

2023- 24_Cobot_Work_Base_Project_V 2.0

by Frazer Graham

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An evaluation of a collaborative robot
capability for implementation into
explosive processing environments

Research Proposal

Frazer Graham

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1. Introduction

Defence Science and Technology Laboratory (Dstl) has invested in a collaborative robot (Cobot) to:

- Demonstrate the benefits of implementing cobots in an energetic environment.
- Identify the challenges to licence and authorise cobots in an energetic environment.  4

To successfully achieve these objectives the following research needs to be undertaken:

- Understand the forces a cobot can generate during operation (intended and un-intended).
- Develop a safe working method for implementation in an energetic environment.
- Develop a process for future equipment to be streamlined into energetic environments.  5

Overall, the objective is to understand the forces a cobot gripper can generate, to inform the development of safe working practices for cobots in an energetic environment. Without this data, safety assurances cannot be provided to the Explosive Safety Representative (ESR) to licence the use of cobots, and associated tooling, within an energetic environment.  6

The success of the project will be determined by inert testing, and report, conducted on the cobot.  7

2. Background

2.1 What is a collaborative robot (cobot)?

The term cobot is derived from the phrase collaborative robot, and was coined by Michael A Peshkin, and J. Edwards Colgate. [1] It refers to a robotic architecture intended for direct physical interaction with human operators [1]. Cobots are designed to be lightweight, smooth surfaced, and have reduced operating speeds/forces to reduce the severity of impact to human operators [2]. This contrasts with industrial robots, which are designed to undertake heavy duty tasks in industrial environments, often at higher speeds (Table No.1).



Figure 1 - Industrial robots enclosed from human interaction [3]



Figure 2 - Cobot assisting a worker with injection moulding [4]

Feature	Robot	Cobot
Deployment	Fixed, complex programming requirements	reconfigurable, drag-and-drop programming
Space	Larger footprint, requiring guards and cages	Smaller footprint, no guards or cages required
Safety	Operating speed not affected by personnel in vicinity	Personnel within vicinity will reduce operating speeds

Table 1 - Difference between industrial robots and cobots [5]

all pictures and tables must be described in text!

2.2 Why are cobots important to Dstl?

Dstl has aspirations to implement Robotic and Autonomous Systems (RAS) into hazardous environments to achieve the following objectives [6]:

- Reduce personnel exposure to hazardous materials and environments by implementing remote and (semi)-autonomous systems.
- Increase frequency and flexibility of energetic processing by implementing (semi)-automated systems

Cobots have been identified as a suitable technology to achieve these goals for the following reasons:



- Drag-and-drop programming allowing flexible (re)-deployment of cobot systems for various repetitive and/or hazardous activities. Allowing operators to attend priority tasks, while also reducing risk to personnel.
- Various tooling, and bespoke tooling, allowing capability for a variety of tasks. Increasing the capability of engineering activities which can be conducted remotely.
- Force sensing capabilities which can be used to set safe working loads and thresholds.

2.3 Explosive legislation and cobots

Cobots have proven their versatility, safety, and efficiency in mechanical environments. Being implemented for applications such as: machine tending, palletizing, screwing, packaging, and welding [5]. However, a problem Dstl faces, similar to the article “*Industry 4.0 and explosion prevention*” by Marek Wolinski, is the lack of robotic regulations in energetic environments [3].



Defence Safety Assurance 03 Part 2 Joint Service Publication 482 (DSA 03 Part 2 JSP482) chapter 8 describes the requirements for electrical equipment operating in Category B¹ and Category C² environments [7]. Unfortunately, there is little guidance for licensing RAS equipment in an energetic environment.

Chapter 8 details physical properties electrical equipment must adhere to for adoption in Category A and B environments; but it does not detail any operational requirements a cobot must adhere to when working with explosives.

Therefore, the objective of this report is to identify and report a process in which future RAS equipment can be streamlined into an energetic environment. Additionally, to establish testing requirements to authorise and licence RAS equipment.

2.4 Explosives sensitivity and robotic handling

For the Explosive Safety Representative (ESR) to authorise the use of RAS in an energetic environment a safety case is required. To build an effective safety case, an understanding of how a cobot could handle energetic materials, or components, needs to be developed.

This is because primary and secondary explosives are sensitive to stimuli such as impact, friction, heat, and static [8]. Using activation stimuli³, and operational test data from the cobot arm, safe working thresholds and procedures can be used to inform the safety case. Enabling the identification of energetic materials the cobot can safely handle.

¹ Category B is an area which contain dust atmospheres

² Category C is an area which contains an explosive/flammable atmosphere.

³ Activation stimuli refers to the energy required to cause an energetic material to undergo an energetic event.



3. Aims and objectives

ID Number	Objective Description
1	Understand the forces a cobot gripper can generate during operation, intended and un-intended, by conducting inert testing in a laboratory environment.
2	Develop safe working practices for cobot implementation in an energetic environment by identifying types of energetic materials the cobot can safely handle.
3	Develop processes to streamline future equipment into energetic environments by hosting discussions with the on-site ESR and DOSG.

Table 2 - Objective ID's and descriptions

Overall the scope of the project is to explore the forces associated and produced by the gripper. With the purpose to create safe operating procedures, and limits, for the arm when working with energetic materials.

4. Experimental Design

4.1 Outline of Experimental Procedure

Inert testing will be conducted on the cobot arm, within a lab environment, to determine if the arm can work with sensitive materials. This will be achieved by measuring the force-torque outputs of the cobot arm during operation of different tasks.

An instrumented test piece⁴ will be utilised to compare the programmed force of the cobot arm against the actual force applied. This will enable a direct comparison between the cobots force-torque sensors and the test piece force sensors to confirm that the programmed forces match the applied forces.

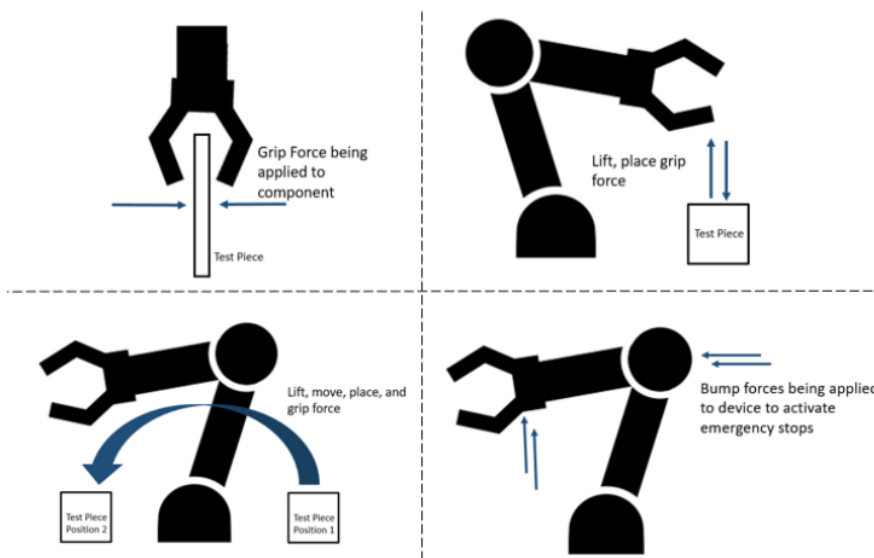


Figure 3 - Draft test configurations

Test Number	Test Description	Data Evaluation
1	To determine the grip force on a component, and to determine if this can be controlled. Showing the gripper can safely grip onto the instrument without crushing it.	Comparing the on board force torque sensors against the instrumented force sensor. Then, comparing both sensors' data against the energy required to initiate an energetic event.
2	To determine the forces the test piece instrument sustains when being picked up and placed. To determine if the device can safely pick up and place energetic components.	To investigate if the instrumented force sensor sustains a greater/smaller force when being picked up and place due to friction and gravity.

⁴ The instrument test piece will have integrated electro-mechanical force sensors via transducers and load cells.

3	Test is to pick up, move, and place the instrumented force sensor. Simulating a working environment.	Determining whether a consistent force is applied and maintained on the test piece during operation.
4	To determine the sensitivity of the bump stops and to determine how a self-sustained bump will affect the gripper forces. Replicating the arm handling an object and being exposed to an incident.	Comparing the force-torque sensors of the arm axis against the gripper sensor and instrumented sensor (held in the gripper). This will then show the forces along the arm and can be compared to determine if any forces cross the threshold to stimulate an energetic event.



Table 2 - Test configurations and data evaluation methods

4.2 Data Collection

- Data will be collected from the cobot on-board force sensors read out from a PC.
- Data will be collected from an instrumented electro-mechanical test piece which contains force sensors (transducers/load cells).

4.4 Risks, Limitations & Mitigations

Risk	Limitation	Mitigation
Device not installed or purchased due to lack of funding.	No testing can be conducted, therefore, no results collected.	University of Wales Trinity St David owns a cobot device. Testing could be conducted using the universities resources.
Force sensor instruments may not have the resolution to record the forces applied.	Testing will be restricted. Therefore, reducing the accuracy of the safety case.	Discuss with the instrumentation team to determine alternative testing equipment and processes.

Table 3 - Risks, limitations, and mitigations

4.5 Ethical Issues

The purpose of the cobot is to achieve remote operation of hazardous activities in energetic environments. However, an ethical consideration is:

- People's perceptions of their job being threatened with the replacement of cobots.

However, a counterargument to this claim is:

- Cobots are to be used as tools to assist workers. Therefore, implementing the technology would result in workers gaining knowledge and experience working with robotic systems and therefore upskilling the workforce.

6. Resources & Planning

6.1 Gantt Chart

No.	Activity	Week Commencing																																																
		Month 1							Month 2							Month 3							Month 4							Month 5							Month 6							Month 7						
		03-Apr-23	10-Apr-23	17-Apr-23	24-Apr-23	01-May-23	08-May-23	15-May-23	22-May-23	29-May-23	05-Jun-23	12-Jun-23	19-Jun-23	26-Jun-23	03-Jul-23	10-Jul-23	17-Jul-23	24-Jul-23	31-Jul-23	07-Aug-23	14-Aug-23	21-Aug-23	28-Aug-23	04-Sep-23	11-Sep-23	18-Sep-23	25-Sep-23	02-Oct-23	09-Oct-23	16-Oct-23	23-Oct-23	30-Oct-23	31-Oct-23																	
1	Project Management																																																	
1.1	Reporting To Work Package Lead					X					X				X					X				X				X					X																	
1.2	Weekly Journal Entry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	
2	Install Equipment																																																	
2.1	Training				X	X	X	X	X	X	X	X	X																																					
2.2	Equipment Risk Assessment	X	X	X	X	X	X	X	X	X	X	X	X	X																																				
2.3	Safe working Methodology	X	X	X	X	X	X	X	X	X	X	X	X	X																																				
2.4	PAT Testing, and Installation	X	X	X	X	X	X	X	X	X	X	X	X	X																																				
3	Develop Testing Environment																																																	
3.1	Research, and planning						X	X	X	X	X	X	X	X																																				
3.1.1	Energetic Requirements																X	X																																
3.1.2	Regulatory Requirements																																																	
3.1.3	Operational Requirements																																																	
3.2	Develop Testing Environment																	X	X	X																														
3.3	Review Testing Environment																			X	X	X																												
4	Conduct Cobot Testing																																																	
4.1	Force Sensing Testing																								X	X	X																							
4.3	Result Analysis																										X	X																						
5	Documentation																																																	
5.1	Project Report																													X	X	X	X																	
5.2	Robotics Awareness Presentation																			X	X																													
5.3	Robotic Testing Results Presentation																										X	X																						

Figure 4 - Project Gantt chart

The Gantt chart does not include the procuring and installing the cobot in Dstl (as of Ethics Form)? Is it something that the company is planning to do in the close future?

6.2 Project Resources

1	Project Management	Activity Description	Hours	Resources
1.1	Reporting To Work Package Lead	Reporting to Work Package Lead and Project Supervisor	3.5	Laptops, Wi-Fi
1.2	Weekly Journal Entry	Time for personal self-assessment and review	8	Journal, Pen

2	Install Equipment	Activity Description	Hours	Resources
2.1	Training	Training to use equipment at Cardiff	8	Travel and Sustenance, accommodation
2.2	Equipment Risk Assessment	Time to develop risk assessment to operate cobot device	21	Laptop, H&S Reviewer
2.3	Safe working Methodology	Time to develop safe operating procedure to be used alongside device (Listed users, safe set-up, set-down, emergency responses)	21	H&S Reviewer, Project Technical Lead
2.4	PAT Testing, and Installation	Time to organise PAT testing and installation into Lab area (Business case)	10	Electrician, Lab Space, Cobot Device

3	Develop Testing Environment	Activity Description	Hours	Resources
3.1	Research, and planning	Time to research the following points to create and develop an accurate inert testing environment. Additionally, to understand what data is required and its format. Finally, time to discuss with regulators for future processes	53	Time to network and discuss with ESR, DOSG, Work Project Lead, Instrumentation team, laptop, library resources
3.1.1	Energetic Requirements			
3.1.2	Regulatory Requirements			
3.1.3	Operational Requirements			
3.2	Develop Testing Environment	Time to develop testing regime, identifying equipment, printing resources, organising lab time with device etc.	14	Electronics, 3D Filament, Cameras, Force Sensors
3.3	Review Testing Environment	Time to share testing regime, identify errors and amend	21	Electronics, 3D Filament, Cameras, Force Sensors, Rule

4	Conduct Cobot Testing	Activity Description	Hours	Resources
4.1	Force Sensing Testing	Time to execute testing regimes	15	Lab Time, Cobot Arm, Journal, Pen, 3D prints, Electronics
4.2	Result Analysis	Time to analyse data and format	7	Laptop

5	Documentation	Activity Description	Hours	Resources
5.1	Project Report	Time to write up report, and progress.	15	Laptop, meeting room
5.2	Robotics Awareness Presentation	Time to present new capability for further collaboration	3	Laptop, meeting room, UR arm
5.3	Robotic Testing Results Presentation	Time to present to team / audience safe system discoveries	3	Laptop, meeting room

Hours Total	202.5
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Table 4 - Project milestones, objectives, objective descriptions and resources required.

7. References

- [1] J. E. C. Michael A Peshkin, "Cobot Architecture," *IEEE Transactions on Robotics and Automation*, vol. 17, no. 4, pp. 377-389, 2001.  17
- [2] International Federation of Robotics, "Demystifying Collaborative Industrial Robots," International Federation of Robotics , Frankfurt, 2018.
- [3] M. Wolinski, "Industry 4.0 and Explosion Prevention," *Fire and Environmental Safety Engineering*, vol. 247, p. 6, 2018.
- [4] E. Demaitre, "UR Injection Molding Machine Interface to help plastics manufacturers integrate cobots," Collaborative Robot Trends, 23 April 2020. [Online]. Available: <https://www.cobottrends.com/injection-molding-machine-interface-helps-integrate-ur-cobots/>. [Accessed 16 March 2023].
- [5] A. H. R. P. S. Mohd Javaid, "Significant applicatios of cobots in the field of manufacturing," *Cognitive Robotics*, vol. 2, pp. 222-233, 2022.  18
- [6] Defence Science and Technology Laboratory , "Robotics and autonomous systems: defence science and technology capability," Dstl, 01 June 2022. [Online]. Available: <https://www.gov.uk/guidance/robotics-and-autonomous-systems-defence-science-and-technology-capability>. [Accessed 16 March 2023].
- [7] Defence Ordnance Safety Regulator , *DSA 03. OME Part 2 (Formerly JSP 482) Chapter 8 - Safety Standards for Electircal Installations and Equipment in Explosive Facilities*, MoD, 2023.
- [8] J. Akhavan, *The Chemistry of Explosives*, Cambridge: The Royal Society of Chemistry, 2011, pp. 72-81.
- [9] Z. G. B. M. U. Alena Paulikova,  19 "Analysis of the IMpact of Human-Cobot Collaborative Manufacturing Implemntation on the Occupational Health and Safety and the Quality Requirements," *International Journal of Environmnetal Research and Public Health* , vol. 18, p. 15, 2021.

FINAL GRADE

GENERAL COMMENTS

80/100

Intro / Aim & Objectives (150 words)		
<i>Project title. Identification of a specific problem to be investigated. Well-defined aims and SMART objectives.</i>	2016 Background	16
<i>Explaining why this project is worth doing. Discussion of what the project needs to do to be a success.</i>		
<i>Description of any deliverables that will be produced at the end of the project</i>		
The title clearly describes the scope of the project and the specific problems to be investigated are identified.		
The aims are particularly well-defined but the objectives are not SMART (e.g. Table 3)		
A clear statement of why this project is important. See the comment in the text	2018 Project	18
Well-thought discussion of what steps should be undertaken for the success of the project		
There is no clear list of deliverables.		
Background to the Project / Literature Review (450 words)		
<i>Description of how the work to be done in the project relates to the work identified in the literature review. Discussion of any ethical issues raised by the project Identifying what</i>		

<i>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.</i> Links with previously published literature are made and evaluated. Exceptionally good understanding of the topic demonstrated by a clear connection between the system itself, operation procedures, risks/mitigations, and ethical issues. Highly relevant literature sources selected		
Project Design (200 words)		
<i>Clear statement of which development methods are to be used and why they are appropriate.</i> <i>A clear statement of which tools are to be used and why they are appropriate.</i> <i>A clear description of how data collected will be analysed</i> You have a very clear idea of what/why methods and tools to use but data analysis is not well discussed.	30	24
Resources / Planning (200 words)		

<i>List of any deliverables. Clear diagram showing both timing and resource use. Completed ethics form.</i> <i>Limited and relevant appendices</i> Final deliverables are not clearly presented Gantt chart shows the detailed activities and time to complete them; Table 4 lists all resources The ethics Form was submitted by email	15	11
Document Presentation		
Correct spelling. Grammar and punctuation. The flow of narrative/fluency. Coherence. Word processed. Correct use of referencing with bibliography. Strict word limit for main text – 1000 words. Correct spelling, grammar, and punctuation. The use of tables and bullet points provides a great level of clarity and better focus but in the final project use more descriptive writing. Good use of footnotes for explanation Submit a Word document, not pdf next time, please IEEE referencing method applied with small inaccuracies (please see the notes within the text)	15	11

You did not adhere to the required word limit. Text in tables that contain major information is included in the word count		
TOTAL	100	80

PAGE 1

PAGE 2



Comment 1

on page 2 there is Contents as well



Comment 2

very good Table of content; well formatted, sections are numbered for clarity, page numbers provided.

PAGE 3



Comment 3

references are not required here

PAGE 4



Comment 4

is there any literature that could support these statements? develop them more; what would be these benefits? what challenges?

you say it in more detail later but here 'safety' and 'flexibility' would make these statements stronger



Comment 5

very clear aims



Comment 6

aim is what you want achieve and objective is how. this is still aim



Comment 7

this is the objective

PAGE 5



Comment 8

what is the purpose of cobots? 'physical interaction with humans to achieve what?

Text Comment. all pictures and tables must be described in text!

PAGE 6



Comment 9

the main differences between robots and cobots are presented in table 1. Additionally, cobots have been indentified to achieve the above goals for...

this would allow you to refer to the table 1 and create stronger connection



Comment 10

great link to literature, very well presented



Comment 11

smart use of footnote

PAGE 7

PAGE 8



Comment 12

excellent graphics, but Figure 3 is not mentioned anywhere in the text



Comment 13

expected outcome



Comment 14

expected outcome

PAGE 9



Comment 15

expected outcome

PAGE 10



Comment 16

detailed, self-guiding Gantt chart

Text Comment. The Gantt chart does not include the procuring and installing the cobot in Dstl (as of Ethics Form)? Is it something that the company is planning to do in the close future?

PAGE 11

PAGE 12

PAGE 13



Comment 17

M. A. Peshkin, J. E. Colgate, W. Wannasuphoprasit, C. A. Moore, R. B. Gillespie and P. Akella,



Comment 18

M Javaid, A. Haleem, R. P. Singh, S. Rab, R. Suman, these are the authors



Comment 19

Pauliková A, Gyurák Babel'ová Z, Ubárová M. these are the authors