

Understanding the Effects of Blast and Fragmentation on Steel and Cladding Materials

by Charlotte Knight

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Understanding the Effects of Blast and Fragmentation on Steel and Cladding Materials

Research Proposal

Charlotte Knight

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1. Introduction

The Collateral Damage Model (CDM) is a UK government Business Critical model used operationally to estimate potential collateral damage and probability of risk associated with a weapons strike [1]. It works by allowing the user to recreate the scene of their target area, and place scaled structures such as buildings and walls, along with population data to give an accurate casualty and structural defeat estimate. The model has fully characterised the blast and fragmentation effects of a variety of warheads for common structural materials such as concrete, masonry and steel using data from battle damage and trials [2].

To enable the model to provide accurate and representative results, the collateral response of structural materials within the CDM must be repeatedly validated against trials data. Additionally, new materials must be regularly added to allow the model to become responsive to the modernisation of building materials as well as any changes to combat locations. To achieve this, this project aims at producing a repeatable test methodology that captures the blast and fragmentation data for structural materials, which can be used for both validation and new material introduction within the CDM. The materials tested within the first test series are mild steel and cladding.

2. Background to the Proposed Research

Despite there being several studies on the separate blast and fragmentation effects on structures, there is little research on their combined effect. When an explosive detonates inside a structure, the blast imparts high impulse to the nearby walls. Any fragmentation from the casing transmits additional momentum to the structure, as well as creating structural damage due to penetration [3]. To capture this data, witness boards containing multiple layers of strawboard are often used, as these allow the position, mass and penetration of each fragment to be documented [4]. Velocity foils attached to these boards then allow the fragment velocity to be recorded. These feature two aluminium foil layers separated by a known distance. When the fragment hits both of these layers, a time signal is generated. This signal, along with the distance between the two foils allows the fragment velocity to be calculated [5]. Pressure gauges are then used to show the pressures experienced within the blast wave. The proposed trial will need to include all three techniques in order to fulfil the CDM requirement.

The chosen materials for this test series is mild steel and cladding. Although data on mild steel is already inside the CDM, it is still viable to test it in order to validate the model against the new test methodology used. Cladding is a relatively modern material used in buildings from homes and high-rise buildings to offices and warehouses [6]. Due to the wide range of building types that use it, it would be beneficial to have data added to the CDM to help optimise its performance. Research has already been completed on the effects of blast on reinforced cladding. It was discovered that increasing the core strength and faceplate thickness reduced the energy input to the system whilst simultaneously increasing the amount of energy absorbed within the cladding, causing greater protection [7]. Unfortunately, typical commercial cladding will have significantly smaller values for both of these key features; therefore, it can be assumed that it will offer less protection, resulting in greater collateral effects. Consequently, it is key the experimental set-up can capture the full effects of this predicted wall failure.

3. Aims & Objectives

3.1 Aims

- To collect blast and fragmentation data on the structural defeat of steel and cladding walls and compare that with the predicted results within the CDM
- To input this new experimental data into the model
- To produce a low risk repeatable trials process that can be used annually for adding trials data into the CDM

3.2 Objectives

- Model the results of both materials in the CDM
- Conduct the trial safely, following approved processes
- Collect blast and fragmentation data for all shots
- Compare the modelled data with the experimental results

4. Experimental Design

4.1 Pre-trial:

The cassette will be installed inside the chamber by range staff, and a steel wall placed inside.

Strawboard fragment packs will be placed a set radius away from the detonation point in the chamber, as per figure 1. Velocity foils will be placed over them.

Pressure gauges will be placed between these packs and the chamber.

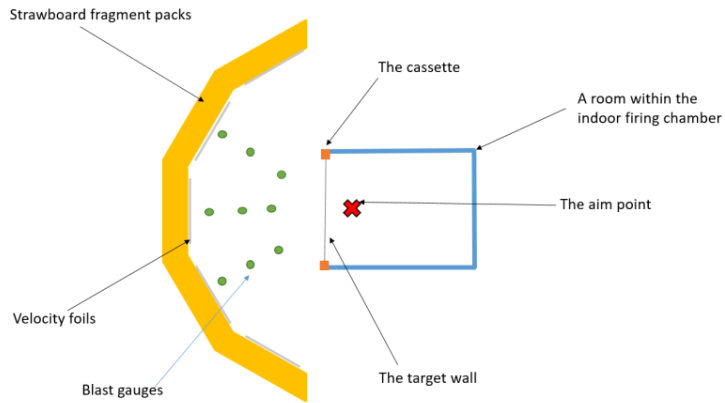


Figure 1- The predicted setup of the trial, with a simplified view of the blast chamber

4.2 Outline of Experimental Procedure

The explosive will be placed inside the chamber at the aim point shown in figure 1. An RP-83 detonator will be used to detonate the explosive. After the explosion, the fragmentation packs will be collected for analysis, and swapped out for new versions. Any remnants of the target wall need to be cleared away, and a new wall will be inserted into the cassette.

4.3 Data Collection

Data collected by the pressure gauges and velocity foils will be collected, and saved locally and to a hard drive. The strawboards will be analysed, and the fragment sizes, locations and penetration depths recorded.

4.4 Data Evaluation

Once all the data is collected, it will be compared against modelled estimates, and then inputted into the CDM.

4.5 Risks & Limitations

All risks will be tabulated, along with their corresponding preventative measures inside a signed off risk assessment [8]. The main risks are:

- Confinement within the chamber leading to difficulty in emergency escape routes
- Accidental initiation of explosives during storage, transport and work
- Manual handling causing skeletal problems when moving around strawboards
- High levels of noise causing hearing damage

Risks with the overall project will be tabulated inside a risk matrix. These risks are:

- Unavailability of the range during the dates specified, meaning the trial dates have to be moved
- The trial chamber failing its commissioning test, meaning it cannot be used for the proposed trial. In this situation, any data collected from that trial will have to be modelled separately

A limitation is that none of the weapons used within the CDM can be used for the trial due to cost and availability. Representative munitions may not produce the same effects.

4.6 Ethical Issues

An environmental check must occur on the trial site before the setup and trial can commence. This ensures there are no protected animal or plant species present that could be harmed during work.

5. Resources & Planning

5.1 Resources Required

5.1.1 Physical Resources

- Explosive
- RP-83 detonators
- Cassette
- Target material
- Pressure gauges
- Fragmentation packs
- Crane
- Personal Protective Equipment (PPE)

5.1.2 Human Resources

- Trials Conducting Officer (TCO)
- First Aider
- Range staff
- Trials manager

5.1.3 Other Resources

- CDM
- Indoor chamber booking

5.2 Gantt Chart

A rough outline of trials activities is shown in figure 2.

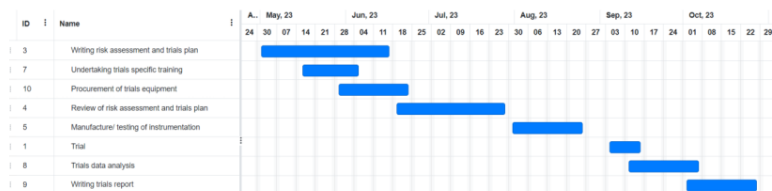


Figure 2- A Gantt chart showing rough timelines of the trial

6. References

- [1] The Ministry of Defence , “Business critical models: Ministry of Defence 2022,” The Ministry of Defence , London, 2022.
- [2] M. Neale, “UK Collateral Damage Model,” Dstl, Salisbury, 2022.
- [3] D. B. A. N. D. Hezi Y. Grisaro, “Investigation of blast and fragmentation loading characteristics – Field tests,” *Engineering Structures*, vol. 167, pp. 363-375, 2018.
- [4] J. S. S. T. E.-S. a. Z. A. Hiroshi Yokohama, “Vehicle Borne Improvised Explosive Device (VBIED) Characterisation and Estimation of its Effects in Terms of Human Injury,” *International Journal of Protective Structures*, vol. 6, no. 4, pp. iii-709, 2015.
- [5] a. D. S. Zhitong Yu, “Study on Fragment Velocity Measurement Technology of Prefabricated Fragment Warhead,” in *3rd International Conference on Materials Science, Machinery and Energy Engineering*, 2018.
- [6] A. J. B. M. M. Alan Brookes, *Cladding of Buildings*, Taylor & Francis, 2008.
- [7] X. Z. ., X. W. ., X. D. a. S. Y. ., Y. W. ., J. J. Hongyuan Zhou, “Protection effectiveness of sacrificial cladding for near-field blast mitigation,” *International Journal of Impact Engineering*, vol. 170, no. 1, 2022.
- [8] C. Knight, “Determining the Effectiveness of Photogrammetry Techniques Against Manual Measurements on Explosively Formed Craters,” Charlotte Knight, Swansea, 2022.

7. Application For Ethical Approval

In order for research to result in benefit and minimise risk of harm, it must be conducted ethically.

The University follows the OECD Frascati manual definition of **research activity**: "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications". As such this covers activities undertaken by members of staff, postgraduate research students, and both taught postgraduate and undergraduate students working on dissertations/projects.

The individual undertaking the research activity is known as the "principal researcher".

This form must be completed and approved prior to undertaking any research activity.

SECTION A: About You (Principal Researcher)

1	Full Name:	Charlotte Knight
2	Student Number:	1907828
3	Email address:	1907828@student.uwtsd.ac.uk
4	Programme of Study:	OME
5	Director of Studies/Supervisor:	Dave Holley

SECTION B: Internal and External Ethical Guidance Materials

	Please list the core ethical guidance documents that have been referred to during the completion of this form (including any discipline-specific codes of research ethics, location-specific codes of research ethics, and also any specific ethical guidance relating to the proposed methodology). Please tick to confirm that your research proposal adheres to these codes and guidelines. You may add rows to this table if needed.	
1	UWTSD Research Ethics & Integrity Code of Practice	☒
2	UWTSD Research Data Management Policy	☒
3		☐

SECTION C: Details of Research Activity

1	Indicative title:	Understanding the Effects of Blast and Fragmentation on Steel and Cladding	
2	Proposed start date:	02/04/2023	Proposed end date: 22/03/2024
	Introduction to the Research (maximum 300 words in each section) Ensure that you write for a <u>Non-Specialist Audience</u> when outlining your response to the three points below: Purpose of Research Activity		

	• <i>Proposed Research Question</i> • <i>Aims of Research Activity</i> • <i>Objectives of Research Activity</i> Demonstrate, briefly, how Existing Research has informed the proposed activity and explain • <i>What the research activity will add to the body of knowledge</i> • <i>How it addresses an area of importance.</i>
3	Purpose of Research Activity To produce a repeatable test methodology that capture the blast and fragmentation data for materials, which can be used for both validation and new material introduction inside the Collateral Damage Model (CDM). (this box should expand as you type)
4	Research Question What are the blast and fragmentation effects from detonation within mild steel and cladding walls? (this box should expand as you type)
5	Aims of Research Activity • To collect blast and fragmentation data on the structural defeat of steel and cladding walls and compare that with the predicted results within the CDM • To input this new experimental data into the model • To produce a low risk repeatable trials process that can be used annually for adding trials data into the CDM (this box should expand as you type)
6	Objectives of Research Activity • To model the results of both materials in the CDM • To write the trials plan and risk assessment and get them signed off by qualified staff • To procure the necessary tools and equipment for the trial • To collect blast and fragmentation data for all shots • To compare the modelled data with the experimental results (this box should expand as you type)
7	Proposed data collection methods (maximum 600 words) Provide a brief summary of all the methods that may be used in the research activity to collect data, making it clear what specific techniques may be used. If methods other than those listed in this section are deemed appropriate later, additional ethical approval for those methods will be needed. You do not need to justify the methods here, but should instead describe how you intend to collect the data necessary for you to complete your project. The blast pressures will be measured by pressure gauges. Velocity foils will measure the velocity of fragments. Witness boards will allow the fragment mass, location and penetration to be analysed. (this box should expand as you type)

SECTION D: Scope of Research Activity

	Will the research activity include:	YES	NO
1	Use of a questionnaire or similar research instrument?	☐	☒
2	Use of interviews?	☐	☒
3	Use of focus groups?	☐	☒
4	Use of participant diaries?	☐	☒
5	Use of video or audio recording?	☐	☒
6	Use of computer-generated log files?	☐	☒
7	Participant observation with their knowledge?	☐	☒
8	Participant observation without their knowledge?	☐	☒
9	Access to personal or confidential information without the participants' specific consent?	☐	☒
10	Administration of any questions, test stimuli, presentation that may be experienced as physically, mentally or emotionally harmful / offensive?	☐	☒
11	Performance of any acts which may cause embarrassment or affect self-esteem?	☐	☒
12	Investigation of participants involved in illegal activities?	☐	☒
13	Use of procedures that involve deception?	☐	☒
14	Administration of any substance, agent or placebo?	☐	☒
15	Working with live vertebrate animals?	☐	☒
16	Procedures that may have a negative impact on the environment?	☒	☐
17	Other primary data collection methods. Please indicate the type of data collection method(s) below.		
	Details of any other primary data collection method:	☐	☒
	(this box should expand as you type)		

If you have ticked NO to every question then the research activity is (ethically) low risk and you may skip section E and continue to section F.

If YES to any question, then no research activity should be undertaken until full ethical approval has been obtained.

SECTION E: Intended Participants

	Who are the intended participants:	YES	NO
1	Students or staff at the University?	☐	☒
2	Adults (over the age of 18 and competent to give consent)?	☐	☒
3	Vulnerable adults?	☐	☒
4	Children and Young People under the age of 18? (Consent from Parent, Carer or Guardian will be required)	☐	☒

5	Prisoners?	☐	☒
6	Young offenders?	☐	☒
7	Those who could be considered to have a particularly dependent relationship with the investigator or a gatekeeper?	☐	☒
8	People engaged in illegal activities?	☐	☒
9	Others. Please indicate the participants below, and specifically any group who may be unable to give consent.		
	Details of any other participant groups: Complete this only if your participants cannot give consent. This includes animals (this box should expand as you type)	☐	☒

Participant numbers and source		
Provide an estimate of the expected number of participants. How will you identify participants and how will they be recruited?		
10	How many participants are expected?	N/A (this box should expand as you type)
11	Who will the participants be?	N/A (this box should expand as you type)
12	How will you identify the participants?	N/A (this box should expand as you type)

Information for participants:		YES	NO	N/A
13	Will you describe the main research procedures to participants in advance, so that they are informed about what to expect?	☐	☐	☒
14	Will you tell participants that their participation is voluntary?	☐	☐	☒
15	Will you obtain written consent for participation?	☐	☐	☒
16	Will you explain to participants that refusal to participate in the research will not affect their treatment or education (if relevant)?	☐	☐	☒
17	If the research is observational, will you ask participants for their consent to being observed?	☐	☐	☒
18	Will you tell participants that they may withdraw from the research at any time and for any reason?	☐	☐	☒
19	With questionnaires, will you give participants the option of omitting questions they do not want to answer?	☐	☐	☒
20	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	☐	☐	☒

21	Will you debrief participants at the end of their participation, in a way appropriate to the type of research undertaken?	☐	☐	☒
22	If NO to any of above questions, please give an explanation			
	You should be able to tick YES for all of these questions. If not, then explain why not in this box. Participants are not required for my proposal. (this box should expand as you type)			

Information for participants:		YES	NO	N/A
24	Will participants be paid?	☐	☒	☐
25	Is specialist electrical or other equipment to be used with participants?	☐	☒	☐
26	Are there any financial or other interests to the investigator or University arising from this study?	☐	☒	☐
27	Will the research activity involve deliberately misleading participants in any way, or the partial or full concealment of the specific study aims?	☐	☒	☐
28	If YES to any question, please provide full details			
	(this box should expand as you type)			

SECTION F: Anticipated Risks

Outline any anticipated risks that may adversely affect any of the participants, the researchers and/or the University, and the steps that will be taken to address them.			
1	Risks to participants For example: sector-specific health & safety, emotional distress, financial disclosure, physical harm, transfer of personal data, sensitive organisational information. If you have identified in section D that there are no participants then enter N/A and go skip to question 3.		
	<table border="1"> <tr> <td> Risk to participants: There are always risks. Do not write N/A unless you have no participants. (this box should expand as you type) </td> <td> How you will mitigate the risk to participants: N/A (this box should expand as you type) </td> </tr> </table>	Risk to participants: There are always risks. Do not write N/A unless you have no participants. (this box should expand as you type)	How you will mitigate the risk to participants: N/A (this box should expand as you type)
Risk to participants: There are always risks. Do not write N/A unless you have no participants. (this box should expand as you type)	How you will mitigate the risk to participants: N/A (this box should expand as you type)		
2	If research activity may include sensitive, embarrassing or upsetting topics (e.g. sexual activity, drug use) or issues likely to disclose information requiring further action (e.g. criminal activity), give details of the procedures to deal with these issues, including any support/advice (e.g. helpline numbers) to be offered to participants. Note that where applicable, consent procedures should make it clear that if something potentially or actually illegal is discovered in the course of a project, it may need to be disclosed to the proper authorities		
	N/A (this box should expand as you type)		
3	Risks to the investigator For example: personal health & safety, physical harm, emotional distress, risk of accusation of harm/impropriety, conflict of interest		

	Risk to the investigator: There are always risks. Do not write NA. Health and safety (this box should expand as you type)	How you will mitigate the risk to the investigator: Conduct a risk assessment that has been approved through Dstl procedures. (this box should expand as you type)
4	University/institutional risks For example: adverse publicity, financial loss, data protection	
	Risk to the University: There are always risks. Do not write NA. Adverse publicity (this box should expand as you type)	How you will mitigate the risk to the University: Conduct a risk assessment and trial plans that have been approved through Dstl procedures. (this box should expand as you type)
5	Environmental risks For example: accidental spillage of pollutants, damage to local ecosystems	
	Risk to the environment: Damage to ecosystems (this box should expand as you type)	How you will mitigate the risk to environment: Conduct a risk assessment that have been approved through Dstl procedures. Inform the environmental lead about the trial, and ensure they are happy with the proposed actions. (this box should expand as you type)

SECTION G: Feedback, Consent and Confidentiality

If you have identified in section D that there are no participants then enter skip this section and continue to section H.

1	Feedback What de-briefing and feedback will be provided to participants, how will this be done and when? N/A (this box should expand as you type)
2	Informed consent Describe the arrangements to inform potential participants, before providing consent, of what is involved in participating. Describe the arrangements for participants to provide full consent before data collection begins. If gaining consent in this way is inappropriate, explain how consent will be obtained and recorded in accordance with prevailing data protection legislation. N/A (this box should expand as you type)
3	Confidentiality / Anonymity Set out how anonymity of participants and confidentiality will be ensured in any outputs. If anonymity is not being offered, explain why this is the case. N/A

	(this box should expand as you type)
--	--------------------------------------

SECTION H: Data Protection and Storage

	Does the research activity involve personal data (as defined by the General Data Protection Regulation 2016 "GDPR" and the Data Protection Act 2018 "DPA")?	YES	NO
1	"Personal data" means any information relating to an identified or identifiable natural person ('data subject'). An identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person. Any video or audio recordings of participants is considered to be personal data.	☐	☒
If YES, provide a description of the data and explain why this data needs to be collected:			
2	(this box should expand as you type)		
	Does it involve special category data (as defined by the GDPR)?	YES	NO
3	"Special category data" means sensitive personal data consisting of information as to the data subjects' – (a) racial or ethnic origin, (b) political opinions, (c) religious beliefs or other beliefs of a similar nature, (d) membership of a trade union (within the meaning of the Trade Union and Labour Relations (Consolidation) Act 1992), (e) physical or mental health or condition, (f) sexual life, (g) genetics, (h) biometric data (as used for ID purposes).	☐	☒
If YES, provide a description of the special category data and explain why this data needs to be collected:			
4	(this box should expand as you type)		

	Will data from the research activity (collected data, drafts of the thesis, or materials for publication) be stored in any of the following ways?	YES	NO
5	Manual files (i.e. in paper form)?	☒	☐
6	University computers?	☐	☒
7	Private company computers?	☒	☐
8	Home or other personal computers?	☒	☐
9	Laptop computers/ CDs/ Portable disk-drives/ memory sticks?	☒	☐
10	"Cloud" storage or websites?	☐	☒

11	Other – specify:	☐	☒
12	For all stored data, explain the measures in place to ensure the security of the data collected, data confidentiality, including details of backup procedures, password protection, encryption, anonymisation and pseudonymisation:		
	All data will be kept in password protected cloud storage on Dstl's computer system which will not be shared. (this box should expand as you type)		

Data Protection			
	Will the research activity involve any of the following activities:	YES	NO
13	Electronic transfer of data in any form?	☒	☐
14	Sharing of data with others at the University outside of the immediate research team?	☐	☒
15	Sharing of data with other organisations?	☐	☒
16	Export of data outside the UK or importing of data from outside the UK?	☐	☒
17	Use of personal addresses, postcodes, faxes, emails or telephone numbers?	☐	☒
18	Publication of data that might allow identification of individuals?	☐	☒
19	If YES to any question, please provide full details, explaining how this will be conducted in accordance with the GDPR and Data Protection Act (2018) (and/or any international equivalent):		
	All data will be encrypted and kept in password protected cloud storage on both myself and works system. (this box should expand as you type)		
20	List all who will have access to the data generated by the research activity:		
	Myself and the trials team (this box should expand as you type)		
21	List who will have control of, and act as custodian(s) for, data generated by the research activity:		
	The principal researcher. (this box should expand as you type)		
22	Give details of data storage arrangements, including security measures in place to protect the data, where data will be stored, how long for, and in what form.		
	All data will be encrypted and kept in password protected cloud storage on both myself and works system. (this box should expand as you type)		

22	Confirm that you have read the UWTSD guidance on data management (see https://www.uwtسد.ac.uk/library/research-data-management/)	☒
23	Confirm that you are aware that you need to keep all data until after your research has completed or the end of your funding	☒

SECTION I: Declaration

The information which I have provided is correct and complete to the best of my knowledge. I have attempted to identify any risks and issues related to the research activity and acknowledge my obligations and the rights of the participants. In submitting this application I hereby confirm that I undertake to ensure that the above named research activity will meet the University's Research Ethics and Integrity Code of Practice which is published on the website: https://www.uwtسد.ac.uk/research/research-ethics/		
1	Signature of applicant: Charlotte Knight	Date: 09/03/2023
2	Director of Studies/Supervisor:	Date:
3	Signature:	

FOR INTERNAL USE ONLY:

Ethical approval given		
1	Signature of assessor:	Date:
2	Name:	
3	Role:	

Understanding the Effects of Blast and Fragmentation on Steel and Cladding Materials

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

86/100

Intro / Aim & Objectives (150 words)		
Project title.		
Identification of a specific problem to be investigated.		
Well-defined aims and SMART objectives.		
Explaining why this project is worth doing.		
Discussion of what the project needs to do in order to be a success.		
Description any deliverables that will be produced at the end of the project	20	16
Clear and concise introduction with clear justification as to why the topic was selected. Realistic and well-defined SMART aims and objectives included. Deliverables have been mentioned, more emphasis could be placed on what the success criteria would be for this investigation.		
Background to the Project / Literature Review (450 words)		
Description of how the work to be done in the project relates to the work identified in the literature review.	20	16
Discussion of any ethical issues raised by the project Identifying what has already been done within the field. Topic familiarity.		
Brief literature review using appropriate sources – 6-8 journal papers and book chapters rather than just websites.		
Selection of relevant models & concepts.		

Clear evidence of topic familiarity demonstrated. A range of relevant references used throughout, most of which are relevant ([6] would be considered dated as it is 15 years old at this point, try and stick to references published in the last five years where possible). CDM described in sufficient detail simplistically enough for non-experts to understand.		
Project Design (200 words)		
Clear statement of which development methods are to be used and why they are appropriate. Clear statement of which tools are to be used and why they are appropriate. Clear description of how data collected will be analysed Clear and concise summary of project design presented. Visual representation of test setup provided to aid understanding. Excellent risk assessment with ethical consideration taken into account. Some additional detail in the data evaluation section as to why this is being done and the potential expected results may have been beneficial.	30	27
Resources / Planning (200 words)		
List of any deliverables. Clear diagram showing both timing and resource use. Completed ethics form. Limited and relevant appendices Deliverables discussed throughout. Comprehensive list of resources included. Gantt chart provided but very little space for error has been incorporated, is there a contingency plan in place in case delays occur? Completed ethics form included.	15	13

Document Presentation		
Correct spelling. Grammar and punctuation. Flow of narrative/fluency. Coherence. Word processed. Correct use of referencing with bibliography. Strict word limit for main text – 1000 words. Correct spelling throughout, some minor grammar errors. Work has a good flow. IEEE referencing correctly used throughout. Kept within the wordcount +/- 10%.	15	14
TOTAL	100	86

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