DUTCH
SAFETY BOARD

MH17

MH17 Crash

Introduction

The crash of flight MH17 on 17 July 2014 shocked the world and caused hundreds of families much grief. In the first few days after the crash the first explanations for the cause of the crash began to appear. The question was also raised as to why the aircraft flew over the conflict zone in the eastern part of Ukraine. On board flight MH17 there were 298 occupants, of which 193 passengers with the Dutch nationality. On Friday 18 July 2014, the Dutch Safety Board received a formal notification from Ukraine that flight MH17 had crashed and that an investigation into the causes of the crash was already underway. The same day, the Board sent three investigators who arrived in Kyiv in the evening.

A few days later, the investigation was delegated to the Dutch Safety Board. The Dutch Safety Board was determined to answer the questions of how this accident could have happened and what caused it on the basis of factual information. Such an investigation requires time, but I hope that our conclusions answer questions that have preoccupied the relatives since 17 July 2014.

Tjibbe Joustra, chairman
Dutch Safety Board

Investigation into the crash of flight MH17

The Dutch Safety Board has extensively investigated the crash of flight MH17. The first part of the investigation focused on the causes of the crash. The Board has aimed at providing an accurate picture of the course of flight MH17 on 17 July 2014 and the causes of the crash. The second part of the investigation focused on the questions of why the aircraft was flying over the eastern part of Ukraine and how, in general terms, flight routes over conflict zones are determined.

Main conclusions

Causes of the crash - The crash of the Malaysia Airlines Boeing 777-200 was caused by the detonation of a model 9N314M warhead, fitted to a 9M38-series missile that was fired from a Buk surface-to-air missile system.

None of the 298 occupants survived the crash.

Flight routes - None of the parties involved adequately identified the risks to civil aviation brought about by the armed conflict in the eastern part of Ukraine.

Passenger information

A second, independent investigation was conducted into the gathering and verification of passenger information and informing the relatives of the Dutch victims of the crash of flight MH17. This investigation has been published in a separate report and corresponding brochure.

Crash

Flight MH17 on 17 July 2014

At 12.31 Dutch time (10.31 UTC), flight MH17 departed from Gate G3 at Amsterdam Airport Schiphol heading for Kuala Lumpur International Airport in Malaysia. On board the aeroplane were 298 people, 283 of which were passengers. The crew consisted of four pilots and eleven cabin crew members.

On the day in question the aeroplane headed southeast, in the direction of Germany. After crossing the German and Polish border, the aeroplane entered Ukrainian airspace. The aeroplane would then have continued its flight, flying over Russia and Asia, to its final destination of Kuala Lumpur.

Airspace restrictions

From mid-March 2014, parts of the airspace over the eastern part of Ukraine were regularly closed for brief periods of time or their use was restricted. Civil air traffic was not permitted to fly there, but military aircraft were. The restrictions were related to the activities of the Ukrainian Air Force. This subject is discussed in more detail in the chapter dedicated to flight routes (see page 14).

Airspace restrictions are announced in a so-called Notice to Airmen (NOTAM, see box on page 16). On 17 July 2014, various NOTAMs were in force with regard to different parts of the airspace over the eastern part of Ukraine, four of them relevant to flight MH17. Fo example, since 14 July 2014, civil aviation was not permitted to fly below FL320 (circa 9,7 kilometres). On 17 July, flight MH17 was in an authorised area, flying at an authorised altitude of FL330 (circa 10.1 kilometres).

Air traffic: route and altitude

In order to conduct air traffic in an orderly, safe and efficient fashion, a system of airways is used. On the basis of these airways, the operator sets out a route and makes a flight plan containing, among other things, information on navigation, times and altitudes. This flight plan is submitted to the air traffic control prior to the flight.

In the air, aeroplanes are separated by flying in different headings and at different altitudes. These altitudes are expressed in flight levels (FL).
For example, an aeroplane can be flying at FL330, which represents a flight altitude of 33,000 feet (10.1 kilometres).

Time zones

The aviation sector uses a universal time zone called Coordinated Universal Time (UTC). During the summer, the local time in the Netherlands is two hours ahead of universal time (UTC+2), while in Ukraine it is three hours ahead (UTC+3). To avoid any confusion, times are specified in universal time (UTC), unless explicitly stated otherwise.

The planned route of flight MH17 on July 17, 2014.

Last contact

At around 13.19, the aircraft was above the eastern part of Ukraine, near the border with Russia. At this point, the aeroplane received permission to fly directly to the Russian Federation. The crew confirmed this notification at 13.19:56. Up until that moment the flight had progressed as normal. A few seconds later, air traffic control gave permission for the next part of the route. This permission was not confirmed, however, and no more signals were received from the crew of flight MH17.

Air traffic control

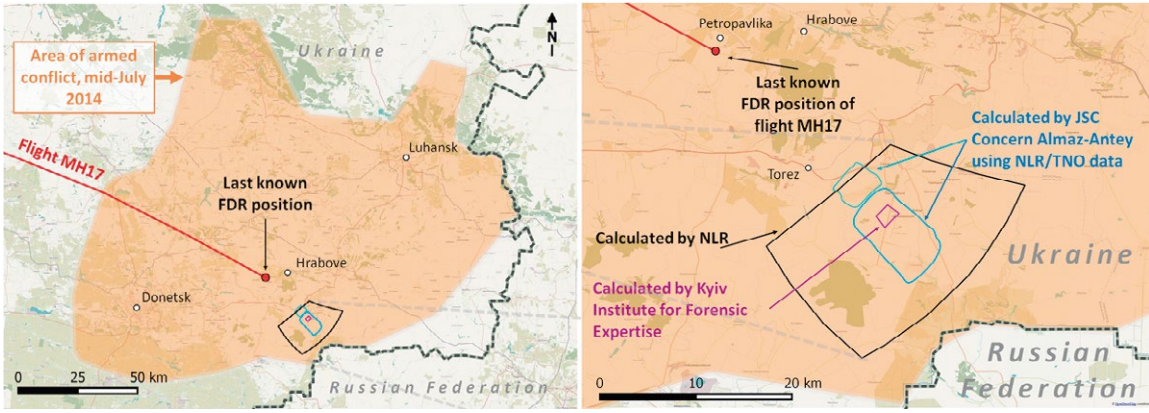
Virtually every country in the world has its own air traffic control service provider controlling the air traffic above its territory. Throughout a flight, the cockpit crew maintain contact with the air traffic control of the country over which the aircraft is flying at that time. This contact involves, among other things, coordinating the flight route and altitude, and making requests to deviate from the original route (for practical reasons). The air traffic control services of bordering areas are also in contact with each other to coordinate the handover of flights and to discuss any special circumstances.

Time (UTC)	Callsign	Means	Spoken text	Translation
13.19:49	DNP (S4)	RAD	Malaysian one seven, due traffic proceed direct to point ROMEO NOVEMBER DELTA	
13.19:56	MH17	RAD	ROMEO NOVEMBER DELTA, Malaysian one seven	
13.20:00	DNP (S4)	RAD	Malaysian one seven, and after point ROMEO NOVEMBER DELTA expect direct to TIKNA	
13.21:10	DNP (S4)	RAD	Malaysian one seven, how do you read me?	
	DNP (S4)	RAD	Malaysian one seven, Dnipro Radar	
13.21:36	DNP (S4)	RAD	Malaysian one seven, Dnipro Radar	
13.22:02	DNP (S4)	RAD	Malaysian one seven, Dnipro Radar	
13.22:05	RST	TEL	Слушаю, Ростов	Listening you, its Rostov
	DNP (S4)	TEL	Ростов, а вы малазийца семнадцатого наблюдаете по...по ответу?	Rostov, do you observe the Malaysian seventeen by... by the transponder?
	RST	TEL	Да нет. Что то начала разваливаться метка его.	No. It seems that its mark has started to break
	DNP (S4)	TEL	Ну у нас тоже. И на вызовы не отвечает	Well, we have the same. And it's not responding for our calls too
	RST	TEL	И не отвечает на вызовы, да?	He is not responding to the calls, is he?
	DNP (S4)	TEL	Да. И не видим пока его. То-есть ему дали отворот, он подтвердил и ...	No. And we don't see it yet. So we gave him a turn, he confirmed and...
	RST	TEL	И все, да?	And that was all, yes?
	DNP (S4)	TEL	Да и исчез.	Yes, and it disappeared
	RST	TEL	Сейчас, подожди, я попрошу.	Wait now, I'll ask
	DNP (S4)	TEL	В пассиве там ничего у вас не наблюдается?	In primary don't you observe anything either?
	RST	TEL	Не не не ничего. Ничего не видим.	No, no, no, nothing. We see nothing.
	DNP (S4)	TEL	Ну хорошо, сейчас мы зовем их сюда.	Ok then, we are calling them here now
	DNP (S4)	RAD	Malaysian one seven, Dnipro Radar	

Transcript (extract) of the conversation between flight MH17 and air traffic control services and between air traffic controllers.

Impact

At 13.20:03 the aircraft was penetrated by hundreds of high-energy objects that originated from a warhead, model 9N314M, fired from a Buk surface-to-air missile system. This has been established on the basis of, among other things, the altitude at which the aircraft was hit, the damage pattern on the wreckage and the particles found in the wreckage and in the bodies of three of the crew members. A number of the particles showed traces of aluminium and glass. This is material originating from the aeroplane that melted when it was hit and thus was deposited on the particles. A number of fragments were found in the wreckage of the aeroplane that were not from the aeroplane. Samples of paint were taken from two of these fragments.



Combination sketch of the calculated areas. The Russian Federation, at the Dutch Safety Board's request, calculated a possible launch area without confirming the use of a 9N314M warhead, a 9M38-series missile or a Buk surface-to-air missile system. (Source: Dutch Safety Board)

These matched the paint samples from the missile parts recovered from the wreckage area. No scenario other than the one described above, involving a Buk surface-to-air missile system, can explain this combination of facts.

Simplified representation of the volume of space of the warhead detonation location according to three independent simulations (Source: Dutch Safety Board)

The investigation revealed that the missile approached the aircraft almost head-on, in the direction of the upper left-hand side of the aeroplane. The warhead exploded to the left of the cockpit. This is evident from the aeroplane's damage pattern, which shows the highest number of impacts on the left-hand side of the cockpit.

It is not possible to determine the exact position and angle from which the missile was fired, the speed at which this occurred and the local circumstances at that moment. Based on the impact pattern, the impact angle and other data a calculation was made to determine the missile's trajectory, which originated in an area spanning approximately 320 square kilometres in the eastern part of Ukraine.

As a result of the impact and the ensuing pressure wave, the three crew members in the cockpit were killed instantly. A large number of fragments from the warhead were found in their bodies.

Recorder data

The recording on the Cockpit Voice Recorder ended abruptly at 13.20:03. A high-energetic sound wave lasting 2.3 milli-seconds was detected in the final 20 milliseconds of the recording. This sound wave originated from outside the aeroplane, above the upper left-hand side of the cockpit. This is consistent with the position of the warhead at the moment of the explosion.

Further analysis of the recorders revealed that no warning signals were activated. The recordings on the Flight Data Recorder ended abruptly and at the same time as those on the Cockpit Voice Recorder. At this point, the electrical power of the aeroplane was disrupted, causing both recorders to stop recording.

Consequences of the impact

The Dutch Safety Board had a digital simulation made of the impact and the pressure wave that followed the explosion of the warhead. The pressure wave caused damage to the front section of the aircraft, up to 12.5 metres from the nose of the fuselage. As a result of the explosion and the impact, the aeroplane broke up in mid-air: the cockpit and the floor of the business class tore away from the fuselage almost instantly and crashed. The rest of the aeroplane continued to fly for approximately 8.5 kilometres in an easterly direction. Sections of the upper side of the aeroplane were torn off as air currents, moving at a speed of approximate 900 kilometres per hour (480 knots), took hold of the damaged aeroplane. Both wingtips broke away and the rear section of the fuselage fractured, causing the tail section to detach itself from the centre section.

From the moment the forward section of the aircraft was struck, it took about 1 to 1.5 minutes until the rest of the aeroplane hit the ground.

Radar data

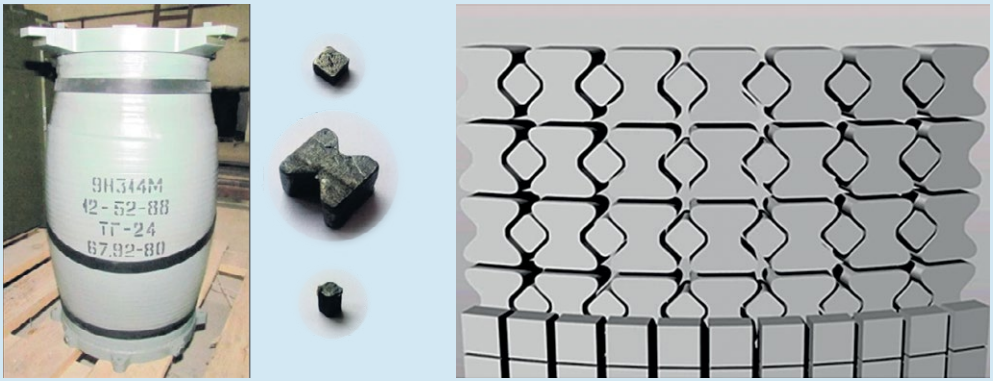
The radar images from Ukrainian and Russian air traffic control show that MH17 was flying level at FL330 (10.1 kilometres) until 13.20. For a few moments, the Russian air traffic control's radar images showed pieces of wreckage falling down as the aircraft was breaking up.

Buk surface-to-air missile system and high-energy objects

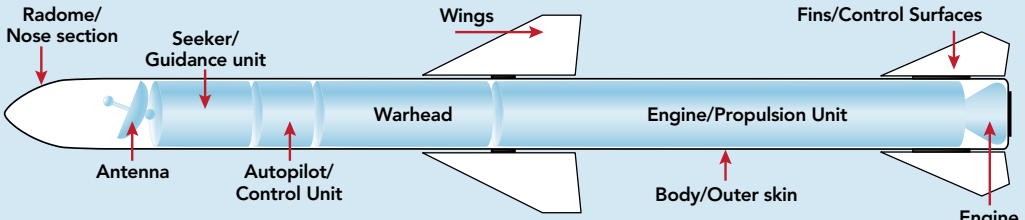
A Buk surface-to-air missile system is an air defence system that consists of different components in various models and configurations. The installation can comprise a number of vehicles carrying the launch and radar systems, but there are also launching systems that work autonomously. The warheads of this weapon system are filled with an explosive charge surrounded by two layers of preformed fragments.

A Buk surface-to-air missile system can reach an altitude of 80,000 feet (approximately 24.4 kilometres). This altitude far exceeds the altitude of 33,000 feet (approximately 10.1 kilometres) at which flight MH17 was flying.

The particles found in the aeroplane and in the bodies of three of the crew members consisted of unalloyed steel. The particles are cube and bow-tie shaped. The number of impacts, the distribution pattern and the shape of the high-energy objects that were found are consistent with the pre-shaped fragments in the warhead of the 9N314M model.



Left: example of a 9N314M-warhead. Middle: The different shaped particles in the warhead. Right: 3D-print of the arrangement of the pre-formed particles.



Generic form of a surface-to-air missile.

Crash site

The aircraft's wreckage ended up in several sites around the villages of Hrabove, Rozsypne and Petropavlivka in the Donetsk region in the eastern part of Ukraine. On 17 July 2014, a conflict was being fought between armed groups and the Ukrainian authorities.

The area where the pieces of wreckage came down covered a total surface area of approximately 50 square kilometres. Within this area, six crash sites can be identified where debris came to rest.

The wreckage that was found near the villages of Rozsypne and Petropavlivka (crash sites 1, 2 and 3) shows that the cockpit and the front section of the aeroplane were the first to break off and crash. Initially the centre and tail sections of the fuselage remained intact and ended up a few kilometres further eastwards, near the village of Hrabove (crash sites 4, 5 and 6). The distribution of the wreckage across these three eastern crash sites shows that the end section of the fuselage, the wings and the tail section came down next, followed by the centre section, which came to rest upside down. A fierce fire broke out at the site where the centre section and the engines hit the ground. As a result, the centre section of the aeroplane was almost completely destroyed.

The crash caused a great deal of damage in the crash area. There were no casualties among the local population.

Operational facts and background

In addition to the direct causes of the crash, operational facts and backgrounds were also investigated. By investigating the aeroplane, the crew, and other factors that can affect a flight, other potential causes could be excluded.

Crew, aeroplane and cargo

The cockpit crew of flight MH17 consisted of two Captains and two First Officers. All pilots were authorised and qualified to be flying a Boeing 777-200. Malaysia Airlines company directives prescribe that there must be two pilot teams - each consisting of one Captain and one First Officer - on board the aeroplane for flights with a duration of approximately twelve hours.

On departure from Amsterdam Airport Schiphol the aeroplane was in airworthy condition and there were no known technical malfunctions that could affect the safety of the flight. There was no known damage and there were no incorrectly performed repairs or engine malfunctions that could have caused the aeroplane to crash.

The aeroplane took off with 283 passengers, 15 crew members, 17,751 kg of baggage and cargo and 96,500 kg of fuel on board. The aeroplane's weight and centre of gravity were within the prescribed limits. There were no hazardous cargo or explosive materials on board.

Flight preparations

The flight plan was prepared in the prescribed manner and submitted to air traffic control. The crew received an operational flight plan, relevant NOTAMs and information about the cargo and the weather.

MH17 recorders

The Cockpit Voice Recorder and the Flight Data Recorder of the flight MH17 aircraft were read out by the investigation team and contained recordings that could be used in the investigation. The Cockpit Voice Recorder did not register any alarms or warnings and the conversation among the flight crew indicated no abnormalities. The Flight Data Recorder data did not record any technical malfunctions or warnings in relation to this flight.

Recorders (black boxes)

Every large transport aeroplane is fitted with two types of recorders, also known as 'black boxes'.

- The Flight Data Recorder records all key flight data, such as information pertaining to the engines, altitude, speed, course, etc. Some recorders can record up to a thousand different flight details over the preceding 25 flying hours. All information is stored in binary form (i.e., in ones and zeros). This is one reason why the painstaking process of reading out and analysing the recorders takes a great deal of time.

- The Cockpit Voice Recorder records conversations and sounds in the cockpit. This includes conversations between the pilots, conversations with air traffic control and sounds in the cockpit such as warning signals. The purpose of the Cockpit Voice Recorder is to enable investigators to better investigate civil aviation incidents. As the recorder registers all pilot conversation, including private ones, it was internationally agreed that the recorder data can be used in investigation but will never be made public in full.

Emergency Locator Transmitter

In addition to the recorders, every large transport aeroplane is fitted with an Emergency Locator Transmitter (ELT). This is activated if an aeroplane crashes or when it is switched on by the crew. Upon activation, the ELT transmits a signal to a receiver station via satellite. This makes it possible to determine the aircraft's position.

The flight MH17 aeroplane was fitted with a fixed and a portable ELT. The fixed ELT was activated automatically upon impact of the warhead; the signal was received around 13.20:36. No signal was received from the portable ELT, which can only be activated manually.

ACARS

In addition to a system for radio communications, each modern airliner is fitted with an Aircraft Communications Addressing and Reporting System (ACARS). This system is used for exchanging flight or aircraft data between the aeroplane and ground stations. The communications run via satellite (SATCOM) or radio frequencies (VHF).

At 13.12 the last ACARS message from flight MH17 was sent via VHF. The messages sent from the ground to the aeroplane after this time were not received by the aircraft.

Weather

The weather forecast indicated that there was a high probability of thunderstorms in the eastern part of Ukraine. This turned out to be true: there were clouds and thunderstorms. At 13.00, after consulting air traffic control, the crew decided to deviate 6.5 nautical miles (approx. 12 kilometres) from the flight route; five minutes later the aircraft returned to the planned route.

Radar images of flight MH17

During the investigation, the investigators only had the raw data from Ukraine's air traffic control's secondary radar at their disposal. According to the authorities, the primary radar system in Ukraine was not active.

Russian air traffic control did not store the raw data from its primary or secondary radar because the accident did not occur on Russian territory. However, Russian air traffic control did provide a video film of the radar screen.

These images show flight MH17 up until the moment when the aeroplane broke up. According to the radar data from both services, three civil aeroplanes were present in the vicinity of flight MH17 at the time of the occurrence. All three were under the control of Ukrainian air traffic control. The nearest aircraft was located at a distance of 33 kilometres from flight MH17. No military aircraft were visible in the radar images provided.

Excluded causes

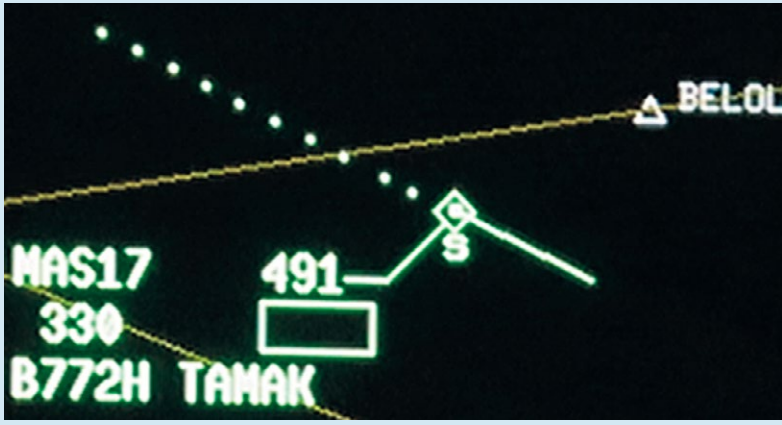
In addition to investigating the causes of the crash, the investigation also focused on excluding alternative scenarios. The investigation has demonstrated that the crash was not caused by metal fatigue, corrosion or existing damage to the aeroplane. Neither was the crash caused by an exploding fuel tank, explosives exploding inside the aeroplane, or a fire on board the aeroplane. Events such as a lightning strike or a meteor impact were also excluded.

Radar

Two types of radar are used in air traffic:

- Primary radar: this system uses reflections of radio waves off objects. The primary radar provides an object's angle and distance, which are converted into a position. This can then be used to calculate the object's speed as well.
- Secondary radar: in this system a transmitter in the aeroplane responds to a signal transmitted from the ground. In addition to position and speed, the secondary radar can display other information about the aeroplane (such as the type of aeroplane, the operator and the destination).

The raw radar data are received by air traffic control, which then converts it into images on a screen.



Sample Ukrainian radar screen display which shows information about the aeroplane and the navigation of flight MH17.

Sources for findings

The circumstances of the flight and the position of the aeroplane at the moment of impact were based on:

- Flight Data Recorder;
- Cockpit Voice Recorder;
- Communications with air traffic control;
- Location where Emergency Locator Transmitter (ELT) was activated;
- Flight plan and flight preparations.

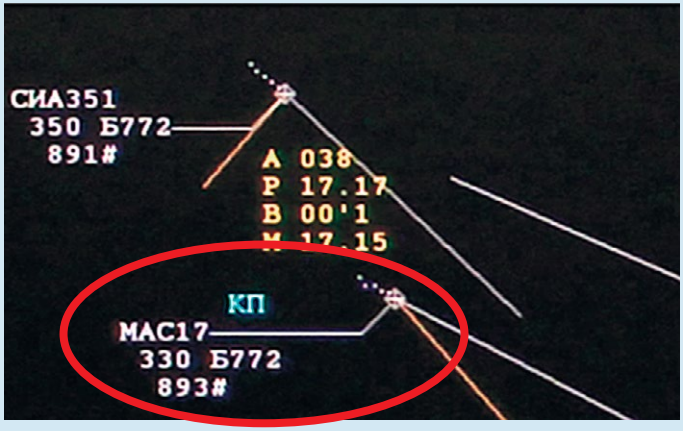
The time when the aeroplane was downed was based on:

- Flight Data Recorder;
- Cockpit Voice Recorder;
- Communications with air traffic control;
- Radar data and radar images provided by Ukraine and the Russian Federation;
- Final ACARS data that was transmitted through SATCOM and VHF system;
- Time at which the Emergency Locator Transmitter (ELT) was activated;
- Distribution of wreckage on the crash site.

The observation that the aircraft was downed with a Buk surface-to-air missile is based on:

- Shape and composition of the particles that were found;
- The impact damage to the aeroplane (impact pattern, spreading of impacts, angle and location);
- Damage to the aeroplane by the formation of the pressure wave;
- Injuries of crew members in the cockpit;
- The missile parts that were found;
- The similarity between the paint samples on the fragments of the missile found in the wreckage and the missile parts recovered from the wreckage area;
- Sound peak registered on Cockpit Voice Recorder;
- The altitude at which the aeroplane was hit.

It was also examined whether there had been an aerial attack by a military aircraft. An attack from the air could not have caused the crash given the high-energy objects found, the damage to the aircraft and the trajectory followed by the high-energy objects. Moreover, analysis of the available material has revealed that no military aircraft were present within at least a radius of 30 kilometres of the aeroplane.



Sample Russian Federation radar screen display which shows flight MH17 and accompanying details.

Conclusions

- On 17 July 2014, Malaysia Airlines flight MH17, carried out with an airworthy Boeing 777-200, registration 9M-MRD, was flying at cruising altitude near the Ukrainian-Russian border under the control of Ukrainian air traffic control and was being flown by an authorised and qualified cockpit crew.
- At 13.20:03 a warhead exploded on the outside, to the left and above the cockpit. This was a model 9N314M warhead, carried by a 9M38-series missile, fired from a Buk surface-to-air missile system.
- The impact killed the three crew members in the cockpit instantly and caused structural damage to the front section of the aeroplane fuselage. This caused the aeroplane to break up in mid-air, after which the wreckage came down in an area of 50 square kilometres near the village of Petropavlivka and the town of Hrabove in Ukraine. All 298 occupants lost their lives.
- Alternative scenarios were examined and excluded.

More information

In the first part of the 'MH17 Crash' report you can read all the findings of the investigation into the cause of the crash of flight MH17.

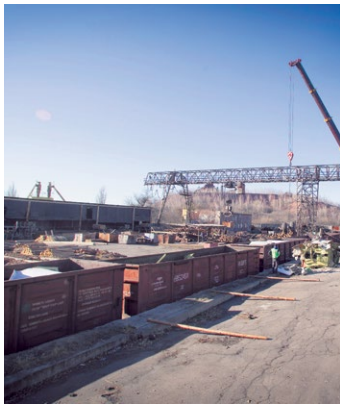
Recovery of the wreckage

For a long time, it was not safe enough for the Dutch Safety Board investigators to visit the crash site. The first wreckage recovery mission began on 4 November 2014. During a six-day period that started on 16 November 2014, under the leadership of the Dutch Safety Board, hundreds of wreckage pieces were collected and taken to the nearby train station in Torez. From there, the wreckage was transported by train to Kharkiv, where it was subsequently loaded onto trucks and low loaders for transport to the Netherlands. The first convoy carrying wreckage arrived at Gilze-Rijen Air Force Base on 9 December 2014. In the months following the crash, local emergency services and residents collected wreckage parts, which were transported to the Netherlands in the spring of 2015. Two more recovery missions were conducted in March and April 2015. During one of the recovery missions parts of the missile were recovered, which were subsequently examined. It turned out that the paint samples on the missile parts matched those on the fragments found in the aeroplane wreckage.

An investigation under special circumstances

Normally speaking, an aviation investigation will begin at the crash site. In the case of this investigation, however, this was not possible. Due to the persistent fighting and unrest in the area, it was not safe for the investigators to visit the crash site and conduct an investigation for several weeks. Therefore, it was decided to begin the investigation using other available material such as photographs, satellite information, the recorders and the radar images.

The Dutch Safety Board's objective has always been to visit the crash site and recover the pieces of wreckage as quickly as possible. The Dutch Safety Board based its actions in this respect on a positive recommendation from the Dutch authorities. The recovery of human remains and personal belongings had priority. It was clear that it would not be possible to recover the wreckage in the short term due to the persistent fighting and repeated negative recommendations with respect to visiting the crash site. That is why a list was compiled of the pieces of wreckage that would be most relevant to the investigation. In November, the recovery mission started as soon as the conditions allowed. Using the compiled list and based on the actual situation at the crash site, a decision was made on which sections of the crash site would be searched during the recovery missions, and when. As many pieces of wreckage as possible were recovered. While the area was being searched, it became apparent that a number of specific pieces of wreckage were no longer present.



More information

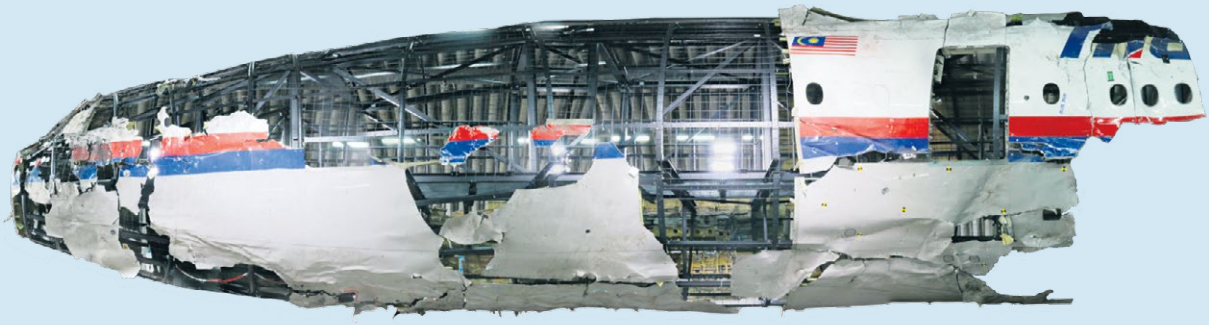
Chapter 7 of the report 'MH17 About the investigation' describes all the activities and decisions relevant to the recovery of the wreckage in more detail.

Reconstruction

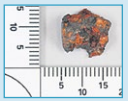
After the pieces of wreckage had been investigated, a reconstruction was made of the front section of the aeroplane. In the course of three months, the cockpit and business class section of the aircraft were reconstructed at Gilze-Rijen Air Force Base. For this purpose, a frame modelled on a Boeing 777-200 was built, to which the pieces of wreckage were attached. Due to the fact that many pieces of wreckage were twisted and bent, the frame is slightly larger than the original Boeing 777-200.

The reconstruction shows the consequences of the impact on the aircraft, the angle at which the cockpit was hit and the manner in which the aircraft subsequently broke up.

Righthand side of the reconstruction



Lefthand side of the reconstruction



This reconstructed section of the cockpit clearly shows the impacts of the high-energy objects. Examination of the impact pattern demonstrated that the warhead detonated on the left side, just above the cockpit, and that the particles spread out in a characteristic pattern and penetrated the aeroplane.

This fracture shows the location where the cockpit separated from the aircraft.

The shape and pattern of the impact show that differently shaped particles hit the aeroplane.

Front of the reconstruction

Investigation into flight routes

The crash of flight MH17 raised the question whether the airspace above the eastern part of Ukraine should have been closed due to the armed conflict. A second question that was raised is why Malaysia Airlines selected this particular route for flight MH17. The Dutch Safety Board therefore conducted an investigation into the flight route of flight MH17 and into the decision-making processes related to flight routes over conflict areas.

Downed Antonov and Sukhoi

On 14 July 2014, three days prior to the crash of flight MH17, a Ukrainian air force transport aeroplane, an Antonov An-26, was shot down in the Luhansk region. In a press release, the Ukrainian authorities reported that the aircraft was hit when flying at an altitude of 6,200 to 6,500 metres. On 16 July, a Sukhoi Su-25 fighter jet was shot down which, according to Ukraine, was flying at an altitude of 6,250 metres. According to Ukraine, these aircraft had been hit by a more powerful weapon than those that had been used to shoot at military aircraft during the period prior to these incidents. The weapon systems that had presumably been used (a Pantsir surface-to-air missile or an air-to-air missile) could also reach civil aeroplanes at cruising altitude. However, the Ukrainian authorities did not recognise this risk.

The armed conflict in the eastern part of Ukraine

An armed conflict was being fought in the eastern part of Ukraine at the time of the crash of flight MH17. From the end of April 2014, the conflict continued to expand into the airspace. The investigation revealed that helicopters and aeroplanes belonging to the Ukrainian armed forces were being shot down ever more frequently.

International attention

The United States authorities issued a general warning to American operators and airmen concerning the airspace above Ukraine and especially Crimea even before the conflict broke out in the eastern part of Ukraine. This was done in response to the unrest in Crimea. Early in April 2014, the International Civil Aviation Organization (ICAO) also issued a formal notice regarding the risks posed by the airspace above Crimea. During the period when the conflict in the eastern part of Ukraine expanded into the airspace up to the crash of flight MH17, foreign authorities and international organisations did not issue any specific warnings pertaining to the use of the airspace above the eastern part of Ukraine.

In diplomatic circles, concerns were expressed about the armed conflict in the eastern part of Ukraine and the shooting down of military aircraft of the Ukrainian armed forces. These concerns mainly arose from military and geopolitical considerations. However, none of the politicians, officials or services made a connection between the military develop-

ments in the region and the possible risks posed to overflying civil aeroplanes.

Identification of the risks by Ukraine

The investigation revealed that Ukraine did not adequately identify the risks to civil aviation. Ukraine reported that two of their military aircraft had been shot down, at altitudes between 6,200 and 6,500 metres, with powerful weapon systems. The systems mentioned by the authorities were also able to intercept overflying civil aeroplanes and as such formed a threat to civil aviation. According to the Dutch Safety Board these reports gave enough reason for Ukraine to close its airspace as a precaution. However, this did not happen. Ukraine did impose restrictions on civil aviation, but these were inadequately to protect civil aviation from the mentioned weapon systems. However, it turns out that - also with respect to other conflict areas - states hardly ever decide to close their airspace because of an armed conflict.

Airspace restrictions

From 6 June 2014, civil aviation was not permitted to fly below FL 260 (circa 7.9 kilometres) above the eastern part of Ukraine. This restriction was intended to enable military air traffic to fly at a greater altitude in order to protect it from attacks from the ground. A few weeks later, Ukraine issued a subsequent NOTAM specifying a restriction to FL320 (circa 9.7 kilometres). These NOTAMs, however, did not include any measures to protect civil air traffic from the weapon systems mentioned by authorities.

As a result, on 17 July 2014 civil air traffic was not permitted to fly below FL320 (circa 9.7 kilometres) in that area. The airspace above this altitude was unrestricted and flight MH17 was flying in the permitted area and at the permitted altitude in accordance with the flight plan. On that day, until the airspace was closed, 160 civil aircraft crossed the area.

Malaysia Airlines

As the airline operating the flight, Malaysia Airlines was responsible for safe flight operations. When determining the route, Malaysia Airlines based its decision on information that was available to the aviation sector. In doing so, the operator did not perform any separate risk assessment for flying over the conflict area in the eastern part of Ukraine. The way in which Malaysia Airlines prepared and operated the flight complied with ICAO regulations.

Flight MH17 was operated by Malaysia Airlines, but passengers were also able to book tickets via KLM. Eleven passengers of flight MH17 had booked their ticket with KLM. This system is called 'codesharing' and is common practice in the aviation sector. A code sharing agreement means that the party operating the flight is responsible for safe flight operations. Malaysia Airlines did not receive any ➔

Responsibilities

The responsibility for the safety of an airspace lies primarily with the state that manages the airspace. However, the operator also has its own responsibility for the safe operation of a flight.

The state that manages the airspace

Each state has sovereignty over the airspace above its territory. This means that countries may determine how they use their airspace. Generally, states receive financial compensation from operators using their airspace to pay for air traffic control services.

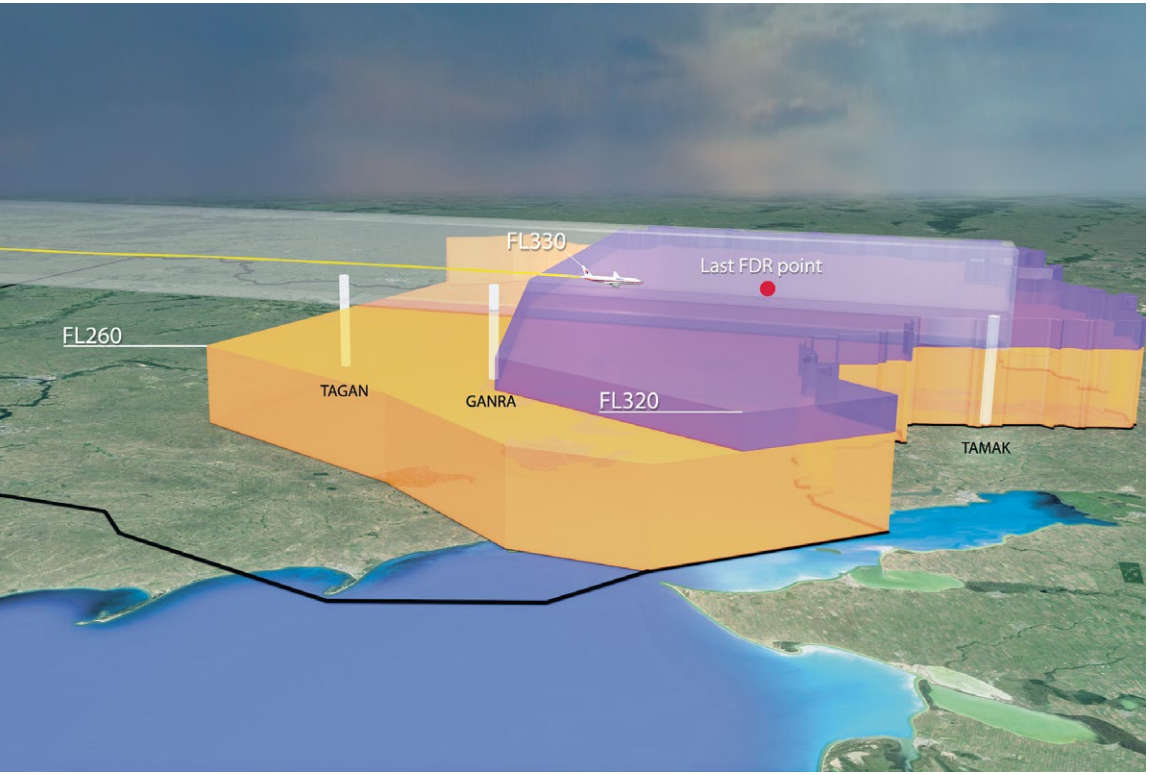
The state an aeroplane is flying over is responsible for assessing the safety of the airspace. For safety reasons, a state can impose certain restrictions. Certain routes or flight levels can be closed, for instance, or the state may close the airspace altogether. Close cooperation between civil and military air traffic control is important when assessing safety. In this way, potential risks to civil aviation posed by military activities on the ground and in the air are minimised.

Operators

Ultimately operators themselves assess whether or not a flight route through unrestricted airspace is safe enough. They then decide on the exact route they would like to use. To do so, they submit a flight plan to air traffic control. In principle, the route prescribed by the flight plan is used, but by mutual agreement between the captain and air traffic control the actual route may be adapted. In some countries, operators are advised by their national authorities about the safety of the airspace in other countries. Furthermore, in some countries authorities can impose a prohibition or a restriction on resident airline operators on flying over a certain country or area.

State of departure

Being the state of departure, the Netherlands bears no responsibility for the safety of flight routes used by foreign operators. Therefore, the Netherlands was not responsible for advising or instructing Malaysia Airlines on the use of the flight route that was selected for flight MH17. Moreover, the Netherlands had no legal authority to prohibit Dutch operators - including KLM as Malaysia Airlines' codeshare partner - to fly over the eastern part of Ukraine.



The flight route and altitude of flight MH17 and the restrictions of airspace over the eastern part of Ukraine.

NOTAM

If a restriction or other change is applied to air traffic, this is announced in a so-called Notice to Airmen (NOTAM). A NOTAM is made available to operators and other users of the airspace via an internationally used system.

A NOTAM includes a concise description of restrictions and changes. This can involve, for example, a minimum flight altitude, partly closed airspace or a runway that is out of use. It also indicates the exact period of time to which the NOTAM applies and the type of air traffic it concerns. In some cases additional background information is provided, but this is not compulsory. The Ukranian NOTAMs relevant to flight MH17 did not contain additional information.

signals from KLM or other operators that the airspace above the eastern part of Ukraine would be unsafe.

Actions by other parties

The Dutch Safety Board ascertained whether other States and operators gathered information about the situation in the eastern part of Ukraine and whether this affected the decision-making process on the use of the airspace.

States

When, from the end of April 2014, the conflict in the eastern part of Ukraine expanded into the airspace, not a single state, as far as the Dutch Safety Board was able to ascertain, explicitly warned its operators and pilots that the airspace above the conflict zone was unsafe; nor did they issue a flight prohibition. States that did gather information were focusing on military and geopolitical developments. Possible risks to overflying civil air traffic were not recognised.

Other operators

In March 2014, before the armed conflict in the eastern part of Ukraine started, one operator decided not to use the airspace above Ukraine anymore. This decision was taken because of the growing unrest in the country. Thereafter, as far as the Dutch Safety Board was able to ascertain, no other operators changed their flight routes for safety reasons related to the conflict in the eastern part of Ukraine. This situation remained unchanged after it was reported that an Antonov and a Sukhoi had been shot down on 14 and 16 July 2014 respectively.

The Netherlands as state of departure

The situation in Ukraine was being monitored from the Netherlands, but when gathering information the focus was on the political balance of forces in Ukraine and how this was influenced by the Russian Federation.

The Dutch ministries and intelligence services did not have any information suggesting an actual threat to civil air traffic using the airspace above the eastern part of Ukraine. The Dutch authorities therefore had no reason to issue a warning to operators or to actively inform them.

Conclusions of the investigation into flight routes

- None of the aviation parties involved adequately recognised the risks of the armed conflict in the eastern part of Ukraine to overflying civil air traffic.
- The current system of responsibilities for safeguarding civil air traffic does not provide sufficient means to adequately assess the risks associated with flying over conflict areas.
- Risk assessments for civil air traffic using the airspace over conflict areas should not only consider actual threats, but also include risks of which the intention or capacity is uncertain.

More information

The second part of the 'MH17 Crash' report describes all findings of the investigation into the flight route of MH17 and the decision-making processes involved related to flight routes over conflict areas.

Recommendations

Passengers should be able to assume that the operator has done all that is possible to operate the flight safely, and that states have ensured that the airspace is safe and will be restricted or closed if it is unsafe to civil air traffic.

In practice, however, this system does not work as intended. In the opinion of the Dutch Safety Board it is therefore necessary to implement improvements at three levels.

Airspace management in conflict areas
States are responsible for the management and safety of their airspace. However, states dealing with an armed conflict very rarely close their own airspace. When dealing with an armed conflict in its territory, a state may find it difficult to ensure the safety of its airspace. Therefore, the Dutch Safety Board thinks it is important that sovereign states in such situations be given more incentives and support in fulfilling this responsibility. In this respect, the following topics require attention:

- The timely closure of the airspace or restriction of its use;
- Providing information (on the armed conflict) to other parties to include in their decision-making process;
- Proper coordination between civil and military air traffic control services.

Risk assessment
Operators cannot take it for granted that an unrestricted airspace above a conflict area is safe. For this reason, operators should make their own risk assessment, also of the countries it flies over. Operators will have to gather information about conflict areas more actively and share relevant information on threats with each other. States should contribute to this by sharing relevant information on the conflict in question. The sharing of information should occur at both the national and international levels and be conducted in a structured manner.

Operator accountability
It is not clear which flights pass over conflict areas. Ideally, operators should actively provide information about routes to be flown by them as well as routes recently flown. That way, everyone can form a judgement, thereby increasing public attention for this issue. A first step toward this would be to require operators to regularly provide public accountability for routes they selected that pass over conflict areas.

In the opinion of the Dutch Safety Board, the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) can play an important role in this matter.

Impact on the occupants

Many of the relatives wonder to what extent the occupants experienced the crash of flight MH17. The Dutch Safety Board conducted an investigation into the impact of the crash on the occupants.

Physical and mental impact

The impact was entirely unexpected, which means that people were barely able to comprehend the situation in which they found themselves. There was hardly any time for a conscious response. The occupants were exposed to extreme factors almost immediately. Depending on variables such as the occupants' location in the cabin at the moment of impact, the factors were not the same for all of the occupants.

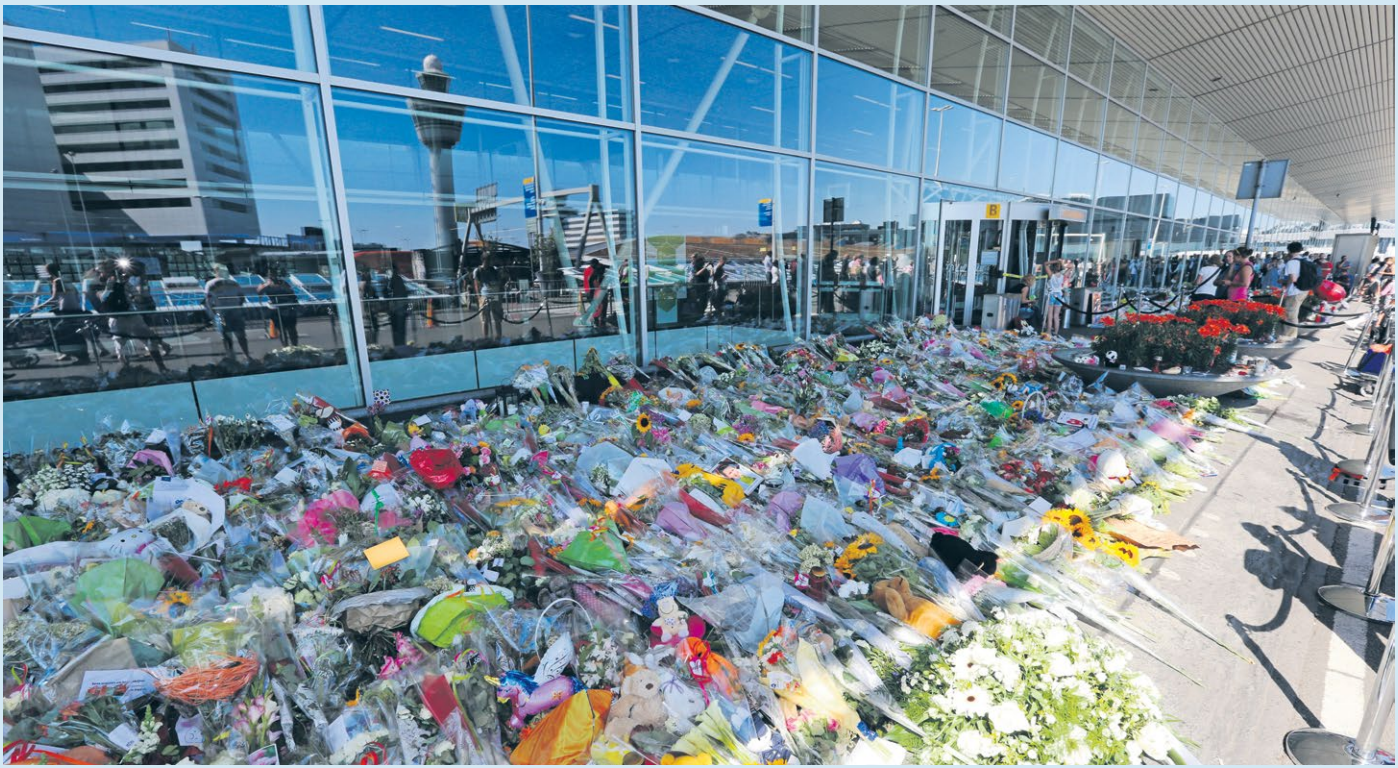
A number of occupants immediately sustained severe injuries as a result of the factors, probably causing death. For others, the exposure caused reduced awareness or unconsciousness within moments. It could not be ascertained at which exact moment occupants died, but it is certain that the impact on the ground was not survivable.

Conclusion

It is likely that the occupants were barely able to comprehend their situation. In the course of the crash, the occupants were exposed to extreme factors.

More information

In Section 2.15, Section 3.13 and Appendix N of the 'MH17 Crash' report all findings can be read.



About the investigation

Major disasters shock the world, especially when they involve numerous casualties. In today's society, an incredible amount of information regarding the circumstances, possible causes and responsibilities is shared immediately after a crash. This also causes uncertainties. A thorough investigation will determine the cause of a crash exactly, presenting the facts and removing the distress caused by speculation. That way, an investigation will provide clarity to the surviving relatives and possibly contribute to aviation safety. Accident investigations focuses on the cause, not on apportioning blame or liability.

Investigations into aviation accidents are conducted in accordance with the internationally established standards and provisions of the International Civil Aviation Organization (ICAO). Based on these, Ukraine was the party that would have led the investigation, but Ukraine delegated this task to the Dutch Safety Board.

The Dutch Safety Board adopted four principles in the investigation:

1. Independence

It is important that the Dutch Safety Board is able to form an autonomous opinion about the facts and interpret them independently. That is why the Dutch Safety Board operates independently of, and separately from, other parties. The Board provides public accountability by publishing the investigation reports and the report about of the investigation.

2. Quality

The investigation team consisted of specialists in different fields, supplemented where necessary with the expertise of external investigators and agencies. Guidance committees provided feedback on the reports. The reports were also assessed for consistency, substantiation and comprehensibility.

3. Determining the cause

The Dutch Safety Board was founded to investigate occurrences and establish their cause and underlying factors. Where possible, the Dutch Safety Board draws lessons to prevent similar incidents in future. In this respect, the Dutch Safety Board differs from other investigative parties, such as the Joint Investigation Team, which is conducting the criminal investigation under the leadership of the Dutch Public Prosecution Service.

4. International nature

The investigation into the crash was conducted in an international context and in accordance with ICAO Standards and Best Practices (see box). Besides the Netherlands, the following states had an accredited representative on the international investigation team: Ukraine, Malaysia, the United Kingdom, the United States, Australia and the Russian Federation. Representatives from Belgium and Germany were also included at various points throughout the investigation.

More information

The report 'MH17 About the investigation' provides more information about the Dutch Safety Board's basic principles and the way in which the different MH17 investigations were organised and conducted.

Investigations into aviation accidents - ICAO Annex 13

When an aircraft crashes, there are guidelines and rules that apply to the way in which the investigation into the crash must be conducted and which parties are to play a role in the process. This was laid down in Annex 13 of the Chicago Convention of the United Nations' International Civil Aviation Organization (ICAO). ICAO's main objective is to increase the safety of aviation, including civil aviation.

Annex 13 describes, among other things, which state is to conduct the investigation, which states are entitled to a role in the investigation, what this role entails and how an international investigation team should be composed. It also stipulates how the international investigation team cooperates and how each party can provide information and respond to the investigation's findings. Annex 13 also describes which matters must be investigated and how the resulting reports must be compiled.

About the Dutch Safety Board

It has been laid down in Dutch law that the Dutch Safety Board can investigate serious incidents and disasters. Its explicit objective is to establish what has happened based on a factual investigation, in order to prevent similar incidents or disasters from happening in future.

In order to provide its investigators with access to all relevant information, the Dutch Safety Board has extensive legal powers to gather such information. Investigators are allowed to enter areas, have the power to seize records and goods, and are able to let an area where an accident took place be closed off for the investigation. As the Dutch Safety Board's investigations never involve matters of blame or liability, they are conducted independently from any criminal investigations.

With international occurrences the Dutch Safety Board investigates according to relevant international laws or treaties.

In order to prevent unwanted interference in its investigations, the Board is independent. Even though the organisation is funded from the central government's budget, neither ministers nor any other persons or bodies can demand access, or give their judgement about investigation's findings or source materials. This enables the Board to reach its own conclusions on the causes of a major incident and determine independently which lessons should be learnt from it.

The Dutch Safety Board is a so-called 'multi-modal' board and has legal authority for conducting investigations in nearly all fields. Well-known examples would be aviation, rail traffic and shipping, but the Board also investigates incidents in the chemical and petrochemical industries, at the armed forces, in the construction sector, in the food industry, in healthcare and with regard to road traffic. Occasionally, the Board will apply its expertise and legal powers to conduct investigations of a more incidental nature in other sectors in response to a serious incident. For example, the Board has investigated digital safety at government organisations, the decision making process on gas extraction in Groningen and the safety of asylum seekers who reside in the Netherlands.

The Board employs circa seventy people, including about forty investigators. Because of the Board's multi-modal nature, they are able to compare developments in the various sectors and apply that knowledge in their investigations as well as the recommendations they make in order to enhance safety in the Netherlands and beyond.

More information about the Dutch Safety Board:
www.safetyboard.nl

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Credits

This is a publication of the Dutch Safety Board, based on the investigation reports and is published in different languages. If there is a difference in texts, the English reports will prevail.
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