The Aircraft Accident Investigation Board of the Islamic Republic of Iran

Flight PS752 Accident Investigation

Final Report

In the Name of God

Crash of
Ukraine International Airlines
Flight PS752

AAIB File Number:	A981018URPSR
Type of Occurrence:	Accident
Date of Occurrence:	Jan. 08, 2020
Place of Occurrence:	Near IKA Airport (OIIE) - I.R of Iran
Aircraft Type:	B737-800
Registration:	UR-PSR
Date of Issue:	Mar. 15, 2021

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Abbreviations and Definitions

AAIB	Aircraft Accidents Investigation Board of I.R.Iran
ACC	Area Control Unit
ACCREP	Accredited Representative
ADS-B	Automatic Dependent Surveillance–Broadcast
ADU	Air Defense Unit
AMO	Approved Maintenance Organization
Annex 13	Annex 13 to the Convention on International Civil Aviation
ANSP	Air Navigation Service Provider
APP	Approach Control Unit
APU	Auxiliary Power Unit
ATCO	Air Traffic Control Officer
BEA	Bureau d'Enquête et d'Analyse pour la Sécurité de l'Aviation Civile
CAM	Cockpit Area Microphone
CAMO	Continuing Airworthiness Management Organization
CAOIRI	Civil Aviation Organization of the Islamic Republic of Iran
CCTV	Closed-Circuit Television
CMOCC	Civil- Military Operational Coordination Center
CSMU	Crash-Survivable Memory Unit
CVR	Cockpit Voice Recorder
EASA	European Union Aviation Safety Agency

ELT	Emergency Locator Transmitter
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
FL	Flight Level
FMS	Flight Management System
FOD	Foreign Object Debris
FS	Frequency Spacing
GND	Ground Movement Control unit
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IDG	Integrated Drive Generator
IFR	Instrument Flight Rules
IKA	Imam Khomeini International Airport
LS	Load Sheet
NTSB	National Transportation Safety Board
PA	Passenger Address system
PSR	Primary Surveillance Radar
QAR	Quick Access Recorder
RSL	Radio Station License

SID	Standard Instrument Departure
SSCVR	Solid-State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
TC	Type Certificate
TI	Trip Information
TMA	Terminal Maneuvering Area
TWR	Air Traffic Control Tower
UIA	Ukraine International Airlines
WPS	Words Per Second

Special Foreword To English Edition

This is a courtesy translation by the AAIB of the Islamic Republic of Iran of the Final Report on the PS752 accident investigation.

As accurate as the translation may be, the original text in Farsi is the work of reference.

Foreword

Flight PS752 departing from Imam Khomeini International Airport for Kyiv crashed shortly after takeoff. 176 people lost their lives in this accident and their next of kin suffered profound grief.

Two major questions following any air accident were raised: what was the cause of the accident and how can similar accidents be prevented?

Aircraft Accident Investigation Board of I.R.Iran instituted the accident investigation in accordance with the international regulations laid down in Annex 13 to Convention on International Civil Aviation.

This report contains facts, analyses and conclusions as a result of the investigation. Based on them, the recommendations which can serve to prevent similar accidents are made to different parties.

Although the prevention of accidents cannot be 100 percent guaranteed in aviation, there are always areas to be improved to minimize the probability of such occurrences. The lessons learned from this accident are used to make recommendations to related parties. It is for those parties to decide what action to take.

The accident-related preliminaries are provided in Section 1 of this report and the factual information is explained in Section 2. The Management of Potentially Hazardous Activities to civil aviation in general and, in particular, regarding this accident is elaborated on in Section 3. Section 4 reviews similar accidents and Section 5 makes an analysis of the issues provided in the preceding Sections. Conclusions, including the Findings, the cause of accident and other contributing cactors are stated in Section 6, and finally the Safety Actions Taken by Iran and Safety Recommendations to the States managing airspace, to States overseeing the airlines activities, to ICAO and to the EUROCAE are listed in Section 7.

Summary

On January 08, 2020, Ukraine International Airlines (UIA) Flight PS752 departing from Imam Khomeini International Airport for Kyiv crashed shortly after takeoff.

Under the Islamic Republic of Iran Regulations and as per Annex 13, the accident investigation team was formed, who collected and analyzed data, made conclusions and safety recommendations with the aim of preventing similar accidents.

The accident aircraft was misidentified by the air defense unit in the suburbs of Tehran and, consequently, two missiles were launched toward it. The operation of aircraft had not imposed any error to the air defense unit.

The cause of the accident was the detonation of the missile.

All 176 people on board lost their lives.

The airworthy Boeing 737-800 operated by qualified crew of Ukraine International Airlines was under control of Iranian air traffic control and the takeoff clearance was issued after coordination with military sector.

The air defense forces were on a higher level of alertness at the time of the accident.

According to the analyses conducted by the investigation team, safety recommendations are made to enhance the process of distribution and gathering information, risk assessment, and implementation of measures when potentially hazardous military activities may put the civil aviation safety at risk, to prevent similar accidents.

1. Introduction

1.1. Accident Investigation Institution

Following the accident involving a Boeing 737-800, UR-PSR operated by Ukraine International Airlines on January 08, 2020, near Tehran, Iran's Vice Minister of Roads and Urban Development and the president of Civil Aviation Organization designated the investigator-in-charge for this accident. The accident investigation team was formed afterwards.

The accident investigation was carried out to implement the Civil Aviation Accidents and Incidents Investigation Bylaw, adopted by Iran's Cabinet of Ministers on August 21, 2011.

This investigation was done in compliance with the provisions of Annex 13 to the Chicago Convention, whose Standards and Recommended Practices were applied accordingly.

1.2. The Objective and Scope of the Accident Investigation

The investigation was carried out to determine the root causes of the flight PS752 accident on January 08, 2020, so that similar events in the future could be prevented accordingly.

The provisions of Annex 13 do not approve of conducting an accident investigation with the aim of apportioning blame or liability and the sole objective of this investigation is the prevention of accidents and incidents.

This prevention can only be realized through identifying the details of events and providing recommendations to implement the necessary improvements for eliminating the roots of such events.

As for this accident, the interference of military activity with civil aviation operations resulted in an accident.

The team addressed three areas in their investigation: military, civil and the area of their cooperation and interactions; however, the identification of the root causes and the provision of recommendations are confined solely to the civil area and its cooperation scope with the military one

In order that the investigation team could independently identify the events, announced by the military authorities, and compare it with other data available and reciprocally verify them, some military operational events, which resulted in the launching of the missiles at the aircraft, were identified.

It was necessary to become aware of such events in the military sector so that the impact of civil operations and practices on the military occurrence could be investigated. The investigation scope and areas probed in civil and military areas are illustrated in Figure 1.

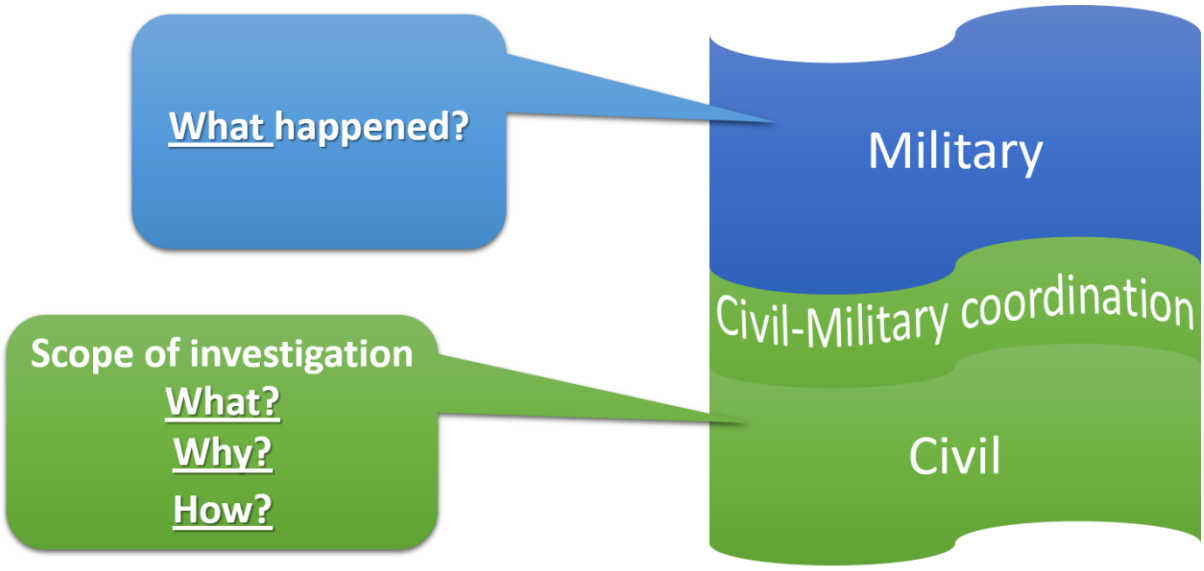

Figure 1-Scope of the investigation

After I.R. Iran General Staff of the Armed Forces publicly announced their air defense system had targeted flight PS752 mistakenly, Iran Armed Forces Judicial Organization commenced judicial proceedings into the accident by order of the Iranian head of the Judiciary.

The accident investigation subject to Annex 13 and judicial proceedings are independent of one another. Nevertheless, given the coordination required in data gathering or recording evidence, joint cooperation was performed in accordance with the standards contained in Annex 13. The investigation team used the results of a simulation performed by the judicial systems, where the required data for judicial investigation was obtained through deploying the defense systems in similar positions and

conducting similar flights and validated some of the findings already gained.

1.3. Investigation Methodology and Participating Parties

The investigation into this accident can be categorized into three general stages:

First, it was initiated upon the accident notification. Under the Air Accident Investigation Regulations, the eleven expert groups were then formed. However, due to the signs of fire and explosion on the aircraft wreckage, the images and videos showing the aircraft being targeted or hit by missile, and the observations of ATC men as well as a passing flight pilot, another group was formed to specifically investigate the explosives.

The initial evidence confirmed that the fire had broken out in the aircraft before crashing into the ground. The analysis convinced the investigation team that the explosion is the probable cause of fire. Having made some analyses, the team focused on three scenarios:

- Explosion in the aircraft due to technical issues
- Explosion in the aircraft due to the presence of 'dangerous goods' inside the aircraft
- Explosion due to unlawful interference from the inside of the aircraft
- The aircraft being targeted by terrorists acts
- The aircraft being targeted by military forces

While the team was gathering facts, on January 11, 2020, i.e. 3 days after the accident, the I.R. Iran General Staff of the Armed Forces announced publicly that its air defense system had fired missiles at flight PS752 due to human error.

The AAIB and the accident investigation team had been made aware of this targeting hours before the announcement of the statement at about 18:30 on January 10, 2020.

At this point, the Accident Investigation Team revised their approach. Given that a significant amount of information was made available from official military and judicial sources, they shifted their focus on identifying other findings and comparing them with the information received from the military sector, to simply ensure that the only cause of the crash had been the defense system's missile launch and identifying the underlying factors.

Once the facts on the missile firing were collected and confirmed, the collection for risk assessment, analysis and preparing safety recommendations was performed.

The following States participated in the investigation by appointing and introducing their accredited representative(s):

- Ukraine (as the State of Registry and State of the Operator)
- The U.S. (as the State of Design and State of Manufacture of aircraft)
- France (as the State of Design and Manufacture of the aircraft engines as well as State providing information and assistance for readout of flight recorders)

There were passengers of different nationalities, and some with multiple nationalities registered while purchasing tickets, reception, boarding and crossing the border. Hence, Canada, the United Kingdom, Sweden, Germany and Afghanistan as the States having special interest in the accident by virtue of fatalities to their citizens, were invited to introduce their experts to enjoy their entitlement according to Standard 5-27 to Annex 13, all of which did so but Afghanistan.

The Canadian and Ukrainian representatives visited the accident site. One day following the crash, a full delegation from Ukraine was authorized to access the crash.

Given the nature of the accident and the need for full coordination of the interested States, the ICAO was also invited to appoint a team of advisors to observe the process and lend their support, where necessary. The ICAO was accordingly kept abreast of the investigation via their representative.

In accordance with paragraph 6.3 of Annex 13, the AAIB sent the draft final report to the accredited representatives of the states participating in the investigation, inviting their significant and substantiated comments. In addition, the draft final report were sent to ICAO representative to receive their advisory comments and UK expert to receive their comments about sections related to information provided by UK.

1.4. Previous Reports

After the accident occurred, the first Preliminary Report containing the initial information related to the accident was published on Jan. 08, 2020.

The second Preliminary Report was published on Jan. 20, 2020, when some supplementary information, such as the recorded radio communication and radar data had been obtained.

A Factual Report was released in June 2020, setting out the details on the missile launch by the air defense unit.

Having read out the flight recorders, the relevant report was also released in July 2020, considering the expectations of the victims' families to become aware of the content obtained in the flight recorders read-out.

Given that the Final Accident Investigation Report had not been released on the first anniversary of the flight PS752 accident, the investigation team published an Interim Statement pursuant to Section 6.6 of Annex 13 to the Convention on International Civil Aviation, providing a brief overview of the progress of the investigation.

1.5. Other Investigations

Under Article 172 of the Constitution of the Islamic Republic of Iran, military courts are established to investigate offenses germane to the military or disciplinary duties of members of the armed forces.

After I.R. Iran General Staff of the Armed Forces publicly announced the air defense unit had fired missiles at PS752 because of human error, the head of Iran's Judiciary assigned the Armed Forces Judicial Organization of I.R.Iran to institute judicial proceedings into the accident.

This type of investigation is carried out within the framework of the Judicial Law of the Armed Forces of the Islamic Republic of Iran, approved by the Parliament of I.R.Iran on May 12, 1985, and the associated regulations, and investigation on errors and violations in military sections fall under their authority.

Coordination between the investigator-in-charge and judicial authorities was conducted pursuant to the standard 5-10 of Annex 13.

1.6. Points to Consider in This Report

The objective of the investigation of an accident subject to Annex 13 to the Chicago Convention shall be the identification of the root causes and prevention of similar incidents and accidents by determining the corrective measures required and implementing them accordingly. This type of investigation is not conducted with the aim of apportioning blame or liability. Such issues are obviously important and will be addressed by other authorities through their investigations, in an accident investigation conducted with the aim of improving safety, if the process is diverted to simply apportioning blame or liability, safety goals will be put at risk for two major reasons:

First, individuals involved in an accident would naturally be led to defending themselves, hence reducing their cooperation in identifying the factors having contributed to it. Even worse, some would consider concealing issues concerning their responsibilities in case of occurrence of an error leading to an accident, so that they can escape blame or avoid liability, and, resort to hiding such sensitive issues rather than reporting voluntarily and cooperating to eliminate the areas of concern.

Second, if the factors contributing to an accident are not well determined and eliminated, the identification of the liable individuals and eliminating them from the system in place will not entail the prevention of similar occurrences. On the contrary, the very factors leading such liable individuals to commit the error, causing the accident, will still be lurking for others; hence, similar accidents will take place through others' negligence in the same area.

This report never blames the entities who are named in this report and has no adversarial position with them. The investigation team did all its efforts to use neutral wording, information, analysis and conclusions to conduct the investigation and preparing the report. No biased or misleading interpretation of this report will be valid.

The dates written in the English version are according to the Gregorian Calendar, and the times according to Tehran Local Time (UTC+3:30), unless specified otherwise.

Considering the different information sources, the key event times, particularly those related to the missile launch and activation had minor differences. The investigation team calibrated the times using available information and techniques; however, the tolerance of direction and distance measurements and the update rate of information resulted in a 2-second uncertainty for the reported time values. Values related to the direction of ADU have a tolerance of ±2 degrees. Even so, these tolerances and uncertainties did not affect the conclusions and results.

The details of an accident could be painful and poignant to the victims' families. Stating the contributing factors could also be interpreted as justifying or downplaying them, or making them look inevitable simply. However, it should certainly be borne in mind that elaborating on the causes of an accident is not supposed to mean it was inevitable. More importantly, no analysis and elaboration on such issues will be in any way worthy of comparison neither to the accident victims' lost lives nor to their families' hurt feelings.

The PS752 accident investigation team would hereby genuinely like to extend their heartfelt condolences and sympathies to those having suffered distress and loss as a result of the accident and show great respect for their deep feelings and emotions.

2. Factual Information

2.1. Flight History

On Wednesday, January 08, 2020, at 00:53, the inbound flight No. 751 of Ukraine International, Boeing 737-800, UR-PSR, en route to Tehran Imam Khomeini INTL. Airport from Kyiv Boryspyl INTL. Airport was cleared for landing, and after four minutes landed on the IKA runway. After disembarking 58 passengers and refueling, the flight crew went on to check into the hotel located at IKA.

From 01:16 to 01:38, the aircraft was refueled with 9510 kg (11800 liters) of fuel. Once the total weight of the cargo received from passengers (310 packages weighing 6794 kg) was determined, in order to comply with the maximum takeoff weight allowed for aircraft, 82 packages in 2094 kg in weight, were separated by Airport Service Company, that is, they were not loaded. Initially, 78 packages of the passengers' luggage were not loaded first, then due to the large volume of passengers' hand luggage, the flight attendants passed some of them on to the Airport Service Company personnel to be placed in the aircraft cargo. After that, 4 packages belonging to the passengers were removed from the aft cargo door, where the hand luggage was placed.

At 04:35, the flight crew embarked on the aircraft. After checking the aircraft and cabin, boarding was announced at 04:45, and passengers started to board the plane.

Based on the available documents, 167 passengers proceeded to the Airport Services Co. counter at the airport terminal, all of whom went on board. Only one of the passengers who received the boarding pass online the night before the flight, due to the delay in arriving in Tehran from another city did not go to the airport in person, and therefore had been removed from the list of passengers provided by the UIA.

At 05:13, the pilot made his first radio contact with the IKA's control tower ground unit and requested the initial clearance for flying, which was issued by the controller subsequently.

At 05:48, all the aircraft documents required to start the flight operations were filled out, and all the doors were then closed at 05:49.

The flight was initially scheduled for 05:15, and based on the flight coordinator's report form, the reason given for its delay was the aircraft being overweight and the decision not to load the passengers' luggage for reducing the aircraft weight.

At 05:51 the pilot notified his position at the airport parking, declared his readiness to exit the parking and start up the aircraft. The IKA tower asked him to wait for receiving the clearance since they wanted to make the coordination required with other relevant units.

At 05:52, the IKA tower made the necessary coordination with the Mehrabad approach unit, who contacted Tehran ACC asking for clearance. Accordingly, the controller in ACC made coordination on Ukrainian flight clearance with the CMOCC. The clearance was issued by the CMOCC.

At 05:54, the Mehrabad approach unit, received the FL260 clearance for the flight AUI752 from ACC, and forwarded it to IKA via the telecommunication system.

Flight no. 752 was detached from the A1 Jet Bridge and at about 05:55 started to leave its parking position, NO 116 on the right, by a pushback truck.

Following that, at 05:55 the ground controller cleared the AUI752 flight for startup and exiting the parking, which was read back by the pilot.

At 06:12, the aircraft took off from the Runway 29 Right of IKA and was delivered to the Mehrabad approach unit. The pilot contacted the approach unit, and announced the IKA 1A radar procedure as SID procedure. Next, the Mehrabad approach identified and cleared the flight to climb to FL260. The controller instructed the pilot to turn to the right after 6,000 feet, and continue straight to PAROT.

After it was read back by the pilot, the controller again instructed the pilot to continue to PAROT point once passing the 6000-foot altitude, which was read back by the pilot.

From 06:17 onwards, upon the disappearance of the PS752 information from the radarscope, the controller called the captain repeatedly, but received no response.

According to the data extracted from the surveillance systems and FDR, the aircraft climbed to an altitude of 8,100 feet; thereafter, the label including the call sign and altitude of aircraft disappeared from the radarscope, yet no radio contact indicating unusual conditions was received from the pilot. FDR recording terminated at 06:14:56. This time corresponds to the termination of Secondary Surveillance Radar (SSR) and ADS-B information.

After the mentioned time, the aircraft was still being detected by the Primary Surveillance Radar (PSR), according to which the aircraft veered right and after approximately three minutes of flying, it disappeared from the PSR at 06:18 too.

The aircraft was conducting the flight under the Instrument Flight Rules (IFR) and the accident occurred around half an hour before the sunset.

The aircraft flight path detected by PSR and SSR is illustrated in Figure 2.

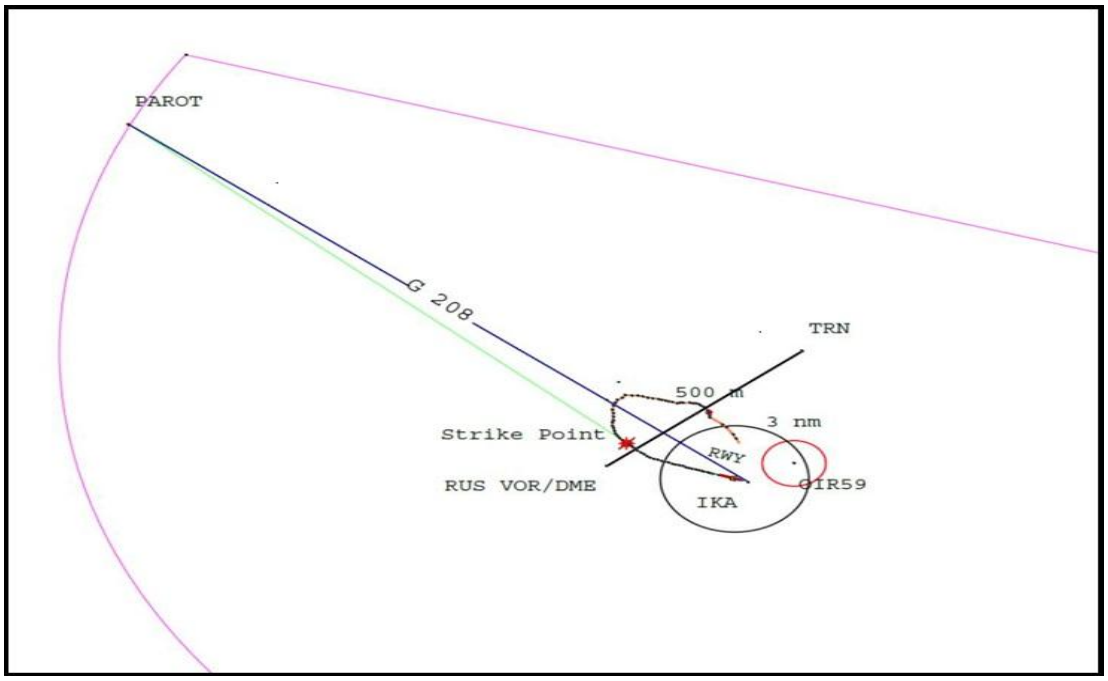

Figure 2- The aircraft flight path detected by PSR and SSR

2.2. Injuries to Persons:

All 176 persons on board this flight lost their lives[1] as shown in Table 1.

Table 1- The number and type of injuries to persons

Injuries	Crew	Passenger	Others	Total
Fatal	9	167	0	176
Serious	0	0	0	0
Minor / None	0	0	0	0
Total	9	167	0	176

[1]- One of the passengers on board this aircraft had been pregnant, whose fetus is reported to have been 7 months old. Under the Laws in Iran, the dead fetus is regarded a person; therefore, in judicial investigations, the number of the victims is reported as 177 people.

Two of the passengers who had purchased tickets did not go to the airport, so they were not onboard this aircraft.

2.3. Identification of Victims

At the AAIB's official request, the following was put on the agenda:

- Identification of the victims
- Tests on flight crew bodies
- The cause of deaths
- The analysis of burning and discovery of metal objects in passengers' bodies

Initially, the Iranian Legal Medicine Organization (Forensic Medicine Organization), in cooperation with domestic entities and coordination made with the involved international authorities, created a DNA data bank for the passengers. By judicial authorities' decision, bodies were handed over to the victims' families for burial and afterwards following their DNA sample confirmation. At the request of some States and victims' families, some of the passengers' bodies were transferred to foreign countries for delivery to their families and burial at their desired location.

2.4. Damage to Aircraft

The aircraft was completely destroyed due to crash and ground impact.

2.5. Other Damage

Apart from the damage to the aircraft, the accident caused further damage to public properties, such as a park and playground, and also private gardens and estates.

After losing altitude and passing by a residential area, called Khalajabad, the aircraft initial impact point was with a gazebo in a recreational park, called Lale. The aircraft fuselage, subsequently, impacted the ground, disintegrating completely after passing a football pitch, which in turn damaged the surrounding agricultural farms and gardens. Following the initial impact, other impacts were observed along the track at the accident site, wrecking the fuselage and spreading across the entire track. (Figure 3)

Figure 3- Accident site scheme

2.6. Organizational and Managerial Information

Ukraine International Airlines was the aircraft operator.

The company was established in 1992 and is headquartered in Kyiv, Ukraine. Its main station is Boryspyl International Airport.

The company is coded AUI in ICAO and PS in IATA. At the time of the accident, the company owned 45 aircraft, conducting flights to approximately 88 destinations.

The price of the ticket, as well as the flight network of this company, was such that it was considered an economic choice by travelers who flew to or from Tehran to travel to third countries. For example, the crashed flight had only two passengers of Ukrainian nationality, and most of the passengers also intended to travel to other countries.

At the time of the accident, UIA had a valid operating license No. UK 021 issued by the State Aviation Administration of Ukraine (valid from 10/14/2019 to 10/13/2021).

The airline had a valid CAMO approval certificate from State Aviation Administration of Ukraine.

The aircraft airworthiness was managed by UIA CAMO and the last aircraft maintenance service was performed by the contractor MAU technic.

2.7. Personnel Information

2.7.1. Pilots

The flight was being operated by three pilots, comprising a flight instructor, captain and first officer together with six flight attendants. According to the report provided by the UIA, the pilots' information is as follows:

Captain, aged 50, had experience of 11590 hours total flight time, including 4462 hrs on B737 NG and 3966 hrs on B737 CL with 4 takeoffs and 5 landings in IKA.

Copilot, aged 48, had experience of 7633 hrs total flight time, including 266 hrs on B737 CL, 2002 hrs on B737 NG and 1374 hrs of B737 experience before joining UIA with 6 takeoffs and 7 landings in IKA.

Flight instructor, aged 42 , had experience of 12052 (9820 B737) hrs total flight time, including 3240 hrs on B737 NG, 6580 hrs on B737 CL and 1075 hrs on Embraer 190 with 13 takeoffs and 14 landings in IKA.

Each of the three flight crewmembers had both valid personal licenses relevant to their duties, and related medical certificates.

2.7.2. Mehrabad Approach Radar Controller's Background

At the time of the accident, the aircraft was being controlled by the Mehrabad approach controller, a forty-one-year-old man with valid air traffic control tower ratings, and Mehrabad Radar Approach with License No. 1073. He holds an English Proficiency Level 4 and medical certification valid up to July 20, 2020.

2.7.3. Flight Attendants

There were two male cabin crew members and four females on the flight. To date, the UIA has not provided information on training, medical

certificate validity, approval for flight security. However, it was revealed that such issues were not relevant to this accident and investigation.

2.8. Aircraft Information

2.8.1. Introduction to the Aircraft

The Boeing B737-8K (WL), serial No. 38124 with manufacture date of June 21, 2016 was operated by Ukraine International Airlines.

The aircraft's type has been certified by the U.S. Federal Aviation Administration (FAA) with TC number A16WE subject to Federal Aviation Regulations (FAR).

The maximum takeoff weight is 72,500 kg (159,835 pounds), and the maximum capacity seating is 189 passengers.

The aircraft was equipped with two CFM56 7B24E, which are certified by Type Certificate Data Sheet no. E000056EN by FAA and E004 by European Aviation Safety Agency (EASA).

The Boeing 737-800 aircraft had a TL 0001 type certificate, the CFM-56 7B24E engine installed on this aircraft had a TD 0038 (TD 0038) type certificate issued by the Ukrainian Civil Aviation Authority.

2.8.2. Aircraft Technical Information

According to the list and documents provided by the State of Registry, the aircraft technical information shows that the aircraft had a valid Airworthiness Certificate. The Airworthiness Review Certificate was valid until Feb. 07,2020.

The UIA had CAMO and the accident aircraft was included in the scope of CAMO approval.

There were no changes in the aircraft that would make it subject to STC.

According to the Aircraft Flight and Maintenance Log page No.068845, Figure 4, on the flight before the accident, the aircraft departed at 21:41 from Kyiv, Ukraine to IKA, and after flight landing and preparations, no technical defect was reported by the pilot requiring a technical action.

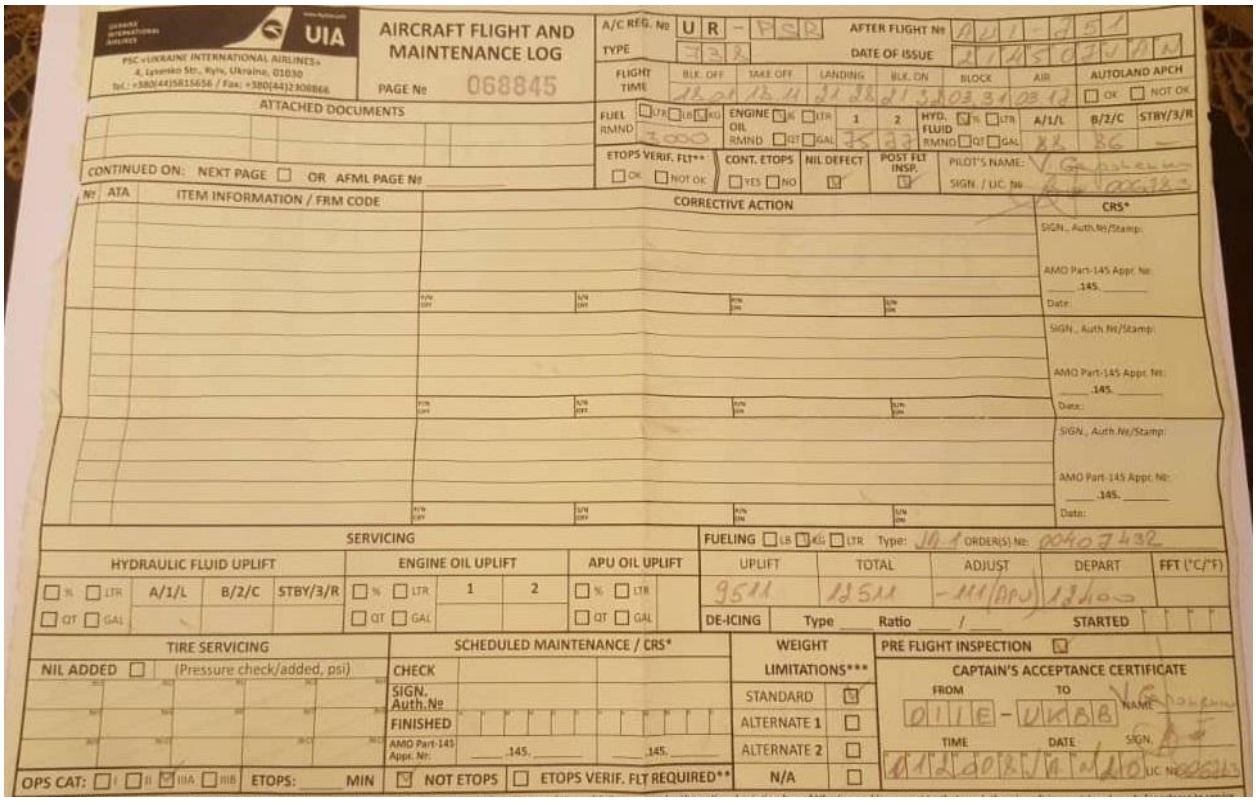

Figure 4- Aircraft flight and maintenance log

The ground handling Co. handled the flight preparations, boarding and loading according to the Trip Information it received from the pilot, including the amount of residual fuel, the maximum takeoff weight (MTOW), the maximum landing weight (MLW), the amount of fuel required to conduct the flight, the flight time and other information on the aircraft defined in the Load Sheet.

According to the aircraft Load Sheet, the maximum allowable weight had been calculated at 72500 kg. Due to the limit on maximum allowable takeoff weight, the ground handling Company did not load 82 pieces of baggage equal to 2094 kg. Ultimately, the aircraft takeoff weight was calculated 72468 kg, which was 32 kg lower than the maximum allowable takeoff weight. After boarding and loading, the pilot finally approved the Load Sheet.

According to the report provided by the ground handling Co., each male passenger's weight was considered 88 and a female 70 kg taking their hand luggage into account, and the excessive packages inside the cabin

were transferred to the aircraft aft cargo, where some were removed. Ultimately, 82 packages were not loaded.

Based on the information obtained from the ground handling Company, it was found that the flight crew brought delivered some luggage onboard to the handling Co. The ground handling personnel were then unloaded some of the passengers' luggage and cargo from the cargo section to comply with the maximum allowable weight.

The pilot had chosen the Odessa airport (ICAO CODE: UKOO) as the alternate airport and made fuel-related calculations accordingly.

2.8.3.Aircraft Systems

A large number of systems have been installed on aircraft, the analysis of each is based on the recorded data parameters.

According to the information obtained out of the FDR read-out, no system failure was recorded till 06:14:56, after which no conclusion can be made on them due to termination of the recording.

Navigation Systems:

The accident aircraft navigation systems include the following:

1. The Flight Management System (FMS) which includes:
   - Flight Management Computer System (FMCS)
   - Autopilot/Flight Director System (AFDS)
   - Auto throttle (A/T)
   - Inertial Reference System (IRS); 2 independent systems
   - Global Positioning System (GPS); 2 receivers
2. Two VOR- Receivers
3. Two ILS Receivers
4. Two Marker Beacon Indications
5. Two ADF Receivers
6. Two DME Transceivers

In addition to the above items, the aircraft is equipped with two ATC transponder devices, one of which can only be active at one time while the other can be used as a backup.

On the flight resulting in the accident, according to the data found from the SSR radar, no defect could be observed in receiving signals from ATC transponder, from the beginning to the moment the flight reached the altitude of 8100 feet. Nevertheless, from 06:14:56, when the aircraft had been climbing at an altitude of 8,100 feet and the ground speed of 276 Kt (according to the FDR), ATC transponder signal was interrupted, and this situation continued until the aircraft crashed to the ground. (At 06:18:23)

Communication Systems:

According to its Radio Station License, the aircraft had three VHF communication systems, manufactured by Honeywell Co., functioning in the frequency band 118-136.992 with a Frequency Spacing of 8.33 kHz.

The pilots made their last communication with Mehrabad Approach Unit at 06:13:23. The CVR read-out indicates that up until the end of recording at 06:15:15, the flight crew had not been attempting to establish communication; therefore, no comment can be given on the performance of communication system after last recorded communication.

Other Systems

The flight recorders read-out and analysis revealed that until 06:14:56, when the recording was continuing, all the systems had normal performance. After the mentioned time, given the end of the FDR recording and transponder messages stopped being received, the warning sound as well as the unusual condition in the cabin, it is highly probable that several electrical buses failed. Considering the objective evidence indicating the fire outbreak and its intensification in the aircraft, the cascading damage to other systems is likely (refer to sections 2.13 and 2.15).

2.9. Meteorological Information

Upon receipt of the accident notification, Iran Meteorological Organization was enquired about the overall situation of IKA's weather, as per the following:

2.9.1. IKA METAR (OIIE)

OIIE 080330Z 28006KT CAVOK M01/ M04 Q1021
OIIE 080300Z 27006KT CAVOK M01/ M04 Q1021
OIIE 080230Z 28008KT CAVOK M02/ M04 Q1021

There were no operational considerations regarding weather conditions for the flight.

2.10. Aids to Navigation

Investigations indicated that the required navigational aids related to the flight had been operational and in good condition.

2.11. Communications

2.11.1. Radio Communications

The review of the radio communications is based on the information received from Iran ANSP.

2.11.2. Iran Aseman Airline's Flight Conversation during Approach

Few minutes before the accident (ground impact), flight No. 3768 of Iran Aseman airlines from Shiraz Airport, approaching to land at Mehrabad Airport, asked Mehrabad ATC about any unusual activity in the region. After landing, the pilot contacted AAIB, and her report was reviewed as a witness by the investigation team.

The transcript of this communication is given in Table 2.

***Note**: The audio file of this radio communication was released through the media. However, the sequence and content of the released file are different from those of the original one.*

Table 2- Transcript of communications between Tehran radar and IRC3768 flight

Speaker	Time	Transcriptions of the Communications
AUI752	06:12:57	Radar good morning AUI752....on course IKIA 1 A
RDR		Good morning AUI752, radar identified on departure climb FL260, crossing 6000 feet turn right PAROT
AUI752		Next PAROT climbing 260 AUI752 information all received, thank you
RDR		Welcome after 6000 to PAROT
AUI752		After 6000 to PAROT AUI752
IRC3768	06:16:25	Approach from Aseman 3768
RDR		You have GPS failure?
IRC3768		No sir, is the area approximately on heading 320 active now?
RDR		320? Area? No. ... how many miles away? Where?
IRC3768		A series of flares ...like that of a missile ... Is there anything like this over there?
RDR		How many miles away? Where?
IRC3768		Well, can't tell how many miles away exactly. But I think it is in Payam vicinity; Karaj whereabouts
RDR		Ummm...We have not been informed of that. No idea.
IRC3768		Now we can see its flare from here.
RDR		What's it like? What does this light look like?

IRC3768		It is the flare of a missile, perhaps
RDR		It's not, by any chance, approaching east, is it?
IRC3768		No, no; it just emerged from there. I mean it was something like this
RDR		We have not received any report on this. Be cautious anyway!
IRC3768		Yes, thanks.
RDR	06:17:50	AUI752 radar, AUI752 radar
RDR	06:18:08	AUI752 Mehrabad radar
RDR	06:18:26	AUI752 radar, AUI752 Mehrabad radar
RDR	06:19:00	AUI752 Mehrabad radar, do you read
RDR	06:19:34	AUI752 radar
RDR	06:19:48	AUI752 Mehrabad radar, AUI752 Mehrabad radar do you read
RDR	06:20:35	IRC3768 9000 QNH1020 cleared approach
IRC3768		OK 9000 feet cleared approach
RDR		3768! Can't you see anything else?
IRC3768		It was an explosion sir; we saw a huge light over there. I wonder what it was really!
RDR		Thanks.
IRC3768		Confirm that everything is normal for us!
RDR		Yes, I don't think it would cause you any problem.
IRC3768		God willing. Thanks.

Note: The blank time cell shows that the communication was made immediately after the previous one.

2.12. Aerodrome Information:

2.12.1. General Information on IKA

Imam Khomeini International Airport is located in the south of Tehran and is the main international airport in Iran. By 2015, it had been operated by Iran Airports and Air Navigation Company, and since the end of 2015, it has changed into Imam Khomeini Airport City Company with the approval of Iran's government. The Company operates the airport independently but air navigation services in this airport are provided by Iran Airport and Air Navigation Company through a contract.

The air traffic control service is provided at IKA by two GND and TWR units in the control tower, and since the IKA is located in Tehran TMA, the APP service is provided through the relevant unit at Mehrabad Airport. According to the operational agreements, just after takeoff from the runway the flight will be delivered to the controller of the approach unit of Mehrabad Airport.

At this airport, three companies, namely Homa, Saman and Hamrah Kooshkish provide ground-handling services, and Saman Co. provided ground-handling services to the accident flight.

2.12.2. IKA CCTV Information

Considering the importance of security issues related to the accident aircraft, all information of the aircraft at the airport parking and the ground handling procedures recorded by CCTVs for the flight were reviewed, from the aircraft arrival time to its parking and exit time. Different individuals' access to the aircraft in addition to the provided ground service to the aircraft were checked in the CCTV footage of the aircraft parking stand close to the airport Jetway. Various services provided to the aircraft are as follows:

Table 3- Key events recorded by IKA CCTVs

Time	Events
01:02:50	The aircraft parked at the stand close to the Jetway

01:07:22	The refueling vehicle arrived
01:10:00	The Jetway was connected to the aircraft for passenger disembarkation
01:16:35	Start of refueling
01:20:35	The end of cargo unloading, the conveyor belt was detached.
01:38:23	The end of refueling.
01:45:32	The Jetway disconnected from the aircraft after crew left the aircraft and the cabin door was locked
03:58:00	Re-connection of the Jetway
04:01:03	The luggage was carried beside the aircraft.
04:20:20	The conveyor belt was connected to the aircraft.
04:24:30	The start of luggage loading
04:41:30	Connection of towbar to the nose landing gear.
04:49:35	End of forward cargo loading
05:27:26	The cargo pallets were carried away from the aircraft.
05:38:07	Some luggage was unloaded from the aft cargo.
05:39:28	The remaining hand luggage was loaded to the aft cargo.
05:41:35	The conveyor belt was detached from the aft cargo.
05:50:25	Jetway disconnection
05:50:50	Connection of tow car.
05:55:00	Start of pushback
06:06:40	The aircraft started taxiing and moved towards the runway.

The airport CCTV shows that except for the individuals responsible, no one else had access to the aircraft and engines, nor was any technical action performed on the aircraft.

2.13. Flight Path, Impact Point and Wreckage Information

2.13.1. Flight Path

Based on the submitted flight plan, the route considered to fly from Tehran to Kyiv was as follows:

OIIE → PAROT → ASPOK → BUDED → TBZ →DASIS → ERZ → KUGOS →

DIGAM → ETNIL → MIMKO→ KONIP

The PS752 planned flight path is illustrated in Figure 5.

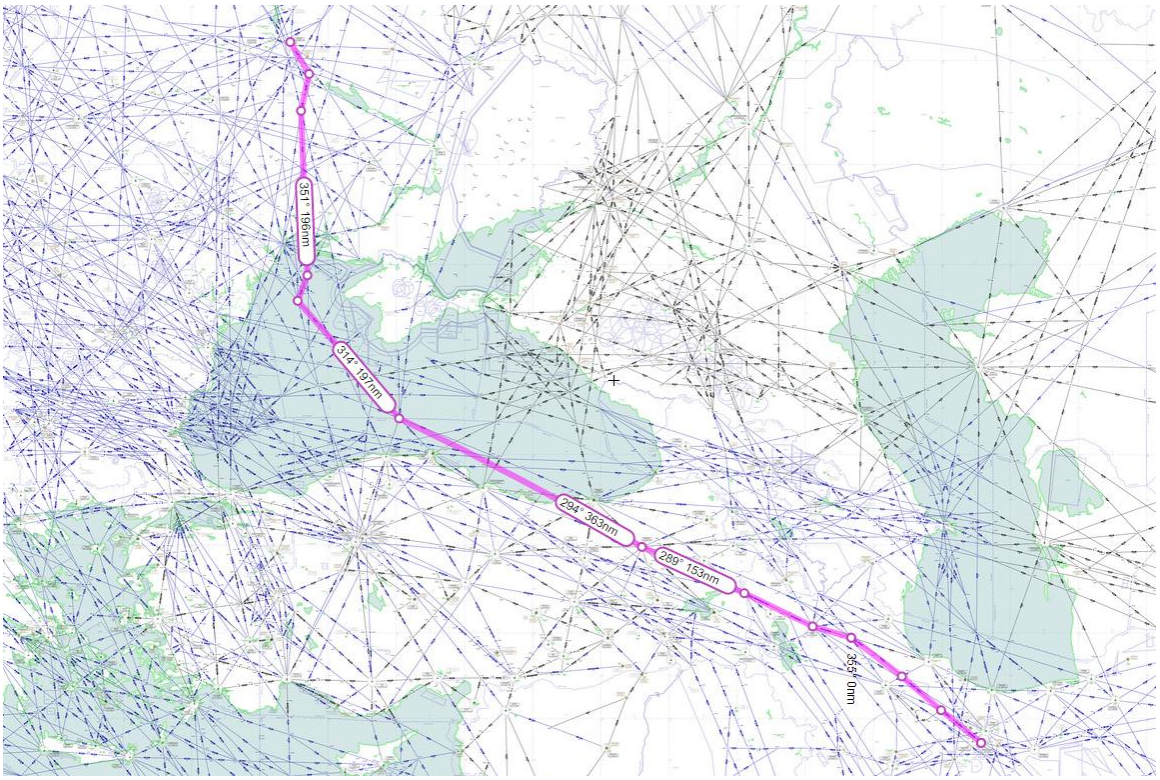

Figure 5- The planned flight path for PS752 according to the flight plan

After takeoff, the aircraft continued flying on the planned path, but at position 35°29'29.79"N 50°57'13.43"E, the ATC transponder signals and FDR recording terminated, shortly afterwards the aircraft began turning to the right and losing height[2]. While already on fire (based on observations of eyewitnesses and recorded videos) , the aircraft crashed into the ground at position 35°33'45.63"N 51°6'11.21"E and exploded. Figure 6 depicts the flight trajectory.

[2] - Losing the height was observed by eyewitnesses.

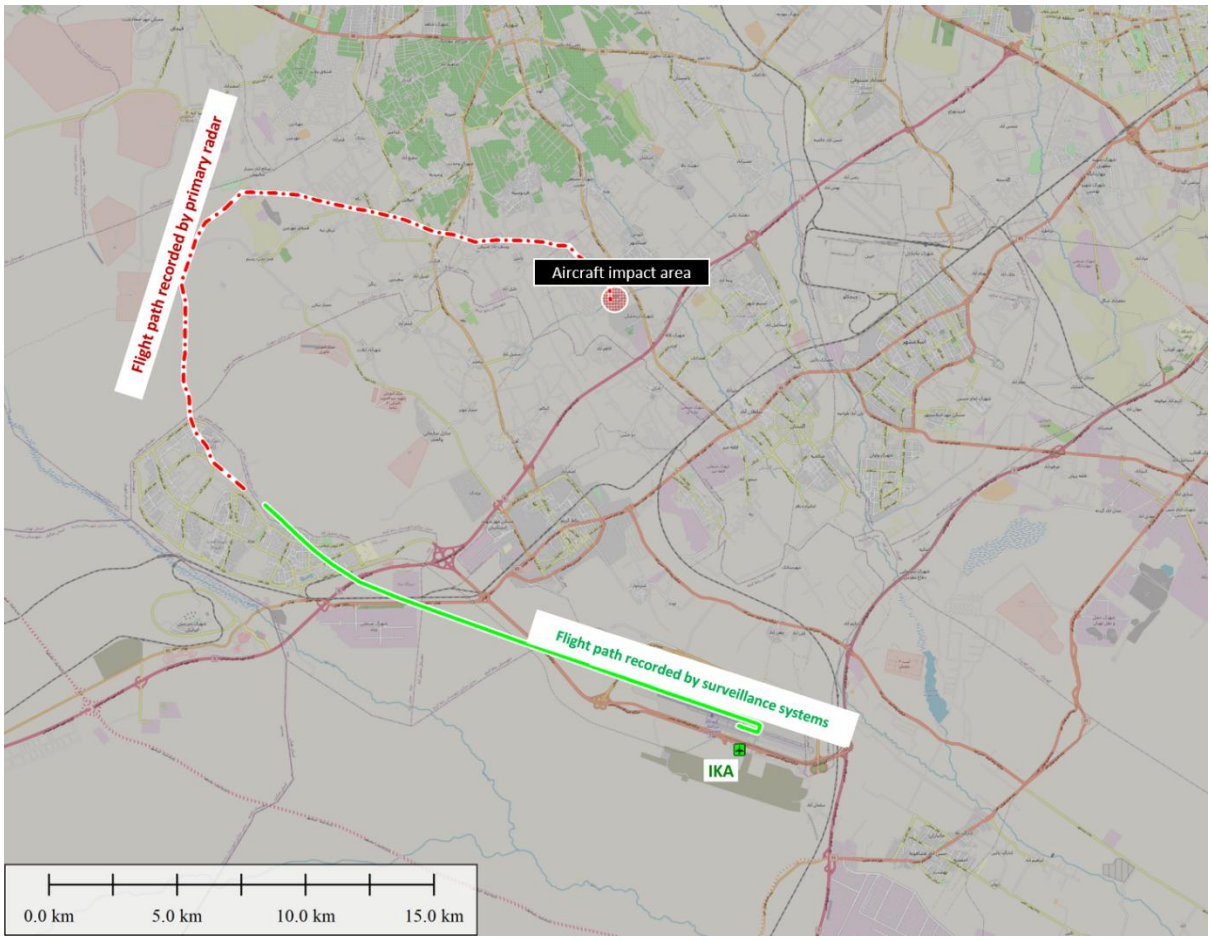

Figure 6- Flight PS752 trajectory

2.13.2. Impact Information

Shortly after the transponder stopped transmitting signals, the aircraft heading was changed to the right and after turning, headed toward the airport. The aircraft lost its altitude gradually and after passing by Khalaj Abad residential area impacted a gazebo roof in a recreation park with the position 35°33'45.4"N51°06'11.3"E and then hit the ground (Figure 7).

The impact with the ground created a large hole in the park, then the fuselage distanced from the ground and went on to a soccer pitch, hit its fences, passed by a water canal, again hit walls of private gardens and disintegrated completely as shown in Figure 8. The evidence and pieces gathered from the aircraft at the main accident site showed that the aircraft still maintained its relative integrity before impacting the ground. Interviews with eyewitnesses along the flight path confirmed this as well.

Due to the vast area of the accident site, it is presumed that the locals accessed it during the minutes after the accident until the arrival of Law Enforcement Officers there. With the arrival of the investigation team, the necessary coordination with the district local authorities was done to preserve the accident site for locating the aircraft parts, to perform general analysis and sampling.

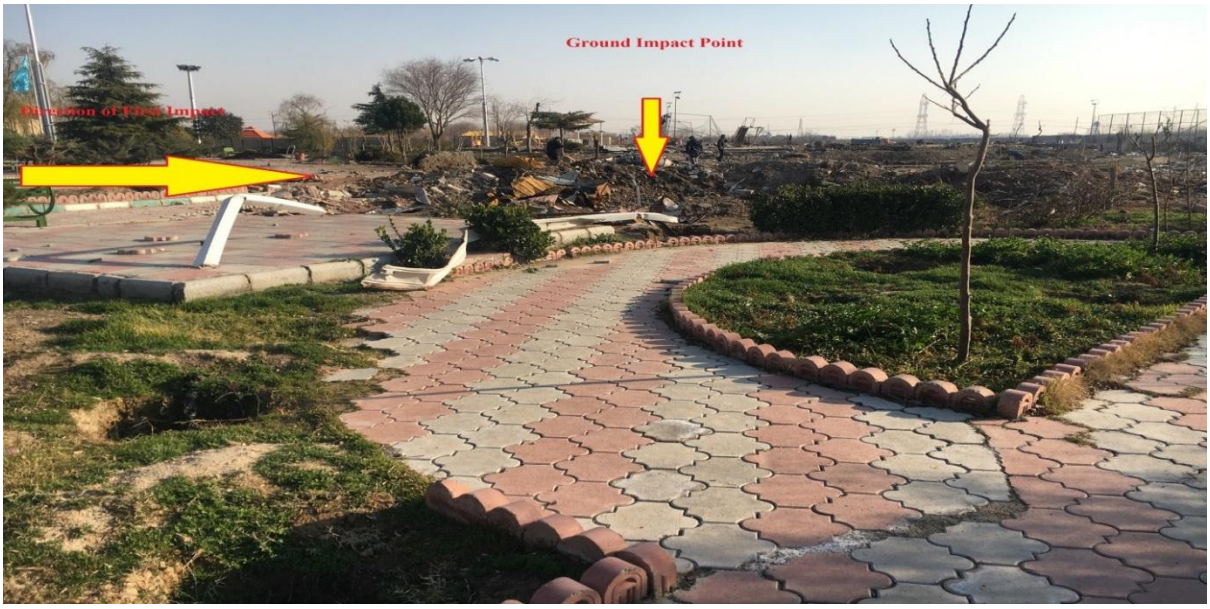

Figure 7- The first ground impact of the aircraft

Figure 8- An overview of the aircraft parts distribution

By the end of the search operation for bodies, the arrangements were made for the ambulances to transfer the bodies to Tehran's Legal and Forensic Medicine Organization. Due to the vast area of the crash site, filled with the aircraft parts, and the impossibility of long-term protection, the wreckage parts were collected and transferred to a safe place at IKA, where they were separated and laid out by the relevant experts.

While flying past a village called Boke near Shahriar, some skin pieces belonging to the aircraft wing back end surfaces (Figure 9) were detached and found on the ground at position 35°35'55"N, 50°59'00"E. Some small pieces and a piece of the air conditioning system (Figure 10) were found at position 35°35'53"N, 50°59'43"E , about 10 kilometers before the crash site, which was collected by the locals in residential complexes and delivered to the respective rural council.

Figure 9- Part of the aircraft wing

Figure 10- A part of air conditioner found on ground before crash site

The flight track on ground was searched, and no other reports on finding any other pieces were received and the rest of aircraft pieces at the crash site were collected finally. The found pieces before the crash site were handed over to the investigation team and transferred to the AAIB.

2.13.3. Findings Obtained from the Crash Site

The outer skin of the left wing had signs of burning. Since there was no sign of fire at the place where the piece was found and the vegetation

surrounding it was undamaged, the burn on the wing had occurred before the crash into the ground. The inner walls of the wing indicated that the fire had not broken out into the aircraft fuel tank. (Figure 11)

Figure 11- The aircraft left wing at the crash site

Some parts of the right wing together with the winglet indicated that the fire had not broken out into the right side of it (Figure 12).

Figure 12- The aircraft right winglet

Smoke and burn were observed on the ground close to the Auxiliary Power Unit (APU) (Figure 13).

Figure 13- Auxiliary Power Unit

2.13.4. Aircraft Wreckage

Evidence shows serious damage to the lower part of the aircraft nose, especially the lower half of the cockpit. As for the upper half (upper body) found at the site, however, even the cockpit windows were still in their own place in the relevant frame (5 out of 6 total), though a lot of heat had spread into them from inside.

Of the main four exit doors of the aircraft, three cabin doors were found at the accident site, which were transported to the wreckage piece layout location.

The upper part of the aircraft had sustained less damage than the lower part.

The passenger cabin equipment was completely shattered, which was barely identifiable. The two wings of the aircraft were connected to the fuselage until ground impact, and as for the winglet, it was detached from the wing without any damage, or signs of destruction at their location, which is available at the layout site.

At the rear of the aircraft, there is an APU connected to the empennage end part, which was found with the horizontal structure and connected to

it at the accident site, indicating the integrity of the end part on ground impact.

The vertical fin at the rear of the aircraft had been entirely detached from the lower part, which was found at the accident main site.

Life vests, seat covers, plates, and the rest of passengers' clothes were on the spot without any signs of burns. The fire extinguishers did not show any signs of fire either, indicating that the fire has not spread completely.

The wing roots and the upper section of the fuselage, equipped with two emergency exit doors, still existed in their place, confirming the relative structural integrity of the fuselage and wings at the moment of ground impact.

The main burn signs were seen in the front left side of the plane and in the connection of the left-wing with the fuselage. In the upper surfaces of the wing, there were more sign of fire than the lower part.

The rear end of the aircraft suffered less damage before hitting the ground.

No traces of fire were found in the passengers' luggage.

The ceiling of the passenger cabin in front of the plane, between the cockpit door and the front cargo, caught fire. Most of the damage seems to have been caused from fire in electronic compartment towards the above, and the avionics equipment was largely destroyed.

The traces of a serious fire can be observed inside the cockpit (Figure 14).

The traces of fire and smoke on the cockpit outer skin mark two situations: before and after the ground impact. In fact, it reveals that the fuselage had caught fire before the ground impact.

Figure 14 - Closer view of the cockpit

An ID card related to instructor pilot was found at the crash site without any signs of burns (Figure 15).

Figure 15- Instructor pilot's ID card

A large number of ruptured holes were seen on the aircraft fuselage, which varied in terms of size, shape and direction in opening, though they were of two different types. One, which was fewer, shows the thick smoke towards outside of the fuselage (Figure 16, Figure 17, Figure 18 and Figure 19), and in the other, with a higher number, only ruptured holes could been observed (Figure 20 & Figure 21).

On the cabin ceiling along the electronic compartment, a few holes and traces could be seen, caused by a small object impact from inside to outside. The thick track of smoke coming out of the holes indicates they had been caused before the ground impact, out of which smoke had been coming out while the aircraft was flying.

Laboratory results from the sample smoke layers around the holes show that the chemical base of the smoke was carbon, in which no traces of explosives were found.

Figure 16- Hole in the fuselage with a trace of a different color of smoke

Figure 17- Hole on the fuselage near the cabin with a trace of different color of smoke

Figure 18- Hole on the fuselage near the cockpit and exhaust fumes

Figure 19- Closer view of the hole on the fuselage near the cockpit and burn signs in the hole area

Figure 20- Crack with an outward hole in the skin of the structure near the cockpit

Figure 21- Holes and cracks on vertical stabilizer

In the central part of the aircraft, below and to the left between the fuselage and the wing, the traces of burns could be seen in the vicinity of the cabin air-conditioning system, which was the installation point of pre-cooling part found before the crash site near Jandaq village. There was

another heat exchanger found at the crash site, on which molten aluminum was observed, indicating a severe fire in this part.

Figure 22- The second heat exchanger found at the accident site and its installation point on the fuselage

Two aircraft engines were found at the accident site, which were totally destroyed (Figure 23). The damage observed on the rotating parts shows that the engines were working. The evidence revealed no explosion or severe fire on the engines and it seemed that most of the damage had been caused by deforming due to ground impact.

Figure 23- The two aircraft engines

2.14. Medical and Pathological Information

It could not be determined if the occupants of the aircraft were injured prior to impact, or if they received fatal injuries as a result of the impact.

Toxicological samples related to crew were sent to a laboratory, where no drug or toxin was observed.

The investigation team requested the pathologist to detect the existence of metal objects in the bodies. It was decided if metal parts were observed in the autopsy process, they had to be reported, and samples had to be handed over to the investigation team for analysis. Forensic experts could not finally discover any metal parts in the corpse tissues of the passengers on board.

DNA tests were needed to identify the bodies, so a blood sample was taken at the official request of the Iranian Legal Forensic Medicine Organization with at an international level. At the same time, the CAO IRI went on to send DNA samples via the official representatives of the States involved in the accident investigation. Thereby, the DNA samples of the deceased were determined and collected in a data bank at Kahrizak Forensic Medicine Center. Afterwards, the bodies were prepared for delivery to the

victims' families, and the necessary arrangements were made to transfer them to their own desired cities.

2.15. Fire Breakout and Extinguishing

The evidence from the aircraft wreckage and the videos and images obtained suggested the occurrence of a fire in parts of the aircraft before the ground impact.

The fire was observable in the front cabin and on its left side.

Fuselage evidence suggested that some holes were made in it. Afterwards, with the occurrence of a fire in the front cabin, the traces of thick smoke coming out of the created holes on the fuselage appeared which were quite different from those of the fires on other exterior parts of the aircraft.

Because of the spreading of the aircraft fuel upon impact with the ground barriers, fire engulfed the crash site, which was extinguished by the fire department in the area.

2.16. Search and Rescue

Under the Emergency Response Procedure and Air Accident Regulations, upon communication failure with the flight PS752, the Rescue Coordination Committee (RCC) was immediately formed in Tehran ACC, and the necessary notifications were subsequently sent to the relevant authorities.

The AAIB notified the Crisis Committees of Iran’s Ministry of Roads and Urban Development and Ministry of Health. Emergency Operations Center (EOC) of the Ministry of Health confirmed the accident and fire at the accident site, and then it ordered the dispatch of forces of both Relief and Rescue Organization and the fire department from Shahriar. Finally, it was announced that all the passengers had, most probably, died.

A Crisis Management Team was at the same time formed, led by the governor of Shahriar.

Following the Emergency Response Plan of IKA, the relevant committee was formed at this airport, which was attended by the representative of the UIA and the CAO IRI.

Initially, helicopters of the Red Crescent and Emergency were dispatched to the site from Tehran.

The necessary arrangements were simultaneously made to send the required forces from state and military organs to the area, all of whose capacities were used to manage the crash site.

No Emergency Locator Transmitter (ELT) signal was received from the crash site.

After the Red Crescent Organization of Iran collected the bodies and announced the search completion, numerous ambulances transported the bodies to Kahrizak Forensic Medicine Center.

2.17. Tests and Examinations

2.17.1. The Aircraft Fuel Examination

No aircraft fuel was found at the crash site for test. Given the importance of such an issue, the refueling vehicle having provided fuel to the aircraft, operated by the refueling company at IKA, was released from operation to be investigated. The fuel in the truck tank was sent to a laboratory for sampling. The test results showed that the fuel met the standards and its quality did not produce any effect on the accident, as shown in Figure 24.

DATE: 16/Feb/2020 FORM NO: QC-FO-04-01

PROPERTY	TEST METHOD		SPECIFICATION LIMITS	Owj-co
	ASTM	IP		RB-206
				RESULT
APPEARANCE			C&B	C&B
DENSITY AT 15°C	4052	365	0.775-0.840 gr/ml min-max	0.8001
SAYBOLT COLOUR	156			29
DISTILLATION	86	123	-	-
I.B.P.			REP. °C	156
10% Recovered %VOL			205°C max	173
50% " %VOL			REP. °C	196
90% " %VOL			REP. °C	237
F.B.P.			300°C max	269
R/L %VOL			1.5ml/1.5ml max	0.5/0.5
EXISTENT GUM mg/100ml		540	7 max	0.4
MICRO SEPARO METER			70 min	99
FLASH POINT		170	38°C min	49
COPPER CORROSION 2hrs @ 100°C	130	154	NO.1 STRIP max	1A
FREEZING POINT	2386	16	- 47°C max	<-55
CONDUCTIVITY	2624	274	50-600 pS/m min-max	115

Figure 24- Aircraft fuel test result

2.17.2. Investigation into the operation of the Aircraft's ELT

Although the global statistics are indicative of the ELT failure in numerous air accidents, it still came under the investigation team's scrutiny. This device is used only to determine the crash location in search and rescue process and has neither an impact on its occurrence nor is considered a contributing factor in this regard. Even so, the reason for its signal transmission failure was investigated.

The accident aircraft ELT should have sent signals in two frequencies, 121.5 MHz and 406 MHz.

The former is intended to locally receive accident warning, no relevant report on which was received, though. As for the 406 MHz signal, the global satellites did not receive such a signal either.

The investigation team came across an automatic ELT and two survival ones at the accident site.

The automatic ELT had been activated due to the impact severity, yet as its signal-transmitting antenna to satellites was detached, the

international satellites did not succeed in locating the crash site. To assess the aircraft ELT performance, the survival ELTs were activated at laboratory[3], but no information was received from the satellite. Due to the damage inflicted on the antennas of the two ELT devices, a new antenna was installed and activated on them. The warning was received this time in the frequency 121.5 MHZ in the local station, but again no information was received from Cospas-Sarsat. Hence, the ELT manufacture company was contacted to provide the necessary explanation. Thanks to the cooperation offered by the French ACCREP and the ECA Group (ELTA group), it became clear that the internal structures of survival ELT might have been damaged by the severity of the impact. Following this conclusion, no deeper analysis was performed..

2.17.3. Test for Metal Object Existence in Passenger Seats

As some holes were observed in the passenger seat pads (Figure 25), they were collected from the accident site to find the FODs possibly penetrating into them due to explosion. Then, using the X-ray scanners, the initial detection of FOD was made, and the observable cases were transferred to the AAIB. Having cut their pads, the metal pieces were extracted and sent to a metallurgical laboratory to be assessed and compared with the missile shrapnel alloy.

[3] - Both survival ELTs were found with the switch on the OFF position.

Figure 25- One of the remaining passenger seats with holes in it

The facilities of the Atomic Energy Organization of Iran and a metallurgical research center were used to perform analysis and tests on such small metal pieces.

Figure 26- Metal objects found in the passenger seats

The results obtained from the X-ray fluorescence (XRF) spectrometry revealed the existence of two different metal types in the objects found in the passenger seat pads, which are related to the aircraft alloys, not the tungsten (missile shrapnel substance), as shown in Table 4.

Table 4- Results of X-ray fluorescence (XRF) spectrometry on the two samples found in the passenger seat pads

Substance		Sample 1		Sample 2	
Element	**Symbol**	Unit (%)	Estimate of error (% ±)	Unit (%)	Estimate of error (% ±)
Aluminum	**AL**	99.09	0.04	71.9	2.40
Barium	**Ba**	0.465	0.025	0	-
Iron	**Fe**	0.464	0.049	1.21	0.23
Molybdenum	**Mo**	0	-	0.071	0.016
Niobium	**Nb**	0	-	0.192	0.023
Titanium	**Ti**	0	-	26.49	2.48
Tungsten	**W**	0	-	0.055	0.046
Zirconium	**Zr**	0	-	0.035	0.007

2.17.4. Explosive and Weapon Test

At the request of the investigator-in-charge and coordination with the relevant authorities, an expert group was formed to examine the unusual cases such as explosives. Having done sampling and tests at the crash site, the possibility of damaging radiation, including laser and electromagnetic radiation (radioactive) strike was ruled out. Further investigation into the aircraft wreckage to detect presence of explosives on the fuselage was made subject to conducting further research and sending samples to a reputable laboratory.

The aircraft pieces and remnants were investigated in a suitable site where they had been separated by examining their apparent signs with cameras and then laid out next to one another on the ground. After that, the burn

signs, explosion, and traces of any suspicious materials on the pieces were first detected using portable devices and trained dogs.

In the investigations performed, neither of the aircraft engines showed any suspicious signs being indicative of fire or explosion in the sky.

It was confirmed that there were cracks and holes caused by shrapnel strike by blaze and the remaining smoke on the aircraft fuselage, which were outward-bound. Likewise, the test result of traces caused by smoke and burn due to explosives from aliphatic (PETN, HMX, RDX, C_4) was confirmed.

The parts detected to have been contaminated with explosives were sent to laboratory, the detected areas of which were sampled there.

Based on the results yielded through GC/Mass chemical analysis, the existence of Trinitrotoluene (TNT) explosives with a chemical formula C7H5N3O6 was confirmed in the aircraft wing skin, which was found before the crash site. (Figure 27)

Figure 27- The wing piece found before the accident site

Gas chromatography–mass spectrometry; GC-MS of this piece can be seen in Figure 28.

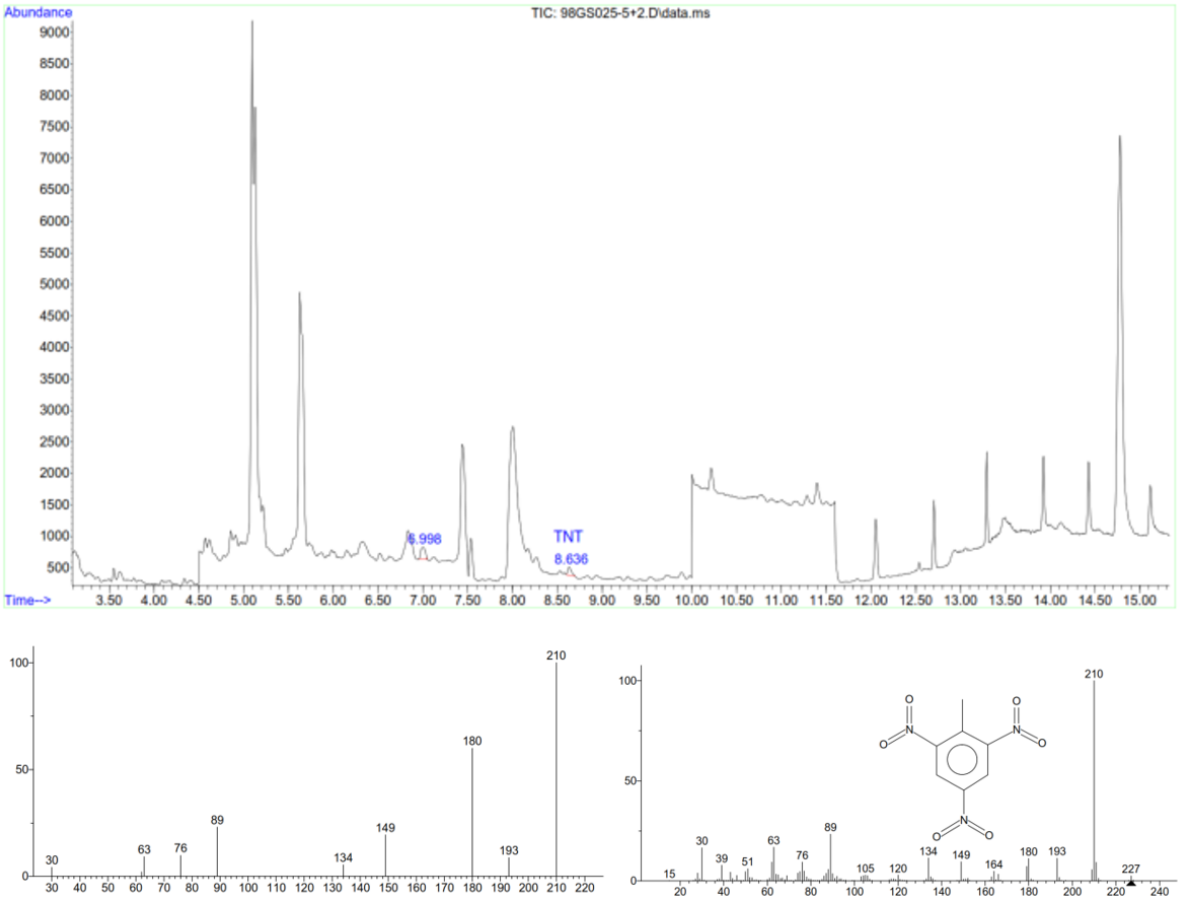

Figure 28- Gas chromatography–mass spectrometry; GC-MS, of aircraft wing skin piece

By sampling the air conditioning system and the two ELT pieces of the aircraft (Figure 29) and performing gas-chromatographic-mass spectrometry on each of the parts, the presence of negligible amounts of Dinitrotoluene (DNT) with the chemical formula $C_7H_6N_2O_4$ was proven.

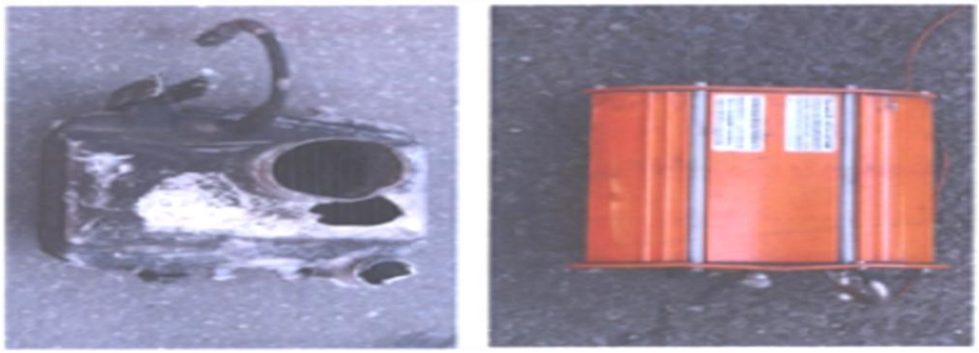

Figure 29- Pieces on which the explosive test was done

The GC/Mass chemical analysis spectrum of the above samples can be seen in Figure 30.

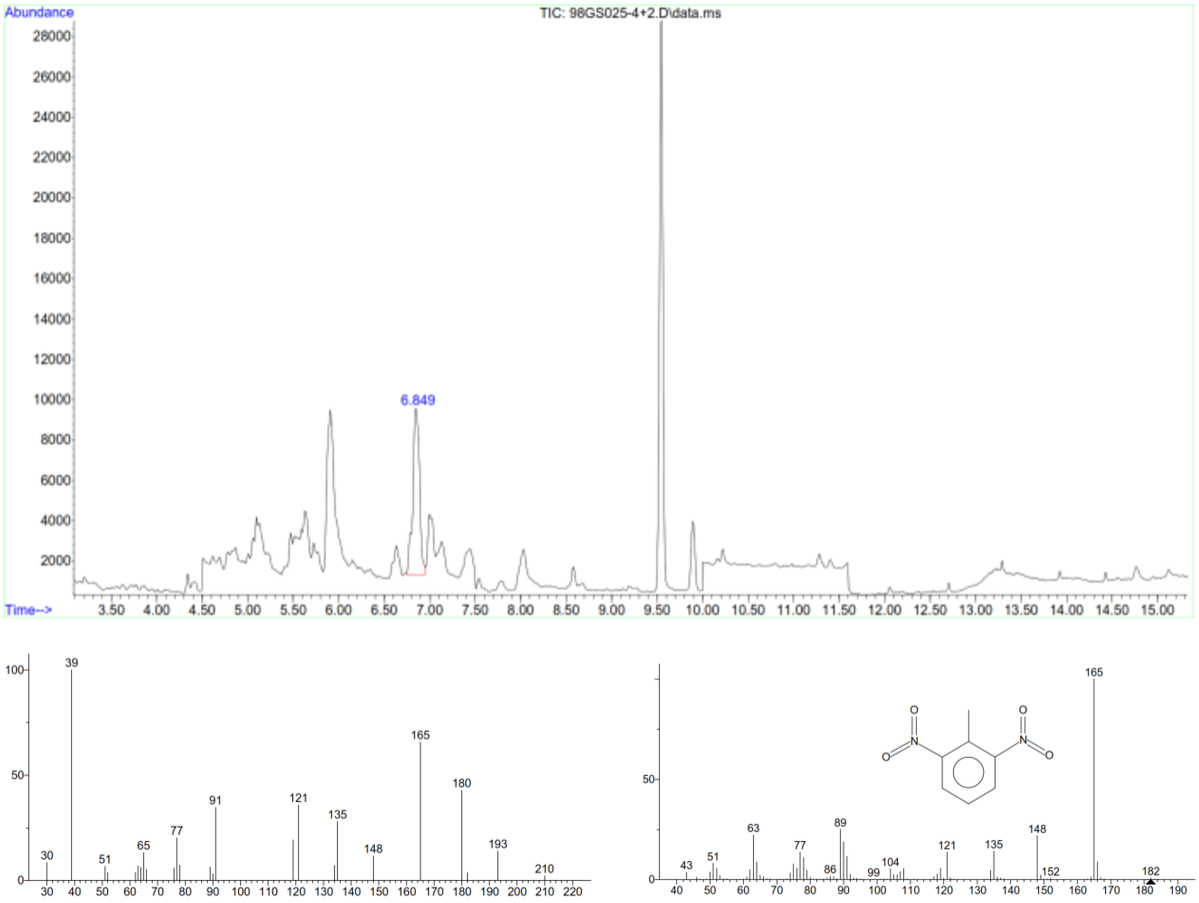

Figure 30- The GC-MS of the ELT and heat exchanger

According to the spectrometry obtained from the interior part of the aircraft cabin window (as shown in Figure 31), the presence of more explosive Trinitrotoluene (TNT) was detected (Figure 32).

Figure 31- The interior of part of the aircraft cabin window pieces on which the explosive test was done

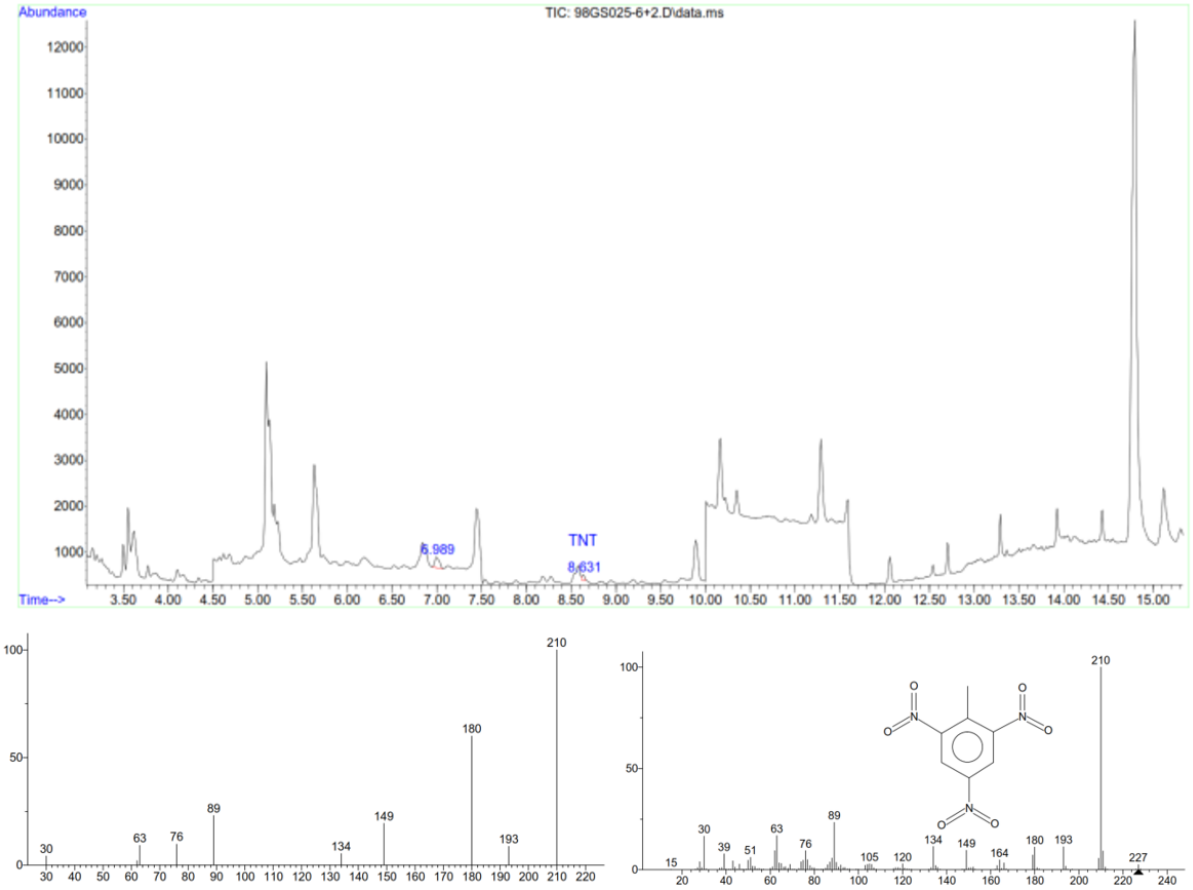

Figure 32- The GC/Mass test result from the interior of part of the aircraft cabin window Pieces

The results of the sample analysis taken from the inside of the upper skin of the aircraft engine showed the presence of (DNT) Dinitrotoluene contamination.

It should be noted that no explosive contamination was observed in the samples taken from the engines and other aircraft pieces or the objects inside the passenger cabin (Figure 33).

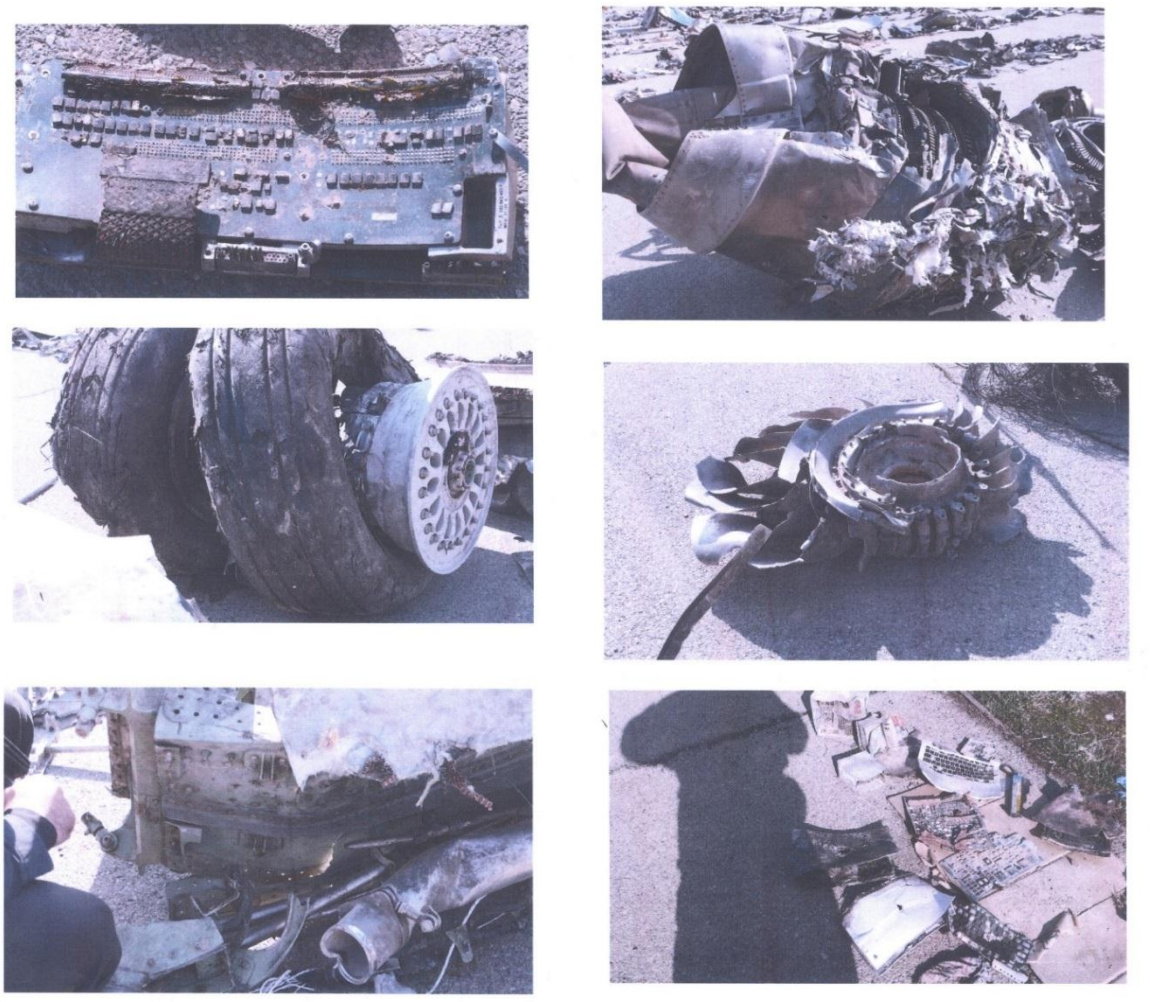

Figure 33 -Some of the aircraft parts free from explosives

As the DNT presence in the remaining evidence of the explosion or fire did not match the expected explosives type from missile, and the fact it was likely such evidence had been caused by the byproduct of other substances, the test results were provided to the State of Design and Manufacturer to investigate the DNT origin found in them.

The NTSB and Boeing's chemistry and flammability experts reviewed the test results and announced that some materials in commercial aircraft, such as fuel and epoxy containing aromatic, may produce DNT during thermal degradation, but in large quantities, this substance is not common.

Following the release of the videos and images showing the firing of two missiles at the aircraft, their authenticity was begun to be checked.

Surveys were then conducted at the accident site on January 10, 2020 through which the authenticity of the videos, which were shot from Bidkane and Parand, was verified. Gaining access to CCTV footage recorded by the organizations near the areas supported the hypothesis that the aircraft had been fired by missile.

2.18. Flight Recorders

2.18.1. Technical Specifications

The aircraft was equipped with Solid State Flight Data Recorder (SSFDR) technology with P/N 980-4750-003 that recorded more than 1200 parameters, Solid State Cockpit Voice Recorder (SSCVR) with P/N 980-6032-003 capable of recording the last two hours of flight audio channels, and a Quick Access Recorder (QAR). The FDR and CVR are manufactured by Honeywell Incorporation (Figure 34).

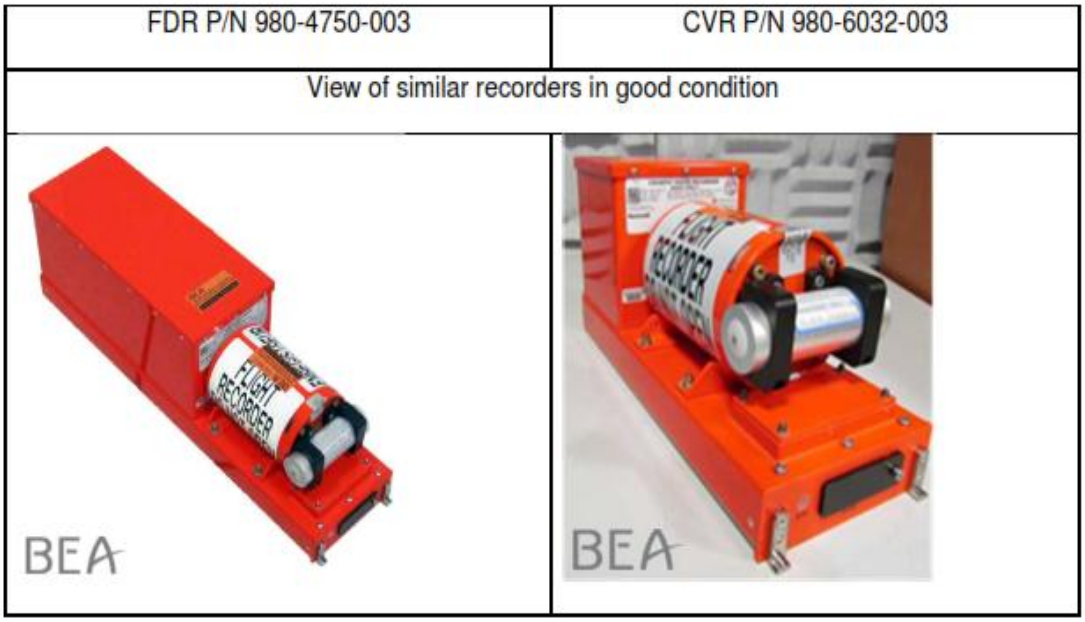

Figure 34- Flight Recorders similar to those installed on the accident aircraft, photo by BEA

2.18.2. The Discovery of the Flight Recorders and Their Condition

The QAR was not found at the accident site, but the FDR and CVR were, both of which displayed physical damage on them.

Damage to CVR had been more serious, whose main memory (CSMU) was detached due to the impact severity. The condition of these recorders indicated that the CVR and FDR had not been exposed to the fire in the aircraft, and after the ground impact, they were damaged or exposed to fire. (Figure 35 and Figure 36)

Figure 35- FDR physical appearnce after the crash

Figure 36- CVR physical appearance after the crash

2.18.3. Readout of Flight Recorders

On January 09, 2020, the visual condition of flight recorders was checked with the presence of Ukrainian delegation at the CAOIRI Aircraft Accident Investigation Board (AAIB).

Having considered Iran's capacity in this area, the investigation team reached the conclusion that restoring the data of the two devices with the facilities and experience at hand would involve a degree of risk or missing them, which was considered unacceptable due the inherent sensitivity of the issue.

The investigation team did not ultimately succeed in obtaining the facilities and resources required to read out the recorders. Despite the fact a list of them had been provided to the team and necessary financial resources were offered for purchase, the required equipment could not still be provided due simply to the U.S. sanctions imposed on Iran as well as the direct and indirect suppliers' concern about penalties.

An Iranian team was sent to Ukraine. They assessed Ukrainian facilities needed for recorders readout. At the same time, Ukraine hosted joint meetings between experts from Iran, Canada and France to decide on further cooperation. Seeing the specialized reports presented by the members in meetings held, the investigation team decided to use a laboratory with more experience and facilities to reduce the risk of losing the data of flight recorders during the recovery process.

Initial agreements were made with the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France to perform the read-out.

Following the outbreak of the COVID-19 pandemic and consulting with representatives of other States whose participation in the read-out process was necessary, the read-out was postponed due to travel restrictions as well as those of the French laboratory. In the end, once the issues were resolved and coordination was made, the read-out was performed from July 20 to 24, 2020 at BEA laboratory.

Figure 37- Fight recorders transferred to BEA

The disassembling of the flight recorders and downloading the data was performed under the control and supervision of the accident investigator-in-charge using the BEA facilities and experts.

The representatives of the U.S. as the State of Design and Manufacture, Ukraine as the State of Registry and Operator, and France as the State providing service and technical advice participated in the process.

The experts of Canada, U.K. and Sweden, as the States having special interest in the accident by virtue of fatalities to their citizens, observed the process to stay informed accordingly.

A representative from the International Civil Aviation Organization (ICAO) participated in this undertaking to observe and facilitate collaboration among the States involved.

Considering the fact some of the crew members' conversations were made in Russian and some others in Ukrainian, the representatives of Ukraine translated such conversations, heard on the Cockpit Voice Recorders (CVR), into English.

The data on both aircraft flight recorders was retrieved without any technical problems and then converted into analyzable information. (Figure 38 and Figure 39)

Figure 38- CVR memory card read-out at BEA laboratory using donor-chassis- Photo: BEA

Figure 39- FDR memory card read-out at BEA laboratory using donor-chassis - Photo: BEA

2.18.4. Flight Recorder Read-Out Results

Four audio channels recorded in the CVR were read out, including those related to the captain, first officer, Passenger Address system (PA), and Cockpit Area Microphone (CAM).

The overall quality of all of audio channels were understandable enough.

Using audio analyzing software, the investigation team listened to the audio files at BEA laboratory. Considering the flight crew's nationality, the ACCREP of Ukraine, together with a pilot from the UIA, accompanied the investigation team to analyze and transcribe the data.

Only, the captain's voice had been recorded in his channel, and it was clear that the other two crew members were not using their active microphones to make conversations inside the cockpit, yet the good quality of CAM channel made it possible to comprehend their conversations without difficulty.

Recording of the last flight started at 05:56:18.949, at the time of engine start up and start of pushback.

The recording had ended at 06:15:15.

A strong and short impulse, similar to a detonation is recorded at 06:14:55.865.

Immediately after sound of detonation, an aural tone consistent with the Altitude Alert C-Chord was present, which continued until the end of the recording.

A drop of frequencies began 2.445s before the end of CVR recording.

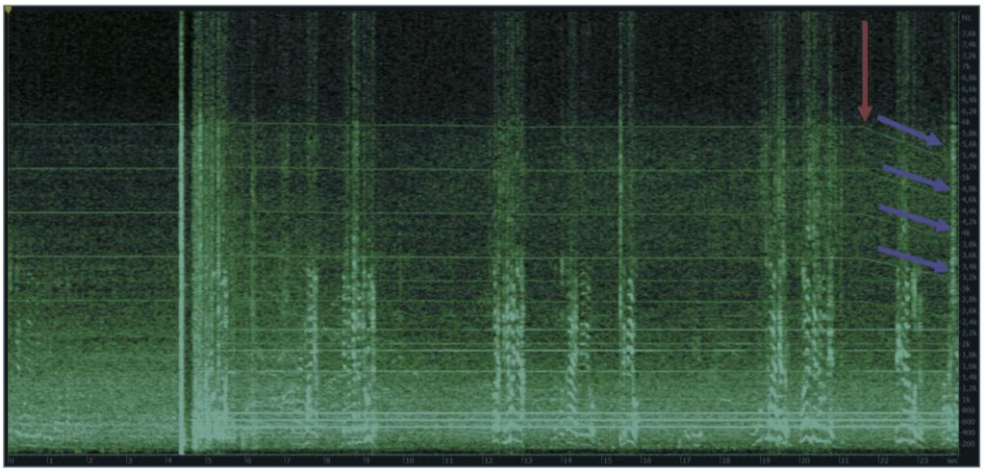

Figure 40- Drop of frequencies recorded in CVR. Photo:BEA

After the sound of impulse, conversations from all three cockpit crews were audible.

The flight crew became aware of the unusual conditions after the impulse sound and immediately started to take necessary actions to control the situation and operation of the aircraft in that condition.

At06:15:05, the instructor pilot instructed to turn on the Auxiliary Power Unit (APU), and a second later, a sound consistent with a switch was heard, which may have been the APU switch.

At06:15:13, the instructor pilot stated that engines were running.

By filtering the sound recorded in the CAM channel, some voices were barely audible from the passenger cabin upon hearing the detonation sound for three seconds, which shows that passengers noticed the unusual event. After almost 11 seconds, some voices was again heard from the passenger cabin.

The transcript of the conversations carried out from the time the aircraft started from the runway is given in Table 5.

Table 5- The CVR transcript

Time	Speaker	Transcript	Remarks
05:56:18		PS752 recording starts	
06:11:39	Captain	Full take-off thrust	
06:11:41	First officer	Ninety-one-point three set normal	
06:11:49	First officer	Eighty knots	
06:11:50	Captain	check	
06:12:09	First officer	V one	
06:12:12	First officer	Rotate	
06:12:21	First officer	Positive rate	
06:12:22	Captain	Gear up	
06:12:26	First officer	(*)	
06:12:27	Captain	check	
06:12:29	Captain	Easy easy don't pull	Russian
06:12:32	Captain	It is not helping you Just this	Russian
06:12:35	Captain	I haven't ability to pull simultaneously you and plane	Russian
06:12:35	Instructor pilot	(Ground) speed	
06:12:37			Trim moving
06:12:38	First officer	Let's do it	Russian
06:12:42			Trim moving
06:12:48	Captain	Report he said change	Russian

06:12:49	First officer	Yes yes	Russian
06:12:55	First officer	Radar good morning AUl752 .... on board on course IKA 1 A	
06:13:00			Trim moving
06:13:01	Mehrabad Approach	Good morning AUl752 radar identified on departure climb flight level 260 crossing 6000 feet turn right PAROT	
06:13:13	First officer	Next PAROT climbing 260 AUl752 information all received, thank you	
06:13:16	Instructor pilot	After six thousand	
06:13:18	Mehrabad Approach	Welcome, after 6000 to PAROT	
06:13:21	Captain	After 6000	
06:13:24	Captain	Flaps up	
06:13:25	First officer	Flaps up speed check flaps up	
06:13:27	Captain	Five thousand PAROT active point	
06:13:29	First Officer	yes	Russian
06:13:30	Instructor pilot	Now the second six thousand he said	Russian
06:13:31	Captain	yes	In Russian
06:13:32			Trim moving
06:13:34	Captain	Six thousand	
06:13:40	Instructor pilot	(*)	

06:13:43	Instructor pilot	Unknown: two six zero speed	Russian
06:13:48	Captain	Just connect it easily	Russian
06:13:49	First officer	What?	In Russian
06:13:50	First officer	Flaps up no light	
06:13:52	Captain	Check after take-off Check list	
06:14:06	First officer	Six thousand PAROT active point	
06:14:08	Captain	Six thousand execute check	
06:14:09	First officer	L-NAV available	
06:14:14	Captain	After take-off?	
06:14:15	First officer	Now executing	In Russian
06:14:18	First officer	Engine bleeds ON packs	
06:14:22	First officer	Auto pressurization normal landing gear up and off flaps up no light after take-off check list completed	
06:14:28	Captain	Ha Ha	
06:14:40	First officer	Unknown: what is the light?	In Russian
06:14:43	Captain	GPS right invalid	
06:14:45	First officer	Yes I see	In Russian
06:14:50	Captain	And left invalid	In Russian
06:14:51	Instructor pilot	Un known: now will flight like....	In Russian
06:14:56			Noise similar to detonation

06:14:56			C-Chord alarm until the end of the recording
06:14:56	Instructor pilot	(...)	In Russian: strong feeling about bad event
06:14:58	Captain	(Breathing) what is this?	In Russian
06:14:59	Instructor pilot	Caution keeping keeping the thrust levers	In Russian
06:15:03	Instructor pilot	Speeds with caution	In Russian
06:15:05	Instructor pilot	Start A P U	In Russian
06:15:06			switch sound
06:15:07	First officer	A P U	
06:15:08	First officer	A P U	
06:15:10	Captain	(*)	In Russian
06:15:10	Instructor pilot	Keep the speed here	In Russian
06:15:11	Instructor pilot	Keep speed here	In Russian
06:15:13	Instructor pilot	Engines are running	In Russian
06:15:15	Captain	(*)	In Russian
02:45:15		END OF RECORDING	

(…); Word or group of words with no bearing on the flight

(*); Word or group of words not understood

At05:13, the captain made his first radio contact with the ground unit of IKA control tower. This conversation was recorded by the airport systems. The recording of the radio communication in the accident flight CVR started at 05:56:18 and the flight was cleared for startup and pushback at 05:55. Hence, there exist no information on the cabin and preflight checks and the probable briefing about the situation and decision-making in the recorded audios.

The FDR had recorded approximately 54 hours (193,242 seconds) of data in 54 areas at a 512 WPS.

The raw data was decoded using data frame provided by the aircraft manufacturer. The accident flight was the last flight recorded on the recorder.

There were 86 bytes with a value of zero at the end of the data file. Data recording is made using four-second frames, each with four one-second sub-frame. The last complete recorded sub-frame was number 2 and the last incomplete sub-frame was number 3. In this last sub-frame, the last valid word recorded was the word 320, and the words recorded after the word 321 were invalid due to inconsistencies with the physical values and hence were not recorded correctly.

An investigation into the last data recorded showed that all the values underwent their own normal changes with no indication of recording any abnormal ones like in altitude, speed, acceleration, etc.

The last recorded values of some important parameters are shown in Table 6.

Table 6- Last recorded values of some important parameters; time column corresponds to the time of recording

	Parameter	Value	Time
1	L Eng. N2 Tachometer	95.5 %	06:14:55
2	R Eng. N2 Tachometer	95.47 %	06:14:52
3	L Eng. N1 Tachometer	91.21 %	06:14:54
4	R Eng. N1 Tachometer	91.09 %	06:14:54
5	Present Position Long.	50.953 deg.	06:14:56
6	Present Position Lat.	35.491 deg.	06:14:56
7	Angle of Attack - L	1.23 deg.	06:14:56
8	Angle of Attack - R	1.05 deg.	06:14:56
9	Radio Height - L	4378 FT	06:14:56
10	Radio Height - R	4382 FT	06:14:56
11	Capt. Display Pitch Att.	9.66 deg.(UP)	06:14:56
12	Capt. Display Roll Att.	2.28 deg.(RT)	06:14:56
13	Vertical Acceleration	0.97 g(UP)	06:14:56
14	Capt. Display Heading	306.86 deg.	06:14:56
15	Longitudinal Acceleration	0.17 g(FWD)	06:14:56
16	Altitude(1013.25mB)	7947 FT	06:14:56
17	Computed Airspeed	250.12 KT	06:14:56
18	Lateral Acceleration	0.00 g(RT)	06:14:56

2.19. Launching Missile at the Aircraft

Following the crash, numerous videos were released in the cyberspace and media showing the launching of missiles at the aircraft. The investigation team investigated the authenticity of videos and inquired the security and military authorities on firing missiles toward the aircraft.

On Jan. 09, 2020, the investigation team reached the conclusion that some of the videos released corresponded to the time and location of the crash. However, there was still no conclusion about the origin of the launched missile, the type, number and effect on the aircraft.

One of the most important evidence was a video which had been recorded in a construction work area showing the missile flight and explosion. The investigation team processed the images and identified the location of the camera. After comparison and matching of calculated point with aerial images, a team of experts were deployed to the same area and by filming in the same position and direction, the validity of the original video was confirmed.

In the afternoon of Friday Jan. 10, 2020, the person who had managed to record the second missile firing was identified by securities. The investigation team had interview with him and found out he was the caretaker of a construction site who could record the flight and second missile with his cell phone after he saw the first missile launch.

This video was a key source for defining the accurate times and positions of key events related to missile launch and matching non-calibrated information with accurate ones like the aircraft path and radar information.

On the evening of Friday Jan. 10, 2020, the Civil Aviation Organization of Iran and AAIB were made aware of the missile launch by Air Defense of the country, and military forces stated that they would announce the event.

In the early morning of Saturday, Jan. 12, 2020, the I.R. Iran General Staff of the Armed Forces released a formal statement about firing missile toward the accident aircraft.

The investigation team received the information related to the missile launch from the Armed Forces.

The declared information was then assessed through the team's independent observations, including the videos, recorded sounds, relevant photos and reports, interviews with some people and review of judicial proceeding documents. The correspondence between such observations and military-related findings, such as the time and location of the recorded events, radar data, and flight recorders was also checked.

Given the error of the time mentioned in the Factual Report published in July 2020, the event times were corrected using the information obtained from the recorder read-out.

2.19.1. Launching

The information in this section was provided by military authorities. The investigation team was able to see evidence that confirmed it.

At 04:54, on January 08 2020, one of the air defense units of Tehran was locally relocated for the last time in order of 100 meters according to tactics of mobile ADUs. This relocation clearly caused a change in the ADU's heading and therefore the ADU suffered an error of 105 degrees due to operators' failure in conducting north realignment properly. The ADU remained on standby mode until 06:07 and after this time, the ADU was set at operation mode. As such, while the Ukrainian aircraft was flying, the direction of objects and targets detected by this unit was being observed with an increase of 105 degrees by the operator.

At about 06:14, the air defense system operator detected a target at his azimuth of 250 degrees flying on a 56-degree course. At the same time, after takeoff, the PS 752 was flying towards the defense system from a 143-degree azimuth. The aircraft was taking a 309-degree course.

At 06:14:19, the operator announced the specifications of the detected target over the communication network of the relevant Coordination Center. The message was not relayed to the Center. In fact, it had not been recorded in the recorded messages of the Coordination Center.

Without receiving a response (command) from the Coordination Center, the operator came to the conclusion that the observed target was a threat and fired a missile at it at 06:14:39.

The system recorded the activation of the missile proximity fuse at 06:14:57.

After the first missile radio fuse was activated, the air defense system radar still locked on the target and kept detecting and tracking it.

Having observed the continuity of the detected target trajectory, the second missile was fired at the aircraft by the ADU crew at 06:15:09.

At 06:15:22, the last communication between the second missile and the defense system was recorded in a place close to the aircraft route. After that, the defense system showed a message indicating the strike had failed, with the aircraft clearing from the radar lock-on after some time.

Figure 41 depicts the trajectory and true location of the aircraft, wrong detected position and locations related to the activation of the missiles.

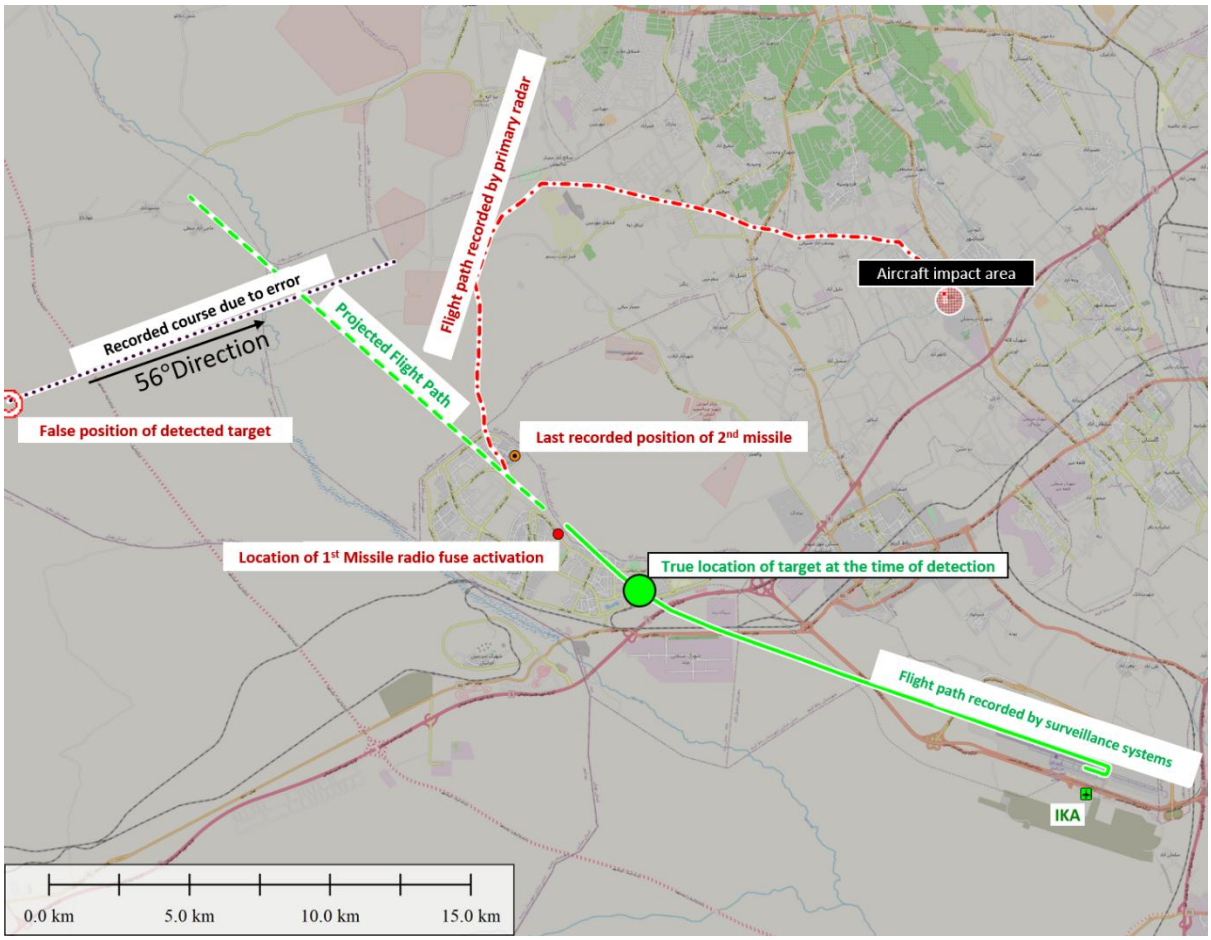

Figure 41- The location of key events in missile launch

2.19.2. Missile Information

The missiles targeting the aircraft were launched from TOR M1 air defense unit.

The M1 Tour system, known in NATO designation as the SA-15 Gauntlet, is a short-range air defense system in which the vehicle's radar and missile launcher system are integrated. The range of this system is about 12 km.

This unit is equipped with radar guided missiles with proximity fuses, while approaching the target the warhead containing shrapnel is detonated throwing about 2500 to 3000 pieces of shrapnel 2.4×7.8×7.8 mm dimension, weighing 2.4 gr of tungsten metal at a speed of about 1,800 m/s.

Missile length is 2898 mm, 167 kg in weight and its warhead 14 kg.

The explosives in the missile are of COMP-B type in which 50 percent of RDX% and 40% of TNT is used.

3. The Management of Potentially Hazardous Military Activities to Civil Aviation

3.1.1. States' and Operators' Responsibilities[4]

Every State has complete and exclusive sovereignty over the airspace above its territory[5], and no aircraft may be operated over an airspace except with the permission of the State managing that airspace[6]. Each State has the authority to limit the operation over the airspace managed by them[7].

On the other hand, the States have oversight on the safety of airlines for which they have issued certificates and may impose restrictions on their activities in accordance with the laws and regulations they enact.

Further, airlines are inherently responsible for the safety of their operation and shall ensure the safety of the routes in which they conduct flights[8].

One of the factors potentially hazardous to flight safety is military activities. Therefore, the States managing the airspace, the ones that have oversight on the airline activities as well as the airlines themselves shall gather information related to military activity hazards, conduct relevant risk assessment and adopt mitigating measures to maintain the associated risk within acceptable levels.

As can be seen in Figure 40, the State managing the airspace may impose restrictions over its own airspace, which can include the prohibition on entry into certain geographical areas, limitations on some routes, flight altitude and some of the normal procedures.

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4 - Responsibilities arising from Convention on International Civil Aviation.

5 - Article 1- Convention on International Civil Aviation

6 - Article 6- Convention on International Civil Aviation

7 - Article 9- Convention on International Civil Aviation

8 - Annex 6 to Convention on International Civil Aviation, part I, 4.1.

Naturally, the State can impose restrictions on the operations of operators certified by them, beyond those done by the State managing the airspace.

The airline shall comply with the restrictions imposed by the State managing the airspace and those of the one that has certified their operation. However, they may consider more operation-related restrictions in that airspace in order to ensure their desired level of safety.

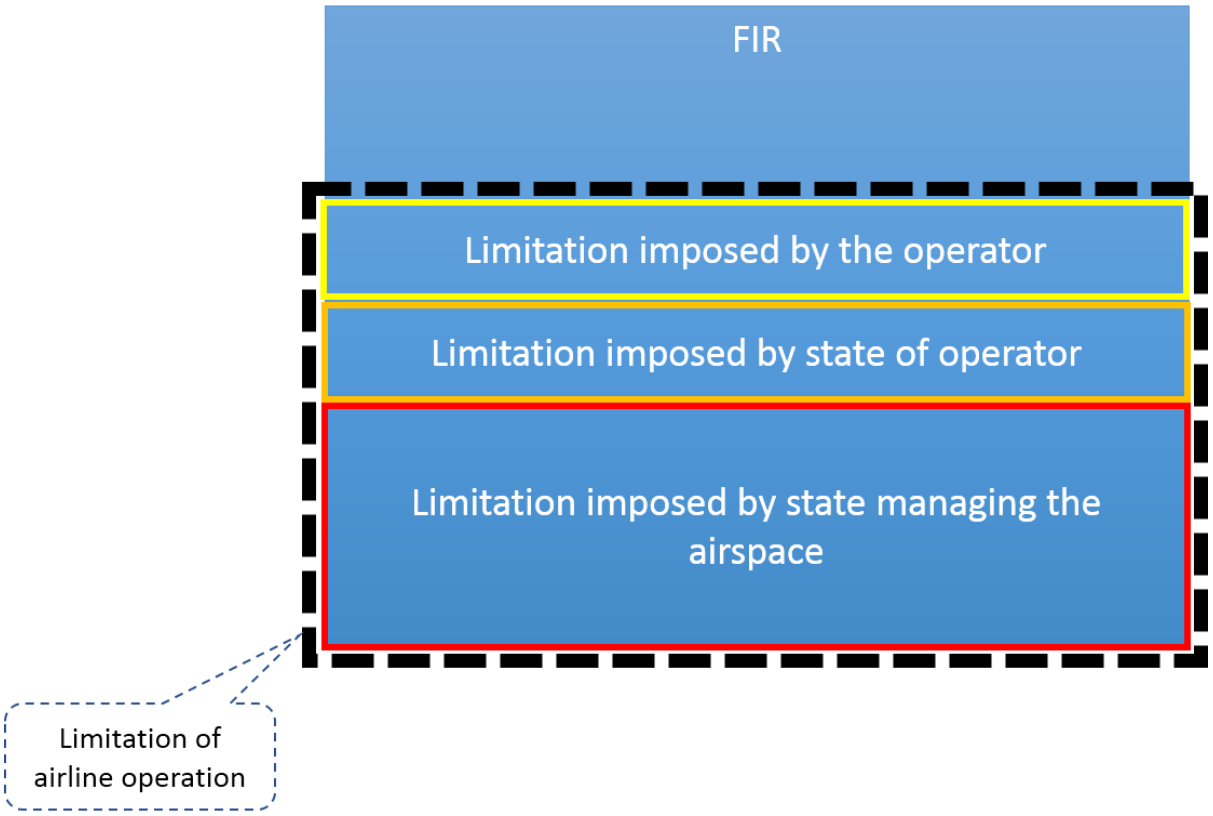

Figure 42- Dimensions of limitations in an airspace from different responsible parties

Taking the very approach, the parties having responsibility for the means to the safe use of flight routes include:

- The State managing the airspace
- The airline using the airspace
- The State issuing certificate for the operation of an airline

Hence, this section deals with the means to perform such a responsibility towards the threats of military activities in Iran as the State managing the

airspace, Ukraine as the State of the Operator of the UIA and the very airline itself.

3.2. Background and Structure of Civil-Military Coordination in Iran

The States' airspace is a place for conducting civil air transport operations as well as military aviation ones.

Further, the airspace of States forms an important and sensitive part of their sphere of sovereignty, and they carry out regular oversight and measures to exercise their sovereignty over the sky from the perspective of military security. As a result, the airspace has always been a place for joint military and civilian operations. This inherent commonality is a ground for expanding the results of actions to one another, from either party.

On the one hand, civil aviation operations may disrupt the military security of the States or be exploited for hostile purposes, and on the other hand, military actions and arrangements can interfere with commercial air activities in this common space due to the errors, threats and shortcomings in the military sector. Therefore, in all aviation-related activities, it is essential to take account of the considerations of the other sector and the way they affect one another, not to mention their coordination method.

The ICAO has developed the standards, recommended practices and guidelines on civil-military coordination in the aviation sector, as well as risk management of military operation potentially hazardous to civil aviation.

The Middle East is a region that is particularly sensitive in terms of the effects of military action on civil aviation for a variety of reasons, including hostility between states, instability due to the presence of insurgent and terrorist groups, and the widespread presence of trans-regional military forces. In the meantime, the continuity of air transport is a necessity for countries, and in Iran, in addition to what is initiated by ICAO, experienced measures and structures have been established to make this

coordination to maintain the continuous and regular air transportation in various conditions that will be described below.

3.2.1. Background of Civil-Military Coordination

On September 22, 1980, with the all-out Iraqi air strike on Iran, a war broke out that lasted for eight years until 1988. During this long war, civil-military coordination was made for commercial flights to be conducted, and the management of Iran's airspace was inherently carried out through the continuous interaction of the military and civilian sectors. Iraq attacked Kuwait on August 1, 1990, as a result of which, on January 17, 1991, the launch of a large-scale air strike by the United States and its allies on Iraq exposed Iran's western borders to a tense air zone military region. This inevitably entailed the civil-military coordination specifically to ensure flight safety and security.

For 12 years, from March 1990 to March 2002, the United States and its allies established two no-fly zones, North and South, over Iraq (Figure 43).

Figure 43- Two no-fly zones in Iraq adjacent to Iran

In the east of Iran, Afghanistan, which suffered from internal tensions, has been embroiled in the US-led war since 2001, which lasted until 2014, after 13 years of continuous conflict and the handover of Afghan security-related responsibilities to the country.

Since 2002, with the start of the Second Persian Gulf War, the U.S. and its allies have invaded Iraq, and the war officially ended in August 2010, but American forces and their bases are still present in this country.

In June 2014, the ISIS group began its strong presence in Iraq by attacking and controlling the city of Mosul, raising tensions over aviation security concerns on Iran's western border.

This tense regional atmosphere, having existed for such a long time, has led to the domestic formation of measures of civil-military coordination in Iranian aviation based on objective needs as well as a long-standing structure in this area in the field of risk analysis as well as precautionary and preventive measures.

Due to the widespread presence of American forces in the south of the Persian Gulf and the expansion of their forces in the western and eastern neighbors of Iran (Figure 44), such measures are constantly practiced and implemented in the border areas of Iran.

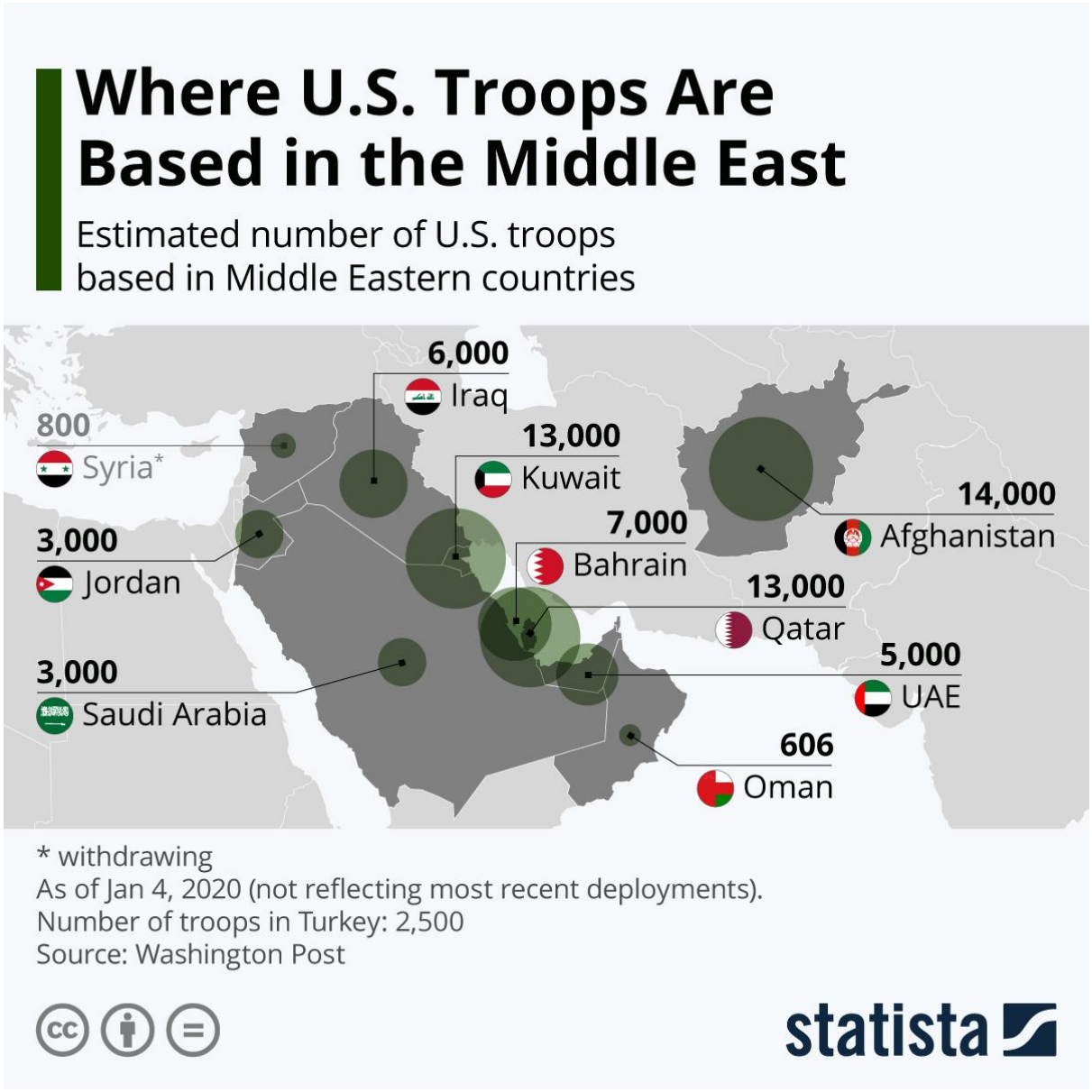

Figure 44- U.S. military bases around Iran – source: Washington Post

3.2.2. Structure of Civil-Military Coordination

Civil-military aviation coordination in Iran is carried out at three levels: strategic, tactical and operational.

At the strategic level, the Secretariat of the Supreme National Security Council determines the manner of cooperation and responsibility of each sector by determining the general requirements and communicating the necessary policies, and the relevant sectors, including the Civil Aviation

Organization, ANSP and armed forces plan and monitor the effective implementation of these policies.

At the tactical level, specific procedures are defined for the implementation of strategies, which are implemented operationally and usually in the form of actions of air traffic control units and representatives of the air defense sector. A significant number of such measures apply to the management of the country's airspace, and there is also a section related to the flight operations of Iranian airlines in the airspace outside Iran, which is implemented in cooperation between airlines and the CAOIRI in the context of Security manuals and airlines Safety Management System.

At an operational level, since the war between Iran and Iraq, a structure part of Iran's air defense has been assigned to make coordination with the airspace management with the aim of ensuring the security of the airports and flights against possible enemy attacks besides separating commercial flights from anonymous and hostile flights. This hierarchical structure makes coordination between the air defense sector and the civil flights at an operational level.

Figure 45 demonstrates Iran's civil-military operational coordination structure at the time of PS752 accident.

The civil-military operational coordination center (CMOCC) is located in the Tehran ACC. This center communicates all civilian flights information to the military sector, and this information exchange is used to identify civilian flights in the military network. Also, the military flight-related information is provided to the civil airspace management sector to enable integrated air traffic management. CMOCC is in direct contact with State Air Defense Operation Center (SADOC).

In the military sector, Air Defense Sectors have been established, each of which is responsible for an area of the country's airspace. In addition to communicating with the CMOCC, these centers communicate with some airports through the Air Defense Coordinators.

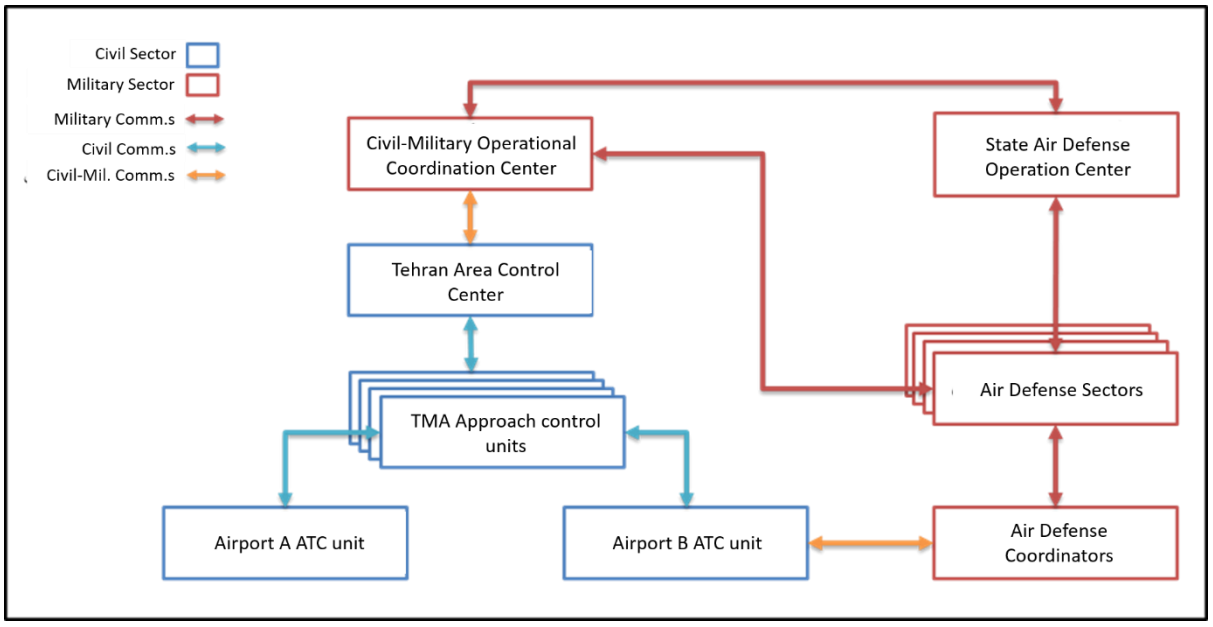

Figure 45- Civil-military Coordination Structure in Iran

The TMA Approach control units are in contact with both the Tehran ACC and air traffic control units of the airports within that area, and depending on the necessity, there would be an air defense coordinator in some airports.

The military units are in contact with one another. Apart from the military communications, the CMOCC and air defense coordinators are both in contact with the civilian sector. Such communications are of three types of voice, message data and radar data.

The issued flight permits, which are exchanged on the aeronautical telecommunications network between the air traffic control units, are also provided to the CMOCC through the network.

CMOCC, which is located in the Tehran ACC, has access to information from the surveillance radars of the civilian sector.

3.3. Airspace Risk[9] Management for Civil Aviation in Iran

The information in this section is obtained by review of public and classified regulations, official inquiries, interview with individuals and

9 - Here, a combination of safety and security risk arising from potential military hazardous activities

review of evidence and records and the investigation team was able to independently validate them.

Typically, security and intelligence organizations collect and analyze overt and covert information related to national security.

These agencies are located in different sectors of the country, including military and civilian. There is a structure in the form of the Supreme National Security Council and its secretariat which plays a role in coordinating and integrating issues.

If the information or the results obtained through their analysis have something to do with the aviation security of the country, and the issue falls completely within the duties and responsibilities of a governmental body, it will be transferred to the civilian sector. If the dimensions of the issue fall beyond the functions of the given body, relevant measures will be taken using the capacity of the Supreme National Security Council.

Every military, security or intelligence organization enjoys some autonomy to make specific decisions in urgent situations.

Security risk analysis and assessment are classified into two areas: Iranian airspace and the airspace of foreign areas to which Iranian companies fly.

Risk analysis and management is performed at three levels: strategic, tactical and operational.

At the strategic and tactical levels, the CAOIRI and the ANSP are involved in decision-making in interaction with the civil and military security and intelligence sectors. At the operational level, decisions are made and implemented at the level of air traffic control units and in interaction with the representative of the air defense sector, relevant to predefined strategies and tactics. Of course, these operational measures are continuously analyzed, and based on the feedback obtained from the operations, the strategic and tactical plans are reviewed.

As is common for all military forces, sometimes the nature of threats and their alertness condition is at such a level which necessitates designing

actions that are highly classified and of which the civilian sector should not be made aware before they are implemented.

In such circumstances, the relevant military sector designs the measures necessary to maintain the safety and security of civil aviation by using the already obtained information of the type and structure of civil aviation operations, and finally notifies the civilian sector at the appropriate time at the operational level about the pre-defined measures. The relevant units in the civilian sector determine the method of implementation of the measures that are in accordance with the requirements of civil aviation.

The structure of data collection, risk analysis and implementation of measures are shown in Figure 46.

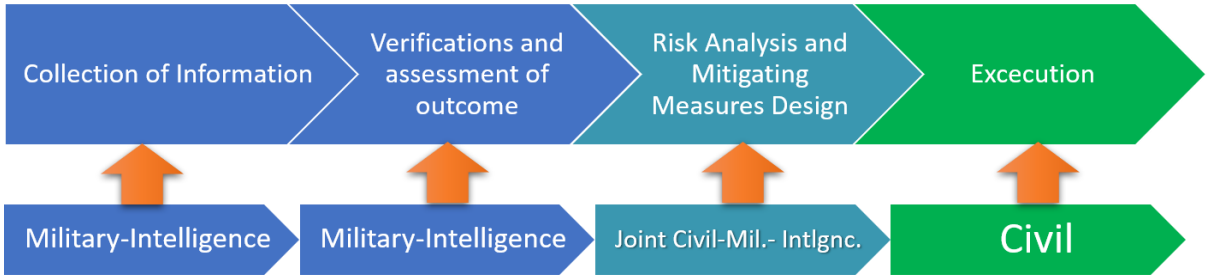

Figure 46- Structure of data collection, risk analysis and implementation of measures related to the management of potentially hazardous military activities to civil aviation operations

Figure 46 shows where each process -monitoring and data collection, validating and analyzing their consequences, risk assessment and designing corrective measures and implementing measures- is carried out. Data is collected, verified and analyzed outside of civil aviation and by the military or security departments of the country. Depending on the urgency and classification of the issue, risk assessment and compensatory measures are designed in joint military-civilian cooperation, but the urgency and classification may be such that the informed departments act directly in this step and ultimately the civilian sector implements the measures. Obviously, if a portion of the mitigating measures are designed for the military side, their implementation will be the task of the relevant military sector.

3.4. Iran Airspace Risk Assessment at the Time of the Accident

3.4.1. Prevailing Conditions

When Major General Qassem Soleimani, one of the top commanders of the Armed Forces of the Islamic Republic of Iran, was on an official trip to Iraq, he was targeted at Baghdad airport in a U.S. drone strike on January 3, 2020, where he and a number of his entourage, including a senior commander of the Iraqi counter terrorism force, lost their lives.

The United States claimed responsibility for the operation. The Iraqi government announced the operation had been carried out without their permission or knowledge.

Iran strongly condemned the assassination and officially declared it a clear example of state terrorism, the responsibility for the consequences of which would rest entirely with the U.S. regime. Iranian officials also vowed they would exact revenge on the U.S. action appropriately.

In the morning of Wednesday, Jan. 08, 2020, at 02:00, in response to the U.S. action, the Armed Forces of the Islamic Republic of Iran started a missile attack on the Al Assad base in Iraq, where the U.S. forces were based; the attack was ended in at 02:05.

Considering the possibility of the conflict escalation through the American counterattack by its military forces in the region, the relevant defensive units, including the air defense sector was placed on a higher level of alertness.

3.4.2. Risk Assessment and Planned Measures

The accident investigation team was provided with information on the measures taken by the military sector.

The investigation team realized that although different and specific definitions, techniques, tools, forms and diagrams are used for risk management in the military sector, they are substantially consistent with the aviation risk management literature.

The identification of Generic Hazards, the determination of Specific Hazards, and the type of operations combinable with hazards are among the components used in the military sector.

The investigation team reviewed the documents and records related to the risk management method in the military sector and given the complexity of these part of evidence, the key aspects and outcomes are described in a coherent manner with conventional risk management literature.

In a situation where the possibility of military movement against Iran and its interests was growing, the players whose activity or readiness was potentially hazardous to civil aviation were taken into account along with their intentions.

The unintentional targeting was classified into two general probabilities:

- **Misidentification**: When a commercial aircraft could be identified and targeted as a hostile target.

- **Accidental strike (Mistargeting)**: When during a conflict with a hostile target, a commercial aircraft is damaged as a result of military actions related to the conflict with another target.

Due to the very high sensitivity of commercial flights in the event of a conflict, it was decided in case of an air attack, all commercial flights, including transit flights in addition to the inbound and outbound ones to Iran's airports, would be stopped. Then, depending on the severity and location of the conflict, a decision should be made and announced regarding the continuation of the aircraft operation. Nevertheless, given that in the event of a conflict, it would not have been possible to immediately stop the aircraft already on their flight paths, the routes more likely to interfere with the enemy military operations in that situation would be gradually cleared of air traffic independently and with no regard to the conflict initiation, with no new flights being directed to these routes.

The three parties below were considered to have had the possibility to perform military activity in Iran's airspace:

- Iranian defense forces

- Possible attacking forces
- Terrorist groups

Terrorist groups have a history of intervention in aviation in Iran, which was limited to hijacking. According to the collected information, the probability of their attack on passenger aircraft was considered quite low considering the extent of their ability and presence in Iran, not to mention the equipment available to them.

Regarding the possible attacking forces, two dimensions, namely intention and type of commercial aircraft operation were analyzed.

According to the analysis, the probability of an intentional attack on commercial aircraft by foreign forces was determined to be low, but the unintentional damage to commercial aircraft was considered probable due to misidentification or mistargeting in the event of a conflict.

Commercial aircraft departing from joint civil-military airports would be at higher risk of misidentification and mistargeting by enemy, and the risk of being misidentified by commercial aircraft departing from commercial airports had been determined to be lower. In order to minimize the risk of misidentification by defense forces, it was decided to identify and track all commercial flights from the beginning so that in the event of a conflict, the military forces would be able to take immediate action thanks to their full knowing of directing flights to safe areas.

In addition, the probability of the attack to joint civil-military airports was considered very high in case of an attack to Iran's airports, and the probability of attack to civil airports was determined low. The probability of attack to IKA was assessed as very low.

The risk of accidental targeting of aircraft entering Iraq from Iran was assessed as high, and the probability of accidental damage to transit aircraft in the area between Iran and Iraq border could not be ruled out.

It was impossible to reduce the risk of targeting the commercial aircraft crossing the Iran and Iraq border to an acceptable level; hence it was

necessary to stop the traffic exchange between airspace control centers of Iran and Iraq.

In the event of a conflict, Iran's western airspace was deemed unsafe and therefore it was necessary to stop flights from four parallel routes in the west of Tehran FIR. Given that in the event of a conflict, there would not have been enough time to clear and direct the aircraft of such routes to the safe ones, the gradual evacuation of routes from transit flights and denying clearance for new traffics in these routes was considered as a preventive measure.

Also, to clear the flights, the risk of the airport and the flight path on which the aircraft would continue flying would have to be considered in an integrated manner, and the risk governing the aircraft flight would be the highest risk.

A summary of the Risk Management Model posed by the generic hazard of a possible enemy air strike for civil air transport is given in Table 7.

Table 7- A summary of the Risk Management Model posed by the generic hazard of a possible enemy air strike

Generic Hazard	**Enemy Attack**		
Type of operation	Area	Level of Risk	Mitigating Measure
Overflights	Tehran-Baghdad Exchange points	Very high	Stop the exchange
	West of Iran	High	Gradual evacuation
	Remaining FIR	Probable	Rerouting to safe areas in case of conflict
Departures	Joint Airports	High	Flight permission only if no attack is predicted
	Civil Domestic Airports	Probable	Flight permission only if no attack is predicted
	Civil International Airports	Negligible	Flight permission only in white alert level

Note: This table is prepared by the investigation team for a coherent presentation

About the conditions resulting from level of alertness of Iran's defense forces, the following considerations were taken into account:

- As previously military forces had used the commercial aircraft cover, and the hostile aircraft had conducted flight near commercial aircraft to enter the Iranian airspace, besides the high probability of using Iraqi airspace for a possible attack, flights entering from the Iraqi airspace to Iran could have endangered the security and been identified as a threat consequently. Or they could have been accidentally damaged through an air defense operation. Suspending the exchange of civil flights between Tehran and Baghdad airspace

would have removed such a concern. The risk associated with these flights was calculated high.

- Preventive measure: stop the air traffic exchange between Iran and Iraq airspace despite no air strike

- In the event of a conflict, it was likely that the defense system would misidentify the aircraft leaving the country's airports as a hostile aircraft. The risk associated with these flights was calculated to be very low.
  - Preventive measure: before issuing a clearance to start up aircraft engine, air traffic control units would have to coordinate with the air defense sector through the Tehran ACC The air defense sector would not allow the engine startup if an air attack was launched.
    In the absence of an air strike report, the start of flights to low-risk areas would be unimpeded once identified in the defense network.

- In the event of a conflict, it was likely that the domestic defense system would misidentify the aircraft crossing Iran's airports as a hostile aircraft. Or they could have been accidentally damaged through an air defense operation. The risk associated with these flights was calculated to be very high.
  - Preventive measure: Iran's western fly zones, including routes of UT430, M317/L319, UL223 and UT331 would be at high risk and there would not be enough time to direct them to safer areas if an air strike began. So, clear air traffic flow in these areas and clear traffic only after issuing an air defense permit.

A summary of the Risk Management Model posed by the generic hazard of a possible enemy air strike for civil air transport is given in Table 8.

Table 8- A summary of the Risk Management Model posed by the generic hazard of alertness and operation of defense forces (This table is prepared by the investigation team for a coherent presentation)

Generic Hazard		**Alertness and operation of defense forces**				
Type of operation	**Area**	**Alertness Level**	**Type of hazard**	**Level of risk**	**Mitigating measure**	**Residual risk**
Overflights	Tehran-Baghdad FIRs Exchange points	Surveillance	Misidentification	Very High	Stop the exchange	Acceptable
			Mistargeting	Negligible	NIL	Acceptable
		Conflict	Misidentification	Very High	Stop the exchange	Acceptable
			Mistargeting	Very High	Stop the exchange	Acceptable
	West of FIR	Surveillance	Misidentification	High	Gradual evacuation and no new flights	Acceptable
			Mistargeting	Negligible	NIL	Acceptable
		Conflict	Misidentification	Very High	Stop the operation	Acceptable
			Mistargeting	High	Stop the operation	Acceptable
Departures	Joint Airports	Surveillance	Misidentification	Low	Flight permission if it is ensured enemy is not ready for attack	Acceptable
			Mistargeting	Negligible	NIL	Acceptable
		Conflict	Misidentification	Probable	Stop the operation	Acceptable
			Mistargeting	Very High	Stop the operation	Acceptable
	Civil Airports	Surveillance	Misidentification	Low	Flight permission after coordination with defense unit in white alert condition	Acceptable

			Mistargeting	Negligible	NIL	Acceptable
		Conflict	Misidentification	Probable	Stop the operation	Acceptable
			Mistargeting	high	Stop the operation	Acceptable

3.4.3. Implementation of the Measures

At the time of the accident, the CMOCC had notified the three following preventive measures to the Tehran ACC chief on duty during an urgent coordination meeting minutes after attack to Al Asad base:

1- The evacuation of four parallel routes in the west of the country
2- The ban on traffic exchange between Tehran and Baghdad FIR
3- Coordination with the air defense sector prior to issuing a startup approval for departure flights.

Civil- Military coordination at the time of flight PS752 is illustrated in Figure 47. In this figure, the communication lines between IKA ATC unit, Mehrabad approach unit, Tehran ACC and CMOCC are shown.

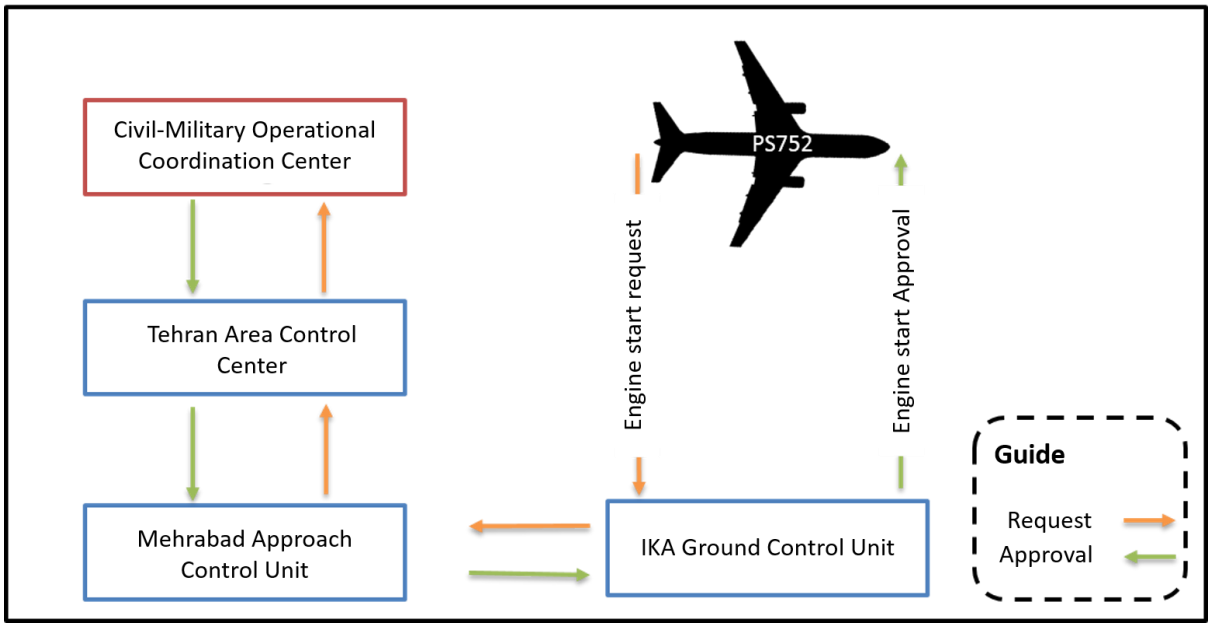

Figure 47- Civil-Military coordination structure at the operational level at the time of the accident

Investigations showed that the measures adopted had been notified to the civil sector based on the planned schedule.

As for PS752, according to the prevailing conditions, the plan was to notify the flight specifications to the defense sector and make coordination with them before issuing clearance for engine startup.

Review of evidence regarding flight PS752 showed that the plan had been implemented and the air traffic control had issued the clearance for engine startup after making coordination with the air defense sector.

Also, the flight PS752 plan had been sent to the military sector, and the CMOCC had been receiving the civil surveillance radar information including the very flight specifications. Considering the location and time of the PS752 takeoff as well as its trajectory to leave Iran FIR, which was not in the limited areas in west of FIR (Figure 48), the measures envisaged in the risk reduction program from this perspective had also been implemented according to the plan.

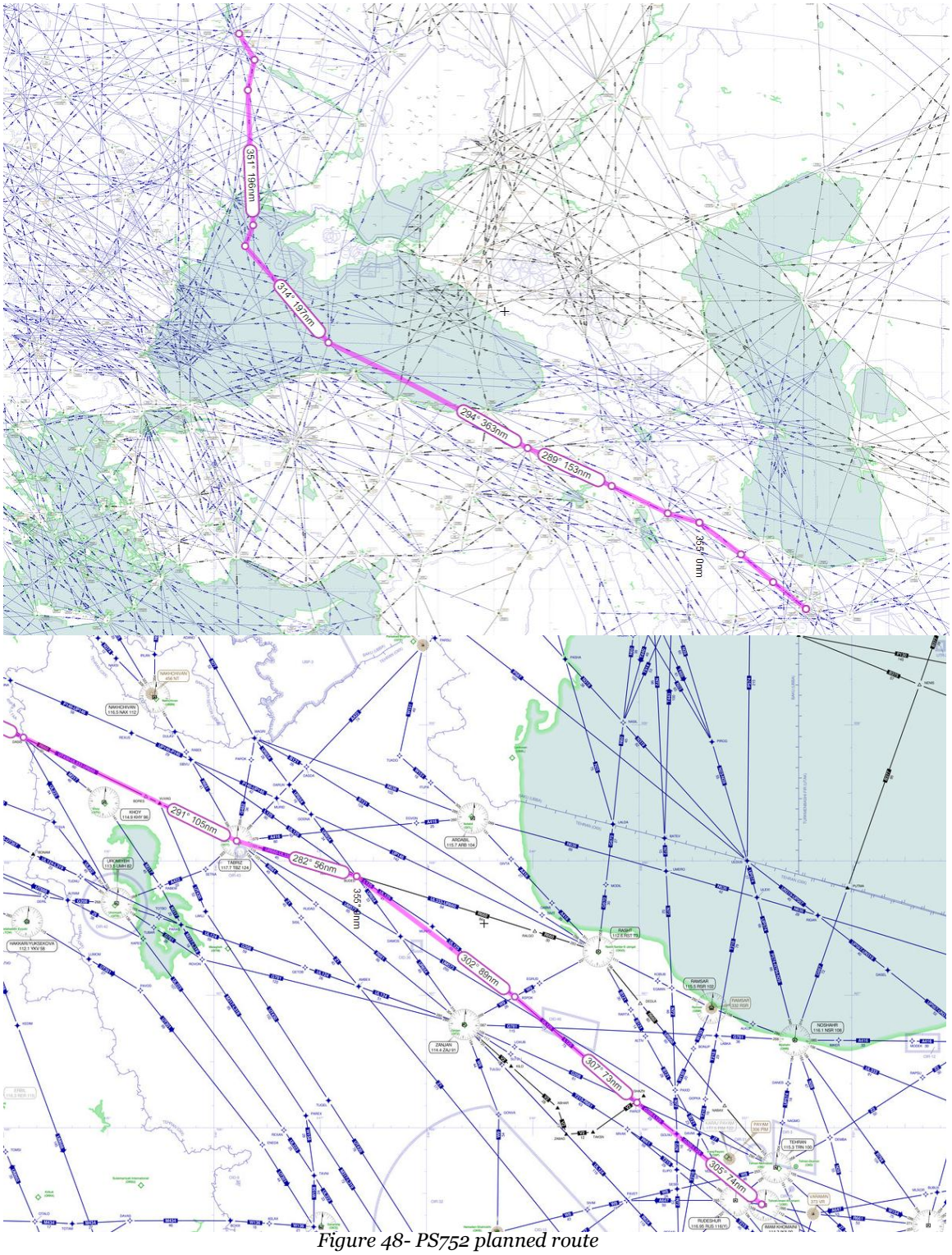

Figure 48- PS752 planned route

The planned measure to clear the four parallel routes in the west of the country had been carried out. The radar observations showed that at the time of the accident, the clearance of four parallel routes No. UT430, M317/L319, UL223 and UT 331 of the transit traffic in the west of Tehran FIR near Iraqi border (Figure 49) had been carried out and there was no flight in this area.

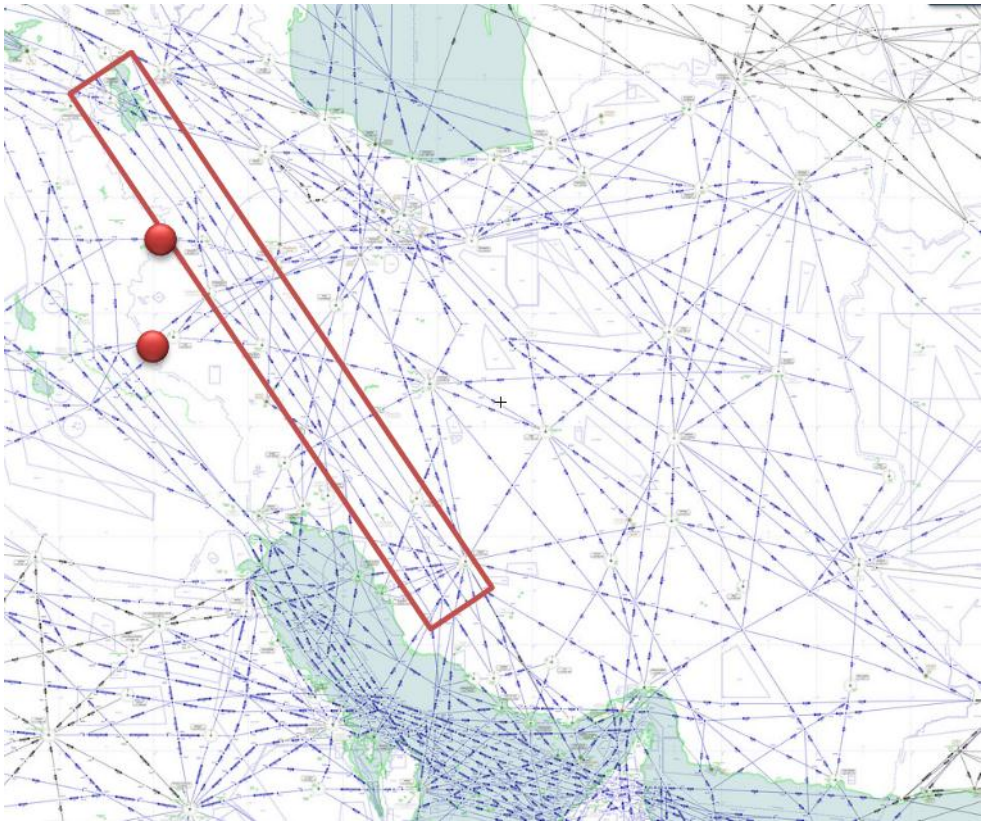

Figure 49- The scope of Iran west routes and exchange points between Tehran and Baghdad FIRs

The observable flight information on these routes corresponds to the one recorded on Internet sources (Figure 50).

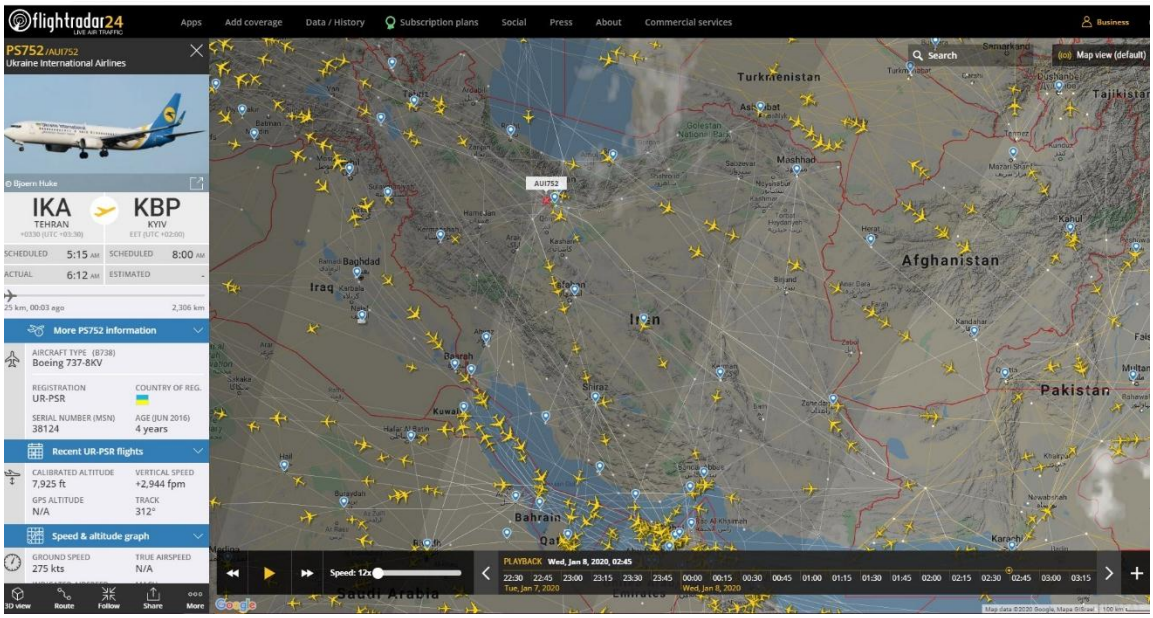

Figure 50- Transit flights status in the west of Iran FIR at PS752 takeoff time (source: FlightRadar24)

For evacuation of routes, at the first the inbound flights were routed to other routes operationally. Considering the rise in the workload together with the conditions persistence, NOTAM No. A0087/20 (Figure 51) was issued hours after the accident at 10:27 on Jan. 08, 2020, whereby new air traffic route scheme was announced.

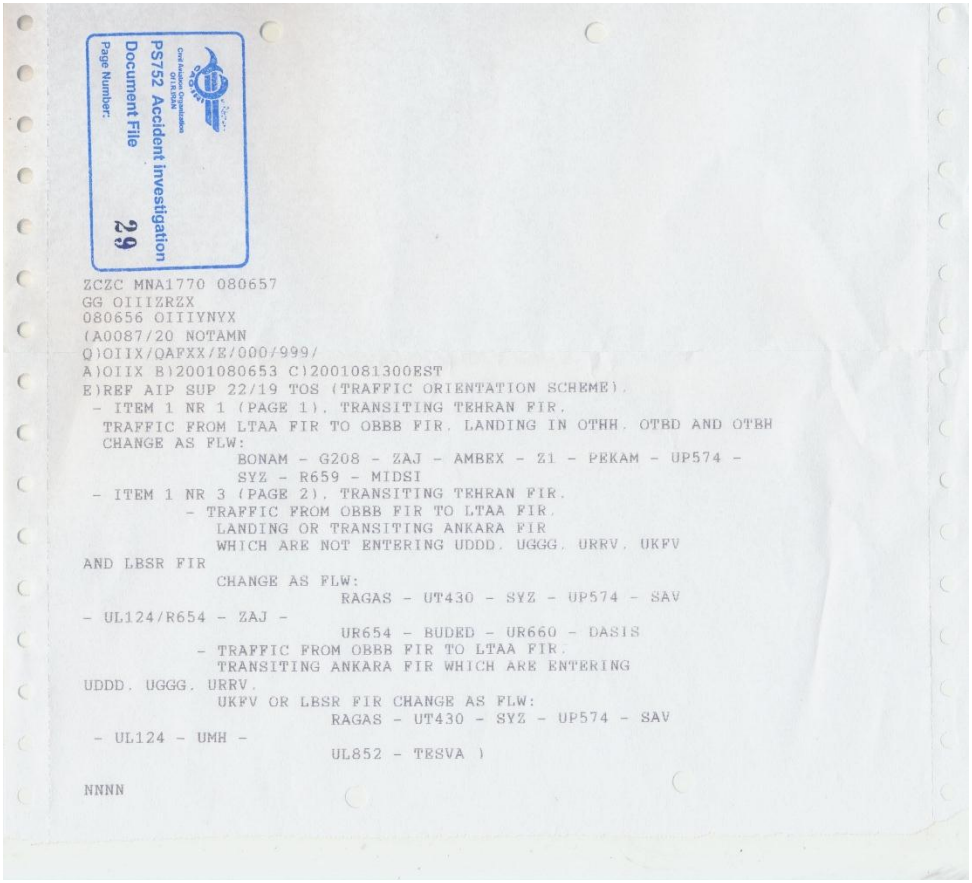

Figure 51- NOTAM issued for change in route scheme

As the air traffic exchange between Tehran and Baghdad FIR had been stopped, four exit flights from IKA to Iraq had been canceled according to the Table 9. The inquiry into the airlines subject to this cancelation showed that IKA did not issue any clearance for the flights to destinations bound for Iraq. Such a restriction had been announced via NOTAM A0086/20 at 09:23 (Figure 52) too.

Enquiry from Turkish airlines showed that the cancellation of flight 899 to Istanbul Sabiha airport was due to the closure of destination airport according to NOTAM A0116/20 and was not a result based on the risk assessment or the situation. On the same basis, the Pegasus flight number 513 to Istanbul Sabiha airport had been cancelled.

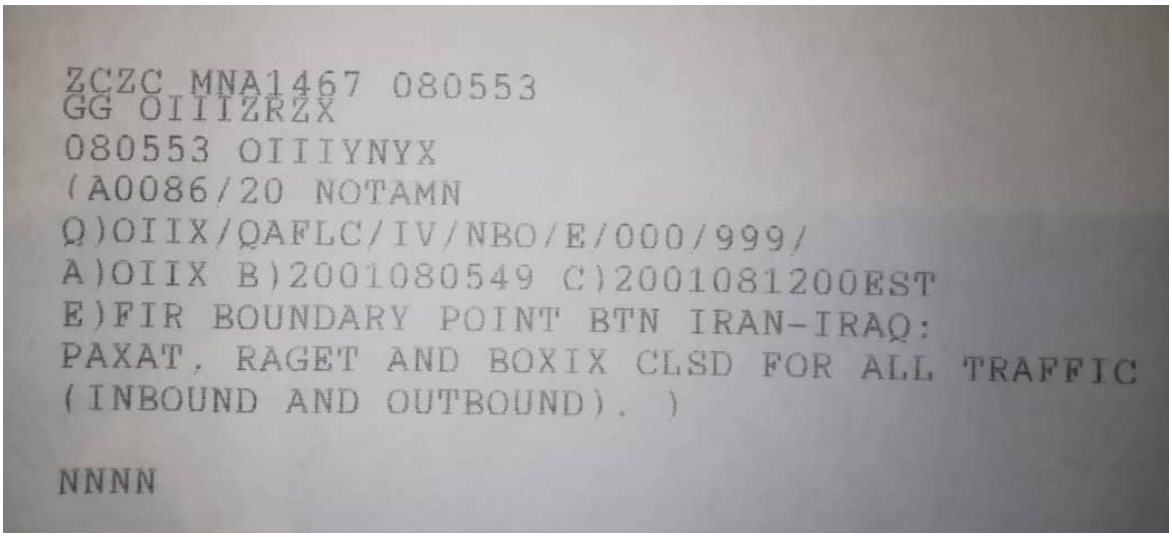

Figure 52- NOTAM issued following the suspension of traffic exchange between Tehran and Baghdad FIR

It was also observed that at 04:11 Iraq ACC requested their counterpart in Iran to accept the entry of British Airways fight BAW124 into the Iranian airspace. This was, however, denied due to the restriction imposed on the traffic exchange between the two countries -Iran and Iraq (Figure 53). Such a negative response was in line with the planned preventive measures.

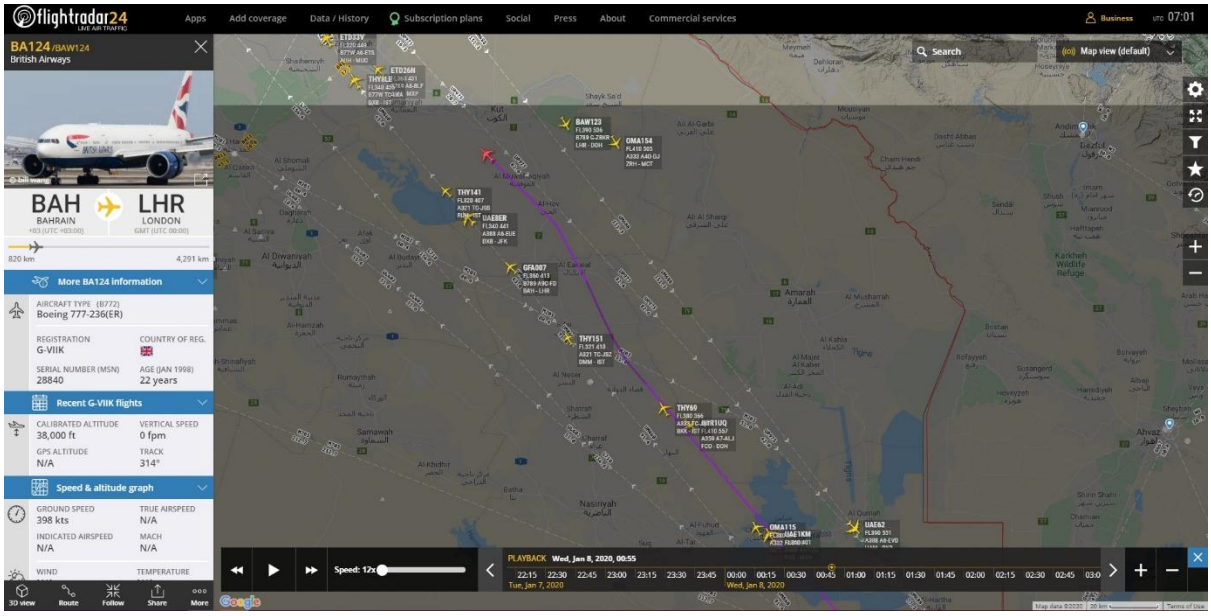

Figure 53- BAW124 whose entry into the Iranian airspace was denied due to the suspension of traffic exchange between Tehran and Baghdad FIR

Table 9 displays the flight schedule of IKA on the day of the accident. Flight 6650 of Ata Airlines, scheduled for 06:00 local time, and Flights No. 5062 and 5042 of Mahan Airlines, scheduled for 06:30 local time, all

to Najaf in Iraq, were canceled due to the traffic exchange suspension between Tehran and Baghdad FIR.

Table 9- IKA departure schedule in morning on the day of the accident

Airlines	Flight Number	Destination	Scheduled Time	Actual Flight Time
Azerbaijan Airlines AHY	9006	Baku UBBB	01:25	01:37
Lufthansa DLH	601	Frankfurt EDDF	02:25	02:43
Mahan IRM	1138	Denizli Cardak LTA	02:30	Cancelled
Turkish Airlines THY	875	Istanbul LTFM	03:00	03:35
Austrian Airlines AUA	872	Vienne LOWW	03:45	04:23
Pegasus Airlines PGT	513	Istanbul – Sabiha LTFJ	04:20	Cancelled
Aeroflot Airline AFL	543	Moscow- Sheremetyevo UUEE	04:30	04:32
Qatar Airways QTR	491	Doha OTHH	04:45	05:00
Turkish Airlines THY	873	Istanbul LTFM	04:45	05:07
Qatar Airways QTR	8408	Hong Kong VHHH	05:15	05:39
Atlas Global KKK	1185	Istanbul LTFM	05:15	05:17
Ukraine International AUI	752	Kiev UKBB	05:15	06:11
Ata Air TBZ	6650	Najaf ORNI	06:00	Cancelled
Turkish Airlines THY	899	Istanbul- Sabiha LTFJ	06:20	Cancelled
Mahan IRM	5062	Najaf- ORNI	06:30	Cancelled
Mahan IRM	5042	Najaf ORNI	06:30	Cancelled

3.5. Risk Management in the Airline and the State of the Operators

According to the information provided by the Ukraine International Airlines, *"the safety risk assessment is carried out by UIA airlines in compliance with the Law of Ukraine On the State Aviation Security Program of Civil Aviation" of March 21, 2017.*

The risk assessment in UIA is in accordance with the Annexes to ICAO Chicago Convention: Annex 17 "Security" and Annex 19 "Safety Management" ICAO Doc 8973 "Aviation Security Manual", ICAO Doc 10084 "Risk Assessment Manual for Civil Aircraft Operations Over or Near Conflict Zones", ICAO Doc 10108 "Aviation Security Global Risk Context Statement" and IATA "Operational Safety Audit Standards Manual.

UAI airlines had performed the assessment of the safety risk assessment for the flight PS 752 on the ground of the following analysis of the information.

There had been requested NOTAMs of the whole route, and, in particular, those ones from the Civil Aviation Authority of Iran, from the State Aviation Service of Ukraine, as well as from the civil aviation authorities of the countries through which the respected route had been scheduled (OIIE PARO2L PAROT UL125 BUDED UR660 ERZ UL851 KUGOS M860 DIGAM ETNIL M435 MIMKO T219 KONIP B246 CY CY1F UKBB), Conflict Zones Information Bulletin (CZIB's) published on EASA web-site[10] had been analyzed, the information related to the respected region risk assessment, which was placed on the site[11] of the State Aviation Service of Ukraine, had been reviewed , there had been considered the world map of risk zones on the web site https://www.controlrisks.com/riskmap/maps.

[10]- https://easa.europa.eu/domains/air-operations/czibs

[11] -https://avia.gov.ua/bezpeka-aviatsiyi/aviatsijna-bezpeka/otsinka-zagroz-ta-ryzykiv-aviatsijnij-bezpetsi/

UIA believes that any information having been promulgated by 07.01.20 and the morning of 08.01.2020 did not indicate a presence of threats for PS752 civil fight safety, which was performed by the aircraft with Ukrainian registration from Tehran civil airport being completely opened for civil aviation flights and it did not contain any limitations or warnings as for the opportunity of such a flight performance.

There did not exist any prohibitions and limitations for the use of Iran's airspace en route of PS 752 flight imposed by any governmental and/or international organizations, being competent to introduce such prohibitions. Besides that, there had not been sent any warnings or specific flight performance conditions by the ATS, from military bodies, from airport Imam Khomeini (or the Ukraine's authorities) to the Airlines or to the air crew of PS 752 flight.

Other air carriers, including Iranian and foreign ones, had performed flights on the same day to/from Imam Khomeini airport till PS752 accident."

The operation of UIA showed that no restriction had been imposed on operation of flight PS752 from UIA or State of Ukraine.

One of the sources that could have helped the understanding of the status of the crew's perception of the conditions and possible decision-making about restrictions or measures at operational level was the conversations of the flight crew inside the cockpit. Standard operating procedures at UIA did not require the crew to manually turn on the CVR before engine start and the voices related to the briefing time before takeoff and cabin check and preparation were not recorded. The voices recorded afterwards did not indicate any condition of the airspace, concerns and possible precaution or a decision-making related to the condition.

The investigation activities shows that no other airlines who had departure flight from IKA in the day of accident, imposed restrictions on their operation on the basis of the flight route safety risk assessment results

3.6. The availability of Information and the Level of Access to Them

The provision of adequate and timely information is essential for the proper performance of the responsibilities of the various parties in managing the risk of operations in an airspace from the perspective of potentially hazardous military activities.

Although States use overt and classified information to assess the situation, when the situation is changing rapidly, the timely dissemination of information plays an important role in assisting different parties in taking the necessary measures.

The news on the missile attack on Al Asad airbase on Jan.08, 2020 was publicly announced after a few minutes following the attack.

In an official statement released in the very hours , the U.S. Department of Defense confirmed the attack to the American Forces in Iraq and announced, “It is clear that these missiles were launched from Iran.”[12]

The news of this statement was also published in the mass media. It could be accessed at least at 03:11 on January 08,[13].

The Islamic Republic of Iran Armed Forces released an official statement regarding the missile operation, which was covered by Iranian news agencies[14] at around 02:40 on January 08, 2020 Tehran time and published in the international mass media shortly.

12- https://www.defense.gov/Newsroom/Releases/Release/Article/2052103/dod-statement-on-iranian-ballistic-missile-attacks-in-iraq/

13 - https://www.usatoday.com/story/news/world/2020/01/07/iran-state-tv-tehran-fires-iraqi-base-housing-us-troops-ain-assad/2837693001/

14 - Irna news agency- Jnuary08 2020, 02:41 Tehran local time- news code 83625435

https://www.irna.ir/news/83625435/%D8%A7%D9%86%D8%AA%D9%82%D8%A7%D9%85-%D8%B3%D8%AE%D8%AA-%D8%A8%D8%A7-%D8%B4%D9%84%DB%8C%DA%A9-%D8%AF%D9%87%D9%87%D8%A7-%D9%85%D9%88%D8%B4%DA%A9-%D8%A8%D9%87-%D9%BE%D8%A7%DB%8C%DA%AF%D8%A7%D9%87-%D8%A2%D9%85%D8%B1%DB%8C%DA%A9%D8%A7%DB%8C%DB%8C-%D8%B9%DB%8C%D9%86-%D8%A7%D9%84%D8%A7%D8%B3%D8%AF

At 03:15 on the 8th of January, the Federal Aviation Administration (FAA) of the U.S. issued the following NOTAM number A0001/20 prohibiting conducting flights in Baghdad FIR for the persons and operators already described under its oversight:

A0001/20 NOTAMN

Q) KICZ/QRDLP/IV/NBO/AE/000/999/

A) KICZ

B) 2001072345

C) PERM

E) SECURITY..UNITED STATES OF AMERICA PROHIBITION AGAINST CERTAIN FLIGHTS IN THE BAGHDAD FLIGHT INFORMATION REGION (FIR) (ORBB). THOSE PERSONS DESCRIBED IN PARAGRAPH A (APPLICABLITY) BELOW ARE PROHIBITED FROM OPERATING IN THE BAGHDAD FLIGHT INFORMATION REGION (FIR) (ORBS) DUE TO HEIGHTENED MILITARY ACTIVITIES AND INCREASED POLITICAL TENSIONS IN THE MIDDLE EAST, WHICH PRESENT AN INADVERTENT RISK TO U.S. CIVIL AVIATION OPERATIONS DUE TO THE POTENTIAL FOR MISCALCULATION OR MIS-IDENTIFICATION.

A. APPLICABILITY. THIS NOTAM APPLIES TO: ALL U.S. AIR CARRIERS AND COMMERCIAL OPERATORS; ALL PERSONS EXERCISING THE PRIVILAGES OF AN COMMERCIAL OPERATORS; ALL PERSONS EXERCISING THE PRIVILEGES OF AN AIRMAN CERTIFICATE ISSUED BY THE FAA, EXCEPT SUCH PERSONS OPERATING U.S.-REGISTERED AIRCRAFT FOR A FOREIGN AIR CARRIER; AND ALL OPERATORS OF AIRCRAFT REGISTERED IN THE UNITED STATES, EXCEPT WHERE THE OPERATOR OF SUCH AIRCRAFT IS A FOREIGN AIR CARRIER.

B. PERMITTED OPERATIONS. THIS NOTAM DOES NOT PROHIBIT PERSONS DESCRIBED IN PARAGRAPH A (APPLICABILITY) FROM CONDUCTING FLIGHT OPERATIONS IN THE BAGHDAD FIR (ORBB) WHEN SUCH OPERATIONS ARE AUTHORIZED EITHER BY ANOTHER AGENCY OF THE UNITED STATES GOVERNMENT WITH THE APPROVAL OF THE FAA OR BY A DEVIATION, EXEMPTION, OR OTHER AUTHORIZATION ISSUED BY THE FAA ADMINISTRATOR. OPERATORS MUST CALL THE FAA WASHINGTON OPERATIONS CENTER AT 202-267-3333 TO INITIATE COORDINATION FOR FAA AUTHORIZATION TO CONDUCT OPERATIONS. C. EMERGENCY SITUATIONS. IN AN EMERGENCY THAT REQUIRES IMMEDIATE DECISION AND ACTION FOR THE SAFETY OF THE FLIGHT, THE PILOT IN COMMAND OF AN AIRCRAFT MAY DEVIATE FROM THIS NOTAM TO THE EXTENT REQUIRED BY THAT EMERGENCY. THIS NOTAM IS AN EMERGENCY ORDER ISSUED UNDER 49 USC 40113(A), 44701(A)(5), AND 46105(C). ADDITIONAL INFORMATION IS PROVIDED AT:

HTTPS://WWW.FAA.GOV/AIR_TRAFFIC/PUBLICATION

F) SFC

G) UNL END

At 00:10 on the 8th of January, the Federal Aviation Administration (FAA) of the U.S. issued the following NOTAM number A0002/20 prohibiting conducting flights in Baghdad FIR for the persons and operators already described under its oversight.

A0002/20 NOTAMN

Q) KICZ/QRDLP//////

A) KICZ

B) 2001080010

C) PERM

E) SECURITY..UNITED STATES OF AMERICA PROHIBITION AGAINST CERTAIN FLIGHTS IN THE TEHRAN FLIGHT INFORMATION REGION (FIR) (01IX). THOSE PERSONS DESCRIBED IN PARAGRAPH A (APPLICABLITY) BELOW ARE PROHIBITED FROM OPERATING IN THE TEHRAN FLIGHT INFORMATION REGION (FIR) (01IX) DUE TO HEIGHTENED MILITARY ACTIVITIES AND INCREASED POLITICAL TENSIONS IN THE MIDDLE EAST, WHICH PRESENT AN INADVERTENT RISK TO U.S. CIVIL AVIATION OPERATIONS DUE TO THE POTENTIAL FOR MISCALCULATION OR MIS-IDENTIFICATION.

A. APPLICABILITY. THIS NOTAM APPLIES TO: ALL U.S. AIR CARRIERS AND COMMERCIAL OPERATORS; ALL PERSONS EXERCISING THE PRIVILEGES OF AN AIRMAN CERTIFICATE ISSUED BY THE FAA, EXCEPT SUCH PERSONS OPERATING U.S.-REGISTERED AIRCRAFT FOR A FOREIGN AIR CARRIER; AND ALL OPERATORS OF AIRCRAFT REGISTERED IN THE UNITED STATES, EXCEPT WHERE THE OPERATOR OF SUCH AIRCRAFT IS A FOREIGN AIR CARRIER.

B. PERMITTED OPERATIONS. THIS NOTAM DOES NOT PROHIBIT PERSONS DESCRIBED IN PARAGRAPH A (APPLICABILITY) FROM CONDUCTING FLIGHT OPERATIONS IN THE ABOVE-NAMED AREA WHEN SUCH OPERATIONS ARE AUTHORIZED EITHER BY ANOTHER AGENCY OF THE UNITED STATES GOVERNMENT OR BY A DEVIATION, EXEMPTION, OR OTHER AUTHORIZATION ISSUED BY THE FAA ADMINISTRATOR. OPERATORS MUST CALL THE FAA WASHINGTON OPERATIONS CENTER AT 202-267-3333 TO INITIATE COORDINATION FOR FAA

AUTHORIZATION TO CONDUCT OPERATIONS. C. EMERGENCY SITUATIONS. IN AN EMERGENCY THAT REQUIRES IMMEDIATE DECISION AND ACTION FOR THE SAFETY OF THE FLIGHT, THE PILOT IN COMMAND OF AN AIRCRAFT MAY DEVIATE FROM THIS NOTAM TO THE EXTENT REQUIRED BY THAT EMERGENCY. THIS NOTAM IS AN EMERGENCY ORDER ISSUED UNDER 49 USC 40113(A), 44701(A)(5), AND 46105(C). ADDITIONAL INFORMATION IS PROVIDED AT: HTTP://WWW.FAA.GOV/AIR_TRAFFIC/PUBLICA

F) SFC

G) UNL

END

Further, according to the information provided by British Airways through UK Expert, this airline had been made aware of the Iranian missile attack on the American base at 03:25 on Jan. 08, 2020, so even before receiving the formal FAA NOTAM, it had already put in place processes to stop operations entering the Baghdad and Tehran FIR, and to leave those FIRs as soon as possible if already in them, but focusing initially on the Iraqi airspace. The request of BAW124 flight for entering Tehran FIR was the result of the risk assessment at the time, but the airline was focused on securing the preference to operate through Saudi airspace.

The States' information and actions taken by them were not necessarily limited to the above-mentioned. Nevertheless, since the investigation team had dealt with the availability of the information to the States and operators about the conditions to plan and take necessary measures, such cases are simply presented as existing examples.

4. Review of Similar Accidents

Many civilian aircraft accidents caused by military activities have been recorded so far.

Although such accidents are different in terms of the aircraft type, being commercial or non-commercial, the cause and nature of the attacks, the accident type and severity, they all had commonalities in that they were all the aircraft engaged in civilian transport, were not a military threat and occurred as a result of armed activities outside the aircraft.

In various sources, there exist several cases of accidents suspected to have occurred by downing through armed activities, yet they have never been officially confirmed.

It is obvious that due to the consequences, the official acknowledgment of a civilian aircraft shoot-down is extremely hard and unappealing. More importantly, if the shoot-down has been intentional, there will be a natural general tendency for states to conceal matters, not to mention their great reluctance to declare that the accident has occurred due simply to the unsafe airspace under control their control. As a result, it could be concluded it is highly likely that there exist accidents of such nature and yet never been declared.

In the following, reference will be made to official similar accidents to commercial aircraft. Considering of the overall similarities and differences of such accidents, along with the PS752 one's, can help prevent similar events.

Following any aircraft accident caused by military activity, there is a change in the approach and level of attention to this threat at the national and international levels. A review of such changes shows that the processes resulting from MH17 accident can be considered a turning point in the development of theoretical foundations of safety in this area while staying focused on such issues and continuous follow-up of improvements.

4.1. Korean Airlines Flight No. 007

On September 01, 1983, Korean Airlines Flight 007, a Boeing 747 with registration number HL-7442, was scheduled to fly from New York to Seoul via Anchorage, Alaska. It was shot down by a Soviet Union's interceptor airliner en route from Anchorage to Seoul. All 269 people on board the aircraft, including 246 passengers and 23 crew members, lost their lives in the accident. The crash came after the Korean aircraft entered a Soviet-controlled prohibited zone due to a navigation error and the military forces identified it as a threat.

4.2. Flight No. 655 of the Islamic Republic of Iran Airlines (IranAir)

On July 03, 1988, Flight 655, Airbus A300B2-203 of the Islamic Republic of Iran Airlines with the EP-IBU registration mark, departed from Bandar Abbas Airport, Iran, to Dubai in the United Arab Emirates at 06:47. While it was on a planned route and altitude, climbing from an altitude of 12,000 to 14,000 feet, it was hit by two surface-to-air missiles fired from a U.S warship and crashed near Qeshm Island at 06:54:43. All the 16 crew members together with the 274 passengers onboard were lost their lives.

4.3. Flight No. 1812 of Siberia Airlines

On October 04, 2001, Siberian Airlines, Flight 1812 was hit by a surface-to-air missile on a flight from Tel Aviv to Novosibirsk using a Tu-154 aircraft registered RA-85693. At the time of the flight, military exercises were underway in the area, and the aircraft was shot down by one of the rockets fired over the Black Sea. All 66 passengers and 12 crew members aboard were killed in the crash.

4.4. Malaysia Airlines Flight No. 17

On July 17, 2014, a Boeing 777 of Malaysia Airlines with the registration mark 9M-MRD was flying from Amsterdam to Kuala Lumpur with MH17 flight number over eastern Ukraine, where military disputes were raging. It was hit in the air by missile and crashed. All 298 occupants, including 283 passengers and 15 crew members onboard the aircraft were killed.

4.5. 2020 African Express Airway accident

On 4 May 2020, an Embraer-120 aircraft of African Express Airways with the registration mark 5Y-AXO, originated a flight from Baidoa to Berdale in Somalia. The aircraft was hit by 23 mm shells (ZU-23) emanating from Sector 3 AMISOM (African Union Mission to Somalia) forces. 04 crewmembers and 2 airline staff were killed in the crash.

5. Analysis

5.1. Missiles Function

The times provided by the military sector on the first missile launch and detonation, along with the location of the warhead fuse activation, corresponded to the time and location of the strike heard on the CVR, the termination of FDR recording and termination of the ATC transponder of the aircraft.

The investigation conducted showed that the TNT explosives found on the outer layers of the fuselage were similar to the aliphatic compounds used in the missile launched at the aircraft, and that the small amount of DNT observed could be a by-product of the thermal degradation of the aircraft conventional substances like fuel and epoxy. The DNT could be a small amount of aliphatic explosives impurities with lower quality nitrite.

The explosives found on the remaining parts of the aircraft had to do with the missile function. In fact, no explosives of an unknown origin were found in the tests and analyses.

The tests conducted on other small pieces found on the passenger seat pads revealed that none were of the missile shrapnel material, but rather the ones used in manufacturing the aircraft, and that they had spread out all across due to the explosion caused by ground impact.

Due to the termination of FDR and CVR recording before the probable time of activation of the second missile, no conclusion could be made on the effect of the second missile based on the flight recorders data.

The recorded data in ADU shows that the second missile failed and was not successful.

The video which had been recorded in a construction work area showing the missile flight and explosion supports the conclusion that the 2nd missile exploded near the aircraft.

The investigation team analyzed the last recorded position of the two missiles, which is most likely the position of the detonation. The recorded data shows that the last position of the first missile was located about 400

meters south of the aircraft track, and the last position of second missile was located about 500 meters north of the aircraft track. Since the first missile affected the aircraft, the calibration of data related to the missiles position was proven necessary. The main source of this error is the error of ADU north heading calculation, which had been determined 105 degrees. After the direction recalibration of ADU in order to align the last recorded position of the first missile to aircraft track, the locations are shifted 400 meters northward, and hence the last location of the second missile differs 900 meters from the aircraft track and in this case the missile had no chance to affect the aircraft.

Considering all the above analysis, due to the residual uncertainty of information and analysis related to second missile detonation, the proven effect of the first missile, the proven launch of second missile and the fact that for prevention of similar accidents, this information is enough, the investigation team concluded that making the conclusion about the detonation and effect of the second missile is not reliable and does not affect the outcome of this investigation.

5.2. Aircraft Technical and Operational Conditions

Aircraft technical and operational functions had been normal by the missile strike.

The technical condition and operation of the aircraft systems did not play a role in creating errors for the operator of the ADU or strengthening the context of error.

In the judicial proceedings, in a similar environment, a simulation was run to investigate how the error had been formed and how the missile was launched. All the processes in the military, civil sector, and the cooperation between them were made just as the events occurring on the day of the accident, based on the records made in all sectors using a BOEING 737 flying twice from IKA on a flight trajectory similar to that of PS752. The accident investigation team participated in the simulation to observe the events taking place in the civil and joint cooperation sectors.

Two ADUs were placed at the location of the launching ADU. The north alignment error like the launching system was repeated in one system,

considered as the main one, while in the other, as the reference one, the north alignment error was corrected.

The simulation also indicated that the aircraft flight operation did not play a role in the occurrence of the error made by the air defense unit operator. In the two times of simulation, the reference unit operators detected the aircraft from the IKA direction (Figure 54), while the main unit operators detected it approaching from the western area (Figure 55).

Figure 54- The target direction in the reference ADU in the simulation with correct North alignment

Figure 55- The target direction in the ADU in the simulation with repeated north alignment error

After the detonation of the first missile in the proximity of the aircraft, the ATC transponder and FDR recording terminated simultaneously due to damage to the aircraft. The aircraft sustained cascading damage, as a result of which, after about 16.5 seconds, the rotation frequency of one of the generators (Electrical power supply - IDG) started to decrease, causing a reduction in frequency of recorded audios in CVR and termination of recording after 2.5 seconds.

As civil aircraft are not designed and manufactured in a way to be missile resistant, the analysis of the way the missile affect the aircraft systems is pointless to safety enhancement goals. In addition to this, the severity of the damage caused by aircraft impact to the ground and the resulted explosion does not make such an analysis practicable.

5.3. CVR Turn-on

The first radio communication of PS752 with the IKA ground control unit was made at 05:13:11 and recorded in the aeronautical communications systems. The CVR of the accident aircraft started recording at 05:56:18 and the flight received the clearance for engine startup and pushback at 05:55. According to the recorded voice, it can be said that the CVR was turned on automatically after the first engine was switched on.

Given the fact the flight crew had already been present at the cockpit for some time, listening to their conversations before takeoff could have helped understand if they had been made aware of Iran's missile attack to the U.S. base in Iraq, or if they had ever talked about or made any decision regarding the conditions at the time.

The ICAO standard for the start of voice recording is set out in Annex 6 to the International Civil Aviation Convention. According to the text in Section 3.1, Part 1 of Appendix 8 (Aircraft Operations), 10th edition, Amendment 41, the CVR shall start to record prior to the aeroplane moving under its own power and record continuously until the termination of the flight when the aeroplane is no longer capable of moving under its own power. In addition, depending on the availability of electrical power, the CVR shall start to record as early as possible during the cockpit checks prior to engine start at the beginning of the flight until the cockpit checks immediately following the engine shutdown at the end of the flight.

Although the second sentence of Section 3.1 of Appendix 6 sets out the start of voice recording when the cockpit checks are performed, the condition for the existence of electrical power complicates the effective implementation of this action, making it unattended.

The civil aviation authorities have similar instructions in national regulations in this respect too, sufficing to state the same text in Annex 6. In approving the Operation Manuals of the airlines, the review of procedure related to CVR switch during cockpit checks and the clarification of the meaning of "the availability of electrical power" by the airlines are not taken very seriously either.

Studies show that some airlines typically do not set specific requirements for the time to turn on the CVR and simply follow the usual manufacturer's instructions provided on the Flight Crew Operating Manual (FCOM).

It has been observed that in the FCOM of some aircraft manufacturers, the CVR switch is put on the ON mode at the beginning of the cockpit check/briefing.

The FCOM of the Boeing 737-800 series, compiled by Boeing, states the CVR switch mode "as required". Such a requirement must be specified by the airline, taking into account their policies and national regulations and the conditions of the electrical power supply, not to mention other factors.

Even though the recording and analysis of such conversations did not pose a serious challenge to the investigation of this accident, the investigation team concluded that the transparency of the regulations in this area, in such a way that it ensures the recording of the cockpit voices during checks, technical and operational conversations, and decision making, will be beneficial for safety studies related to cockpit conversations. At the very least, it seems that recording radio calls from inside the cockpit, conversations about performing the necessary checklist items and those on deciding whether to initiate, continue or end a flight operation are some of the matters that shall be recorded in the cockpit.

5.4. Operational Conditions of the Flight Crew, and the Aircraft

The flight crew held the necessary qualifications to conduct the flight.

Both the flight crew performance and the aircraft flight operation were normal, not playing any role in inducing the error for the ADU operator, nor contributing to it.

After takeoff, the aircraft had been continuing to fly on the expected trajectory at an appropriate altitude and speed until hit by the missile.

The flight delay had been caused by unloading some cargo to reach the aircraft total weight appropriate for flight.

5.5. Risk Assessment

5.5.1. Risk Assessment by the State Managing the Airspace

As the missile attack on Al Asad base had been planned in Iran, there was enough time and information at hand to predict the situation and assess the risk for civil flights in Iranian airspace.

Due to the information classification, the risk assessment had been done before, and the mitigating measures had been planned to reduce the risk to civil aircraft.

The civil sector had been notified of such measures, which were thoroughly performed accordingly.

Eventually, the actual risk for the "misidentification of civil aircraft departing from an international civil airport following the defense system's initial identification" exceeded the risk level predicted, making the planned measures for this type of operation concerning the PS752 ineffective, due to the materialization of an unforeseen chain of events.

At the time, other flights had taken off form IKA, though a misidentification causing a missile launch at them never occurred.

Considering that the pattern of error making and the materialization of its consequences follow the famous patterns of the chain of events or Swiss Cheese Model, it is concluded that the presence of grounds for errors is not equivalent to the occurrence of final event. In other words, it is only in special and rare conditions that the entire chains necessary for the accident to occur are formed, while in other cases, by breaking one of the links in the chain or the effective performance of one of the anticipated defense layers, the existing latent condition would become unlikely to be materialized.

In order to realize what happened in military side, investigate the role of civil aviation operation in this event, and provide an answer into how the existing error caused an accident for this certain flight, the investigation team still submitted a request for investigating the measures and events leading to the missile launch in addition to the actions having been planned to prevent it. The military sector and the judicial authority

responsible for this accident provided the information required to the investigation team accordingly.

The investigation team found that the operating military unit was not basically responsible for monitoring the targets; it was just obliged to perform the actions planned within the command hierarchy only if a target was assigned to them from the command center.

Following a tactical relocation, the relevant ADU failed to adjust the system direction out of human error, causing the operator to observe the target flying west from IKA as a target approaching Tehran from the southwest at a relatively low altitude.

The target specifications were announced to the command center, but the message was never relayed. Without receiving a go-ahead or response from the command center, he came to identify the target as a hostile one and fired missile at the aircraft against the procedure planned.

The chain of events observed by the investigation team leading to firing missile at PS752 is illustrated in Figure 56.

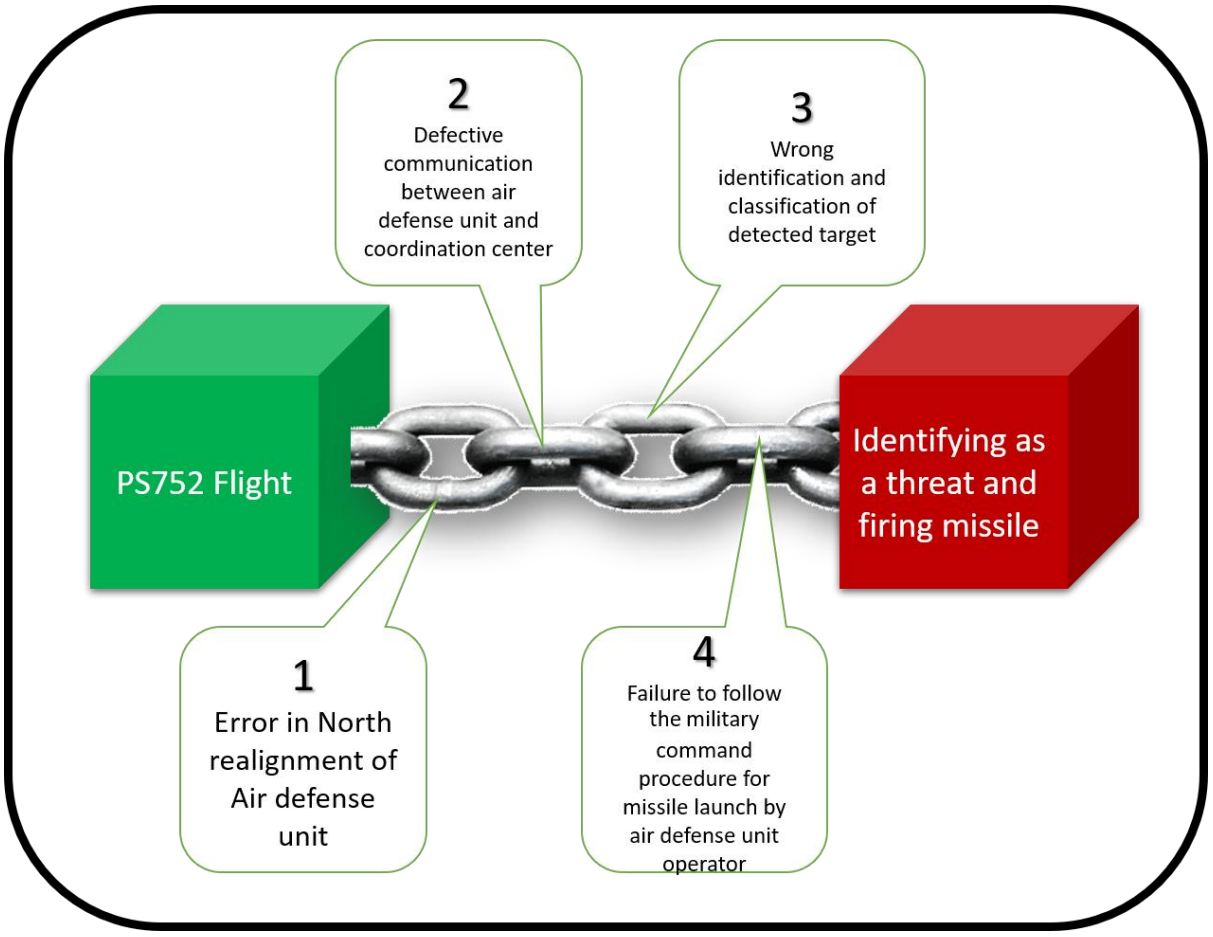

Figure 56- The chain of events leading to firing missile at PS752

The existence of this threat and the possibility of such chains being formed had not been predicted, and had not been considered in the calculations of the risk associated with misidentification.

The chain leading to the accident demonstrates the extent to which the hazards resulting from human performance are serious with a far-reaching consequence. It shows how much the ignoring the contribution and the possibility of complex combinations of rare events, could affect the accuracy and efficiency of risk management.

If normal condition with no conflicts or the possibility of that is considered at one extreme end, and on the other hand, a major military conflict at another extreme end, there would be a spectrum in between, where a series of measures must be taken to ensure the safety of civil aviation, from no operational restriction to the suspension of any civil operation depending on the very conditions.

In vast geographical areas, due to differences in the amount of risk in various parts of an area, the set of measures governing one area may vary from those governing another one.

To reduce the probability of hazards for civil sector, military forces normally implement measures to minimize overall organizational errors and their associated consequences, as well as eliminating the contributing factors. All these analyses would form the basis for the development of operational procedures. Considerations related to human errors and their tolerability, the classification and definition of various conditions, such as normal, different levels of alertness, conflict and requirements of the operating environment, hardware, procedures, command hierarchy, human performance, among others are taken into account in developing the operational procedures.

Once all the considerations and executive measures have been implemented, there will be a level of residual risk that must be commensurate with the operational context. The more operations, the higher the probability of an error, and the need for the contributing factor to be reduced to such an extent that the residual risk is maintained at an acceptable level.

During the conditions when the PS752 accident happened, the risk of commercial aircraft being accidentally struck while trying to target the hostile aircraft was estimated to have been negligible before the start of a military operation. Nonetheless, given the fact the Iranian air space is always monitored independently of a military attack, the risk of misidentification is also considered at all time, which was higher in the alertness conditions at that time.

It can finally be concluded that the risk assessment conducted was not commensurate with the real conditions at the time, and an unpredicted chain of events was materialized at the end.

The investigation team requested the authorities who had done the risk assessment to repeat the assessment considering the information gathered after the accident. The result of such assessment was similar to the previous one, and again, clearance for PS752 to conduct the flight was

evaluated to be safe and coordination with air defense before startup approval was evaluated to be enough to eliminate the possibility of misidentification.

The investigation team found that in the conducted risk assessment, only the steady state of conditions had been considered. In other words, only the elements of hazards raised from the alertness of the military forces had been taken into account, but no element representing the rapid transition from one alertness level to another had been stipulated in calculations.

The investigation team identified three states for any change between the two hazard levels. The first state is the initial state of the system. After the change of condition to the next hazard level, due to the occurrence of a change in conditions which is initially unknown in terms of the extent, duration and dimensions, the system enters a transient condition. When the new condition remains stable and the elements of system, including humans get used to the new condition, the system enters into the next steady state level.

This is while entities who had conducted the risk assessment considered only the three following levels of hazards and defined and implemented the related safety measures.

The first level was the initial condition. It was predicted that after the missile attack on Al Asad airbase, the system would enter the second level, namely the alertness condition. In case of a counterattack, the conflict condition as the third level had been predicted with strict safety measures including the no-fly zone.

Transient condition is applicable to all systems. Each level of conditions has its own hazards and any change in condition includes special hazards related to the nature of change. At the time period close to the change, the change hazards must be added to hazards related to the new condition until the system enters steady state and the hazards related to change disappear.

During the investigation, some studies were done to determine the characteristics of transient condition.

The time period and level of hazards associated with transient condition are related to the range of change and the components of the system, and defining the characteristics of transient condition would not be accurate and real at this step. However, from the human factors perspective, it seems that the transient condition period must last longer than the working hours of the personnel who were working in the system at the time of transition. The personnel who work in each section of the system are less affected by the change of condition, at least in terms of situational awareness, if they start their work shift after that change, and obviously, if the change happens during their work shift, they are more affected by this change.

In PS752 accident case, taking into account that the prevailing conditions rapidly changed at about 02:00, it is likely that at the time of the accident, the transition time was not finished yet and this transient condition contributed to human errors and the existing hazards within the whole system.

An illustration of this concept is shown in Figure 57.

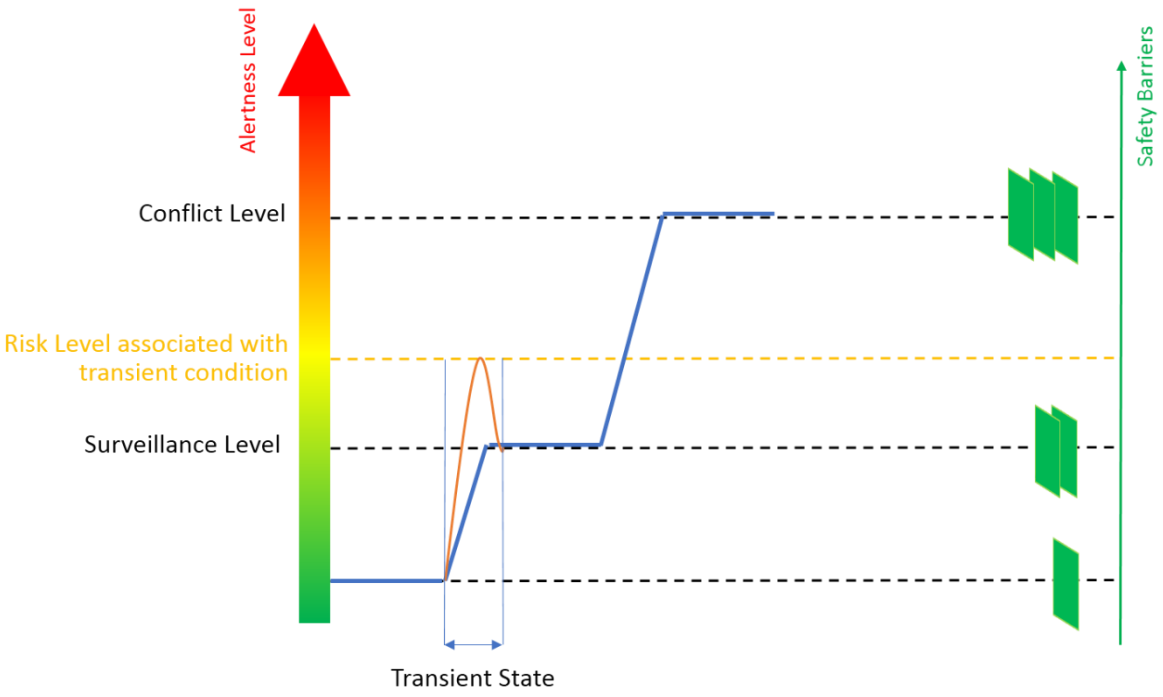

Figure 57- Alertness levels and risk in transient condition

5.5.2. The Airline's and the State of the Operator's Risk Assessment

In PS752 accident condition, it was found that some airlines had performed a risk assessments in a short period of time and implemented various measures to the point of suspension of their flight operations in some areas.

It was also found that some States quickly set and announced restrictions on the activities of airlines under their oversight.

However, some had not taken any clear action on the situation, and others had not made any assessment of the situation at a pace commensurate with that changing trend.

As for PS752, no restriction whatsoever had been imposed neither by Ukraine nor the UIA.

Figure 58 illustrates the risk assessment flowchart for the operators provided in ICAO DOC10084. The first step of assessment is collecting information, whose source could be the published aeronautical information, the special information provided to the operators by the States, special information network -where the States and operators participate-, aerodromes as well as open source information.

the collection of relevant information is a vital step in the success of risk assessment, because if the information is not available or is not collected properly and in a timely manner, the risk assessment process can not be initiated.

The speed of information collection and the vastness of its sources become far more important during the conditions like those in PS752 accident, when the changes were very rapid and in the order of few hours than when they do over a longer period of time, about a few days.

The conditions changed at such a pace and time that the exclusive sources for the provision of aviation-related information useful for the airlines did not publish any new information, but the open and public sources had released the news on the attack to Al Asad base hours before, and official

authorities in the States issued statements and notifications about that event.

The investigation reveals that such information sources was not considered in the risk assessment by the operators who had departure schedule from IKA..

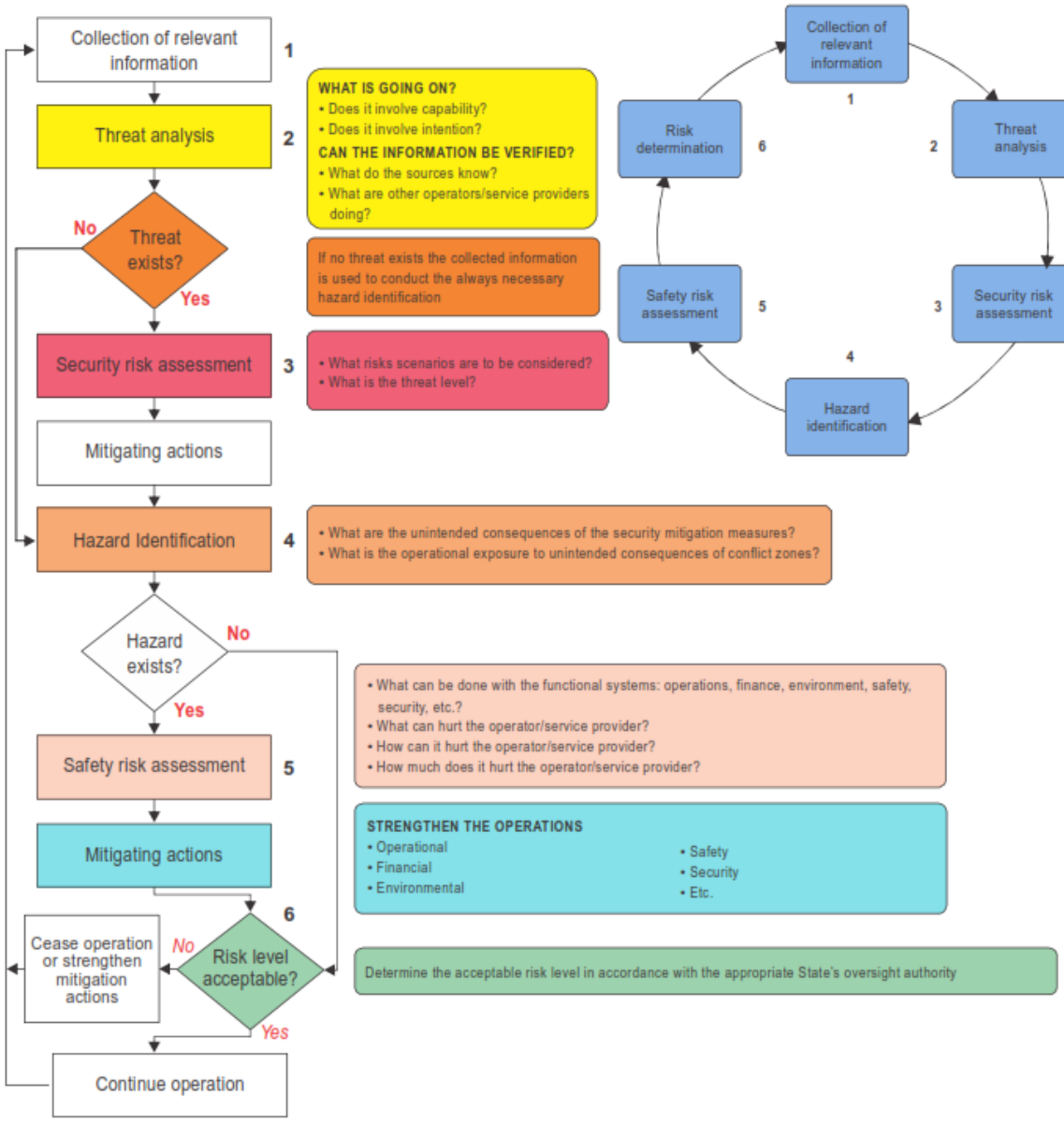

Figure 58- flow chart of the risk assessment cycle for operators and service provider

It is observed that the airlines and operators tend to consider the NOTAMs issued in the form of "conflict zones" bulletins as an information source to initiate the risk assessment process.

This is while such bulletins or notifications, like NOTAMs, normally contain prohibition and restriction made through a risk assessment process, obtained on the basis of some initial information.

That is, such notifications and bulletins are some information-bound mandates. Although their content can be utilized as information to initiate another process, the very initial information leading to the issuance of those notifications must be collected and analyzed by operators.

5.6. Availability of Information for Risk Assessment

The change in the military condition was public and widely reported in the media. At around 02:40 Jan. 08 2020, the official authorities of the U.S. and Iran had announced the strike against the Al Asad airbase in Iraq. Actually, the open source information about this issue was available to States and various airlines to conduct an assessment of the situation.

Apart from the tensions having existed in the Middle East for many years, the U.S. had declared a drone strike against one of the Iranian top commanders at Baghdad airport, following which Iran announced revenge would definitely be taken. As such, there had, certainly, been adequate information to pay more heed to the condition in the region and possible hazards at the time.

Iran ANSP had implemented changes in the way air traffic flow was managed, based on already planned measures for mitigating the risk to civil aviation from military alertness but the related NOTAMs had issued hours after the accident.

At first, due to limited traffic demand, the management of traffic flow was practicable with operational technics. By the increase in traffic volume, NOTAMs were issued to change the traffic flow scheme.

The investigation team investigated the reasons for time difference between the execution of measures and issuance of NOTAMs.

Operationally, all the planned measures were implemented promptly, but the ANSP assumed that based on definitions and criteria for issuance of NOTAM in ICAO Annex 15, NOTAM is an operational tool for people involved in air navigation, and the workload and predicted traffic was in such a way that the operational technics were enough to manage the demand. As a result, it was assumed that issuance of NOTAM was not necessary for management of air traffic at that time.

The issuance of NOTAMs, in addition to the operational benefits associated with air navigation and air traffic flow management, can be used as a significant source of information about changing conditions in a flight zone to analyze the flight risk. Taking this into account, if there is a change in the way airspace is managed for military or security reasons at any time, NOTAMs will prove effective. In other words, apart from direct operational application of NOTAMs, they can be used as a source of information for assessment of risk for operations even outside of the scope of that NOTAM.

It should be noted that the planned limitations were implemented, and within the very limitations and considering the planned route, the initiation of Flight PS752 was assumed to be safe. The existence of NOTAMs would not impose any limitations on flight PS752, but it was possible that by receiving such NOTAMs, which did not affect the flight route, a process of risk assessment was initiated by departing airlines from IKA.

5.7. Effective Implementation of Standards and Measures

Various standards and measures have been envisaged and set by ICAO for safe management in PS752-like conditions.

Thanks to the investigation conducted into the MH17 accident, and following up on the implementation of its recommendations, greater attention has been paid to the development of necessary regulations and structures and their effective implementation.

On the other hand, the implementation of such new requirements in States and the establishment of national regulations for airlines to manage

flight risk in a situation, where potentially hazardous military activities are occurring, have been inconsistently conducted.

It can be understood that the effective implementation of safety oversight elements in States regarding the requirements developed by ICAO for years are applied by them in a tangible and daily manner, yet still needs to be improved (Figure 59).

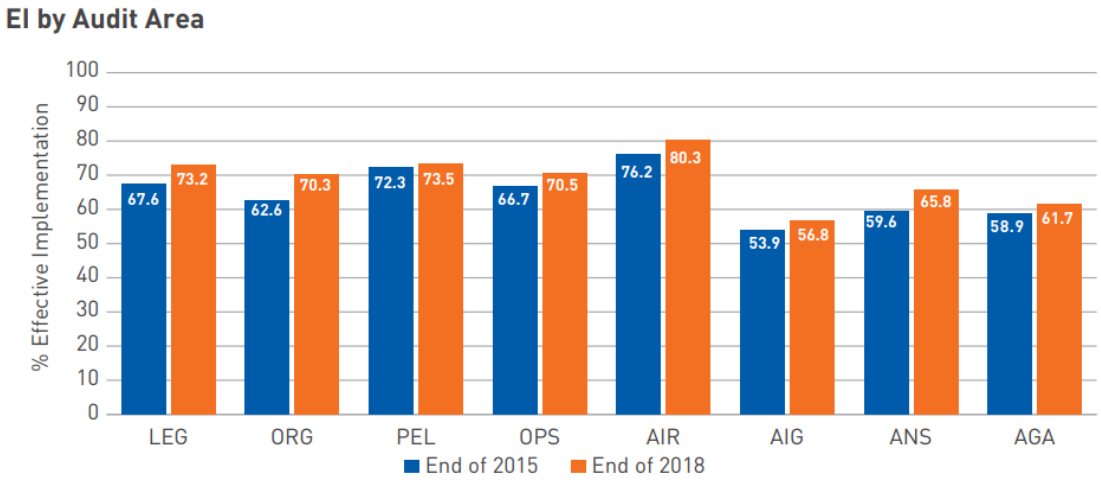

Figure 59- Effective implementation of the safety oversight elements in the world in various areas - ICAO Safety Report

As a result, given their newness, the status of implementation of measures in the field of aviation activity in areas where potentially hazardous military activities are underway cannot be better than that of traditional aviation standards, hence monitoring their effective implementation in Sates and assisting them to do so as for these patterns is essential.

Since conditions vary from one area to another, it is necessary to have a regional approach to assist and monitor the implementation of such measures, taking into account the conditions and priorities of each region.

5.8. Similar Accidents

5.8.1. Transparency and Speed in the Announcement of Events

Transparency and acknowledgment of events leading to similar accidents have always been an important challenge.

As far as civil aviation safety is concerned, reporting errors and their associated details are always encouraged. There are a variety of tools to do so, which in turn will promoting safety. In accidents, where an aircraft has been targeted by weapons, some of the factors involved in its occurrence fall outside the context of civil aviation and the procedures governing it, so the implementation of common measures in civil aviation to encourage reporting without apportioning blame is seriously challenged.

Further, to discover and prove the reality, a vast number of resources are wasted simply due to secrecy, confidentiality or denial of the event, not to mention the harm caused to the precious data and time to enhance safety.

A review on the previous similar accidents indicate that operating military or para-military forces did not admit their role in the accidents openly, putting the blame on other parties and trying to downplay their own role in such occurrences.

In the meantime, PS752 was one of the accident cases where the operating military forces publicly announced their role in it within a short time period. Providing the accident investigation team with access to the details allowed them to focus on the underlying factors besides the corrective and preventive measures instead of wasting resources to discover the reality behind the event.

5.8.2. The Proportion of Military Threats in Civil Aviation Safety

Figure 60 indicates the results of a review on the number of fatalities in air accidents of aircraft above 5700 kg from 2008 to September 2020, in terms of three important safety factors, including Runway Safety, Controlled Flight into Terrain and Loss of Control, Other Factors, and Hazardous Military Activities for Civil Aviation. The data of this graph is obtained from ICAO[15] reports while fatalities of MH17 and PS752 accidents are added as a new risk factor.

[15] - https://www.icao.int/safety/iStars/Pages/Accident-Statistics.aspx

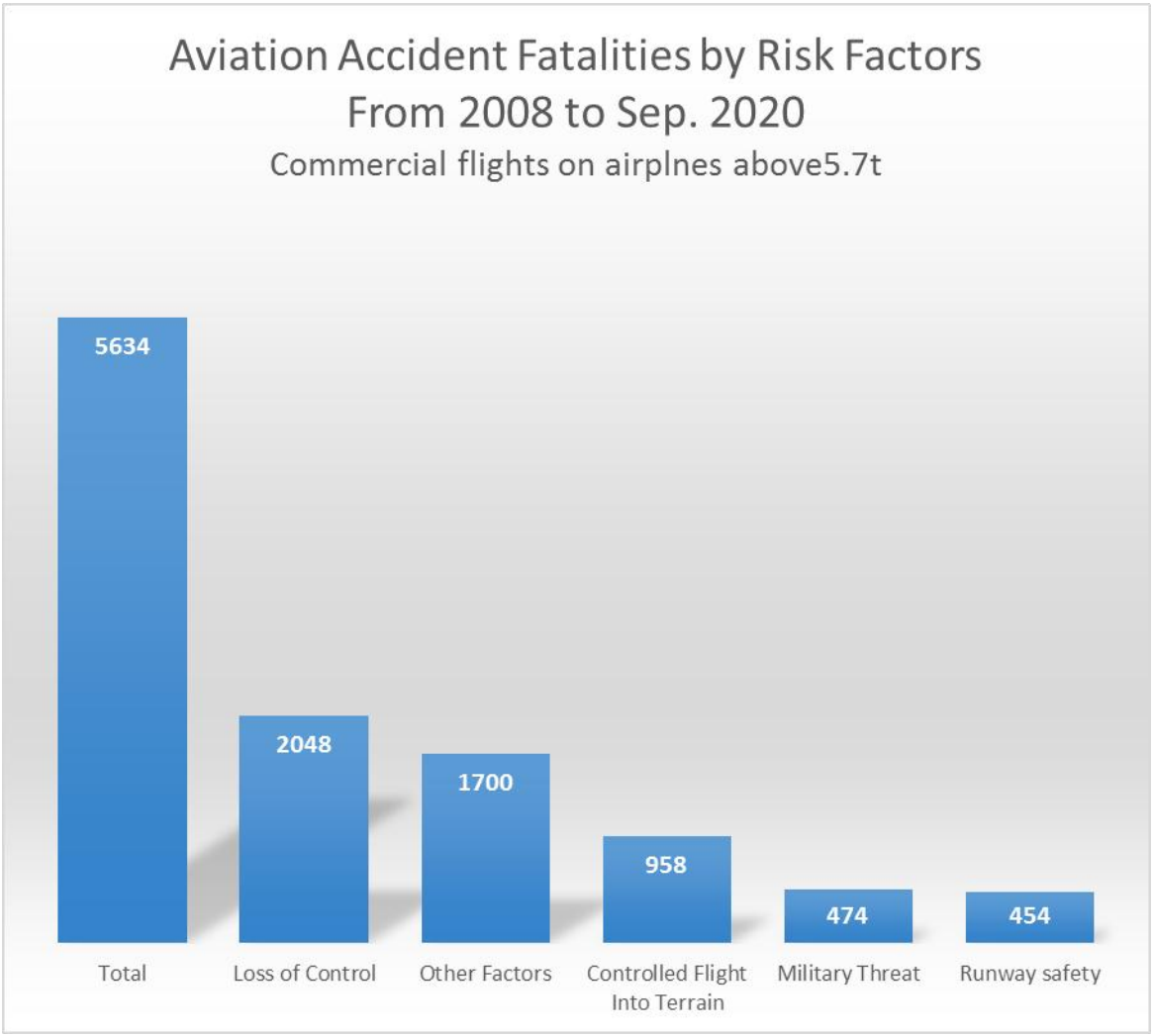

Figure 60- Aviation Accident Fatalities by Risk Factors

Despite being considered a very rare occurrence, targeting a civil aircraft by weapons has claimed more lives than the events resulting from runway safety on commercial flights with aircraft above 5,700 kg since 2008. Of course, the nature of military threats is completely different from other types of threats, and in terms of safety analysis, their probability are lower but have a higher severity of consequences.

A key challenge for mitigating such a risk factor would entail access to data, reconsidering the strategies and procedures at international, regional and national levels.

The fact is following the aircraft crashes of 1983 in Korean airlines, 1988 Iran Air, 2014 MH17 in Ukraine, the global approach to this hazard has undergone fundamental changes. Such crashes have, in effect, paved the

way for a reconsideration of the issue at hand and the development of mechanisms leading to improvement.

Proven safety lessons show that for any fatal accident, there are a significant number of near-miss cases. Such cases are always an effective tool to seize the opportunity to correct and improve performance before an unfortunate event occurs. Nevertheless, in the case of hazardous military activities for civil aviation, only the statistics revealed following a fatal accident are citable and analyzable. Misidentification, wrong unnecessary interception, increased alertness due to an authorized civil aviation operation and failed firings are among the cases that have not been probed and analyzed just because they passed off well. This is while these are the very events and untapped conditions which will provide the ground for unfortunate and deadly occurrences. In other words, the mentioned crashes are only the visible part of an iceberg whose bigger portion is hidden. (Figure 61)

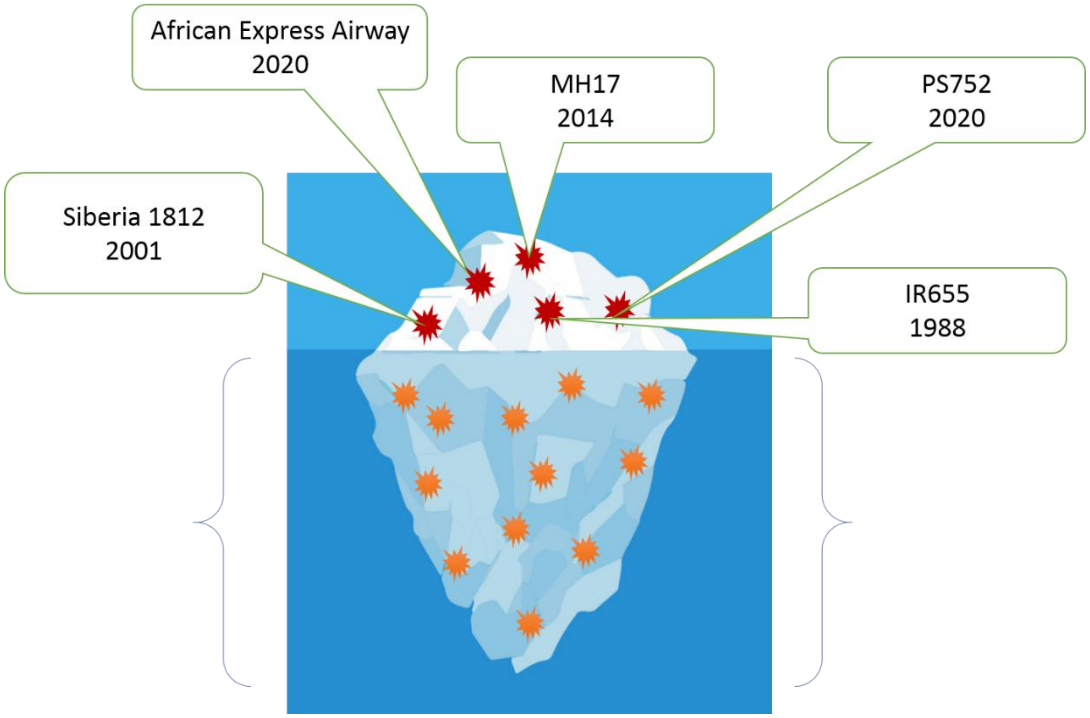

Figure 61- The announced air accidents; Iceberg Model and the abundance of near-miss events

Although in recent years, especially after the MH17 accident, much attention has been continuously paid to aviation safety against military

activities, it can be said that, in comparison with other safety factors, there is still no reporting and data-driven improvement, which causes significant revisions and improvements to be considered only after a fatal accident.

The Iceberg Model suggests that this hazard might occur quite often in different parts of the world, and that the investigated accidents are only signs of hidden conditions in the international air transport.

There is a significant correlation between such events and geographical areas and political conditions. Naturally, the type of hazards in these areas varies from one to another. In some areas, in line with their aim to pose security threats, militant groups' activities are more distinct, seeing commercial aircraft suitable targets for demonstrating their power and dominance therein. In others, however, the presence of criminal groups armed with dangerous weapons to commercial aircraft is more worrying. There are military threats between countries in some regions, and in other conditions, trans-regional military forces are present in third countries.

This altogether suggests that the assessment and evaluation of conditions must be continuous and contextual, geographical and time-dependent, and that only when the integrated mechanisms have different information sources can they produce different outcomes that prove effective for that area and situation. This requires the establishment of a statistical system and much more data than the announced accidents.

A significant proportion of this data is now provided by monitoring threat and tension levels. Since military systems are a large and important component of this set, it has to be determined that the available risk in their system, created by a wide assortment through organizations, hardware, software, manpower and environmental conditions have still remained in balance with the civil aviation operation level after analyzing the conditions and adopting the defensive layers pertinent to the very condition. It is possible to assess this balance in the military sector, which possesses its own performance information, analytically, but the part of the threat related to the performance of another military force cannot be properly analyzed. Nor does the civil sector have accurate information about the level of tolerable error in the military one.

6. Conclusions

6.1. Findings

1. At 06:12, on January 08, 2020, Flight PS752 operated by UIA, an airworthy Boeing 737 registered UR-PSR, along with qualified flight crew, took off from IKA runway and crashed at 06:18 near the airport.
2. The aircraft was misidentified as a hostile target by an air defense unit; two missiles were fired at PS752.
3. At 06:14:56, the warhead of first launched missile detonated in the proximity of the aircraft and, almost simultaneously, the aircraft transponders stopped transmitting radio signals, together with the termination of the FDR recording.
4. The missile detonation near the aircraft caused damage to the aircraft systems, after which the cascading damage was observable.
5. After the detonation of the first missile, the three cockpit crew members were all still alive. They appeared to have sustained no physical injuries and were just involved in managing the situation.
6. At 06:15:09, the second missile was launched towards the aircraft by the air defense unit. It is likely that this missile did not affect the aircraft, yet it is not possible to comment on this explosion and its impact with acceptable certainty.
7. The aircraft had maintained its structural integrity by the time it crashed into the ground and exploded at 06:18:23 in Khalajabad near Shahriar, the southwest of Tehran.
8. The automatic ELT had been activated, and due to the impact severity its signal-transmitting antenna to satellites was detached; the international satellites did not succeed in locating the crash site.
9. According to the ELT manufacturer the internal structures of survival ELTs are unable to withstand impacts, thereby their internal systems might have been damaged due to the impact severity.
10. Neither the aircraft technical and operational condition, nor its flight path and altitude contributed to the misidentification.
11. Within the airspace management, the information based risk assessment had been conducted, and various mitigations had been

devised to provide civil aviation safety for the threats caused by potentially hazardous military activities.

12. In the risk management, only the stable conditions was considered, not the transient conditions.
13. Civil-Military coordination was done according to the planned program and the considered mitigation measures for reduce the risk of misidentification and mistargeting of civil aircrafts was implemented in both civil and military sectors.
14. The risk management was not effective due to occurrence of an error, which had not been previously predicted.
15. The UIA and the State overseeing it had not imposed restrictions or prohibitions on the flight PS752.
16. No airline with departure schedule from IKA in the day of accident imposed restriction on their flights on the basis of risk assessment of flight route safety.
17. The process of information collection from open and public sources in airlines, which forms the basis of risk assessment in potentially hazardous military activities scope, has not yet tuned into a procedure, at least not for the times when changes occur so rapidly. Even though some airlines and States had imposed restrictions using open and public information, none of the airlines whose flights departed from IKA had made any change in their flights on the basis of a risk assessment.

6.2. Accident Causes and Contributing Factors

6.2.1. Cause of the Accident

The air defense's launching two surface-to-air missiles at the flight PS752, UR-PSR aircraft, the detonation of the first missile warhead in proximity of the aircraft caused damage to the aircraft systems, and the intensification of damage led the aircraft to crash into the ground and explode instantly.

6.2.2. Other Contributing Factors

- The mitigating measures and defense layers in risk management proved to be ineffective due to the occurrence of an unanticipated error in threat identifications, and ultimately failed to protect the flight safety against the threats caused by the alertness of defense forces.

7. Safety Actions Taken and Safety Recommendations

7.1. Safety Actions Taken

- The NOTAM procedure was revised by Iran Airports & Air Navigation Company (ANSP) to promptly issue NOTAM about any change in Tehran FIR airspace management that results from the outcome of a conducted security risk assessment or military instructions.
- In order to provide even further access for the users outside of the aviation communication networks, the "Airspace Safety and Security Warning" section was created on the Iran Aeronautical information Management (AIM) website as a repository to announce security NOTAMs regarding airspace. This website has been launched since December 03, 2020, which was notified to users via AIC 2-20 and ICAO in a separate letter.
- The concept of transient risks was added to the risk assessment procedures of Civil and Military organizations responsible for safety and security of Tehran FIR.

  In the amended procedures, an additional risk called "adaption risk" has been added to available risks for each change in level of threats to civil aviation. The specification of the nature and duration of related safety measures shall be defined during each risk assessment task. For each change in existing situation, an adaption period has been considered, where "adaption risk" and related safety layers shall be applicable during that period.

- CAO.IRI ATM/ANS safety oversight manual was amended to include oversight activities of the risk management of potentially hazardous military activities. The ANSP is mandated to perform periodic airspace security management exercise.
- Iran Military authorities informed AAIB that based on their investigation results, adequate corrective actions have been implemented for prevention of events which caused misidentification of flight PS752.

7.2. Safety Recommendations

7.2.1. To the States Managing the Airspace:

- Promptly issue NOTAMs regarding any limitation or any change on the provision of services followed by the change in civil-military coordination status in short term, even if the issuance of such NOTAMs appear to have no effect neither the airlines flight operations nor the services provided by the State managing the airspace operationally.
- Since during transition from a level of military alertness to a higher one, the risk of whole system is affected by the nature of transition apart from the new conditions, in risk assessment of potentially hazardous military activities to civil aircrafts, in case the types of changes in military alertness conditions or its associated reason has not been frequently experienced before, consider the risk of the misidentification or mistargeting at times closer to transition more cautiously than stable conditions.
- Conduct oversight on effective implementation of the measures adopted for the risk management of potentially hazardous military activities and perform periodic exercises for risk assessment based on different types of probable conditions; apply the results obtained from the monitoring and exercises to identify the hidden threats and enhance the risk management accordingly.

7.2.2. To the States Overseeing the Airlines:

- Conduct oversight on effective implementation of the measures adopted for the risk management of potentially hazardous military activities and perform periodic exercises for risk assessment based on different types of probable conditions; apply the results obtained from the monitoring and exercises to identify the hidden threats and enhance the risk management accordingly.

- Ensure that the airlines are able to quickly apply the open and public information issued by non-aviation sources in their processes of risk assessment.

7.2.3. To ICAO:

- Revise the Standards related to the issuance of NOTAMs in such a way that air navigation service providers promptly issue the NOTAMs in case of any change or restriction imposed in the provision of services due to potentially hazardous military activities or civil-military cooperation considerations independently of the operational application, in a format that these NOTAMs could indicate that the change has been made due to security or military considerations.
- Develop a framework necessary for gathering information on the near-miss accidents and events caused by targeting a civil aircraft, including the provision of definitions and examples, the method of information collection, reporting and sharing. Such database should allow for the revision of relevant standards and guidelines, as appropriate, based on information submitted by States at national, regional and international levels.
- Considering that the initiatives and measures established to minimize the risks caused by potentially hazardous military activities are newer compared to other traditional safety measures, develop and/or amend related Universal Safety Oversight Audit Programme (USOAP) and Universal Security Audit Programme (USAP) protocol questions as necessary, and prioritize the assessment of those States that should have implemented such measures due to potentially hazardous military activities in their airspace.
- Support and encourage States to improve the efficiency of risk assessment of civil aircraft operations over or near conflict zones, and civil-military coordination with due consideration of the regional priorities and models.
- Given that more clarity of the regulations relating to switching on the CVR, in such a way that it ensures the recording of the

cockpit voices during checks, technical and operational conversations, and decision making, would be beneficial for safety and safety studies related to cockpit conversations., ICAO should revise and clarify the provisions in Annex 6 — Operation of Aircraft and associated guidance material related to switching on the Cockpit voice recorder (CVR).

- Given that information gathering is a key step to conduct flight risk assessment in potentially hazardous military conditions, review and enhance the available guidance material, such as the Risk Assessment Manual for Civil Aircraft Operations Over or Near Conflict Zones, Doc 10084, to provide further assistance to States and aircraft operators on the nature and method of gathering initial information, including its difference with NOTAMs issued. .
- Study the effects of stable and transient conditions in risk assessment, determine the threat level specifications in transient conditions and update the provisions and associated guidance material addressing civil aircraft operating over or near conflict zones accordingly.
- The prevention of accidents would only be achieved through identification of the root causes, issuance of safety recommendations and implementation of the necessary corrective measures. It was challenging to investigate the actions and their root causes within the military sector; thus, the investigation team requested the investigation of the events leading to the missile launch and the corrective actions planned to prevent recurrences. The relevant military sector provided the information required accordingly. This convinced the investigation team of the importance of establishing well-advanced agreements on investigation cooperation with the military authorities.

  Recognizing the need for timely cooperation during investigations of occurrences involving the military, ICAO should develop or expand guidance material (e.g. MOU) addressing cooperation and coordination between States' accident investigation authorities and the military authorities.

7.2.4. To the EUROCAE:

- The EUROCAE ED-62B Minimum Operational Performance Specification for Aircraft Emergency Locator Transmitters provide specifications for the design and manufacture of emergency locating transmitters. The problem with the antenna hardware connections failing between the ELT unit and the ELT antenna is known to the aviation industry. To improve this situation, the ED-62B specification need to be assessed and revised.
  It is recommended that EUROCAE revisit the EUROCAE ED-62B Minimum Operational Performance Specification for Aircraft Emergency Locator Transmitters to assess if the specification adequately addresses the design of the hardware connecting the automatic ELT unit to the ELT antenna.

8. Table of Figures and List of Tables

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