

Final submission

by George Tucker

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Investigation into Scaling of Controlled
Fragmenting Cases
Research Proposal
By George Tucker

Contents

List of Tables	3
1. Introduction	4
2. Background to the Proposed Research.....	5
3. Aims & Objectives	6
4. Experimental Design	7
4.1 Outline of Experimental Procedure	7
4.2 Data Collection.....	7
Impetus modelling software allows for fragment shape identification, and can produce various different plots showing fragment distribution and trajectory paths.....	7
4.3 Data Evaluation	7
4.4 Risks & Limitations	7
4.5 Ethical Issues	7
6. Resources & Planning.....	8
6.1 Resources Required	8
6.1.1 Physical Resources:	8
6.1.2 Human Resources:	8
6.1.3 Other Resources:.....	8
6.2 Gantt Chart.....	9
7. Reference List.....	10
References	10
8. Appendix A – SOAC ethics form	11

List of Tables

Table 1 - Gantt chart showing indicative weeks where time can be allocated to the major project
(subject to change depending on external factors) 9

1. Introduction

Understanding the mechanisms of how a case fragments is important in munition warhead design. There are different ways of achieving fragmentation effects in munitions: naturally fragmenting cases, controlled or “fire-formed” fragmenting cases, and the inclusion of pre-formed fragmentation surrounding a warhead. Whilst past investigations have looked at the scaling effects on naturally fragmenting cases, there is scope to explore the effects of scaling different parameters on controlled fragment formation. If a relationship can be identified and understood, then the potential benefits include the ability to trial controlled fragmentation cases in a scaled-down fashion. Ultimately this reduces overall costs and material quantities.

2. Background to the Proposed Research

Several studies have been carried out looking at the effect of scaling on naturally fragmenting cases and how these can be modelled. [1] [2] These studies have included physical trials work to help corroborate or inform any model data and have shown that there are identifiable relationships between fragments and scaling of overall charge size – such as larger cases producing more fragments when scaled up but charge/mass ratios are kept the same. [3]

No work has been identified on the effects scaling has on casings designed to fragment in a controlled manner. They all focus on the ability to predict how scaling naturally fragmenting cases will affect fragment properties.

Naturally fragmenting cases are not the only type of fragment generation used in warheads. The understanding of controlled fragmentation is important in controlling terminal effect performance in warheads, aiding in understanding and minimising collateral damage effects. [4] However, there are many different variables that contribute to how well any surface features influence the fragments created from a case. These range from the geometry of any introduced weak points, to the method of control employed: inner or outer case scoring, or introduction of profiled sleeves that sit within a case. To help understand these effects, live explosive trials are often used, such as “frag arena trials”. [5] These can be large in scale and costly due to material costs, and larger charges need bigger safe distances on ranges etc. [6] If anything can be done to show that reduced size charges can provide good indicative results for controlled fragmentation warheads, this could help make trialling easier, limiting the need for full-scale testing or at least inform early design. [3]

The use of modelling to simulate case fragmentation under explosive loading is not new. Several pieces of research have covered this and there have been several models developed over time to aid in predicting fragmentation, informed by mechanics observed through experimentation. [7] This can be useful in scenarios such as assessing munition vulnerability to accidental initiations after frag attack, for example. [8]

One such modelling software is Impetus, which has can model blast and fragmentation effects using physical 3D models which can be created in computer aided design (CAD) software. Impetus can be used to determine fragment shape, size, distribution, and velocity/trajectory. This makes it a perfect candidate to examine the effects of scale on several different fragment properties when looking at controlled fragmentation. [9]

3. Aims & Objectives

Aim:

To conduct an investigative study into the effect of scaling on controlled fragmentation cases through modelling.

Objectives:

- 1) Carry out further research into fragmentation scale relationships conducted in the past
- 2) Understand the different variables that can be adjusted (scaling for volume/mass ratio, groove depth, groove profile, controlled fragment sizes, etc.) and how many iterations will need to be run to gain meaningful data
- 3) Learn how to use and then operate the Impetus modelling software for fragmentation
- 4) Run a suite of simulations on scenarios as identified in objective 2
- 5) Collect data on fragment formation, size, shape, distribution, trajectories, velocities
- 6) Carry out post-processing on the data obtained from the modelling to identify if there are any relationships
- 7) Write up and present findings in report, presentation, and poster

4. Experimental Design

4.1 Outline of Experimental Procedure

This study will be done using the modelling software Impetus. This will allow for numerous iterations with different variable changes to run and the results gathered. Also due to the cost of materials and range bookings the use of modelling for an investigative piece of gives some assurance over the ability to get the work completed on time.

4.2 Data Collection

Impetus modelling software allows for fragment shape identification, and can produce various different plots showing fragment distribution and trajectory paths.

4.3 Data Evaluation

The data can be processed using tools such as Microsoft Excel alongside statistical analysis methods taught in ACDA0921.

4.4 Risks & Limitations

Risks include the availability of a senior modeller to teach the operation of Impetus software. Additionally, modelling has several limitations compared to physical field-trials. There are limitations that can be applied to all models such as their resolution, representation of physics (air resistance, mechanical properties etc.), and material models. Impetus will also have limitations specific to itself which will have to be fully explored and used to caveat all results.

4.5 Ethical Issues

This research is purely to discover and understand any relationships that may exist and affect fragmentation formation when scaling occurs. As this stands, there are no direct ethical implications for this piece of research. For further details on the ethical impacts of this study, please see the ethics form in Appendix A.

6. Resources & Planning

6.1 Resources Required

6.1.1 Physical Resources:

- Access to IT with Impetus software installed and software license
- Access to IT for data analysis and report write-up

6.1.2 Human Resources:

- Academic project supervisor to liaise and discuss project with
- Senior modeller to teach the Impetus software
- Principal researcher

6.1.3 Other Resources:

- Imagery services to print out final poster

6.2 Gantt Chart

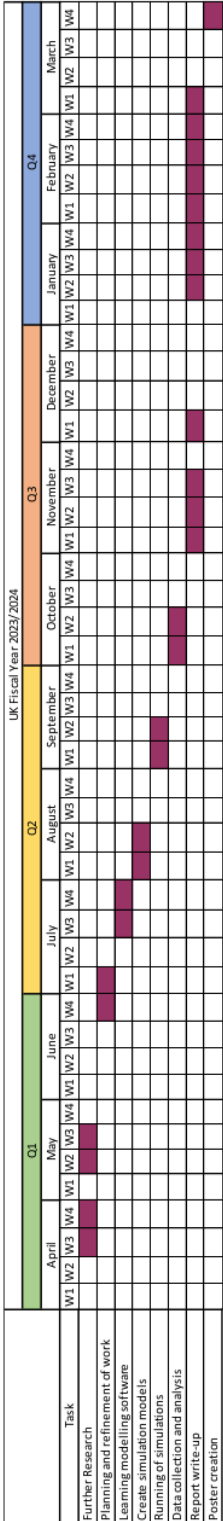


Table 1 - Gantt chart showing indicative weeks where time can be allocated to the major project (subject to change depending on external factors)

7. Reference List

References

- [1] A. J. B. Norbert M Burman, "A CONCEPT FOR THE PREDICTION OP FRAGMENT MASS/NUMBER DISTRIBUTIONS OF FRAGMENTING MUNITIONS," Defence Science and Technology Organisation, Maribyrnong.
- [2] J. Saunders, "A Report on TTCP Workshop on Fragmentation Characterization Methodology," Royal Armament Research and Development Establishment, London, 1986.
- [3] A. J. Bedford, "Scaling of Fragmentation," Materials Research Laboratories, Maribyrnong, 1975.
- [4] J. T. F. R. S. S.-K. Berko Zecevic, "Chapter 20 - Lethal Influence Factors of Natural and Preformed Fragmentation Projectiles," in *DAAAM International Scientific Book*, Vienna, DAAAM International Scientific, 2015, pp. 219-234.
- [5] P. D. A. H. I. L. R. T. I. G. Cullis, "Numerical simulation of the natural fragmentation of explosively loaded thick walled cylinders," *Defence Technology*, vol. 10, no. 2, pp. 198-210, 2014.
- [6] J. T. Klopčič, "An Efficient Technique for the Collection and Analysis of Fragment Mass Distributions from Fragmenting Munitions," Army Research Laboratory , Aberdeen, 1996.
- [7] K. F. H. H. H. T. T. Hiroe, "Deformation and fragmentation behaviour of exploded metal cylinders and the effects of wall materials, configuration, explosive energy and initiated locations," *International Journal of Impact Engineering*, vol. 35, no. 12, pp. 1578-1586, 2008.
- [8] W. W. H. John Starkenburg, "Benchmark Tests and Analysis for Ordnance Fragmentation and Propagation Models," Army Research Laboratory, Aberdeen, 2000.
- [9] Impetus Afea AS, "Impetus," Impetus Afea AS, 2023. [Online]. Available: <https://www.impetus.no/>. [Accessed 16 03 2023].

8. Appendix A – SOAC ethics form

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:	George Tucker
2	Student Number:	1906898
3	Email address:	1906898@student.uwtsd.ac.uk
4	Programme of Study:	OME Degree Apprenticeship
5	Director of Studies/Supervisor:	Gareth Collet

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:	Investigation into Scaling of Controlled Fragmenting Cases		
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: • <i>Purpose of Research Activity</i> • <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 The purpose of the research activity is to further the understanding of fragmenting mechanics at different scales when observing the break-up of controlled fragment warhead cases. (this box should expand as you type)
4	Research Question To what extent do scaling factors influence the formation of controlled fragmentation? (this box should expand as you type)
5	Aims of Research Activity To conduct an investigative study into the effect of scaling on controlled fragmentation cases through modelling. (this box should expand as you type)
6	Objectives of Research Activity Objectives: 1) Carry out further research into fragmentation scale relationships conducted in the past 2) Understand the different variables that can be adjusted (scaling for volume/mass ratio, groove depth, groove profile, controlled fragment sizes, etc.) and how many iterations will need to be run to gain meaningful data 3) Learn how to use and then operate the Impetus modelling software for fragmentation 4) Run a suite of simulations on scenarios as identified in objective 2 5) Collect data on fragment formation, size, shape, distribution, trajectories, velocities 6) Carry out post-processing on the data obtained from the modelling to identify if there are any relationships 7) Write up and present findings in report, presentation, and poster (this box should expand as you type)
	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.
7	The data that will be needed for this investigation shall be obtained from the outputs of any modelling work done to answer the research question. This data can be outputted into several formats, both numerical and graphical for analysis. Past data from other modelling work may also be used from existing research papers examining related phenomena, or trials work that might be able to help assess the validity of modelling results. (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: No participants (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

		<i>(this box should expand as you type)</i>
11	Who will the participants be?	N/A <i>(this box should expand as you type)</i>
12	How will you identify the participants?	N/A <i>(this box should expand as you type)</i>

	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			
	N/A <i>(this box should expand as you type)</i>			

	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			
	N/A <i>(this box should expand as you type)</i>			

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.	
	Risk to participants: N/A <i>(this box should expand as you type)</i>	<i>How you will mitigate the risk to participants:</i>

	(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: Strain on the body from working at a computer (this box should expand as you type)	How you will mitigate the risk to the investigator: Making sure to use correct height-adjustable desk/monitor and to take regular breaks from sitting down and working at a computer for extended periods of time. (this box should expand as you type)
4	University/institutional risks For example: adverse publicity, financial loss, data protection	
	Risk to the University: (this box should expand as you type)	How you will mitigate the risk to the University: (this box should expand as you type)
5	Environmental risks For example: accidental spillage of pollutants, damage to local ecosystems	
	Risk to the environment: N/A (this box should expand as you type)	How you will mitigate the risk to environment: (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: Data will mainly be saved on work computers which are encrypted and regularly backed up to prevent loss of data. Transfer of reports etc, will be done by email if required to secure password-protected accounts. The data will not be shared outside of the company or university staff supervisor and moderating personnel. (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):		
	No personal data will be collected. <i>(this box should expand as you type)</i>		
20	List all who will have access to the data generated by the research activity:		
	Principal researcher, project supervisor, work supervisor <i>(this box should expand as you type)</i>		
21	List who will have control of, and act as custodian(s) for, data generated by the research activity:		
	Principal researcher <i>(this box should expand as you type)</i>		
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.		
	Data will mainly be saved on work computers which are encrypted and regularly backed up to prevent loss of data. Transfer of reports etc, will be done by email if required to secure password-protected accounts. The data will not be shared outside of the company or university staff supervisor and moderating personnel. <i>(this box should expand as you type)</i>		
22	Confirm that you have read the UWTSD guidance on data management (see https://www.uwtss.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.uwtss.ac.uk/research/research-ethics/			
1	Signature of applicant:	G. Tucker	Date: 23/03/2023
2	Director of Studies/Supervisor:		Date:
3	Signature:		

FOR INTERNAL USE ONLY:

Ethical approval given		
1	Signature of assessor:	Date:

2	Name:	
3	Role:	

Final submission

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

63/100

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 to be a success.		
Description of any deliverables that will be produced at the end of the project		
	20	14
The topic area is clearly identified and well-justified. Good attempts were made to explain the benefits of this investigation, however, there needs to be more detail included about the success criteria. Good aims and objectives have been proposed with clear reference to SMART, well done. Usually, no more than five objectives are included in a project of this scale, it is not necessary to include a report, presentation, and poster production as an objective for the project.		
Background to the Project / Literature Review (450 words)		
Description of how the work to be done in the project relates to the	20	13

work identified in the literature review. 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, suitably simplified for a nonexpert to understand. A range of references have been used, good effort, but a lot of them are quite dated at this point and the first reference has no date with it. Try and stick to sources published within the last five years where possible. This section may have benefitted from including diagrams of the current models and potentially a theoretical model diagram based on the proposed research, this could aid the reader in understanding the difference between the current and proposed models.		
Project Design (200 words)		
Clear statement of which development methods are to be used and why they are appropriate. A clear statement of which tools are to be used and why they are appropriate.	30	19

A clear description of how data collected will be analysed Reasonable design is suggested however it does lack detail in some areas, for example in the data evaluation section suggestions as to which statistical analysis could be performed etc. Good consideration of limitations and ethical issues surrounding this project.		
Resources / Planning (200 words)		
List of any deliverables. Clear diagram showing both timing and resource use. Completed ethics form. Limited and relevant appendices Deliverables were discussed throughout but could potentially have been done in greater detail in this section. Gantt chart has been included with sufficient space to reschedule tasks if delays occur. Gantt charts tend to be included as appendices as the ethics form has been. The ethics form has been included.	15	8
Document Presentation		
Correct spelling. Grammar and punctuation. The flow of narrative/fluency. Coherence. Word processed.	15	9

Correct use of referencing with bibliography. Strict word limit for main text – 1000 words. Error in Table of Content, missing point number five and skips straight from point four to six. There also appears to be a line of text included as a point in the TOC (between points 4.2 and 4.3), consider having someone proofread your work before submitting it to avoid these mistakes. The narrative has a reasonable flow. Stuck within the wordcount +/- 10%. IEEE used correctly throughout with the exception of the missing date for reference [1].		
TOTAL	100	63

PAGE 1
PAGE 2
PAGE 3
PAGE 4
PAGE 5
PAGE 6
PAGE 7
PAGE 8
PAGE 9
PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18
