modified in order to be capable of operating in its intended manner at the time of engine failure with no special operations necessary on the part of the crew in order to make the automatic feathering system operative. 3. Review the engine TV3-117VMA-SBM1 operating manual (parts 072.00 and 073.00) and, if necessary, correct related charts and procedure based on the CAO IRI remarks.	Comment was not agreed by the CAO.IR AAIB.