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Munition Identification Trial – Data Capture Critique

A REVIEW OF DATA CAPTURE TECHNIQUES USED

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Abstract

This report reviews the analysis of the results of a munitions identification trial conducted at COTEC in October 2024 and critiques the techniques used to obtain these results. Where weaknesses in the techniques are identified, this report proposes alternative techniques to increase the resolution and/or accuracy of the results.

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1 Introduction

1.1 Background

In October 2024, a Fragmentation Arena Trial was conducted at the Cranfield Ordnance Test and Evaluation Centre (COTEC), with the goal of using the data collected from this trial to identify the munition used. Analysis of the supplied list of potential munitions [1] and the chemical, fragmentation, and pressure data from the trial [2] determined that this munition was an RGD-5 Hand Grenade.



Figure 1: An RGD-5 Hand Grenade, Similar to the one fired at COTEC [3]

1.2 Purpose and Scope

Whilst the data gathered at the trial was sufficient to identify the munition within a reasonable degree of certainty, the limited amount of data gathered overall does present some uncertainty. For this reason, it is necessary to consider how this data collection could be improved. This report will identify areas of potential improvement in each data collection method used, and propose solutions to them, as well as proposing additional data capture methods which could increase the total amount and variety of data gathered.

2 Chemical Analysis

2.1 On the Trial

No in-situ chemical analysis or detection equipment was deployed to the trial, however fragments were collected from the trials site to attempt to extract traces of explosive residue for analysis in the laboratory.

2.2 Laboratory Analysis

Once the fragments had been received in the laboratory, half of them were washed in Acetone, and Half were washed in Isopropyl Alcohol. The samples were then analysed by Fourier Transfer Infrared Spectroscopy (FTIR). This is an analytical technique in which infrared light is shone onto a sample, and the bonds inside the sample molecules absorb specific wavelengths of this light. When the light is then reflected onto a detector, a spectrum is produced showing the percentage of each wavelength that was reflected [4]. Any molecule detectable by FTIR possesses a unique spectrum which can be compared to a library of spectra, or data on which bonds correspond to which wavelengths. In this trial, TNT was detected in the acetone solution only, indicating that the munition detonated was filled only with TNT. FTIR is a relatively sensitive technique, with the limit of detection being estimated as between 0.12 and 0.16mg/mL [5]. However, considering that the munition was using commercially manufactured explosives, which are likely to have been almost fully consumed on detonation, it is possible that other explosives were present but at quantities below the LoD of the FTIR. Therefore, to improve this analysis, it would be necessary to use a more sensitive technique.

2.3 In-Situ Proposal

The detection of trace explosives in-situ is an area of interest in both military and civilian research. A common technique used in both Airport Security and Military Search is Ion Mobility Spectrometry (IMS). IMS works by measuring the movement of ions in gases under an electric field. A typical IMS instrument used by both military and civilian users is the Ionscan 600. This instrument can detect a variety of explosives including TNT, RDX, TATP and HMX with an analysis time of less than ten seconds [6]. Because of the risks associated with publishing this information, the limits of detection of Explosive Trace Detectors is not published, typically being either classified, or manufacturer proprietary information. Despite this, it is assumed that a dedicated trace detection system such as the Ionscan 600 would have a better limit of detection than FTIR, which would allow more accurate and reliable detection of the trace explosive on the fragments before they were even transferred to the lab.

2.4 Laboratory Proposal

To support the results of an on-site explosive trace detector, more analysis could be conducted in the laboratory. This report proposes the use of Ultra-High Pressure Liquid Chromatography-Mass Spectrometry and/or Gas Chromatography-Mass Spectrometry. These are both hyphenated techniques in which samples are separated into their components in the chromatography instrument, before being ionised and detected in the Mass Spectrometer. Whilst limited literature exists on the limits of detection of explosives for these instruments, studies suggest that target molecules can be detected at concentrations at least as low as 0.02ng/mL for LC-based techniques [7], and at least as low as 2ng/mL [8]. Whilst this varies greatly depending on the instrument, the target analyte, and the method used, this does indicate that limits of detection several orders of magnitude greater than that of FTIR would be achievable using dedicated trace analysis instruments. If an UHPLC-MS or GC-MS instrument was deployed in the lab alongside an in-situ system deployed to the trials site, the explosive present in the munition could be determined with significantly greater certainty.

3 Fragmentation

3.1 On The Trial

On the trial, fragmentation velocity was measured using velocity foils. Their method of operation is discussed further in [2], but to summarise, the foils are placed at a known distance from the munition, which can then be divided by the time of arrival to determine the velocity of the fragment. This provides an effective approximation of the fragment velocity, especially at the short distance (1.5m) used in the trial, however it lacks resolution, as it provides only a single data point for each fragment, and in this trial, seemed to underestimate the fragment velocity.

3.2 Post-Trial

After the trial, the fragments were measured and weighed to determine their total and average masses. This allowed the data on the fragments to be compared to the data on the munitions provided in [1] to aid in identifying the munition. The case mass was assumed to be approximately double the total fragment mass as not all of the fragments were directed towards the foils and witness packs. If all of the fragments could be successfully collected, this would improve the measurements of fragment mass and allow for a better understanding of the case shape and mass.

3.3 In-Situ Proposal

To improve the fragment data, two changes could be made to the trials set up itself. The first of these is ensuring that a greater proportion of the fragments are measured and collected. This could be achieved by using a greater number of witness boards placed in a longer arc around the munition. In the image below, it can be seen that the rears of the witness boards are not completely covered, and so it is possible that the highest velocity fragments could fully penetrate the board and not be seen or collected.



Figure 2: The trials team preparing to assemble the arena. Note the blocks do not fully cover the mounting points for the witness boards



Figure 3: The Assembled Arena, note that it only covers a small angle around the munition

Considering this, it is proposed that to improve fragment collection, a larger number of witness boards be used, and that they all be fully backed with a hard surface to ensure high velocity fragments are successfully captured.

To improve the measurement of fragment velocity, it is proposed that additional measurement techniques be used to measure the velocity in addition to the foils. The two techniques proposed were discussed in a series of briefs delivered by COTEC and the Defence Science and Technology Laboratory (Dstl) [9]. The first of these techniques is High-Speed Video. In this technique, a camera recording at extremely high frame rates records the fragment in flight, and given that the fragment covers a known distance, the time taken to cover that distance (derived from the number of frames in which the fragment is visible between two known points) can be used to calculate the velocity at a much higher precision and resolution than velocity foils provide. A similar technique, also discussed in the briefs is Heterodyne Velocimetry, also known as Photon Doppler Velocimetry. This technique uses the doppler effect which occurs as the result of the reflection of electromagnetic radiation off of a moving object to calculate its' velocity relative to the sensor. This technique is similar to the pulse-doppler radars used in aircraft, but typically uses near-infrared radiation. If techniques such as this were used, the velocity of the fragments could be potentially recorded at a much higher resolution from the beginning of their flight until their impact into the witness boards, which would allow for much more accurate comparisons between the experimental data and the predictions given by models and [1].

4 Pressure

4.1 On the Trial

On the trial, three pressure gauges were used. They were placed at distances of 1.003m, 2.036m, and 3.016m from the munition and set up to measure incident overpressure. The sampling interval was 4 microseconds. Overall these gauges produced acceptable data, showing a decrease in overpressure with distance. However, the data was extremely noisy, which resulted in a loss of resolution around the peaks when any kind of smoothing was applied which could affect the results by making the pressures appear significantly lower than they actually were. In addition, the fact that only one set of pressure gauges were used means there is no way to verify the accuracy of the gauges. Therefore, consideration needs to be given to improving the setup of the gauges to increase the resolution and accuracy of the pressure measurements.

4.2 In-Situ Proposals

Given that the primary limitation to pressure measurements was the number of gauges, the simplest method to improve these measurements is to add more gauges at the same distance from the munition but at different angles. Assuming a spherical charge, the overpressure measured at any gauge at a given distance from the munition should be approximately equal to the overpressure measured at another gauge at the same distance but a different angle from the munition. If a larger number of gauges were deployed in this manner, it would be possible to calculate the average incident overpressure at a given distance which would greatly help in reducing the noise present in the results from a single gauge. In addition, multiple results allow anomalous results to be detected and discarded. To further improve the collection of data, additional gauges could also be placed at new distances in addition to the 1, 2, and 3 metres used in this trial, for example 0.5 and/or 4 metres from the munition. In addition, the use of more specialist software, such as an analysis script programmed in a language such as R could improve the processing of the data.

5 Additional Measurements

In addition to improving the measurements already taken in the trial, it is necessary to consider potential additional techniques which could be used to further increase the amount of data available from the trial. The Dstl brief [9] discusses several of these, and their application to this trial is discussed here.

The first of these techniques is the measurement of infrared radiation to determine temperature. This could be used to measure the temperature of both the fireball and the fragments. If this was recorded successfully, it could be used to compare the fireball temperature to that seen in previous trials and explosions to assist in the determination of explosive composition, and the colder fragments would stand out against the fireball allowing their motion to be observed and tracked, albeit at a significantly lower resolution than what would be possible with a high-speed camera.

The second technique that could potentially increase the amount of data collection is Schlieren. This requires a backboard to be placed behind the munition, and an appropriate sensor, but works by recording the difference in density of a medium, thus allowing pressure waves to be effectively visualised. This would help identify the shape of the munition and the behaviour of its blast wave.

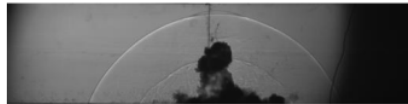


Figure 4: Visualisation of Blast Waves using Schlieren [9]

If additional novel techniques such as these were used, it would enable far more information to be determined about the munition, moving beyond simply identifying it, and into the field of characterisation allowing the munitions performance to be accurately determined.

6 Conclusions

6.1 Technique Overview

In this report, the potential to improve the data collection in a future munitions identification trial was discussed. The original and proposed techniques are summarised in the table below.

Measurement	Techniques used for Trial	Disadvantages	Proposed New Technique	Advantages
Chemical	FTIR	Low limit of detection, not optimised for aqueous traces	On-site trace detection [6] and Chromatographic Methods	Increased Limit of Detection [8] [7] and optimised for trace detection
Fragmentation	Witness Boards and Copper Foils	Low Resolution, High Variance	Increase number of boards and foils, use High-Speed Video	Increased resolution
Pressure	Pressure Gauges	High Noise, Limited Accuracy with one set of gauges	Increase number of gauges used	Increased accuracy, reduced noise
Other	None	N/A	Thermal Imaging and Temperature Measurement, Schlieren [9]	Increase in available information about munition, enables characterisation.

Table 1: An overview of the techniques considered in this study

6.2 Overall Conclusion

It is believed, based on the initial analysis of the trial [2], that the munition used was an RGD-5 grenade. However, the low resolution and limited data points provide a degree of uncertainty such that the conclusion is not certain enough to be considered factual in the case of an operational forensics or exploitation task. If the techniques discussed in this report were applied and used to replace or compliment the techniques used in the original trial, it is likely that the data produced would increase in resolution and accuracy such that the conclusions reached could be put to use with a much higher degree of confidence.

References

- [1] G. Collet, *Types of Munition of Potential Interest*, Swansea: UWTSD, 2024.
- [2] S. G. Blevins, "Munition Identification by means of Trials Data," UWTSD, Swansea, 2024.
- [3] United States Department of Defense, "RGD-5 Russian Anti-Personnel Grenade," ODIN, 2024. [Online]. Available: <https://odin.tradoc.army.mil/WEG/Asset/dbbb3f9bc5636019c9fdcadbb8804add>. [Accessed December 2024].
- [4] ThermoFisher Scientific, "FTIR Academy," Thermo, 2024. [Online]. Available: <https://www.thermofisher.com/uk/en/home/industrial/spectroscopy-elemental-isotope-analysis/molecular-spectroscopy/fourier-transform-infrared-spectroscopy/resources/ftir-spectroscopy-academy.html>. [Accessed December 2024].
- [5] L. Lux, Y. Phal, P.-H. Hsieh and R. Bhargava, "On the Limit of Detection in Infrared Spectroscopic Imaging," *Applied Spectroscopy*, vol. 76, no. 1, pp. 105-117, 2022.
- [6] Smiths Detection, "Ionscan 600 Portable Explosives and Narcotics Trace Detector," Smiths Detection, 2024. [Online]. Available: <https://www.smithsdetection.com/products/ionscan-600/>. [Accessed December 2024].
- [7] G. Zeleke, S. De Baere, S. Suleman and M. Devereese, "Development and Validation of a Reliable UHPLC-MS/MS Method for Simultaneous Quantification of Macrocyclic Lactones in Bovine Plasma," *Molecules*, vol. 27, no. 3, p. 998, 2022.
- [8] P. J. Underwood, G. E. Kananen and E. K. Armitage, "A practical approach to determination of laboratory GC-MS limits of detection," *Journal of Analytical Toxicology*, vol. 21, no. 1, 1997.
- [9] L. Groom and J. Mungham, *Data Capture & Evaluation*, Salisbury: Dstl, 2024.

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GRADEMARK REPORT

FINAL GRADE

72/100

GENERAL COMMENTS

Dear Silas,

This was a well laid out report, which argued the strengths and weakness of the data capture and evaluation techniques used at COTEC. It was clearly Level 6 quality and informs me that you have a strong grasp of this subject matter.

Your use of diagrams was clear throughout and each was appropriately captioned.

I was pleased to see that you thought about the shortfalls in chemical analysis as well as the strawboard trial itself. Yes, there was an under-estimation in velocity from one detonation and your proposals to improve that capture are sound.

Again, I cannot fault your analysis of the improvements in pressure readings that could be conducted.

You can only have one conclusion in a submission like this so the technique overview could have been placed in the discussion section. For your overall conclusion (the conclusion), this is a very sensible outcome. I agree that it may have been an RGD-5 but better resolution in data capture and evaluation needs to be applied. I believe that your proposals do just that.

Well done, you have smashed this module. Only 6008 and Major Project to go! A pleasure as always.

On the 1:1 rubric you scored as follows:

1. Engagement with an extensive range of relevant and credible literature, informed by the latest research. Consistently accurate application of referencing. 7/10

2. Excellent coherent and detailed knowledge and systematic understanding of the principles and theories of current research and scholarship. Clear awareness of challenges to established views and the limitations of the knowledge base. 14/20

3. Excellent critical thinking, analysis, synthesis and evaluation. Ability to investigate contradictory or incomplete information and make strong, persuasive, arguments and sophisticated judgements. Some evidence of independent thought and ability to 'see beyond the question', suggesting a grasp of the broader field and wider concepts. 22/30

4. An advanced application of a range of methods, materials, tools and/or techniques.
The context of the application is well considered, and insightful.
Application and deployment extend beyond established conventions. Can identify complex problems and propose excellent solutions. Innovation and creativity evident. 22/30

5. Can communicate professionally confidently and consistently in a suitable format.
Work is coherent, very fluent and is presented professionally. Can work autonomously with initiative. Where relevant can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations. Demonstrates excellent graduate employment skills and an appetite for further development. 7/10

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