

Adv OME Assignment - Mariupol Theatre

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Submission date: 30-Apr-2026 08:36PM (UTC+0100)

Submission ID: 281736422

File name: 42755_Tom_Appleby_Adv_OME_Assignment_-_Mariupol_Theatre_710853_165594944.docx (4.32M)

Word count: 2993

Character count: 16312

Scientific Principles of OME Report – Mariupol Theatre

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1.0 Introduction (250)

The report will analyse and conclude why the Mariupol Drama Theatre was attacked, allegedly by the Russian federation on 16th March 2022 at 10:00am and the significance of the attack during the early stages of the Ukraine-Russian war (2022 to Present). The Mariupol Drama Theatre served as one of the city's largest air-raid shelter / aid station during the early weeks of the Russian invasion. Despite the word 'DETI' (Children in Russian) in large white letters being written on the pavement outside to signal its civilian status.

The report investigates and will calculate the Net Explosive Quantity (NEQ) of the munitions used as well as blast overpressure calculations to explain some of the damage caused to the building. Using the information garnered from the calculations the report will go into determining what munition could have been used during the attack. For this report, the author has been told to assume that the aircraft used to undertake the attack is a Flanker type aircraft. This was provided in the assignment brief given by the lecturer.

2.0 Background Context (1000)

2.1 Mariupol

In the Donetsk region in Southeast Ukraine, near the Russia Ukraine border sits the city of Mariupol which is a coastal city in the Taganrog Gulf on the edge of the Sea of Azov. At the time of the attack the city had a population of around 425,500 people and was a key trade hub as well as a centre for a lot of higher education in the region.



Figure 1 - Mariupol Drama Theatre before the attack



Figure 2 - Mariupol Drama Theatre after the attack

2.2 Theatre

One of the key locations during the assault of Mariupol was the Donetsk Regional Drama Theatre. It was a big auditorium, able to seat about 800 people with another 50 in the drama company. The theatre was also used as a teaching facility. During the attack, an estimated 600 – 1200 [1] local residents were sheltering in the theatre basements with their children [9].

As the Theatre was being used as an aid station and a refugee camp, they had written the word 'children' in Russian on the tarmac either side of the building in the hope that it would act as a deterrent to Russian attack.

The attack happened on Wednesday 16th March 2022. Survivors and witnesses reported hearing a bomb blast. One of the witnesses, Grigoriy Goloviov, was interviewed by Amnesty International and was quoted as saying "I was walking down the street leading to the drama theatre... I could hear the noise of a plane... but at that time I didn't really pay attention because [planes] were constantly flying around... I saw the roof of the building explode... It jumped 20 metres and then collapsed... then I saw a lot of smoke and rubble... I couldn't believe my eyes because the theatre was a sanctuary. There were two big 'children' signs." [10], Another quote from a civilian nearby to the theatre at the time of the attacks talks of seeing missiles launched from a plane towards the theatre.

2.3 Russian Air Base

Based on the information provided by the lecturer, that a flanker type aircraft was the likely delivery vehicle of the ordnance, then the likely air base that they were launched from would be Kushchyovska Air Base which is located 165km away from the theatre. The base is home to the Supreme Command of the Russian Federation Air Force and has an array of aircraft situated there, some of these aircraft include a number of different

variations of the Su-27 type aircraft all of which falling under the NATO designation 'Flanker' [6]. Mariupol is easily within the range of these aircraft which are quoted as having a combat radius of 810 nmi (1,500 km) to 915 nmi (1,700 km) depending on altitude; they travel at a speed up to 2.35 mach (1,555 mph). [5]

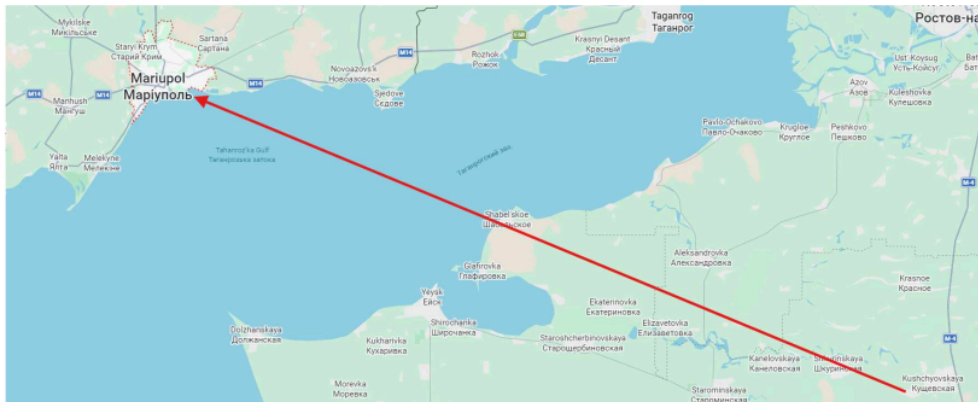


Figure 3 - Map between Kushchyovska Air Base and Mariupol



Figure 4 - Satellite view of Kushchyovska Air Base

2.4 Type of attack

As discussed in the previous section the likely aircraft that carried out the attack was a Su-27 Flanker, flying out Kushchyovska. These aircraft have the ability to carry a range of different ordnance which will be discussed later in this report. They also have the ability to carry out these attacks from a range of different altitudes.

Several eye witnesses are quoted as saying they noticed a plane fly over prior to the attack on the theatre, this implies that the attack may have been conducted as a low altitude attack as if the planes were conducting a high altitude attack (+16,000 ft) then the witnesses would not be able to notice the planes before. If the attack was carried out at low altitude it is likely that an unguided bomb would be used, this could be due to the cost of an unguided bomb being much less than that of a guided bomb. If this is the case,

then the claim by the Russian Federation that this was an accidental strike can be refuted.



Figure 5 - Su-27 'Flanker' Aircraft

2.5 Impact Location

Forensic Investigators including those from Amnesty International and the Center for Spatial Technologies (CST) used 3D modelling and architectural forensics to determine the epicentre of the blast.

The absence of a large impact crater in the ground beneath the theatre suggests the munition did not detonate on contact with the floor. Instead, the debris dispersion patterns indicate that an air burst occurred between the ceiling of the theatre and the floor, likely triggered by a time delay fuze. The roof was pushed upwards and outwards before collapsing and the stage area suffered intense thermal and kinetic damage. This indicates that the warhead penetrated the roof and detonated inside the auditorium space to maximise overpressure.

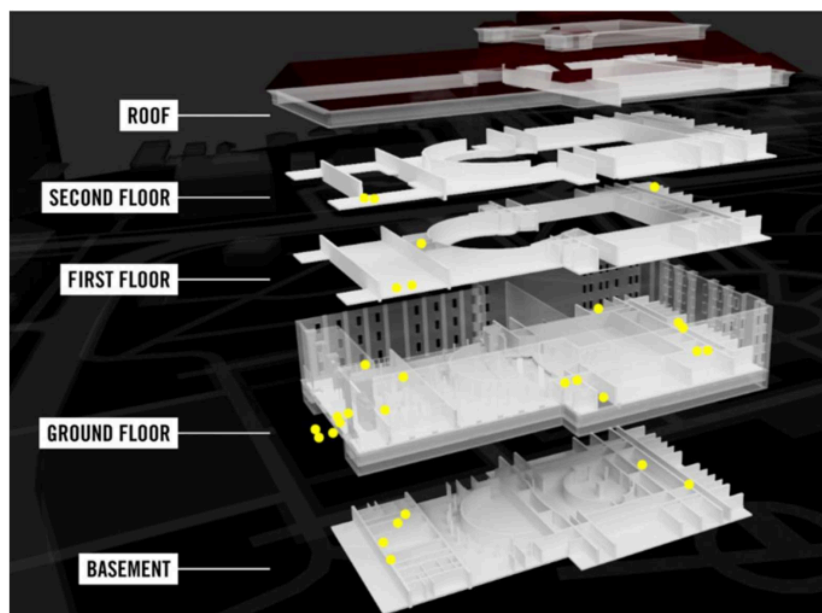


Figure 6 - Floor model of Mariupol Drama Theatre



Figure 7 - Mariupol Drama Theatre auditorium after the attack

2.6 Elimination of Alternative Theories

To maintain a technical integrity, we must address and disprove other possible causes:

- 1) **Internal Sabotage (Russian Claim):** Russia claimed the Azov Regiment blew up the building from inside. Forensic analysis refutes this; the debris was scattered outwards from the roof and upper walls, which is consistent with a heavy object falling from above and detonating inside the building rather than a ground up demolition which would have left a different structural footprint [1].
- 2) **Thermobaric Weapons (TOS-1A):** While highly destructive, thermobaric weapons produce a distinct vacuum effect and long duration heat. The Mariupol Theatre showed more classic shattering (brisance) and fragmentation damage typical of high explosive blast warheads.
- 3) **Artillery Rockets:** This is not a common belief amongst both Ukrainian witnesses and industry experts.
- 4) **Cruise Missile:** Although Russian Federation soldiers were fighting in the area, it is against guidelines for such weapons to be used in these circumstances [2].
- 5) **Fragmenting Warheads:** As the aim of the attack seems to be the total destruction of the building a fragmenting warhead would be an unlikely choice. Fragmenting warheads can require up to 50% explosive output in order to break apart the ordnance casing. Whereas a blast warhead with a thin-walled casing would have a greater relative to explosive mass.

3.0 Munition Used

3.1 NEQ Calculations (250)

Kingery-Bulmash is named after Charles Kingery and Gerald Bulmash, the scientists who developed the equation on blast overpressure and how it can be derived from the mass of the charge of an explosive. The equation is a way of comparing different explosive output and how they perform after detonation. Blast overpressure is the wave of pressure created by the expansion of gas from an explosive under detonation.

The bare mass charge is the amount of explosive within a system. In order to determine the potential munition used in this case it is necessary to use the equation to work backwards to reverse engineer the results. The area of where the blast had an effect is known thanks to imaging post attack.

In order to work out what the potential munition could be, first one must determine the size of the charge that would be required to cause the damage that was seen in the attacks on Mariupol Theatre. To enable us to work out the Net Explosive Quantity (NEQ) the bare mass charge must be calculated. The equation for this can be seen below in [16].

$$W_b = 1.19 \left(\frac{1 + M_r(1 - M_c)}{1 + M_r} \right) c$$

Equation 1 - Kingery-Bulmash Equation

W_b – Bare Mass Charge

M_r – The ratio of the mass charge to the mass of the case (m/c)

C – mass of the charge

M – mass of the case

M_c – 1 when M_r > 1 and m/c when M_r < 1

Explosive	Density (Kg/m ³)	VoD (m/s)	Gurney (m/s)	TNT Equiv
AMATOL 50/50	1500	6290	2117	0.91
AMATOL 80/20	1550	6570	2212	1.1
ANFO	920	4200	1414	0.74
Comp A-3	1600	8180	2754	1.14
Comp B	1720	7980	2720	1.13
HMX	1890	9110	2800	1.45
HMX/TNT 75/25	1900	8400	2820	1.15
HMX/Wax 95/5	1850	8000	2960	1.13
LX-14	1835	8650	2970	1.25
PBX9404	1840	8800	2900	1.82
PBX9502	1885	7670	2377	1.11
PBXN-109	1700	7480	2560	1.66
PBXW-11	1810	8720	2936	1.6
Pentolite	1660	7520	2531	1.33
RDXTNT 60/40	1750	7500	2800	1.13
RDXTWax 95/5	1800	7900	2950	1.14
Rowanex 3001	1750	8100	3000	1.25
TNT	1700	7000	2600	1
Torpex 9	1900	7400	2492	1.3
Tritonal	1720	6520	2320	0.9
XF-11585 (NTO/RDX)	1730	7300	2290	
XF-12366 (HMX)	1750	7215	2429	
XF-13333 (NTO)	1750	6976	2349	
TGAF-5	1670	7600	2600	1.13

Table 1 - Explosive Data Table

The above table shows the highlighted data for TGAF-5, this explosive is commonly used as the main fill in large Russian Federation bombs. The values for this were taken from a characterisation report of TGAF-5 by M Miszczak [14]. This information is important as it allows the data produced for the report to be representative of what is seen during the attack.

external dimensions

length = 1.093 metre
diameter = 0.400 metre
case thickness = 0.010 metre

Calculate Fragment Velocity and Direction

Point of Initiation

centre face rear

Case

Aluminium

density = 2700 kg/m³

Explosive

TGAF-5

density = 1670 kg/m³

Gurney constant = 2600 m/s
Velocity of Detonation = 7600 m/s

mass of explosive = 207.038 kg
mass of case = 36.162 kg
fragment velocity = 3165 m/s
Taylor angle (front) = 11.8 °
Taylor angle (rear) = 0.0 °
beam angle = 11.8 °

Figure 8 - Charge case calculator

Information on the dimensions of the suggested ordnance were used as the inputs for the calculator. This information can be found from various distributors webpages [12] [13]. The suppliers only advertised the length of the full bomb but in order for the data to be representative the author had to determine the length of the charge. This was done by adjusting the length factor in the calculator until the explosive weight equalled that which was quoted by the distributors.

3.2 Potential Munition Used (500)

Precision vs unguided bombs

In order to surmise which bomb was used in the attack on the theatre it is important to understand the difference between the two and the means in which they are deployed. The precision of a guided bomb needs to be trusted that it will perform reliably and consistently reach its intended target. It needs to be precise and can be fired from a range much further than its unguided counterpart.

An unguided bomb will, therefore, need a much more highly skilled pilot to deploy, as if a specific target is to be hit the reliability of the bomb accuracy is reduced.

Witness statements cite that there was an aeroplane flying low above the city shortly before the explosion. Most of the witnesses' report hearing one explosion, though there were a small number who suggest two bombs may have been dropped. This could be the case, or the 'second explosion' could be put down to an echo, reverberation, or the sound of the building collapsing. If, however, there were two bombs they would have to be

released very carefully, as if they were too close together the blast from the first would have to be placed so as not to detonate the fuze on the second missile. This would make the task of precisely hitting the theatre almost impossible.

The altitude of the planes suggests that the pilot would have to get very close to the target to enable him to reliably hit it. If the bomb(s) were guided there would have been no need for the plane to be flying so low and putting itself at risk of attack.

The fact that the bomb, or bombs, hit and destroyed the theatre would have taken great skill and it leads the author to consider if the theatre was, indeed, the intended target of the attack.

A report by CNN in the New Delhi edition of The Statesman, printed only 4 days before the attack on Mariupol, states that Russia had relied more heavily on “dumb” bombs than its precision guided missiles in the Ukraine War. It reports that recently (to March 2022) Russia had used a combination of missiles, artillery and rocket launchers to pummel major Ukrainian cities. CNN reported that “the number of precision-guided munitions that are being dropped from aircraft... is small”. US officials said that they were unsure as to why Russia wasn’t using more highly sophisticated weapons, but was using more unguided bombs [as in Syria].

They go on to report that Precision-guided munitions, or PGMs, are more expensive, time-consuming and complex to produce than unguided munitions and there has long been speculation that Russia’s supplies were relatively low. It was thought by some that Russia was simply holding its precision guided missiles in reserve for later in the conflict – or as an emergency precaution in case Russia found itself in conflict with NATO.

This would support the theory that it was a “dumb” bomb used in Mariupole.

4.0 Blast Overpressure calculations (500)

If the munition used is assumed to be a FAB-500 unguided bomb, then the data from that can be used to determine the peak pressures produced by the blast. The bomb has a length of 2.47m and is 0.4m wide [12], with case diameter of 10mm [13]. The explosive used as the fill of a FAB-500 is known as TGAF-5, the explosive is made up of a combination of totyl, hexogen, aluminium powder and a stabiliser [14].

TGAF-5 has a relatively low density of around 1670 Kg/m³ when compared to other explosives of a similar velocity of detonation (7600 m/s).

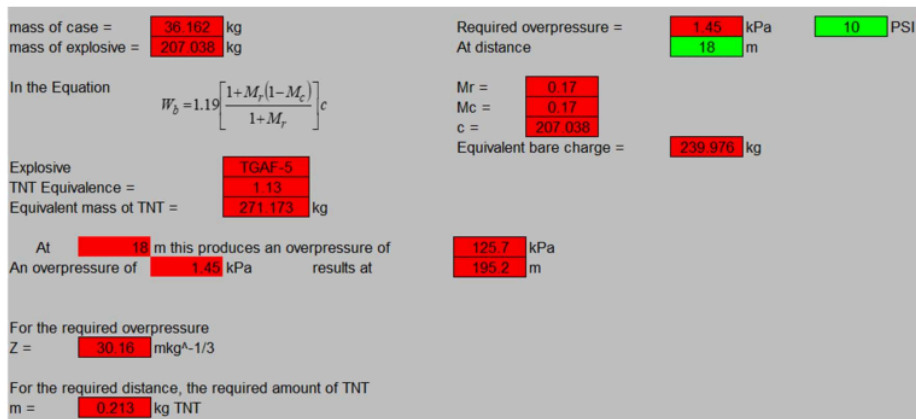


Figure 9 - Blast calculator results

The values gained from the calculator show us that at 10 PSI (overpressure required to demolish the walls of the theatre) and 18m, which was the distance from the centre of the auditorium to the outside wall, that the blast overpressure would be 125.7kPa (18.2 PSI) this means that the overpressure to demolish the walls was over 1.8 times the required overpressure.

5.0 Conclusion (500)

Throughout this report there has been the weighing up of different methods of delivery of the munition and what the munition may be. The data collected and analysed indicates that a Flanker type aircraft most likely set off from Kushchyovska Air Base beyond the Russian border on a mission to bomb the Mariupol Drama Theatre.

The data indicates that the damage may have been caused by the detonation of a singular FAB-500 'dumb' bomb, launched from low altitude. The low flying plane would need to have been very skilfully and accurately flown as the precision from an unguided bomb is much less than that of a guided one. As reported by CNN it was thought at the time that PGM supplies were running low and that Russia were routinely using unguided ordnance[19]. The bomb was released and hit the roof of the theatre before exploding inside, causing an overpressure large enough to lift the roof into the air and to push the walls outwards.

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Adv OME Assignment - Mariupol Theatre

GRADEMARK REPORT

FINAL GRADE

50/100

GENERAL COMMENTS

Hi Tom,

Thank you for the submission. The report was written reasonably well and demonstrated that you have a fair grasp of scientific principles. You argued the case for the munition well, but rather situated the appreciation. Work out the amount of explosive required to generate 10 PSI at 18 metres or so, then apply that to the NEQ's of the munitions. Your M/C calculation was way out, and you chose the wrong casing material. The actual culprit, based on witness testimony and damage is likely a KAB/FAB-500 with guidance, so you should have mentioned CEP and target isolation. It may also have been useful to include statements on why some witnesses thought two bombs, and others thought one. There is a reason why people recall events differently in trauma.

Your scores against the rubric are as follows:

Engagement with literature skills 7/15.

Engagement with a limited range of mostly relevant and credible sources. Some omissions and minor errors.

Knowledge and Understanding 13/25. Knowledge is reasonably detailed, accurate with a good systematic understanding of the field of study and to some extent, current research and scholarship.

Cognitive and Intellectual Skills 10/20. Some critical thinking, analysis, synthesis and evaluation. Can analyse new and/or abstract concepts and data without guidance. An emerging awareness of different

stances and ability to use evidence (that may be incomplete) to support the argument. Mostly valid arguments and logical judgements. Some tendency to assert/state opinion rather than argue on the basis of reason and evidence.

Practical Application 10/20. A good and appropriate application of standard methods, materials, tools and/or techniques. Clear appreciation of the context of the application. Mainly consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose mostly appropriate solutions in complex and unpredictable contexts.

Transferrable Skills 10/20. Can communicate effectively in a suitable format, but may have minor errors. Mostly coherent, organised work, in a suitable structure and is for the most part clearly expressed. Demonstrates the skills required in graduate employment, with some areas of strength and some of minor weakness.

In detail:

1. Good table of contents, which was clearly laid out. Made submission easy to follow and dip back into after reference checking. My only comment relates to List of Figures, then List of Tables, then List of Equations below the TOC.

2. Think of your sentence construction. Last sentence of para 1.0 is not a sentence. There should be something coming after the full stop to finish it off.

3. You have Figure 1 and Figure 2 sat within the text. Where is the cross reference to the caption in the

text to explain why they are there? You must get used to doing this.

4. Where you have mentioned Amnesty International, the reference [10] should come after that. It is this document that includes Goloviov's statement.

5. Your introduction and background is good, providing just sufficient information for the reader.

6. Nice discussion about where the aircraft may have come from, but this would be hearsay. What we need to underpin is the knowledge that aircraft of this type were in operation, were seen in the vicinity, and carried particular payloads.

7. At 2.5, reference for AI and CST after you mention them in the first sentence.

8. You argue the 'suspects' well, discounting some based on your knowledge of SPOME. Well done.

9. For 5) on page 10, a greater relative to 'what' explosive mass?

10. You should have a reference for K&B.

11. I have not seen Table 1 before, well done. Is reference [14] the whole table though, or just for TGAF-5? If so, where did the rest of the table come from? Is it credible?

12. You have approached Figure 8 in a logical fashion, thinking of the cylindrical warhead. However, you have taken the case material to be aluminium, which gives you an erroneous value for M. The M/C will be approaching one for a blast munition, yet you have it at 0.18. This would not be usable given the weight of the explosive. Furthermore, are we immediately assuming what the munition is before we have worked out the NEQ necessary to create 10 PSI at the theatre walls?

13. You are assuming that the munition is a FAB-500. Have you seen the mass of the case for that? The explosive fill is about 207 kg, and the weight of the bomb just under 500 kg in total. Therefore the weight of the case will be in the region of 200 kg (ish). This would then allow you to determine the correct equivalent bare charge mass.

14. Figure 9 carries forward the same incorrect data, but your PSI reading is correct for the overpressure. So, a few errors along the way but you have grasped the principle, jut applied the maths in a different way that needs additional support / validation.

15. Your referencing was 'okay', but please note my comments about where some were needed and how they should be applied.

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