Serapis Tasking Form

Tasking Form Part 1: *(to be completed by the Authority's Project Manager)*

To:	Lot 6 Frazer-Nash Consultancy Ltd	**From:**	The Authority, Dstl.

Any Task placed as a result of your quotation will be subject to the Terms and Conditions of Framework Agreement Number:

LOT 6 DSTL/AGR/SERAPIS/UND/01

VERSION CONTROL

REV1 09/09/2021

REQUIREMENT

Proposal Required by:	[30/09/2021]	**Task ID Number:**	[U57]
The Authority Project Manager:	[REDACTED-PERSONAL INFORMATION]	**The Authority Technical Point of Contact:**	[REDACTED-PERSONAL INFORMATION]
Task Title:	**U57** (QEI Pathfinder (Quantum Accelerator - Uni of Glasgow)		
Required Start Date:	[04/10/2021]	**Required End Date:**	[30/03/2022]
Requisition No:	[1000168114]	**Budget Range**	Uni of Glasgow upto £50k

TASK DESCRIPTION AND SPECIFICATION

Serapis Framework Lot	☐ Lot 1: Collect ☐ Lot 2: Space systems ☐ Lot 3: Decide ☐ Lot 4: Assured information infrastructure ☐ Lot 5: Synthetic environment and simulation ☒ Lot 6: Understand

Development of a Quantum SPOTTER-like algorithm: Transferred learning to allow quantum trained neural nets to run on digital processors

BACKGROUND TO INVITATION TO TENDER

Quantum Accelerator Desired Outcomes

A set of neural net algorithms which:

- allow feature detection in a digital RGB image using neural nets trained without supervision on a D-Wave processor;
- can be transferred automatically to digital processors without loss of accuracy or functionality, thereby allowing the speed of D-Wave quantum processors to be exploited in field-deployed image processing applications;
- where possible, algorithms will be optimised to minimise image processing times.

Background

- The previous StratCom funded Quantum Digital Training project successfully demonstrated the Restricted Boltzmann machine (RBM) training of neural nets on D-Wave for image processing using unsupervised

feature detection. The project also demonstrated that quantum trained neural nets could be transferred to digital processors and execute successfully;
- The Quantum Accelerator will further develop this quantum approach to image processing, scaling up the methods developed for small 5x5 digital images to the largest size which can be processed by D-Wave quantum processors;
- This contract will develop algorithms which will automatically allow the transfer of weights and biases from a quantum trained neural net to a second implemented on a digital chip;
- A separate contract with OxbrdgRbtx is addressing the scale up of the image processing neural net algorithm. The two teams will work closely together.

Assumptions:
- The University of Glasgow and OxbrdgRbtx must work closely together to achieve the desired outcomes;
- Image sizes will not be too large to prohibit use of D-Wave, whose processor has ~5,600 qubits currently, unless novel algorithms are created which overcome this limit;
- During the development of quantum neural net algorithms for quantum image processing, DOTA[1] or other suitable dataset will be used for benchmarking, although simpler datasets, such as MNIST, may be used during initial quantum algorithm development;
- At least initially, quantum algorithms will be based on RBMs to minimise technical risk in the project
- As the target digital processor for Transferred Learning, commercial CPUs or GPUs will be used initially. Extension of the work to special purpose/reduced instruction set chips will be decided in discussions with the Technical Authority.

Computer vision tasks:
Demonstration of two computer vision tasks using quantum trained neural nets running on digital processors should be attempted:
- Image classification;
- Object detection.

Unsupervised Feature Detection:
- The speed of quantum processors makes unsupervised learning tractable and the RBM quantum stack can be used to create feature detectors in an unsupervised learning mode. Only after this has been achieved can the labels on the input data be used to classify.

Supervised Image Classification:
- The utility of the algorithm developed will be investigated using RGB images of dimension suitable for the D-Wave hardware which will output the probabilities of the image belonging to each class within a closed-set of N pre-defined classes in the labelled data;
- Accuracy is the key metric of performance (percentage of a test set being classified correctly, i.e. top match), with secondary metrics being total training time and inference time (per image);
- Key non-quantum algorithms of this type are neural network architectures, such as Inception and ResNet, and should be used as a baseline if sensible comparisons are possible.

Object Detector:
- Efficient utilities must be developed to pipeline data into and from the D-Wave processor as well as to measure algorithm execution times. The maximum training throughput regardless of algorithm must be investigated and reported;the algorithm(s) must be able to import an RGB image of suitable dimensions for the D-wave;
- The project will compare and contrast results of quantum algorithms executed on D-Wave processors (later on NISQ processors when suitable architectures are available) with those obtained using classical algorithms on digital processors for each pre-defined class/object-type of interest. If it proves possible, the algorithm should output: the class label, the pixel coordinates within which the class is present, and a score relating to the probability of that sub-image containing the states class;
- Ideally, the analysis of single images should have no restriction on the number of objects within the scene, or their size, but the D-wave may have hardware limitations. It would be preferable if the algorithm would be able to handle overlapping objects, such as a person riding a bicycle;
- Key non-quantum algorithms of this type are neural network architectures such as YOLOv4, RetinaNet and Mask-RCNN, and should be considered as a baseline or similar;

- The key comparison metric for object detectors is mean-average-precision (mAP), with secondary metrics being inference time (per image) and training time (per total number of training images).

STATEMENT OF REQUIREMENTS

In the QDT project, the transfer of weights and biases for an image processing neural net, NN1, obtained from unsupervised learning using a Restricted Boltzmann model implemented on a D-Wave quantum processor, to a second neural net, NN2, implemented on a digital architecture was carried out manually. The reverse process was also demonstrated (i.e., Classical NN → Quantum NN). This manual approach is impossible for any but the smallest nets. Working closely with OxbrdgRbtx, this contract will:

- By generalisation of the methods used in the QDT, or otherwise, automate the NN transfer processes (Classical→ Quantum) for arbitrary net sizes and develop algorithm(s) which do not require user intervention;
- Carefully characterise the algorithms' execution-times on the size and complexity of the neural nets and other relevant figures of merit, including functionality of the transferred neural net;
- Identify and report limitations to deployed use of the algorithms, e.g. run-time stabilities, hardware and software dependences, architectures of the 'host' and target' processors between which transfer is required and any other constraints on the applicability of the transferred NNs;
- **Stretch goal**: it is expected the separate work developing a quantum image processing capability initially will address smaller images compatible with the current D-Wave architecture. In the future, processing very large images, such as some in the DOTA set, will be necessary and the extension of the methods developed in this contract to such use cases should be considered and, where necessary, modified algorithms proposed and tested.

Procurement Strategy

☐ Lot Lead to recommend ☒Single Source / Direct Award

Pricing:

☒ Firm Pricing ☐ Ascertained Costs* ☐ Other*

Firm Pricing shall be in accordance with DEFCON 127 and DEFCON 643

Ascertained Costs shall be in accordance with DEFCON 653 or DEFCON 802.

*only at Authority's discretion

Task IP Conditions

Task IP Conditions (Follow the NIPPY guide to identify your information and IP requirements for each deliverable)	**Summary of the Authority's rights in foreground IP (IP generated by the supplier in performance of the contract)**
DEFCON 703 ☐	Vests ownership with the Authority
DEFCON 705 Full Rights ☒	Enables MOD to share in confidence as GFI or IRC under certain types of agreements. Can be shared in confidence within UK Government.
OTHER IP DEFCONS: 14* ☐, 15* ☐, 16* ☐, 90* ☐, 91* ☐, 126* ☐	Generally only suitable for deliverables at TRL 6 and above.
BESPOKE IP Clause ☐ *	Details to be added and agreed by IP Group
* Do not use without IPG advice and approval	
Please state in this text box if MOD or the customer has a requirement a) that one or more Other Government Departments is able to share confidentially with their own suppliers, b) to publish but you do	

not think there is a requirement to own or control the deliverable, or c) to share under a procurement Memorandum of Understanding (MOU).*

*If any of these three issues applies, please contact IPG for advice before completing this form. *Listing research MOUs is not required, but can be a helpful courtesy to the supplier.*

DELIVERABLES

Ref	Title	Due by	Format	TRL	Expected classification (subject to change)	Information required in deliverable	IPR DEFCON
D-1	*Delivery Report*	*30/03/2022*	*Presentation (.pptx)*		*Official*	*Presentation pack to include but not limited to:* *• Review of technical progress* *• Risks/issues.* *• GFA and supplier performance*	*705*

DELIVERABLE: ACCEPTANCE / REJECTION CRITERIA

Unless otherwise stated below, Standard Deliverable Acceptance / Rejection applies. This is 30 business days, in accordance with DEFCON 524 Rejection, and DEFCON 525 Acceptance.

Standard Deliverable Acceptance / Rejection:-

Yes ☒ (DEFCON 524 Rejection, and DEFCON 525 Acceptance)

No ☐ (if no, please state details of applicable criteria below)

Deliverable Acceptance / Rejection Criteria:-

If there are any other specific acceptance/rejection criteria you would like to apply to any of the deliverables, please state them here.

Government Furnished Assets (GFA)

ISSUE OF EQUIPMENT/RESOURCES/INFORMATION/FACILITIES (*if not applicable, delete table and insert "None" in this text box)*

Unique Identifier/ Serial No	Description	Classification	Type	Available Date	Issued by	Return or Disposal Date	Any restrictions?
Serial no	*Description*	*Official-Sensitive*	*Equipment*	*00/00/0000*	*Issuer*	*00/00/0000*	*Include details here*

QUALITY STANDARDS

☒ **ISO9001** (Quality Management Systems)

☐ **ISO14001** (Environment Management Systems)

☒ **ISO12207** (Systems and software engineering — software life cycle)

☐ **TickITPlus** (Integrated approach to software and IT development)

☐ **Other:** (Please specify in free text below)

SECURITY CLASSIFICATION OF THE WORK

The highest classification of this SOR

OFFICIAL ☒ OFFICIAL-SENSITIVE ☐ SECRET ☐ TOP SECRET ☐ STRAP ☐ SAP ☐

The highest expected classification of the work carried out by the contractor

OFFICIAL ☒ OFFICIAL-SENSITIVE ☐ SECRET ☐ TOP SECRET ☐ STRAP ☐ SAP ☐

The highest expected classification of Deliverables/Output

OFFICIAL ☒ OFFICIAL-SENSITIVE ☐ SECRET ☐ TOP SECRET ☐ STRAP ☐ SAP ☐

Is a Security Aspects Letter (SAL) required? *(A Security Aspects Letter (SAL) will be required for each Task above Official-Sensitive and above)*

Yes ☒ No ☐

TASK CYBER RISK ASSESSMENT. *(In accordance with DEF STAN 05-138 and the* Risk Assessment Workflow)

Cyber Risk Level	[Very Low]
Risk Assessment Reference	[**RAR-CHMF3VQE**]

ADDITIONAL TERMS AND CONDITIONS APPLICABLE TO THIS CONTRACT

Please ensure all completed forms are copied to DSTLSERAPIS@dstl.gov.uk when sending to the Lot Lead.

Tasking Form Part 2: *(To be completed by the Lot Lead)*

To: The Authority	From: The Lot Lead

Proposal Reference 014057-96125L U57 QEI Pathfinder Quantum Accelerator - Frazer-Nash Proposal **(attached)**

Delivery of the requirement:

The proposal <u>shall</u> include, but not be limited to:

- A full technical proposal that meets the individual activities that are detailed in Statement of Requirements (Part 1 to Tasking Form).
- Breakdown of individual Deliverables, with corresponding Intellectual Property rights applied.
- Breakdown of Interim Milestone Payments, with corresponding due dates.
- A work breakdown structure/project plan with key dates and deliverables identified.
- A list of required Government Furnished Assets from the Authority, including required delivery dates.
- A clear identification of Dependencies, Assumptions, Risks and Exclusions which underpin your Technical Proposal.
- Sub-Contractors Personnel Particulars Research Worker Form and security clearances (if applicable)

PRICE BREAKDOWN

You are to use the costs detailed in Item 2 Table I in the Schedule of Requirement and at Annex E Table 2 of the Serapis Framework Agreement. Please also provide a price breakdown which should include, but is not limited to: Lot Lead Rates, Sub-contractors costs and rates, travel and subsistence. In support of your Proposal you are requested to provide clear details of all Dependencies, Assumptions, Risks and Exclusions that underpin your price.

Offer of Contract: *(to be completed and signed by the Contractor's Commercial or Contract Manager)*

Total Proposal Price in £	**£67,360.20**		(ex VAT)
Start Date:	October 4th 2021	**End Date:**	March 23rd 2022

Lot Leads Representative	Name	[REDACTED-PERSONAL INFORMATION]
	Tel	[REDACTED-PERSONAL INFORMATION]
	Email	[REDACTED-PERSONAL INFORMATION]
	Date	October 4th 2021
Position in Company	Senior Consultant	
Signature	[REDACTED-PERSONAL INFORMATION]	

Core Work – Breakdown

[PRICING TABLES REDACTED IN ENTIRETY-COMMERCIAL INTERESTS]

[SUB CONTRACTOR PRICING TABLES REDACTED IN ENTIRETY-COMMERCIAL INTERESTS]

[T&S PRICING TABLES REDACTED IN ENTIRETY-COMMERCIAL INTERESTS]

Core Work – Milestone breakdown costs

Proposed Milestones Payments

Your TMS bid costs shall be included in milestone 1.

The final Milestone must reflect the actual cost of the deliverable, and be greater than 20% of the Task value, unless otherwise agreed with your Commercial POC

Please duplicate the template per milestone table format below as necessary, and rename milestone number accordingly.

[MILESTONE PRICING TABLES REDACTED IN ENTIRETY-COMMERCIAL INTERESTS]

Total Cost (All Milestones)	**£67,360.20**

Tasking Form Part 3:

To be completed by the Authority's Commercial Officer and copied to the Authority's Project Manager.

1. **Acceptance of Contract:**		
Authority's Commercial Officer	Name	[REDACTED-PERSONAL INFORMATION]
	Tel	[REDACTED-PERSONAL INFORMATION]
	Email	[REDACTED-PERSONAL INFORMATION]
	Date	08/10/2021
Requisition Number		R1000168114
Contractor's Proposal Number		014057/96125L
Purchase Order Number		DSTLX-1000163593
Signature		[REDACTED-PERSONAL INFORMATION]
Please Note: Task authorisation to be issued by the Authority's Commercial Officer or Contract Manager. Any work carried out prior to authorisation is at the Contractor's own risk.		