Annex 56

Air and Space Defense Corporation
"Almaz-Antey"

REPORT

on the results of studies related to the technical investigation into the crash of the Malaysian airlines Boeing 777-200 9M-MRD (flight MH17)

PART 1

Moscow, 2023

Annex 56

TABLE OF CONTENTS:

PART 1

page

PART 2 Exhibits to the Report

1. Study Objects

1. The materials of the Dutch Safety Board (DSB) investigation report into the crash of the Malaysian airlines Boeing 777-200 9M-MRD (hereinafter referred to as Boeing 777), which crashed on 17 July 2014 during flight MH17 from Amsterdam to Kuala Lumpur, which were obtained with permission from the DSB.

2. The scheme prepared by DSB specialists, which shows how the aircraft fragments are linked to the structural design of Boeing 777,[1] as well as photo and video footage made by Almaz-Antey Corporation specialists and by Rosaviation and Central Research Institute of Air Force experts during inspections of the aircraft fragments at the Gilze-Rijen air base in February, May and August 2015.

3. Design and technical documentation for 9K37M1 SAMS.

4. Final report on the testing of the 9H314M warhead with preformed fragments, 1981.

5. Technical report on verification of the 9H314M warhead's zone of damage parameters, 1981.

6. Warhead 9H314M. Technical reports on control tests by explosion at ground stationary conditions, reports on results of control and periodic tests, 1981-1991.

7. Photo and video footage made during field experiments (31.07.2015 and 07.10.2015) as well as special research concerning the penetration capability of projectiles.

8. Elements of the target layout used in experiments and tests.

9. Samples of projectiles and missile (warhead) fragments collected from the sites of the experiments and recovered from the targets' structural components.

10. Design and technical documentation for the air-route radar complex (ARRC) "Utes-T".

11. Results of Utes-T ARRC tests.

12. Photo and video footage and in-flight recording control data obtained in the course of field experiments and studies to confirm the technical characteristics of the primary radar of Utes-T ARRC located at Ust-Donetsk position at the Rostov Regional Centre of the UATMS (Rostov Region, Russian Federation).

[1] The structural design of the Boeing 777 aircraft was obtained from DSB experts in February 2015 during the first phase of joint work at the place of preliminary layout of fragments.

2. Purpose and objectives of the research

The purpose of the studies was to determine the possible involvement of BUK 9M38 or 9M38M1 missiles in the attack on Boeing 777 and to assess the credibility of the findings of the Dutch experts.

In order to achieve this objective, the following tasks were carried out during the studies:

1. To assess the credibility of the findings of the Dutch experts as regards the weapon type and the conditions under which the Boeing 777 was hit in mid-air.
2. Comparing the damage to the Boeing 777 with the pattern of damage caused by the impact of the 9M38 or 9M38M1 missiles.
3. Identifying conditions under which the impact of 9M38 or 9M38M1 missiles on the Boeing 777 aircraft can cause the destruction of the aircraft in mid-air.
4. Identifying the possible launch area in light of the hypothesis of the Boeing 777 being hit by a 9M38 or 9M38M1 missile.

3. Research conditions

The source data for organising and conducting the research was the Preliminary Report, the Draft Report and the DSB Final Report to the extent related to the type of weapon and the conditions of its encounter with the Boeing 777 aircraft.

In the final version of the DSB Final Report "Crash of Malaysia Airlines Boeing 777-200, 9M-MRD, flight MH17" the Dutch experts concluded that the cause of the MH17 crash was the detonation of a 9H314M warhead delivered by a 9M38-series anti-aircraft missile from a BUK surface-to-air missile system, which was moving "in an opposite direction".

The conclusions about the type of weapon and the alleged location of the missile launch "from the east of Ukraine"[2] were made on the basis of "best matches" based on the results of the analysis of the location, size and boundaries of the damage area, assessment of the number and density of holes in the wreckage of Boeing 777,[3] and identification of the mutual location (conditions of encounter) of the aircraft and the missile.

In the DSB Report, the "best match" refers to the aircraft-missile encounter conditions (angles in the horizontal and vertical planes, final missile speed)[4] corresponding to the version that the aircraft was hit while flying in an "opposite direction" (Figure 3.1).

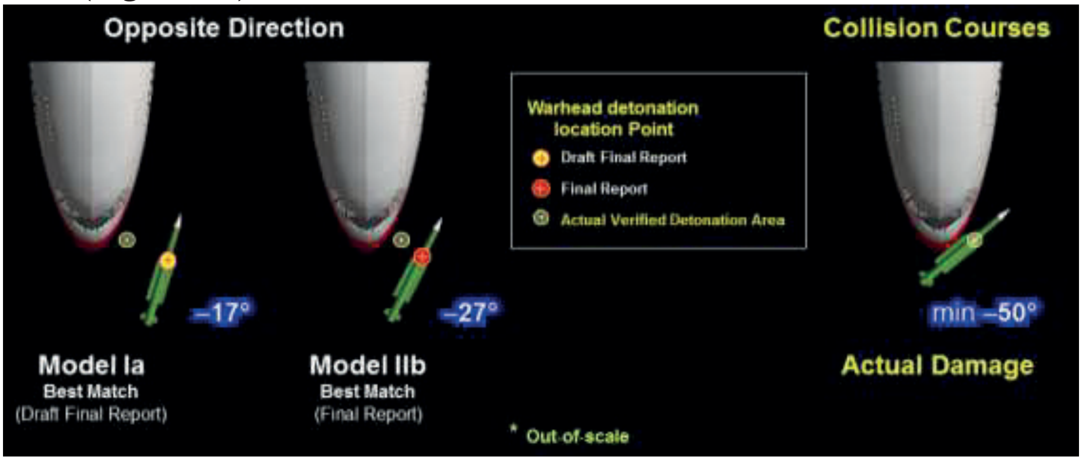


Figure 3.1 - Missile encounter conditions: left - "opposite course" (DSB); right - "collision course"

However, the area of detonation (destruct) of the 9H314M warhead, according to the Dutch experts, "was in a volume of space smaller than 1 m^3, about 4 m above the tip of the nose of the aircraft to the left of the cockpit".[5]

[2] Final Report. 11. Missile flight parts, p.256
[3] Final Report. 6. Fragmentation spray of pre-formed fragments, p.255.
[4] Final Report. 3.8.3. Warhead simulations, p.140.
[5] Final Report. 3.8.5. Volume of space containing the detonation position, p.142.

4. Conclusion

Based on the analysis of the operation of the BUK surface-to-air missile system and 9M38 and 9M38M1 guided missiles; damage to the outer skin, interior and the structure of the Boeing 777; and the results of experiments and special studies by specialists of Almaz-Antey Corporation, the following conclusions were drawn:

1. If the crash of the Boeing 777 was caused by a BUK missile, it could only have happened "on collision courses". The most probable angle of approach of the missile to the aircraft in the horizontal plane could be 72^{+2}_{-10} angle degrees. In such case, the launch area could be the area shown in the presentation[6] at the Almaz-Antey Corporation press conference regarding the results of the full-scale experiment, which was held in October 2015 (Figure 4.1).

Figure 4.1 - Possible launch area: for 9M38M1 missiles (red area); for 9M38 missiles (blue area)

Table 4.1 shows the coordinate values for six points corresponding to the possible launch areas: points 1, 2, 3 and 4 correspond to the possible 9M38M1 launch area; points 3, 4, 5 and 6 correspond to the possible 9M38 launch area.

Table 4.1 - Coordinates of possible launch area

1	47.984290	38.482380	47° 59' 3.444" N	38° 28' 56.568" E
2	47.979410	38.535590	47° 58' 45.876" N	38° 32' 8.124" E
3	47.967230	38.467960	47° 58' 2.028" N	38° 28' 4.656" E
4	47.961720	38.536280	47° 57' 42.192" N	38° 32' 10.608" E
5	47.932970	38.465210	47° 55' 58.692" N	38° 27' 54.756" E
6	47.927220	38.530790	47° 55' 37.992" N	38° 31' 50.844" E

[6] Results of the Field Experiment to Assess the Causes of the Crash of MH17, October 2015.

The study of the materials related to the missile fragments with unique serial numbers, specialists of the Almaz-Antey Corporation found, based on technical documents of the missile manufacturer, that both numbered fragments: the missile engine and the nozzle, were installed in the 9M38 missile (without the "M1" index, that is, an older modification) with the serial technical number "8868720. The missile was given the tail number "9M38 886847379" and on 31 December 1986 it was put into service.[7]

Accordingly, the most likely launch area for the 9M38 missile is limited by points 3, 4, 5 and 6 with their respective coordinates.

2. A missile from a BUK complex cannot approach an aircraft "on a collision course" from any of the three areas[8,9,10] identified by experts of the Netherlands Aerospace Centre (NLR). This is confirmed by calculations made with the use of the software of the BUK missile control system previously provided to Dutch experts in response to their request for legal assistance.

3. The area of the missile launch from the side of Snezhnoye and Pervomayskiy towns (Donetsk Region, Ukraine), i.e. "in the opposite direction", is not confirmed by the in-flight control data recorded by the Utes-T radar complex located at the Ust-Donetsk radar position. In the primary data registration file "14-07-17.kt" of the Utes-T radar complex for the period from 13:02 to 13:32 UTC 17.07.2014, no markings from a weapon are registered, which indicates the absence of an object moving towards the Boeing 777 in "the opposite direction" in the observation space.

4. As a result of experiments, tests and special research carried out by Corporation, the credibility of the conclusion of the DSB report "Crash of Malaysia Airlines Boeing 777-200, 9M-MRD, flight MH17" about the aircraft being hit by a 9M38-series anti-aircraft missile with a 9H314M warhead "on the opposite course" is not confirmed.

5. The lack of complete objective data from metallurgical examinations and the mismatch between the weight and dimension characteristics of the fragments specified in the materials of the Dutch experts and the reference samples obtained during the tests do not allow for unequivocal identification of the type of projectiles or for reliably determining the type of warhead and weapon.

6. If other conditions of the missile aircraft encounter ("on an opposite course") are considered, the BUK missile could not have caused the crash of the Boeing 777.

The main points of this report are set out in official letter to the DSB No. 01-09/548k dated 29.07.2015.

Subsequently, the field experiments, tests and special studies confirmed the

[7] PART 2. Exhibit E. Fragments of the 9M38 missile.

[8] **250** km^2. Draft Final Report. 3.8 Launch area. Figure 47. Area of missile launch (Source NLR), p.132.

[9] **320** km^2. Final Report. Visualisation of NLR fly out simulation result. Figure 62, p.144.

[10] **75** km^2. More precise launch area identified by NLR specialists. Its image is available in open-source materials.

conclusions set forth in this letter and defined the most likely type of the missile more accurately.

5.3.2. Possible launch area

5.3.2.1 Calculation to identify the possible launch area

The inputs for calculating the possible launch area are the conditions of the aircraft-missile encounter - their relative position in space[126] and the final velocity of the missile at the time of detonation.

The position in space of the missile relative to the aircraft:

in the horizontal plane – 72^{+2}_{-10} deg;

in the vertical plane – 22^{+4}_{-3} deg.

The missile's final velocity range, corresponding to the "cross-course" rendezvous conditions, is 620 to 730 m/s.

The launch area, which was calculated in October 2015, even before the identification of the missile model, was shown in a presentation at the Almaz-Antey Corporation press conference.[127] This launch area, calculated for two types of missiles, is shown in Figure 5.3.3.

Figure 5.3.3 - Possible launch area: for 9M38M1 missiles (red area); for 9M38 missiles (blue area)

The coordinates corresponding to a possible missile launch area are given in Table 5.3.1.

Table 5.3.1 - Coordinates of possible launch area

1	47.984290	38.482380	47° 59' 3.444" N	38° 28' 56.568" E
2	47.979410	38.535590	47° 58' 45.876" N	38° 32' 8.124" E
3	47.967230	38.467960	47° 58' 2.028" N	38° 28' 4.656" E
4	47.961720	38.536280	47° 57' 42.192" N	38° 32' 10.608" E
5	47.932970	38.465210	47° 55' 58.692" N	38° 27' 54.756" E
6	47.927220	38.530790	47° 55' 37.992" N	38° 31' 50.844" E

[126] Taking into account drift angles, attack angles and associated magnetic declination.

[127] "Results of a field experiment to assess the causes of the crash of MH17", October 2015.

By examining the materials relating to the rocket fragments recovered, which have unique serial numbers, the serial number of the item in which the fragments were found was established.

This product is an older modification of the missile, the 9M38, produced in late 1986.[128] Without the "M1" index, which can definitely be confirmed by relevant technical documentation.

Accordingly, the most likely launch area for the 9M38 missile is limited to points 3, 4, 5 and 6 with their respective coordinates.

5.3.2.2. Comparative analysis of calculations to identify the possible launch area

A comparison will be made for variants of the launch area calculation carried out by Dutch experts.

Missile flight model and estimated launch area NLR

During the DSB technical investigation, calculations of the possible launch area were carried out by experts from the Netherlands National Laboratory for Aeronautics and Space Research (NLR).[129, 130]

There is no detailed description of the flight models of the NLR missile in the DSB report materials, but it is stated that the Dutch specialists took into account the peculiarities of the guidance method of the BUK missiles. Therefore, the validity of the model can only be assessed from the results obtained.

The initial modelling carried out by NLR was announced during a joint team effort in Gilze-Rijen (Kingdom of the Netherlands) in February 2015.

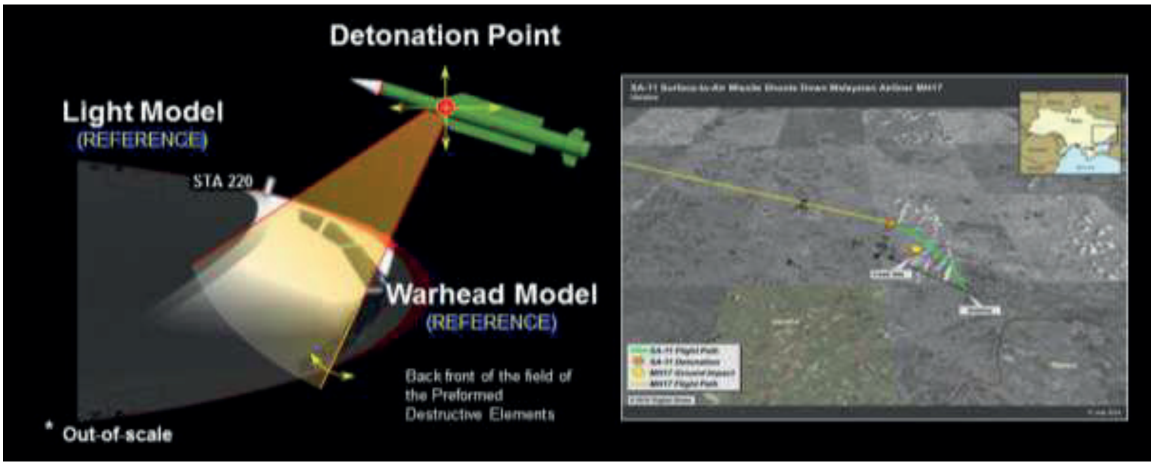


Figure 5.3.4 - Model Ia - First "Best Match" option (NLR, February 2015)

In NLR's first version (Model Ia), all three "Best Match" components were matched so well that an exact "almost pixel-for-pixel" match was obtained for the

[128] PART 2: Exhibit E: Fragments of the 9M38 missile.
[129] As follows from the caption to Figure 47 of the Draft DSB Final Report (Figure 47, p.132).
[130] As follows from the caption to figure 62 of the DSB report (Final Report. Figure 62, p.144).

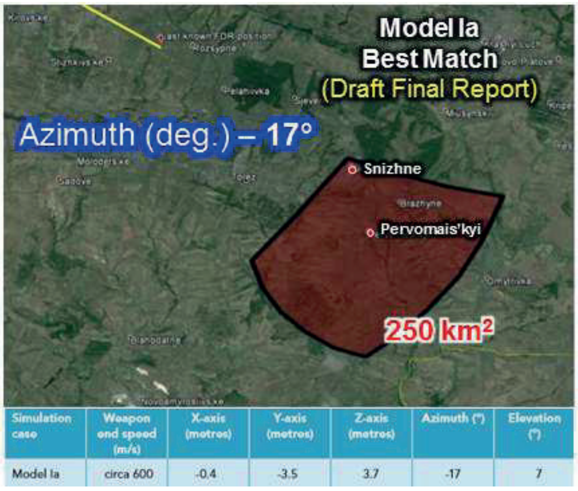
figure published on the Ukrainian embassy website (Figure 5.3.4).[131]

As a result of the resulting matching of the selected parameters with the original "Best Match" version, the NLR experts calculated the first version of the possible missile launch area. This 250 km area in the Draft Final Report was shown in Figure 47, page 132.

After abandoning the original "benchmark" warhead and detonation point, a second possible missile launch area was calculated by NLR experts on the basis of the new "Best Match" version, which formed the basis of the findings of the DSB Report on the possible missile launch area "from eastern Ukraine".[132]

This 320 km^2 area was represented in the DSB (Final Report) by Figure 62 (page 144)[133], and the conclusions drawn from it are presented on page 256.

The new location of the possible launch area has some differences from the one given in the Draft Report. For comparison, both variants of the possible missile launch area calculations are shown in Figure 5.3.5.



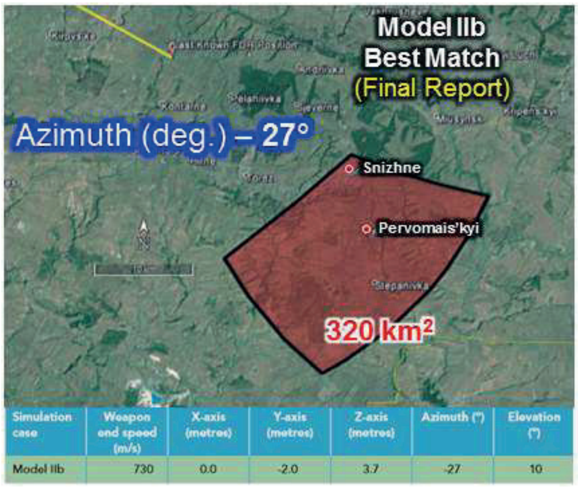


Figure 5.3.5 - Calculated missile launch areas by NLR experts for two different "Best Match" variants at 250 and 320 km

The comparison results show that the main difference between the two calculations is the significant increase, of more than 25%, in the area of this range from 250 to 320 km^2, which contradicts the technical characteristics of the BUK missiles. Moreover, compared to the initial calculations (February 2015), the NLR specialists had an opportunity to refine their "Missile Flight Model" using data provided in May-August 2015 by Ukrainian specialists and specialists of the Almaz-Antey Corporation.

[131] The inconsistency of all three "Best Match" components underlying the findings of the DSB Report is given in Exhibit G.1. (PART 2. Exhibit G.1)
[132] Final Report. 11. Missile flight parts, p.256.
[133] Visualisation of NLR fly out simulation results.

For example, the model demonstrated by Ukrainian specialists in August 2015 determined the launch area (less than 10 square kilometres) and the amount of allowable error in the missile approach angles in the horizontal plane within ±2.5°.[134]

According to the data provided by the specialists of Almaz-Antey Corporation, errors in approach angles when aiming the missile at a non-maneuvering aerodynamic target in the horizontal plane under specified conditions and normal autopilot operation amount to ±4-6°.

The second important feature of the second version of NLR's calculations is that by changing the position of the missile axis relative to the aircraft in the horizontal plane in the second version of Best Match by 10 degrees (from -17° to -27°), the right upper bound of the calculated area has not changed. It again includes Snizhne, even though the probability of launching from this point is close to zero, given the parameters presented by the NLR in the new Best Match.

The retention of Snezhnoye as part of the "possible launch area" when the conditions of the missile's encounter with an aircraft change significantly (more than 18°)[135,136] contradicts the claims made in the NLR material about the way this area is determined by the final conditions of the missile's orientation at the moment of detonation (due to the use of the proportional navigation method).[137, 138, 139]

Figure 5.3.6 - "Refined Possible Launch Area" presented in the new NLR report has shifted north. "Best Match" value from Final Report

---

[134] Results of examination of causes of MH17 crash over the territory of Ukraine 17.07.2014. 10-12.08.2015, Gilze.

[135] In the second Best Match variant, the angle of intersection of the aircraft and missile axes in the horizontal plane increased by 10 degrees: from -17 to -27.

[136] Taking into account the actual relative position in space of the aircraft and missile due to local magnetic declination (minimum 4 degrees) and the overestimated final velocity of the missile (an additional minimum 4 degrees.

[137] Draft Final Report. 3.4.9 BUK surface to air weapon system, p.114; 5.4.4 BUK missile, (NLR Appendix), p.319.

[138] NLR report (Appendix X). 6.6 BUK missile, p.46-47.

[139] Final Report. BUK operating characteristics, p.134.

-27° with a tolerance of ±5° does not fall within the new "refined launch area"

As a result of the calculation of the "refined probable launch area" in the new NLR report, a new 75 km^2 area is shown, the main feature of which is that the boundaries of the calculated launch area have shifted significantly northwards (Figure 5.3.6), compared to the Final Report. [140]

Accordingly, the results obtained are radically different from those of the final DSB Report: the range of angles of direction to the "Last recorded FDR position" from the new "clarified area" is about 34° (-5° ±17°),[141] that is in the range from "plus" 12° to "minus" 22° (instead of the range from "minus" 35° to "minus" 17° Final Report). This directly contradicts the results previously obtained by the Dutch experts during the technical investigation and reflected in the Final Report,[142] including the results obtained directly by the NLR experts.[143]

The new calculated area not only does not match the conclusions of the DSB "best fit" report obtained for -27° conditions,[144] but even taking into account errors of ±5 degree excludes these conditions (see Figure 5.3.6), i.e. **directly contradicts the results obtained in** the DSB-led technical investigation.

Thus, during the technical investigation, NLR specialists carried out calculations of the "likely launch area" three times using different models. The main feature of these calculations was that, despite changing the parameters of the warhead model, damage model, detonation point areas, and missile flight models, the calculated area always "included the town of Snizhne. In all cases, the "matching" was done by fitting the parameters of the warhead, damage model, and detonation region, as well as by fitting the parameters in the missile flight model.

Alternate calculated launch area

As shown in Exhibits E and G.3,[145] the most reliable from the range of initial conditions of the technical investigation documents is a horizontal angle of the missile crossing the longitudinal axis of the aircraft of at least -50°.

The results show that when using "missile end state" input data (aircraft-missile encounter conditions), no contradicting the actual damage, the version of a launch from the area of Snezhnoye and Pervomayskoye settlements **is not confirmed**.

[140] An image of the new area is freely available (in open-source materials)

[141] These values are obtained for the angles of intersection of the aircraft course line projection on the map taking into account the real position of the aircraft longitudinal axis in space, i.e. taking into account the local magnetic declination and the drift angle

[142] Final Report. 3.8.3 Warhead simulation, p.140.

[143] NLR report (Appendix X). 6.17 Matching modelled and observed fragmentation damage, p.56.

[144] Final Report, p.140.

[145] PART 2: Exhibit F, Exhibit G.3.

Using the baseline not contradicting the actual damage to the Boeing 777 from fragmentation and high-explosive effects, and using the characteristics of the BUK missiles from the technical documentation, **the version of** a BUK missile launched from the area of Snezhnoye and Pervomaisky settlements **is not confirmed**.

5.4 Identification of weapon

As a result of the investigation of the combat damage on the Boeing 777 fragments, it was established that the aircraft was hit by a remote-controlled high-explosive warhead loaded with ready-to-use high-explosive fragments. The warhead exploded no more than 1.6-2.0 metres from the window of the cockpit on the left side.

The number of damage of all types from prefabricated and hulled destructioners is:

on fragments of the outer skin of the nose section of a Boeing 777 installed in a 3D reconstruction of about 350;[146]

there are about 60 holes in the airframe elements, the position of which can be established with a high degree of accuracy;

more than 120 fragmentation injuries on the cockpit floor, interior and transverse structural elements of the cockpit floor;

The "inside-out" portside exit holes (punctures and non-pitch damage) are concentrated below the second portside window and distributed further along the portside;[147]

The left wing and left engine have combined fragmentation damage, which includes through holes from prefabricated projectiles up to 14 mm in size.

Most of the high-energy objects that struck the aircraft moved predominantly along the longitudinal axis of the aircraft or at slight angles to it. The highest density of damage to the outer skin and the structure was recorded in the area of the windshield and the vent on the left side of the cockpit, and further along the port side and the upper left part of the aircraft roof. This is confirmed by the mutual location of fragments of the outer skin, the structure and the cockpit floor with maximum damage densities on the 3 D-reconstruction. Damage to the cockpit floor is concentrated along the port side, while damage to the power structure (bends) - on the left side of the roof and on the port side - is spread further than the outer skin damage.

In accordance with the missile manufacturer's technical documents (DNPP), it was established that both numbered fragments: the engine part marked "9D1318869032" and the nozzle part marked "9D131.05.000 No. 8.30.113" were installed in the 9M38 missile (without the "M1" index, i.e. an older modification) with the factory technical number "8868720".

[146] There are no "inside-out" exit punctures on the starboard side of the Boeing 777.

[147] About 70 more holes have been accounted for by Almaz-Antey specialists in the fragments that were not represented in the final 3D rendering.

The analysis showed that **the 9M38 missile** of the BUK system **could only be the cause of the** destruction of the aircraft in mid-air if it **encountered the aicraft** "**on a collision course**".

This is confirmed by the actual boundaries of the fragmentation area, the direction of damage, the shape, number and density distribution of the holes to the outer skin, structure, floor and internal equipment of the cockpit, as well as the characteristics of the 9H314M warhead impact field confirmed experimentally.

When considering the conditions of the aircraft missile encounter "on an opposite course", the 9M38 missile could not be the cause of the crash of the Boeing 777. In this case, the nature of the damage to the starboard side and the structure does not correspond to the most important characteristics of the impact field - the density of the fragmentation field and the penetration effect of the flow of preformed projectiles produced by the detonation of the BUK warhead, and the location of the detonation point area contradicts the non-contact fuse algorithm.

In the "opposite direction" version, the aircraft was hit by another unidentified weapon with a high-explosive fragmentation warhead loaded with preformed fragments of one or two fractions.

6. Analysis of the results obtained

As a result of the research including calculations and modelling confirmed by a series of full-scale experiments and tests, specialists of Almaz-Antey Corporation have confirmed their conclusions, which were first announced in May 2015 during a meeting at Gilze-Rijen Air Base.

The essence of these conclusions is as follows:

1. If the crash of the Boeing 777 was caused by a BUK missile, it could only have happened "on a collision course" and it could only have been an older version of the missile, the 9M38.

2. Based on the results of the analysis of the full-scale experiment carried out under the conditions in the findings of the Dutch experts, the results of special studies of the penetration capability of projectiles, assessment of the damage to the outer skin, internal equipment and the structure of the Boeing 777, and the full-scale experiments involving the Utes-T ARRC, it was established that the DSB findings that the aircraft was hit by a 9M38M1 missile flying "in an opposite direction" were not confirmed.

3. If the Boeing 777 had been hit by a BUK missile with a 9H314M warhead "on an opposite direction", the damage pattern would have been radically different – the number and density of holes in the outer skin would have been 2-3 times greater than what is actually observed. The structure of the aircraft would have been penetrated through from the starboard side, and the outer skin of the cockpit would have many holes with a "butterfly" shape which is characteristic of "bowtie shaped" projectiles.[148]

4. Calculations and experiments[149] proved that taking into account the detonation point area corresponding to the actual damage to the Boeing 777 and considering all the basic characteristics of the 9H314M warhead damage area, the version about the impact of BUK missiles can only be considered under the missile aircraft encounter conditions where the missile crosses the aircraft course in the horizontal plane with angles 72^{+2}_{-10} degrees.

5. The methodologies used by the Almaz-Antey Corporation specialists to calculate the missile launch areas are largely the same as those used by independent specialists. When the same source data are used, the calculation results for the main parameters are the same.

By making necessary adjustments to the source data for the aircraft damage model (fragments with a high density of damage) taking into account the fragmentation field boundary and the actual position of the aircraft in space (taking into account local magnetic declination), the possible launch area calculated according to the methodology of independent specialists will shift to the west, which

[148] Experiment in a combined target layout conducted on 07.10.2015.

[149] Shielded target experiment conducted on 31.07.2015.

is closer to the results of Almaz-Antey specialists' calculations.

Thus, the studies using adjusted source data in the models do not support the version of a missile launch from the area of Snezhnoye and Pervomaysky settlements.

6. BUK missiles launched from any of the three areas[150, 151, 152] determined by calculations of specialists from the "Netherlands Air and Space Centre" (NLR) cannot approach an aircraft under actual encounter conditions that can explain the damage to the outer skin and airframe which is objectively observed in the airliner's fragments. This is confirmed by calculations made by the 9M38 and 9M38M1 missile (including the non-contact fuse) control system software and in-flight control data recorded by Utes-T ARRC.

7. The lack of complete objective data from metallurgical examinations and the and the mismatch between the weight and dimension characteristics of the fragments specified in the materials of the Dutch experts and the reference samples obtained during the tests do not allow for unequivocal identification of the type of warhead and weapon. This does not exclude the possibility that the aircraft was also hit by another, unspecified, weapon.

[150] **250** km^2. Draft Final Report. 3.8 Launch area. Figure 47. Area of missile launch (Source NLR), p.132.
[151] **320** km^2. Final Report. Visualisation of NLR fly out simulation result. Figure 62, p.144.
[152] **75** km^2. A new area, images of which have been published in the public domain.