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LAB REPORT ON THE DETERMINATION OF AN UNKNOWN ENERGETIC DEVICE THROUGH TRIAL RESULTS

References. See footnotes and embedded documents section at end of document.

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2. Introduction and Background

The intent of this report is to analyse and propose improvements to the trial conducted at the Cranfield Ordnance Test and Evaluation Centre (COTEC) on the 15th of October 2025 by the student and their peers. The full report of the trial and evaluation of the data was submitted as part of a separate assessment [1]

"The intent of the Trial was to determine the munition involved from the resultant data." "The trial was a mixture between an unplanned event and a planned event as the trial was setup to best capture the information from the blast but the munition was unknown and therefore the trial could not be fully customised" [1]

This report is broken down into a series of sections that closely reflect the different data capturing devices and aspects of the trial. In addition, other methods of capturing data are considered. At each section recommendations are made in how the method could have been applied differently to provide additional data if the trial were re-run.

3. Gauges

The three gauges used on the trial were standard piezoelectric pressure transducer blast gauges such as in Figure 2. The gauges were mounted tangentially in 'spitting' disks that divide the blast wave to ensure an even 'pulse' across the sensor see Figure 1.

The gauges are secured in a rubber 'sleeve' and any metal on metal connections in the setup were additionally dampened by rubber sheet. These rubber components assist in the reduction of ringing from fragment strikes.

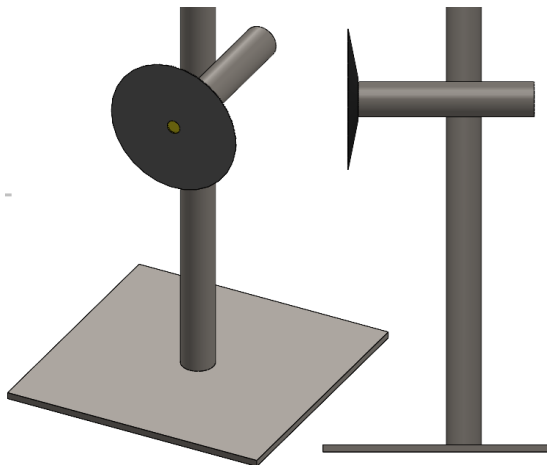


Figure 1 - Blast Gauge, Splitter, and Stand



Figure 2 - M8 Blass Pressure Gauge [2]

The cabling was routed out the rear of the stands and down the pipe to the floor where it was protected with sandbags and I or C channel back to the control box.

During setup, the gauges were assessed to confirm functionality with a simple tap whilst monitoring the output. The gauges were staggered from right to left from the centre of the blast outward. This allowed the face of each gauge to 'see' a clear line to the blast and not be impacted by object reflections.

As expected, the closed gauge (G4) and stand took considerable damage from the fragmentation. Mainly 2 fragment strikes hit the gauge. One causing no internal damage but the other severing the connecting wires rendering the gauge inoperable.



Figure 3 - Gauge 4 Damage

The undamaged gauges produced relevant data once the ringing was removed using a smoothing method. The data showed a clear direct blast wave followed up by the significantly larger reflected blast wave of a magnitude expected for the pipe bomb.

The use of piezoelectric blast gauges is common across munitions testing to evaluate performance, damage characteristics and safety measures required. In this trial the loss of 1/3 gauges significantly limited the results achieved. This could have been prevented by improved protection to the functional parts of the gauge and increased mass in the gauge stand. This would have the additional benefit of reducing fragmentation ringing that was masking much of the pressure data. The stand could also have been isolated from the ground using rubber matting or compressible cardboard. This would likely also reduce the ground shock and ringing.

Lastly an additional series of three gauges could be used these would ideally be placed at 90° to the originals to allow an understanding of the distribution of blast pressure as the munition design may not be rotationally symmetric.

4. Strawboards

Strawboard is a form of calibrated pasteboard that is generally made of low-cellulose paper materials. It is made to sufficient precision (density, thickness, and homogeneity) and packaged together to form packs. This results in a layered product that requires a specific amount of energy to penetrate each layer and thus allows for the calculation of fragment velocity. Strawboard has been used for decades as the primary method of fragment capture in ballistic trials. [3]

In this trial the 8 Strawboards were supported on 4 metal stands and placed 1.4m away from the charge centre arranged in an arc of $\sim 108^\circ$ and seen in the extract Figure 6 - Figure 6 and full trial layout in Annex 1.



Figure 4 - Strawboard Layers



Figure 5 - Strawboard Layout

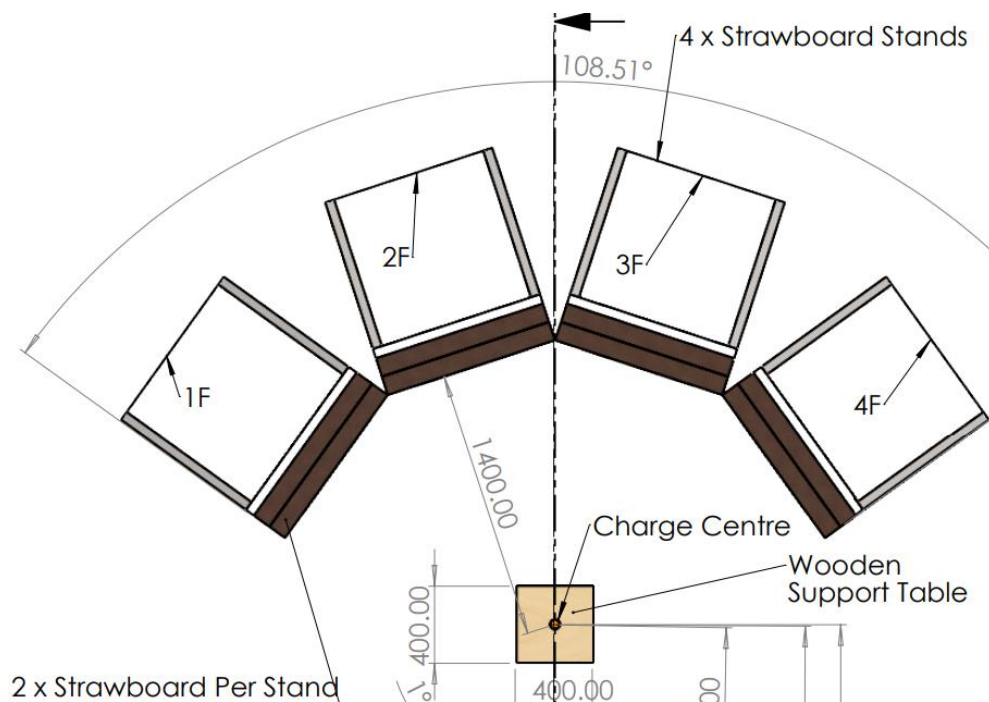


Figure 6 - Strawboard Layout

When intending to capture fragmentation alongside other variables compromise and assumptions must be made to suit the munition at hand. For example, when lot testing the L109 HE hand Grenade used by the UK Military an internal bunker is used to standardise environmental conditions and the grenade is placed in one corner of a square room surrounded by a 90° arc of aluminium plates. This setup is used as the preformed fragmentation created by the grenade is uniform and can be extrapolated from this segment. In addition, the grenade lands on a witness plate to capture the downwards fragments as seen in the image below.



Figure 7 - L109 Witness Plate



Figure 8 - Fragment Board 3F

As the munition was unknown it was not possible to assume a uniform fragmentation pattern. Therefore, the fragmentation observed in the Strawboards could have been misleading. For example, if the munition were a claymore facing the gauges we would have likely observed similar plastic fragmentation pattern in the strawboards but missed the obvious preformed tungsten balls that would not have been captured. Although this is likely not the case as more damage would have been seen on the gauges etc it demonstrates how a strawboard arc of 108° is likely insufficient for this trial. By increasing the number of boards both radially and vertically it would be possible to capture increased fragments.

Although every effort was made to radially align the boards and stands these were likely significantly misaligned from perpendicular to the charge centre. With additional time and measurements this could have been calculated and repositioned to further increase accuracy of placement.

Lastly the most vital piece of information that a strawboard captures is the depth and trajectory of penetration. Due to time limitations, it was not possible on the COTEC trial to individually track and log fragment penetrations as they passed through the boards. Had this been done a wealth of additional data could have been collected for the fragment distribution pattern, mass, velocity, and trajectory.

5. Velocity foils

The velocity foils (VF) also referred to as 'make' or 'break' foils are thin sheets of laminated conductors that are used to sense when a projectile passes through them. To do this they either make or break a connection. When considering conductive fragmentation, a make foil can be used as when the fragment passes through the foil there will be a circuit made and a signal can be received. If the fragments being trailed are nonconductive then break foils must be used. The main disadvantage of break foils is that they can only function for the first fragment as once the circuit is broken it cannot be re made. On the contrary make foils can be 'hit' multiple times as every conducting fragment can form the bridge to create a signal. Make foils will only capture the first couple of strikes due to the foil or signal wires becoming damaged.



Figure 9 - Fragment Test System [4]

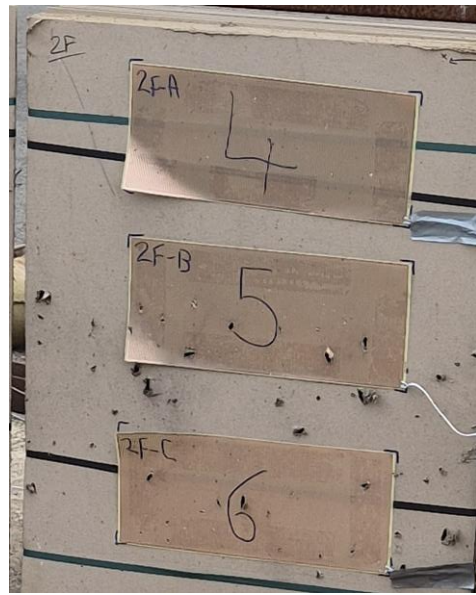


Figure 10 - VF Fragments

When reviewing the VF trial data minimal results were achieved and a substantial proportion of the VF's sensed no impacts despite being obviously impacted. This could have been due to initial impacts being on the conducting wires or fragmentation failing to be of sufficient size to make the connection as they passed through. In addition, whilst the distance from charge centre to the centre of the velocity foil was measured this measurement was largely contaminated with human error. This could be attributed to the estimation of velocity foil centre and charge centre.

To improve this data type additional velocity foils could be placed to provide a more complete coverage of the fragmentation band.

6. Fragment Evaluation

As the fragments were extracted from the strawboards they were assessed for mass, size, and geometry. This information would normally have been collected during the fragment mapping and trajectory calculations from the strawboards.



Figure 11 - Fragments Recovered

Although the fragment external characteristics were analysed additional evaluation could have been performed to assess the composition of the material. It was assumed that this was a steel or similar metal but without further assessment this could not be confirmed. In a conventional trial this assessment would not be required as the munition component materials would be known but could be performed to understand where the fragmentation is being derived from. For example, in a complex munition it would be valuable to understand if the structure of the munition is creating additional fragmentation over the warhead.

The recommendation for this stage would be to use FTIR analysis to chemically analyse the fragments and confirm material. This may require precleaning to remove surface deposits from the blast.

7. Chemical Analysis

Post event forensic swabs were taken of the blast site and surrounding area. These were then soaked in acetone and assessed using an FTIR.



Figure 12 - Forensic Swab [5]

This is an uncommon method on a munitions trial as all materials involved should be known. This would form a critical part of understanding in an unplanned event such as a terrorist attack. Whilst more than twenty swabs were taken of the site only one FTIR spectra resulted due to time constraints. This limited the productiveness of this data.

To better improve this data the precise location of the swabs could be taken and mapped to the overall site. Then post individual evaluation the resultant spectra and discovered compounds could be mapped to their locations for a more in depth understanding of the event.

8. Equipment Protection

As with all explosive trials equipment protection is a vital stage as without proper preparation the explosive will do its job and destroy. This can lead to the loss of expensive and difficult to acquire equipment, loss of data and even lead to the trial failing and having to be repeated. These scenarios are often unacceptable as project timelines and budget must be met.

With more complex trials pieces of equipment such as Flash X-Ray, Cameras, Microphones, Sensors, Fire Pits, Lights and Data Recorders all must be protected.

When considering protection in a trial the threat presented by the munition is the first piece of information required. This allows for appropriate measures to be taken. For example, is a camera required to be protected from a shaped charge jet or simple secondary fragmentation. Or does a sensitive data recorder need protecting from an artillery shell and insulating from ground shock. All these scenarios would greatly impact the level and type of protection. Over protection without limiting ability to capture data is always better to do than less protection.

This trial only involved three types of equipment that needed to be protected. The gauges, cables, and VF controller. The remainder of the articles are designed to be placed in harm's way without issue. Figure 13 below shows the cable protection implemented in the form of I beams and sandbags these physically cover the cables and prevent fragmentation from impacting them.



Figure 13 - Cable Protection

As can be seen in the distance, top left of Figure 13 cable protection extends significantly beyond what would be expected for the danger area of this trial but this information was only available post blast. Looking closer to the gauges it is possible to see the exposed cables which are unideal. Despite the best efforts to protect the gauges the cables were struck losing one gauge.

To improve this trial the gauges could have been better protected with additional metal structure and more mass on the base of the stands. This would have prevented the loss of G4 and reduced ringing.

9. Mapping and Distance Measurements

During the trial setup a Leica 'DISTOlite' laser distance measure and standard tape measure were used to measure the position of items. This provided sufficient information for the purposes of this trial but would not constitute the ideal method. Ideally a 'Total Station' could be used to accurately map the setup and create a digital 3D model. This allows for the detailed recording of positions, angles and aspects that may be missed from a simple measurement survey.

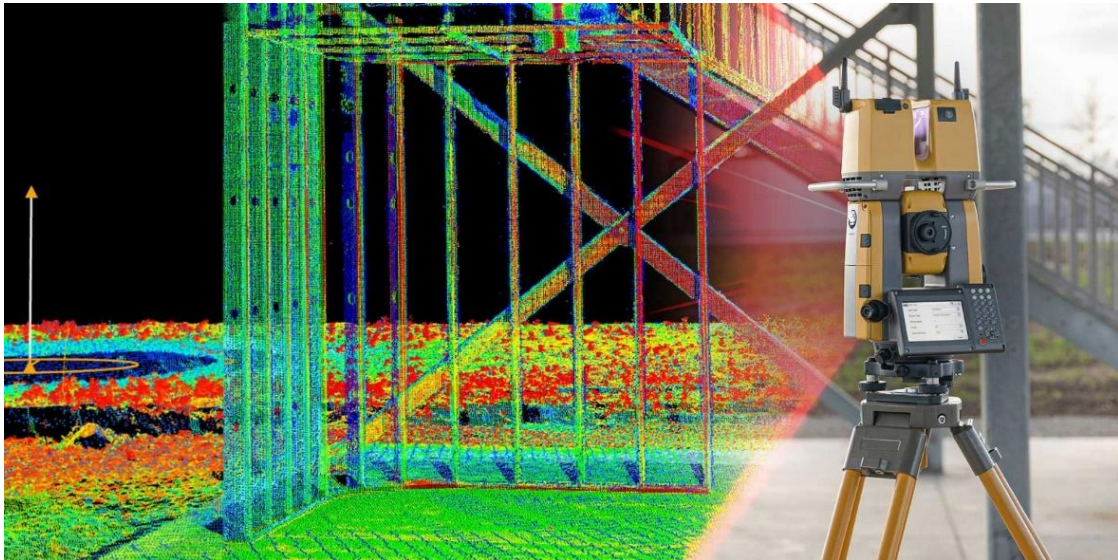


Figure 14 - Total Station [6]

The 3D mapping of the pre and post blast scenes would allow for the projection of fragment data on to the scene. This could then be used to reverse calculate what the munition may have been by reconstructing the munition piece by piece. Lastly a 3D record of the pre and post event would allow for latter interrogation of the data without loss of context. This technology would be a simple, quick, and cost-effective way to introduce a higher level of analysis to the trial.

10. General Trial Aspects

Outside of the key aspects of the trial a few other factors remain that could have been changed or limited to ensure better trial results. For example, the munitions support table was constructed of wooden legs and a plywood top held together with screws. This wooden structure introduced significant fragmentation that may have affected the results of the velocity foils. With a greater understanding of the munition size and weight this structure could have been reduced in size and potentially made from cardboard. This would have still supported the munition in the correct position but could have also reduces secondary fragmentation. Lastly there was significant dirt and debris on the trials site, as would be expected in a concrete and tarmac area. This debris may have presented an issue of secondary fragmentation generated from the blast. A simple and cost-effective measure to remove this concern would be to perform a simple sweep or blow down of the area prior to the blast. Again, this would be a low cost 'peace of mind.'

11. Banned Methods

The below methods are “banned” due to them being able to capture visual data of the trial. This would therefore be against the task to determine the munition as they would provide visual evidence of the device pre and during blast.

11.1. Flash X-Ray [7]

Flash X-ray is an advanced technique that utilises x-ray imaging technology to capture an image of an event. Due to the nature of x-rays, it is possible to ‘see’ through the detonation products (Gas, Light and Heat) and visualise the metallic components in the detonation.

This technique is often used to see shaped charge development and fragmentation patterns as the metal involved becomes clearly visible through detonation products.

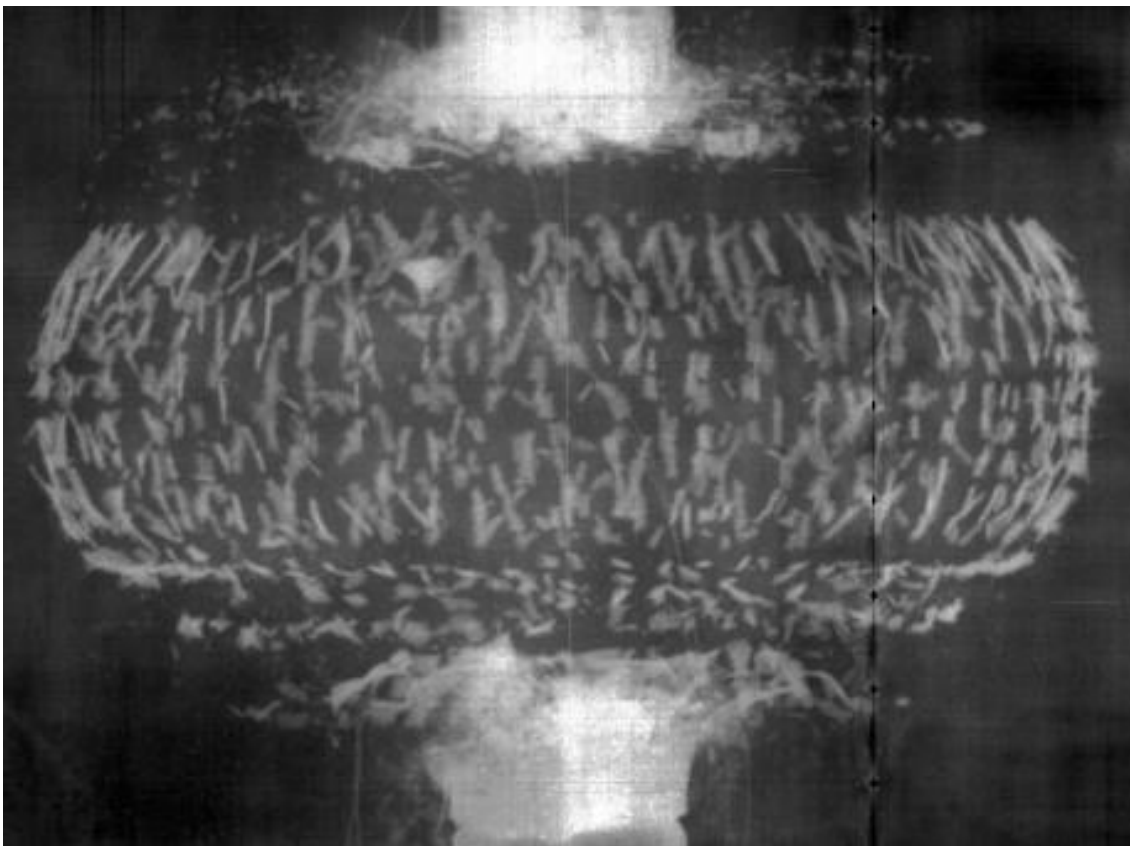


Figure 15 - Flash X-ray Fragmentation [8]

In the case of this trial Flash X-Ray would be able to provide critical information for the understanding of the munition and fragmentation pattern. Even if this method were ‘allowed’ it would not be used due to the excessive cost, complexity, and safety considerations that it would introduce to a simple trial.

11.2. High Speed Video [9]

High speed video footage is a critical aspect of most explosive trials. It involves the use of a camera that can record frames per second (fps) from 10's of thousands to 100's of millions. This high framerate allows for the recording of events in an extremely fine detail to deeply understand the evolution of the event. As with any piece of technology there is an inverse relationship between the framerate and resolution of the image as current technology can only process a certain amount of data in a certain time. This is shown below in Figure 16.

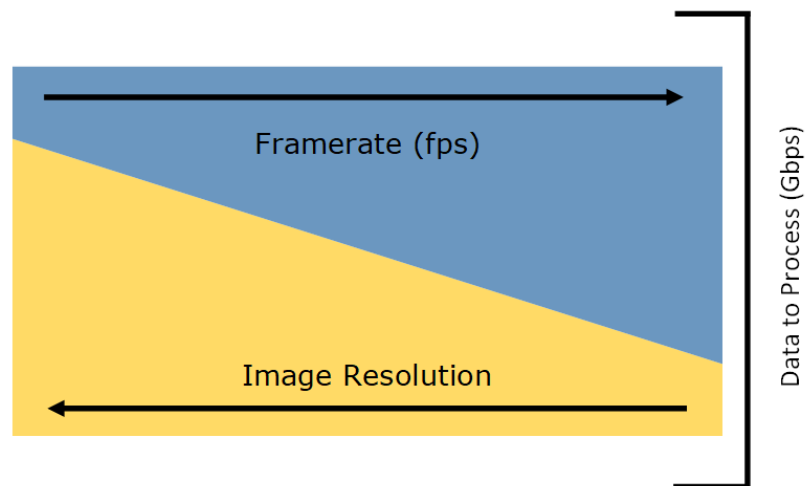


Figure 16 - Image Processing

High speed Video footage such as that produced by a 'Phantom' Camera can be tuned and calibrated to the munition and the information required. For example, when filming the development of a small scale shaped charge, the resolution can be limited to a tight area as possible to increase frame rate to 1 million fps and capture a smoother evolution as depicted in Figure 17



Figure 17 - Shaped Charge Evolution [10]

In this trial the addition of high speed video would be a logical choice due to its lower cost and relatively low complexity.

12. Conclusions

This report has explored the key aspects affecting the results of the COTEC trial and how these could be improved. The gauges could have been better protected, and a second set of gauges could have been introduced for better data validation. Increasing the Horizontal and vertical Arc of Starboards would have allowed for a greater proportion of fragment capture. Additional and Vertically orientated Velocity Foils would have better covered the central Arc of fragmentation for more results. FTIR analysis on the fragmentation would have provided additional material information and the introduction of a 3D survey would support in tying the resultant data together with the Pre and Post blast scenes. These changes can be seen below and detailed in Annex 2.

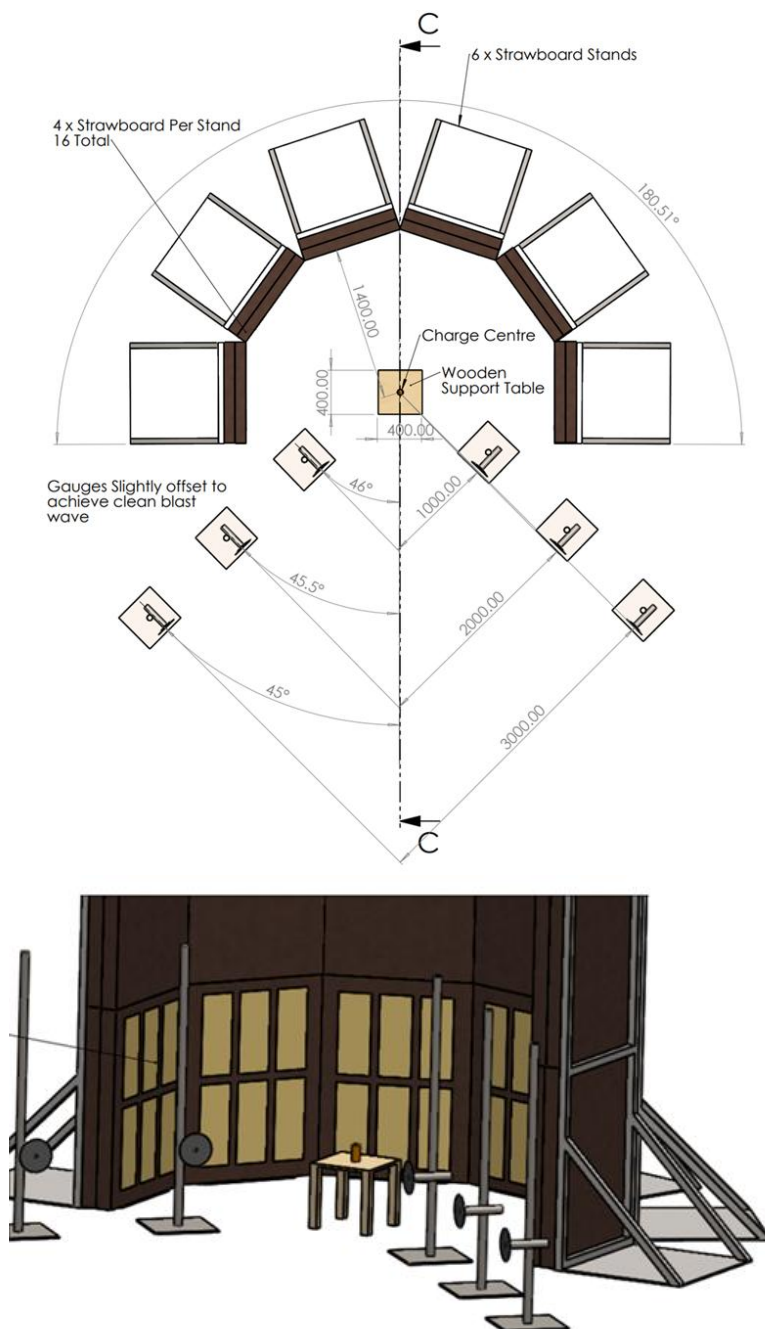
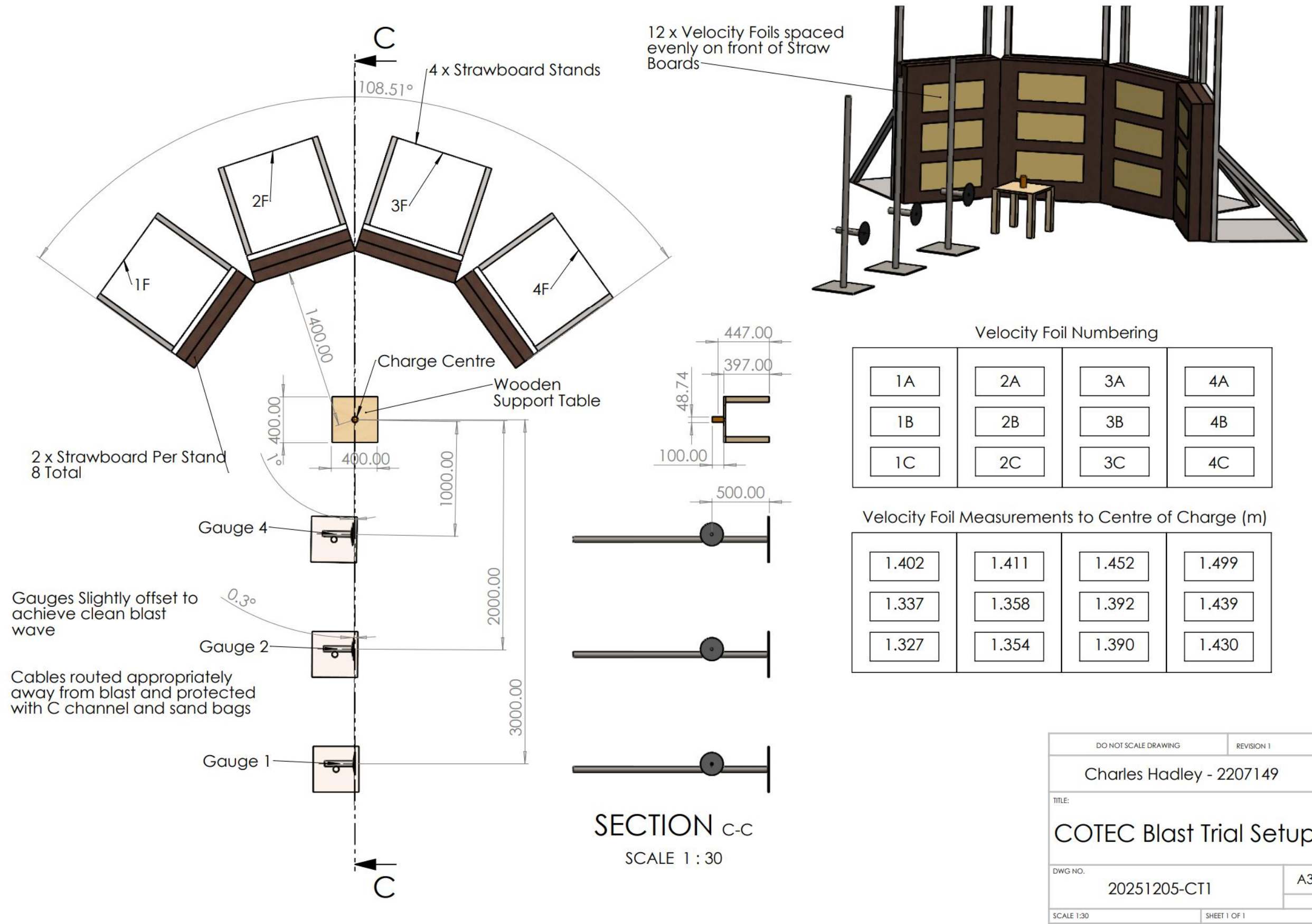


Figure 18 - Trial Layout V2

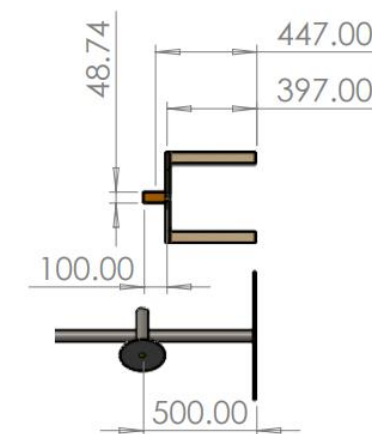
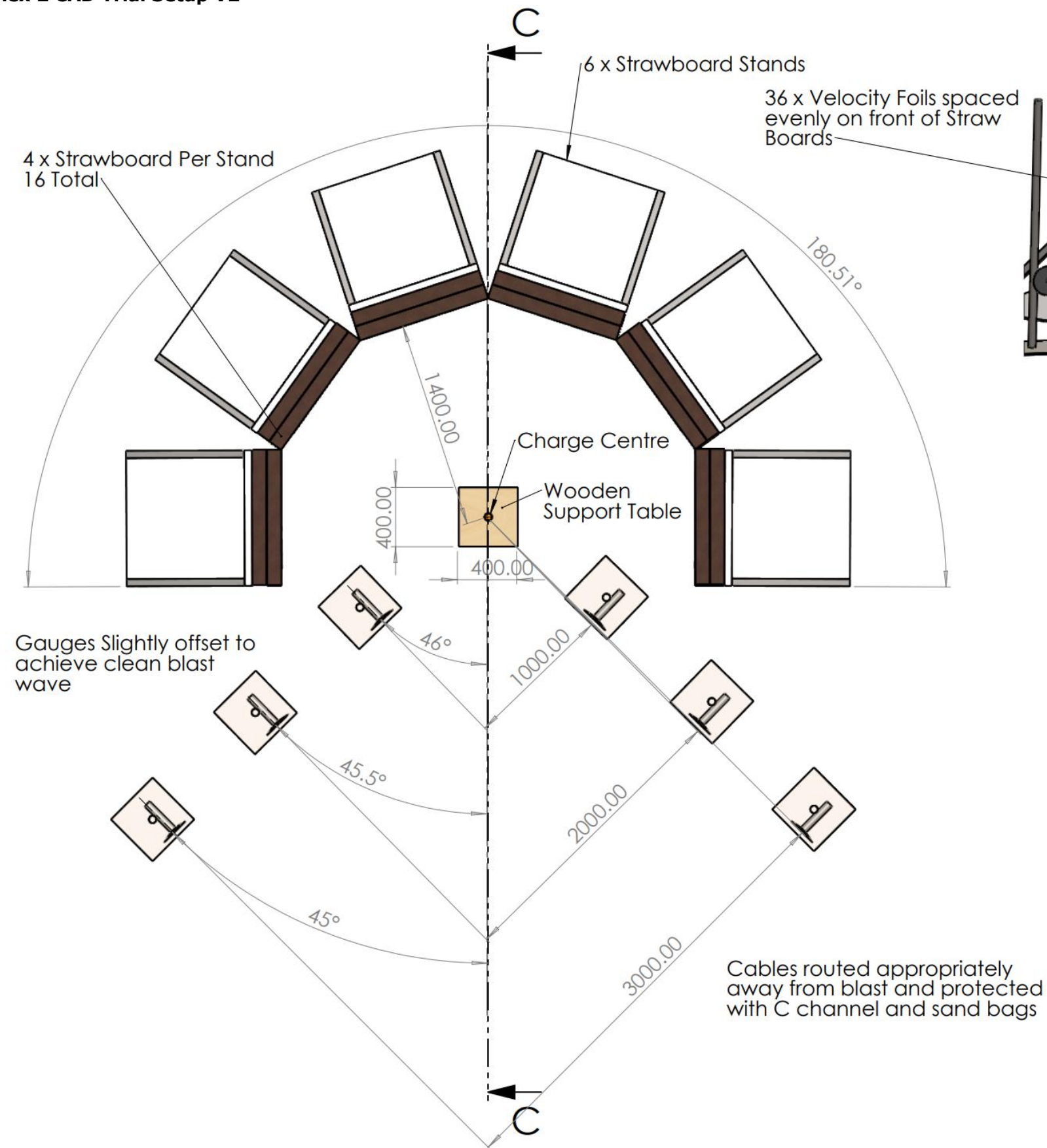
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14. Annex 1 CAD Trial Setup



Annex 2 CAD Trial Setup V2



SECTION C-C
SCALE 1 : 30

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