



LEVEL 5 GROUP PROJECT PORTFOLIO

‘An Ode to OME’ – Designing, planning and preparing a graduation firework display to commemorate and celebrate completion of the Ordnance, Munitions and Explosives HNC.

ACDA5022

Level 5 Group Project

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Abstract

To celebrate the successful completion of the Level 4 HNC in Ordnance, Munitions and Explosives, a brief was issued to design, plan and prepare, in teams, for a graduation fireworks display to take place on campus. The project was designed to allow students to use knowledge gained about the explosives industry over the three years of the qualification in a real world setting, and required a deep understanding of project management, systems engineering principles and how to use them and be guided by them, understanding the principles of OME and the safety parameters associated with OME, including but not limited to manufacture, test, disposal, storage and transport – as well as understanding why regulations exist and how adherence to the regulations can prevent incidents with mass casualty potential. The successful application of this knowledge, divided efficiently between a functioning, well-co-ordinated team, resulted in a successful presentation of the plans being delivered to a panel of pyrotechnics experts. The report goes in to greater detail on the work that went in to producing the presentation and display, and how the process of producing the display was dictated by the use of established systems thinking tools to greater understand important requirements and act accordingly to satisfy the customer.

Introduction

To mark the graduation from the OME HNC course, the university set a brief to collaborate in teams to produce a fireworks display centred on a set of expressed requirements to celebrate the completion of the qualification. A scope statement issued by the customer expressed that:

- A fireworks display must be themed around the OME course.
- Fireworks will be fired from the quayside close to the IQ building, with the audience in and around the IQ building.
- A duration of a minimum of 30 seconds is required, but up to 2 minutes is desirable.
- There is a materials budget of £2000 per minute of display, and a maximum budget of £10,000.
- The display must adhere to regulations and statutory rules.
- Fireworks fall-out must be assessed and any associated safety issues related to debris mitigated.
- Logistical and safety plans need to be in place.
- The environmental impact of the display must be considered and documented.

Taking this scope statement on board, the first decision that was made through a team meeting was the assignment of roles to team members, starting with the assignment of a project manager (PM), through whom progress against requirements was tracked and stakeholders were engaged. Roles were also handed out for systems engineering, firing, test & evaluation (T&E), procurement, safety & legal compliance, simulation design, and weather tracking (and associated risk mitigation). Through the organisation of the PM, the team were able to co-ordinate and work in synchronisation to systematically work through the brief as outlined throughout the remainder of the report, remaining in frequent communication as the plans came together.

The Top Level – Project Management

First Steps

Critical Success Factors

At the top level of the project was the project manager. The PM was tasked with measuring progress against the defined critical success factors (CSFs), those being the potential variables against which the team needed to be successful in order for the goals of the project to be achieved. These were

determined to be adherence to the given budget, ensuring that time critical deadlines were met, the satisfaction of the customer and other stakeholders, and the upholding of quality and standards in the face of the temptation to cut corners to meet time and budget constraints. Progress against the four defined CSFs was tracked through the frequent gathering of the entire team for team meetings, where discussions could be held about next steps and the team could consistently remain in alignment with each other.

Stakeholder Engagement

Initial stakeholder engagement played a key part in establishing the expectations of the customer in producing the display, and this engagement by the PM allowed for a clearer input of requirements for the systems engineering process, which in turn allowed for a smoother flow for the entire project with a clear and defined set of requirements to track progress against throughout. Understanding who a project's stakeholders are, and what their expectations are, can often be an understated part of a complex project, but the value for ensuring there is clarity on what must be achieved by the project team was incredibly valuable to have throughout the duration of the planning process.

Post Systems-Engineering

Tracking Progress & Running Logs

The PM sat in on meetings led by the systems team, supplying requirements issued by the customer during stakeholder engagement. Once the systems component of the task was complete, the PM was charged with arranging further meetings between the team, where progress would be discussed and any encountered hurdles could be overcome. Throughout, the PM would take minutes and update the team's 'running log', an open-edit word document where thoughts, ideas and progress made by team members could be added for the other team members to see, which could then be discussed further at meetings. The running log proved to be a crucial part of the team's communication plan, and ensured total transparency throughout between the entire team.

Compartmentalising the Process with Systems Thinking

Pre Stakeholder Engagement

Tool Selection

During the PM's stakeholder engagement phase, the systems team began the process of selecting tools to best aid the team in establishing key functionalities and requirements and comparing them to find the most important ones and then solutionising effectively to meet them.

It was emphasised early on within the team that, although there was no physical product being designed, the planning of a fireworks display was still a system comprised of a number of individual components and sub components that had to come together effectively in order to complete a display, and therefore the establishment of the correct systems thinking tools and requirements for them was a critical milestone for the project. As well as using systems thinking tools to improve the delivery of a project or product, systems tools also help identify potential areas of failure within the project, and offers the chance to mitigate accordingly.

Following discussions between the systems lead and the PM, the QFD (Quality Functional Deployment) 1 & 2 were identified as key tools for the process, as well as the use of pairwise comparison charts to prioritise requirements, and an FFMEA (functional failure mode and effects analysis) to identify potential failure points.

Post Stakeholder Engagement

Following the conclusion of the initial tool selection phase, team meetings, led by the team's lead systems thinker, were held to go through the tools and requirements in order to prioritise workload and targets for the rest of the project.

Use Case

Through the creation of a simple use case, the team were able to identify a small number of extra requirements, particularly around safety and compliance, which were not expressed explicitly by the customer in the initial scope statement. The use case also allowed for the drawing of the functional requirements of the project, which could then be grouped easily in to logistics, set-up, display and clean-up groups.

Level 1	How Much	Level 2
Logistics	Deliver pyrotechnics	Deliver all pyrotechnics required
	Store pyrotechnics	Store all pyrotechnics on site
Set up	Set up viewing areas	Set up viewing areas at appropriate distance from display
	Set up firing point	Set up firing point depending on weather conditions
Display	Conduct fireworks display	Conduct display effectively
Clean-up	Conduct clean-up operations	Conduct clean-up operations in and around the display area

Figure 1: Gathering requirements for the display

Use Case for a fireworks display

Use case for a fireworks display at UWSTD campus

Author Jon Walton Issue - 1 Reviewed 26/09/2023 Date 25/09/2023

Actors: -
Display crew, audience, other members of the public

Pre-conditions: -

1. Campus is ready to receive pyrotechnics
2. Pyrotechnics have been selected and a ready for delivery
3. Display has been designed
4. Viewing points for spectators have been considered in relation to weather forecasts

Post-Conditions: -

1. Display is finished
2. Spectators/public are safe
3. Clean-up is finished

Basic Flow: -

- Deliver pyrotechnics
- Store pyrotechnics
- Set up viewing areas
- Set up firing point
- Conduct fireworks display
- Conduct clean-up operations

Alternative Flow: -
None

Exception Flow: -

- Poor weather conditions
 - Temporarily postpone display
 - Resume basic flow

Figure 2: The produced use case for the fireworks display

Pairwise Comparison

The use of a pair wise comparison tool allowed the team to reliably create a priority hierarchy when comparing the customer requirements. Whilst every customer requirement is always treated as

important and efforts are made to hit all requirements as given, often in projects the need to prioritise one over another can arise in order to ensure successful delivery and implementation of the project. It is perhaps unsurprising that the need to ensure legal compliance came out as the most important requirement, and this was driven by a consensus within the team that the consequences of failing to hit this requirement are the most severe, both through legal repercussions, and the risk to the safety of the display crew and the audience – and potential for a mass casualty incident. Compliance with legal limitations is not limited to simply the two minutes for which the display takes place, but in the days leading up to and after the display, where compliance with the law on storage and transport of fireworks, clear-up and environmental regulations is also required.

Those other requirements that also come with possible legal constraints featured highly in the comparison. The creation of the pairwise tool served as a key reminder to the team that, in any circumstance, in a conflict of requirements, adherence to the law must always be the priority.

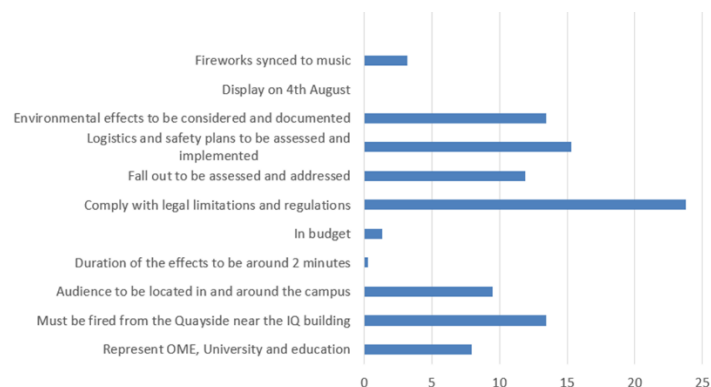


Figure 3: Pairwise Comparison tool for prioritising customer requirements for the display.

QFD 1 – Determining Functional Importance

Comparing functional requirements with non-functional requirements, establishing and identifying relationships, and the strengths of those relationships, is a key factor in determining what in fact are the most important functional requirements. Through the use of the QFD 1 tool, the team were able to identify that the carrying out of the display itself on the day was the most important functional requirement, as it ultimately forms the centrepiece of the customer requirement. Everything else is background work that the customer and audience may not see or appreciate, but failing to deliver on the display itself will cause the most significant and immediate dissatisfaction to stakeholders.

Whilst carrying out the QFD 1 process was a helpful means of establishing a reminder that the physical delivery of the fireworks remained the priority, it could be noted that breaking down the functional requirements in to smaller steps would have provided a better tool for understanding critical functional requirements. The functional requirements are quite top level and breaking these down slightly may have offered a better insight into exactly what functional requirements were most important. Nevertheless, QFD 1 allowed a clear set of priorities, at least at the top level, to be drawn up in the case of functional requirements.

Function Means Analysis

A simple function means analysis was produced, in which possible solutions for each functional requirement were produced by the team, and then whittled down to a best solution through rounds of discussion and comparison between possible methods. The conclusion of the functional means analysis is shown in Figure 4. The outcomes were that:

- Deliver pyrotechnics: Deliver by road (in accordance with ADR regulations).

- Store pyrotechnics: In an approved and compliant iso-container (in accordance with ER2014).
- Set up viewing areas: With crowd fencing and signage.
- Conduct Fireworks Display: Using timed electronic firing systems.
- Conduct Clean-Up: Immediate clean-up, followed by a next-day clean-up.

Function	Means								
Deliver pyrotechnics	By road	By train	By plane						
Store pyrotechnics	Tarpaulin cover	Gazebo	Tarpaulin ground sheet	Iso container	Inside University building	Temporary building erection			
Set up viewing areas	Sign posts	Crowd fence	Gazebo	Polycarbonate barriers	Stanchions				
Set up firing point	Stanchions	Sign posts	Crowd fence	Field modules	Labels				
Conduct fireworks display	Manual timing	Electronic timing	Manual ignition	Electronic ignition					
Conduct clean-up operations	Immediate clean up	Next day clean up	No clean up						

Figure 4: Functional Means Analysis for solutions for function performance.

QFD 2 – Identifying Critical Features

QFD 2 utilises a comparison tool between the identified solutions of the functional means analysis and functional requirements, in order to find relationships between the two, compare the strengths of those relationships and, ultimately, identify the most important features of the project. As the figures show, the tools produced a result which identified the timing and firing of the fireworks using electronic timed modules as the key feature of the display. In theory, it makes sense to be this way, as the quality of the show depends on the accuracy and reliability of firing, to ensure that the display looks and sounds as intended.

The use of QFD 2 as a systems tool during the project allowed the team, particularly the simulation, firing and T&E leads given the result, to understand the importance of certain solutions devised during the systems process –making clear which firing mechanisms would be used, allowing the simulation and firing leads to work around those constraints, and the safety lead to understand how this may affect the restrictions on the display.

Again, as with QFD 1, the functional requirements perhaps being a little too top level prevented the team from taking a deeper dive in to the component level of the project, which could have provided even more clarity on how to meet requirements in the best way.

FUNCTIONAL SUMMARY												
Design feature	Importance	Delivery by road	Store in ISO Container	Warning signs and directions	Crowd fencing	Field modules	Labels	Electronic timing	Electronic firing	Immediate clean up	Next day clean up	
Functionality												
Deliver pyrotechnics	365	9	1									
Store pyrotechnics	379		9	3								
Set up viewing areas	587			9	9							
Set up firing point	679			9	3	3	9	9	9			
Conduct fireworks display	713					9	1	9	9			
Conduct clean-up operations	395									9	9	
		3287	3773	12532	7323	8455	6823	12529	12529	3557	3557	0

Figure 5: QFD 2 comparing solutions to functions

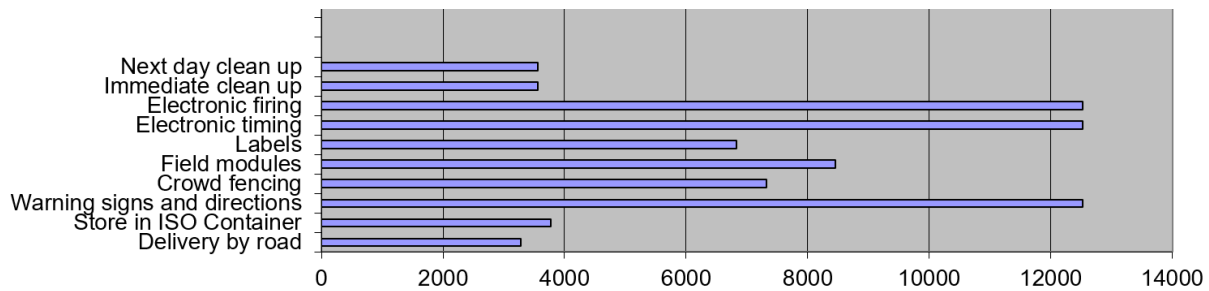


Figure 6: Using QFD 2 to find the critical functionality

FFMEA – Identifying Points of Failure

No system is guaranteed to be perfect. Every system runs a risk of failure. A key part of the systems thinking process is to be prepared for such an incident, by being proactive when it comes to failure. This is done through an FFMEA process, in which potential points of failure are identified before they occur, and mitigations are put in place to minimise both the likelihood and the impact of a failure.

FFMEA works through the identification potential failure modes of each functional requirement within the system, identifying what the effect of the failure would be, the potential cause of the failure, and how such failure can be detected before it happens. Each component of failure is given an individual score out of 10. These scores were multiplied together to produce a total 'RPN' score.

Figure 7 shows a snippet of an FFMEA performed on the setting up of the firing point. Any point of failure with an RPN of more than 100 was treated as a top priority risk which needed to be given unique attention to solve during the process. Failure modes with an RPN between 50 and 100 were noted as potential risks and, where mitigations could be found, they should be. Failure modes with an RPN of under 50 were deemed to have been largely solved by the processes already in place, but should not be forgotten, in case decisions taken throughout the process increase the RPN of those potential failure modes.

Function	Functional failure mode	Effects	S	Causes	Detection		RPN	Design suggestions/Comments
					O Current employed method	D		
Set up firing point	Over set up	Firing point is too complicated	6	Poor planning	Defined area for the firing point has been dictated by the customer	4	96	Planning to take place in tandem with display simulations to determine the size and scope of the display, appropriate timing and firing methods and equipment to be used
Set up firing point	Under set up	Not enough room to set up firing point	6	Poor planning	Defined area for the firing point has been dictated by the customer	4	96	Planning to take place in tandem with display simulations to determine the size and scope of the display, making sure it will fit within the designated area
Set up firing point	Intermittent set up	Timing of display doesn't sync up	5	Poor planning/incorrect equipment used		8	200	Planning to take place in tandem with display simulations to accurately time the fireworks to music. Appropriate timing and firing methods and equipment to be used

Figure 7: FFMEA for failure of firing points.

In all, the systems engineering/thinking process provided the platform from which the rest of the project flowed. Although it can be difficult to master the specific tools, understanding them and being able to utilise them has endless benefits for project delivery. All of the key decisions that were taken throughout the rest of the life of the project were done so on the basis of the information gathered during this part of the process.

Using Requirements to Produce a Simulation

Pre Procurement

Identifying Non-Negotiables and Focus Points

The identification of the non-negotiable aspects of the display as laid out from the requirements established through the systems thinking process forms the first part of the simulation process. The key focus points established through the systems process were:

- The display being themed around, and representing, the Ordnance, Munitions and Explosives course at UWTSD – as expressed by the customer in the scope statement.
- The need to base the firings around electronic firing modules, using electronic timing systems – as was found during the key functionality gathering phase.

Identifying a Theme

With the exception of an overarching theme for the display, that it should be related to the OME course at UWTSD, there was a large degree of freedom around how the team may have wished to express that theme. It was decided quickly that there should be a musical piece or song in the background to serve as the backbone for the display, to aid timings to ensure that there was a 'flow' to the display that best matched the theme that was trying to be conveyed.

Through a number of team meetings on the subject, the decision was made to present the display as a dichotomy between the years, choosing to create a display that centred around the difficulties and struggles in communication and messaging encountered by the team during the first year of the OME course, and the major improvements in all fields that were put in to place to ensure that the following years were far more synchronised. This would be represented through the poor synchronisation of fireworks to the selected backing track in the initial stages of the display, and be followed by an improved, fully synced second half of the display.

The added touch of theming the display around fireworks of red, white and blue colours was also decided upon, as a means of symbolising and celebrating the collaboration between employees of different OME bases across the English Channel, representing both the French Tricolour and the British Union Jack.

Selecting Firing Modules

The first decision to make regarding creating the display itself was on firing points and firing modules. There was a limited space to do so on the quayside. It was decided to split the display area in to three firing areas – left, right and centre – each with two firing points (and a third in the centre), totalling seven points across three areas.

Knowing that an electronic firing module would be required, as derived from the systems engineering tools, a suitable module was selected, in this case COBRA, as it was branded within the recommended FWSim program that was used to produce the display, and contained the most channels of the available modules.

Creating a Simulation Display

With modules and a theme decided, work began creating the core display. The first step was the choice of song, with Neil Diamond's hit *Sweet Caroline* being the selected backing piece, owing both to its immense popularity, as well as the well-defined 'big moments' to centre the display around. In the first instance, the design team used a list of fireworks available on FWSim to create a timed display around the chosen song, initially being given free rein to create whatever display worked, and then using the simulation to influence procurement decisions.

FWSim allowed the design team to create unique displays using a large list of custom fireworks, as well as the opportunity to accurately time the fireworks, 'program' the firing modules, and set an exact firing location, which influenced future decisions taken by the safety and weather teams.

Eventually, a full draft was created on FWSim, and presented to the procurement team, along with a set of figures for numbers of fireworks and total NEQ, all of which had to be researched separately as no such figures existed on FWSim, which was a major drawback for the software, as well as the inability to match the scenery locations and the fact that weather could not be factored in to run a draft under the conditions given by the weather team.

Post Procurement

Once the procurement process concluded, the simulation team were able to re-enter FWSim to make any required changes to the simulation as requested, to match the procured fireworks to the chosen fireworks for the simulation as best possible.

Procuring Fireworks for the Display

The Procurement Process

The procurement process ran over a number of weeks, in constant contact with the simulation team. Procurement and design happened parallel with one another, to best iron out major hurdles as they arose, rather than allowing them to stack up.

The decision was made early on to procure ready-made fireworks using the stock lists provided [1] for the project, as opposed to commissioning custom-made, bespoke fireworks. The benefit of such a decision was that the procurement team could produce a solid set of figures at the end of the process, including a concrete total NEQ of fireworks being purchased, to ensure that all manufacturing laws and regulations were being followed, and would give a firm cost in terms of materials, allowing progress against the budget to be assessed with confidence.

The major drawbacks of this decision was the inability to perfectly fit the procured fireworks to the original concept design. There had to be constant back and forth between the two teams to raise where a firework used in simulation could not be found on the stock lists. Although there were not many changes to make in the end, there were a number of occasions where procurement had to halt the progress of the simulation team to raise small issues on individual fireworks. There was a requirement from both sides for compromise to produce a 'solution of best fit'.

Procurement Totals

At the conclusion of the procurement process, the following totals were established and passed back to the project manager for approval:

Display Time: 2m30s

Fireworks procured: 16 cases, 681 units

Fireworks used: 332 units (349 unused units)

Materials cost: £2,296.85 (against a total of £2500)

Cost for used units: £953.50

Total NEQ: 116.27kg (9g difference from figure provided by simulation team)

HCC 1.3G: 99.42kg

HCC 1.4G: 16.85kg

LEVEL FIVE GROUP PROJECT REPORT

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Figure 8: Final Order Sheet

Test, Evaluation and Disposal Plans

Environmental Test and Evaluation

The first step in the process was identifying the key considerations to be made regarding the display, from a health and environmental standpoint. The key identified factors to consider were:

- **Noise** – There is an upper noise limit of 120dB [2] to be experienced by all observers. This is critical to avoiding physiological damage.
- **Pollution** – Firework displays will pollute the air and, the larger the display, the more pollution that will be created. Fireworks also produce heavy metal particles and toxins that can endanger human health.
- **Litter** – Firework displays also pollute the ground, owing to the use of non-biodegradable materials used in the manufacture of fireworks.

These environmental considerations would be tested with test firings carried out in similar weather conditions to those forecasted for the day of the event, using some of the excess fireworks purchased through procurement. This would allow for accurate measurement of debris distance and fall-out, which would then be compared with the projections produced from the weather team.

Acoustic testing will also be carried out to ensure that noise levels at the viewing site do not exceed 120dB at any time.

Firing Module Test and Evaluation

As decided during simulation, the COBRA firing modules were selected to aid the fireworks display. The COBRA 18M is the main control hub for the system, and the 18R2 is a handheld control device that sends signals and receives commands – and also shows if the igniters are connected, as well as signal strength and battery level of the system. The COBRA audio box sends the audio to whichever sound system is being used at the display [3]. All of this complex kit would also require testing, to ensure that set-up is understood and that the timed script created from FWSim is correct and accurate.

Tests were conducted on the system without any connected fireworks to reduce risk, with the audio box connected to ensure that the music timing was correct. Throughout the test, the lights on the modules were observed and noted in line with the call sheet to check for accuracy.

Carrying out the Display

The display would be conducted by a professional display team with the relevant competencies, which would be checked prior to any display taking place. This enables the team to be confident that the relevant safety checks are carried out beforehand and that all the correct paperwork, such as a risk

assessment and an understanding of the governing regulations which apply to professional fireworks displays.

The firing team would familiarise themselves with the kit and the instructions in the days leading up to the display.

It was decided that fireworks were to be set up in daylight for safety, beginning at a time so as sufficient to complete set up in daylight hours. The firing area is not to be left unattended once set-up of the area has been completed.

The team also got together to decide on the PPE necessary, based on the relevant regulations, which includes flame retardant overalls, ear defenders, gloves, safety goggles, helmets and substantial safety footwear.

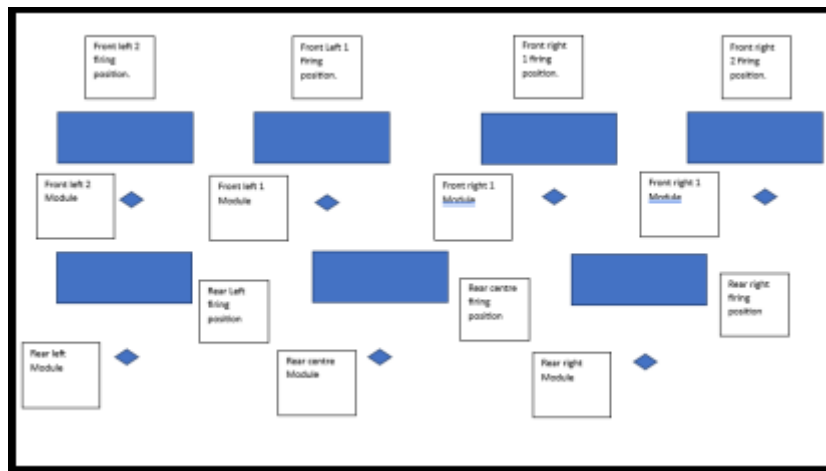


Figure 9: Firing area set-up

Figure 9 shows a set-up for the display, showing all seven firing locations as rectangles. The diamonds in the figure show the locations of firing modules.

These modules can have the time script applied to them to then ignite the fireworks automatically during the display.

Disposal Plan

The work done during the systems engineering phase identified clear requirements for a disposal plan, requiring that a same-day and next-day clear-up was carried out by the display team.

As a result, it was decided that an immediate walk of the area will be carried out post-firing using head-torches, to collect any and all litter associated with the display. The litter is to be collected, bagged and handed over to the local authorities for disposal. There will also be a next-day walk around in daylight to ensure that the area is clear of debris.

Data gathered during the pre-tests and produced by the weather team would produce a focus area for the walk around checks.

Handling Misfires

Misfires are to be left and not approached for a minimum of 30 minutes. In line with technical guidance, misfires are to be fully submerged in water for 48 hours (or whatever time the manufacturer recommends) to break down the chemical compositions inside and make the explosives safe. Misfires,

after submersion, will be stored safely until disposal. If a shell fails to fire, no part of the body is to get in front of the mortar.

Some fireworks do have a secondary fuse, which can be connected to an igniter to function the firework. If this is not the case, the mortar is to be removed from its fixings and tipped away in to a drum containing water, again to aid the breakdown of the chemicals inside and make the explosives safe.

Ensuring a Safe and Legal Display

Introduction

Adherence to all laws and statute legislation was identified as the critical requirement of the entire process. The group agreed a clear grasp of the laws and regulations in place was absolutely essential to a smooth project. With that agreement, the safety lead worked to collate all the necessary rules and regulations that would apply to the team, to ensure everybody was clear on what, and where, compliancy was needed.

The Basics

In the UK, health and safety law is enforced by the Health & Safety Executive (HSE), and flows from the Health & Safety at Work Act (1974). The rules state that employers 'ensure, as far as reasonably practicable, the health of employees' [4]. The Act also states that employees must 'take reasonable care of themselves and other persons who may be affected by their acts or omissions at work' [5].

Fireworks and Explosives Regulations

The HSE has produced substantive guidance and legislation concerning the use of fireworks and explosives, through the Explosive Regulations (ER) 2014 in the case of explosives, and through the Fireworks Regulations (FR) 2004 in the case of commercial fireworks. Both are extremely valid to the project.

The law states that all fireworks to be used commercially must be subject to an official conformity mark [6], and be given a valid 'F' category, which in turn determines the required safety distance for any observers. The categories, and their associated distances, are given in Table 1.

Table 1: Safety distances for fireworks categories [2].

Category	Minimum Safety Distance
F2	8m
F3	15m
F4	25+m (professionals only [7])

A legally required safety distance for category F4 fireworks is not specified within the regulations, but practice dictates that a minimum distance of 25m must be observed, and the final distance is at the discretion of the professional display team based on the work done beforehand to ascertain risk through pre-testing. As mentioned previously, there is a 120dB noise limit that is enforced throughout the display that will ultimately determine the distance to the audience when professional display fireworks are used.

ER2014 states that a private individual cannot acquire more than 50kg of fireworks without a valid licence to do so, unless transporting on behalf of another person who does have a licence, but cannot be in possession of the fireworks for any more than 24 hours [8].

However, it also states that professional display teams, if the desire is to use the fireworks 'for a commercial display or for another work activity, then up to 100kg NEQ of HT3 fireworks can be stored for up to 5 days without the need for a licence, provided that the fireworks are stored in the location in which they are intended to be used [9] [10].

Safety Distances and Logistics



Figure 10: Satellite view of the firing, viewing and storage areas.

Figure 10 shows the full display area. The first task for the safety team was to evaluate the relevant safety distances.

The red circle around the firing area marks out the minimum 25m distance around the firing area. The firing team calculated that the distance to Roberts Road, behind the firing area, as 30.29m, and the distance to the closest part of the viewing area, to be 50.73m, which satisfies the legal conditions set by the HSE.



Figure 11: Detailed satellite view showing interaction of storage area with other areas.

As was decided through the systems tools process, a 20ft ISO container was picked for rental for the storage of fireworks. Figure 11 shows this storage location in more detail.

For the purpose of finding a suitable location for the ISO container, attention was turned to the Separation Distance tables as provided within ER2014. The separation distances are the distances that must be left between buildings containing explosives and vulnerable areas. The distances of interest for the purpose of the display were:

- Class D – The distance to other inhabited buildings or dwellings, or buildings being used for the storage of process of explosives [11].
- Class E – The distance to vulnerable buildings [11].

Table 10 of the Separation Distance tables details the distances required for buildings containing HT3 explosives. It states that for 100-150kg of explosives at HT3 that there is a required Class D & Class E distance to inhabited buildings of 34m [12], which is shown in Figure 10 with the red circle, and in Figure 11 with the blue circle. A separation distance of 34m is shown not to interact with the firing area or the university building itself.

As well as finding a suitable location in terms of separation distances, a location had to be chosen that allowed emergency services access in the event of an incident. An access point on Roberts Road was also found to ensure access. The area would be strictly contraband controlled to prevent potential sources of ignition coming in to contact with the stores.

Addressing Fall Out and Weather Concerns

The Weather Forecast

The first job of the weather was to find and collate the weather information as provided by the Met Office for the date of the display, to gain a picture of the forecast for the night in question [13].

Display Date: Friday 4th August 2023

Weather Data (1800 hours): Overcast, low cloud cover (1500ft – approx. 450m), low chance of precipitation, wind gusts of 32+km/h from the NW direction

Sunset: 20:59

Weather Data (0000 hours): Thunderstorms, low cloud cover (1000ft – approx. 300m), precipitation expected, wind gusts of 25+km/h from the W direction)

It was also identified that there were thunderstorms expected in Swansea in the days leading up to the display, which could have implications on the set-up, storage and transport of the fireworks.

Unpacking and Understanding the Data

Using a program called ShellCalc, which calculates the airborne travel of fall-out, using firework sizes, weights, projection angles and wind speeds and directions, the data found from the forecast was inputted for a number of scenarios using firework types selected for the display, which allowed a set of precautions and mitigations to be made based on the data, as well as providing a focus area for the clear-up after the display.

The program, however, does not account for other weather types, such as a thunderstorm, and it was made clear to the team that a fireworks display could not go ahead during a thunderstorm.

The calculations produced large travel distances for fall-out, sometimes in excess of 300m for some shell types, but in the east-south-east direction, away from the viewing audience, towards the sea. Although fall-out would not be heading for the audience, it was decided that mitigating action would need to be taken to prevent potentially harmful debris being swept out in to the open water nearby, and contain the debris to an area in which it could best be cleared.

The issue of low cloud cover was also a highlighted issue, with some of the firework types being selected initially having burst heights above the lowest forecasted cloud ceiling of the evening, and this would also need to be mitigated.

Mitigations from the Data

A comprehensive set of mitigations was produced in order to most improve public safety and best protect the environment.

- A date change was considered due to the risk of thunderstorms, but the costs of short term cancellations could spiral and, due to a desire to stick to budget, this idea was shelved as a last resort action.
- The display and clear-up **must** be concluded well before midnight, at which point the forecast was totally unsuitable for holding a firework display.
- The display should begin as soon as permissible after sunset to find a balance between having some twilight to carry out the clean-up and enough darkness for the display to work as intended.
- No significant risk was identified from the use of comets, which would have very little travel distance before burnout, but larger shells came with extra environmental risk of being carried in to the sea, where they could contaminate the water, and also came with the possibility of

bursting above the cloud ceiling and being invisible. As a result, comet use was encouraged wherever possible to the simulation team.

- Shells, where used, should be fired at an angle slightly towards the audience, as the strong winds would carry the shells well away from the audience, but the angle should lower the burst height and also limit the fall-out area to the largely disused land around Kings Dock, and limit the amount of fall-out landing in the sea.

As well as the mitigations decided on, the team looked at the possibility of a sudden, unforeseen change in wind direction, and so the weather team went away and produced an image of the worst case scenario. Figure 12 shows the worst case scenario visually.



Figure 12: Worst case scenario as calculated using Shell Calc

In this scenario, where winds blow at the average forecasted 14km/h, but with a sudden change in wind direction, suddenly the debris from the display is projected to land directly on top of the audience area and the university building.

Upon seeing this information, the team decided it was necessary to put some extra procedures in place to prevent the chance of serious injury if there was a sudden change in wind direction.

- Extra vigilance from the display team for sudden changes in wind direction, with readiness to stop or postpone if wind direction becomes dangerous.
- Café doors should remain open at all times to make it easier for the audience to get to hard cover should a sudden change in prevailing wind direction send debris in the direction of the audience.

Conclusion – A Successful Project

The final consensus was one of satisfaction that a display plan had been drawn up which aptly commemorated the OME HNC course, as well as meeting all customer requirements, both expressed

and gathered during the systems engineering process. Every team member made an valuable contribution to ensuring that a display could go ahead in difficult conditions, paying a keen eye to safety and legal compliance, as well as putting on a display within budget and to the required theme, utilising key industry knowledge picked up throughout the duration of the course, particularly those associated with Systems Engineering and the Principles of OME.

The result of a lot of hard work from the entire project team was a successful final plan that was presented to a panel, who all agreed that the groundwork that had gone in to planning the display was relevant and considered all of the key factors necessary. The project was a great opportunity to showcase the knowledge gained by students during the OME HNC.

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