RCloud Tasking Form – Part B: Statement of Requirement (SoR)

Title of Requirement	Machine/Deep Learning for Wireless Signal Classification
Requisition No.	**RQ0000009908**
SoR Version	**0.1**

1.	**Statement of Requirements**
1.1	**Summary and Background Information**
	This Statement of Requirement (SoR) is to initiate a focussed study into the application and implementation of Machine Learning (ML) and/or Deep Learning (DL) algorithms for wireless signal classification onto a Software Defined Radio (SDR). MOD and Dstl need to be pushing at the forefront of innovation and technology trends; and given the complex and ever changing nature of wireless digital signal design, need to determine the best approach for identifying, classifying and understanding signal behaviour in the ElectroMagnetic Environment (EME). This study will necessitate the evaluation of a range of ML/DL algorithms against a broad range of different signal types that operate in the Industrial, Scientific and Medical (ISM) frequency band, to inform the down selection of an optimal configuration to be deployed onto a Deepwave AIR-T SDR. Over the past 40 years, wireless technology has transformed the communications landscape, with the range and breadth of signal types and wireless systems growing immensely. Whereas once signals were stationary in time and frequency and consisted of relatively basic modulation types and exhibited large, distinct magnitudes; many of the modern day digital signals are the polar opposite – particularly those that are assigned into the contested and generally unlicensed frequency bands, such as the Industrial, Scientific and Medical (ISM) band. As a result, signalling techniques have evolved to enable multiple technologies to utilise the limited RF spectrum allocations much more efficiently, becoming robust to interference, jamming and multipath effects. From a spectrum monitoring perspective, however, this introduces a number of challenges as the ability to detect and discriminate between signals, particularly those that are closely located in frequency and hidden within the noise, is a non-trivial task.

	It is envisaged, however, that the use of increasingly popular and pervasive modern ML/DL algorithms and sophisticated Digital Signal Processing (DSP) techniques can provide the necessary means to achieve effective signal identification and classification.
1.2	**Requirement**
	The requirement for this work, therefore, and the long-term goal is to determine the optimal method for effectively identifying and classifying a broad range of signal types in a contested and congested EME, using ML/DL algorithms deployed onto a SDR. The study will be broken up into a number of research areas which include; **Literature Review** A review of the latest and most popular ML/DL algorithms being used across a range of disciplines with a view to down selecting up to three techniques and, if necessary, adapting them for use in an RF signal classification scenario. **Dataset Generation** Development of a synthetic RF dataset based on wireless communication technologies and protocols commonly found within the 2.4 GHz ISM frequency band. Dstl will provide examples and further guidance on the signal types we are interested in understanding at the project kick-off meeting. **Dataset Preparation** Pre-processing the synthetic RF dataset for training a ML/DL classifier using a mathematical transform technique (Fast Fourier Transform (FFT) Spectrogram). This research will be run in parallel to an internal study into understanding the trade-offs associated with training a ML/DL signal classifier using time, frequency or time-frequency transformed data. The focus for the EMR will be determine the benefits of time-frequency and frequency based signal pre-processing for signal classification activities. A modular approach to signal pre-processing will be taken so as to enable alternative transform techniques to be applied to the dataset in future work. **ML/DL Model Development** ML/DL algorithms that are down selected from the literature review will be implemented and trained using the pre-processed RF data. A cross comparison of each model and its performance will be conducted to determine the optimal configuration to be deployed onto the Deepwave AIR-T SDR.

	An Investigation into tuning the model hyper parameters will also be undertaken, and, should any DL neural network based technique be chosen, a further study into modifying the network architecture (increasing/decreasing number of layers, amount of data presented to the network etc.) will also be undertaken to understand what effect this has on the overall classification performance. **Deployment onto SDR** The preferred ML/DL model, along with the data pre-processing method used, will be deployed onto a Deepwave AIR-T SDR to implement an end-to-end RF signal classification workflow. As part of the deployment onto the Deepwave AIR-T, we are particularly interested in understanding the mechanisms involved with targeting the Nvidia Jetson TX2 Graphical Processing Unit (GPU) for accelerated parallel processing of both DSP and ML/DL algorithms to achieve (near) real time signal classification performance. As part of the Government Funded Equipment (GFE) for the project, Dstl will provide a Deepwave AIR-T platform and a customer written report describing previous work undertaken with the platform to support development, however these will need to be returned at the end of the contract. **Testing** In the first instance, the contractor will be expected to undertake preliminary tests of the developed solution to demonstrate the Proof of Concept (PoC) in a laboratory based environment. These tests will aim to provide proof of (near) real time signal classification performance, against a range of signal inputs. **General Development** The contractor is expected to make use of common and popular ML/DL and DSP programming languages, tools, environments and libraries. In particular, the preference is for a solution to be developed using MATLAB and/or Python (in particular using the cuSignal library) where possible.
1.3	**Options or follow on work** *(if none, write 'Not applicable')*
	Depending on progress, scope and exploitation potential, follow on funding could be provided for FY23/24 and beyond. Any follow on work will likely look to build upon the Proof of Concept (PoC) delivered in this contract and would likely involve building capacity to classify additional signal types, improve signal classification performance and reduce Size, Weight and Power (SWaP) footprint where possible.
1.4	**Contract Management Activities**
	Standard CM Activities

1.5	**Health & Safety, Environmental, Social, Ethical, Regulatory or Legislative aspects of the requirement**

1.6	Deliverables & Intellectual Property Rights (IPR)					
Ref.	**Title**	**Due by**	**Format**	**Expected classification (subject to change)**	**What information is required in the deliverable**	**IPR Condition**
D – 1	Sprint Review	Monthly Review	PowerPoint	Redacted under FOIA Section 26 – Defence	Each month the contractor will present a sprint overview to Dstl which will include; • Review of project deliverables • Progress report against project schedule • Update on technical progress • Risks/issues identified Any other business	*Default RCloud Agreement Terms and Conditions shall apply*
D – 2	Literature Review	T0+2	PDF	Redacted under FOIA Section 26 – Defence	A summary of the most recent literature detailing application of ML/DL algorithms and techniques in RF signal classification and associated domains. The review will also include a down selection of up to 3 most promising techniques which will be investigated in the rest of the study.	*Default RCloud Agreement Terms and Conditions shall apply*

D – 3	Report	T0+9m	PDF	Redacted under FOIA Section 26 – Defence	Report detailing the hardware and software design and implementation of the ML/DL RF signal classifier onto the SDR. The report will include details on any limitations, testing, assurance and recommendations for the next steps.	*Default RCloud Agreement Terms and Conditions shall apply*
D – 4	Demonstrator	T0+9m	Hardware & Software	Redacted under FOIA Section 26 – Defence	A hardware and software demonstrator of the RF signal classification system deployed onto the Deepwave AIR-T platform. As part of the hardware and software deliverables, any development codes/scripts should also be included.	*Default RCloud Agreement Terms and Conditions shall apply*

1.7	Deliverable Acceptance Criteria
	Acceptance Criteria are as in the RCloud v4 terms and conditions. Supplier must be able to demonstrate a functional, working implementation of a ML/DL RF signal classification solution deployed onto the Deepwave AIR-T SDR and performing signal classification in (near) real-time. Deliverables must meet the description and format required,

2	Government Furnished Assets (GFA)				
GFA No.	**Unique Identifier/ Serial No**	**Description:** *Classification, type of GFA (GFE for equipment for example), previous MOD Contracts and link to deliverables*	**Available Date**	**Issued by**	**Return Date or Disposal Date (T0+)** *Please specify which*
GFA-1	Dstl Signal Examples	Dstl will supply some example signal captures from which the contractor is expected to develop and validate synthetic forms against for training the ML/DL RF signal classifier	When required	Redacted under FOIA Section 40 – Personal information	Return at the end of the contract
GFA-2	Deepwave AIR-T SDR	Dstl will supply a Deepwave AIR-T SDR to be targeted for the deployment of the ML/DL RF signal classifier and signal pre-processing code.	When required	Redacted under FOIA Section 40 – Personal information	Return at the end of the contract
GFA-3	Deepwave AIR-T Report	Dstl will supply a customer written report outlining previous work undertaken with the Deepwave AIR-T	When required	Redacted under FOIA Section 40 – Personal information	Return at the end of the contract

2	Evaluation Criteria
2.1	Method Explanation
	All respondents must provide a Technical and Commercial Proposal. The Technical Proposal will be evaluated using the mechanism detailed in 2.2; an overall Technical Score will then be obtained for each supplier. The Supplier should use the Evaluation Criteria, in conjunction with the requirement details provided in 1.1 to 1.7, as the basis for their Technical Proposal. The Supplier's Technical Score will then be divided by the Price provided in their Commercial Proposal, to obtain a Value for Money Score. Suppliers will then be ranked on the basis of the VfM of their proposal. An example is provided below:

			Supplier 1						Supplier 1					
ID	**Criteria**	**Weighting**	**R1**	**Total**	**R 2**	**Total**	**R 3**	**Total**	**R 1**	**Total**	**R 2**	**Total**	**R 3**	**Total**
1	Proposal gives confidence that the requirement is understood.	3	7	21	10	30	7	21	10	30	7	21	10	30
2	Proposal gives evidence that the bidder and staff working on the project have the required knowledge, experience, expertise and facilities.	2	7	14	7	14	3	6	3	6	3	6	0	0
3	Proposal contains a clear project plan which gives confidence work will be done in a timely fashion.	3	3	9	0	0	3	9	7	21	10	30	7	21
4	Quality and credibility of the proposed solution.	3	3	9	3	9	0	0	10	30	7	21	7	21
5	Clear evidence of previous signal processing and ML/DL work in the area of RF signal classification.	2	7	14	7	14	7	14	3	6	3	6	3	6
6	Appreciation for ECM exploitation routes/ideas associated with the technical aspects of the task .	2	3	6	3	6	0	0	7	14	7	14	7	14
		15		**73**		**73**		**50**		**107**		**98**		**92**
	Price/ Value for Money evaluation													

Average Score	65.3	99.0
Price	£180,000	£195,000
Vfm Score Score*100/Price	0.04	0.05

2.2 Technical Evaluation Criteria

The supplier must provide a full Technical Proposal detailing its plan to meet Dstl's requirements detailed in Section 1. This Technical Proposal will be evaluated using the following criteria.:

ID	Criteria	Weighting
1	Proposal gives confidence that the requirement is understood.	3
2	Proposal gives evidence that the bidder and staff working on the project have the required knowledge, experience, expertise and facilities.	2
3	Proposal contains a clear project plan which gives confidence work will be done in a timely fashion.	3
4	Quality and credibility of the proposed solution.	3
5	Clear evidence of previous signal processing and ML/DL work in the area of RF signal classification.	2
6	Appreciation for ECM exploitation routes/ideas associated with the technical aspects of the task .	2

Scores will be given on the basis of the below quality ratings, multiplied by the weighting for each ID. Each Supplier's response will be reviewed by multiple reviewers, and an average will be taken

Quality	**Definition**	**Score**
Excellent	The response addresses all elements of the Requirement and provides a comprehensive, unambiguous and thorough explanation of how the Requirement will be fulfilled.	10
Good	The response addresses all elements of the Requirement and provides sufficient detail and explanation of how the Requirement will be fulfilled.	7
Adequate	The response addresses the majority of elements of the Requirement but is weak in some areas and does not fully detail or explain how the Requirement will be fulfilled.	3
Inadequate	The response does not address or explain how the Requirement will be fulfilled and fails to demonstrate the ability to meet the Requirement.	0

2.3 Commercial Evaluation Criteria

The Supplier must provide a full Commercial Proposal, detailing costs, risks, AEDs, and pricing plans, alongside several other documents, all of which are provided via RCloud. The Commercial Evaluation is below, and is pass/fail; all documents and requirements must be provided.

Question		
Has a Commercial proposal been submitted containing: • A firm price • 60 day validity • Unqualified acceptance of the RCloud Terms and Condiions • All relevant points of contacts • Any assumptions, exclusions, and dependencies • Proposed payment milestones		Pass/Fail
Has one full technical proposal been submitted?		Pass/Fail
Has A RCloud Tasking Form C been completed?		Pass/Fail
Has one full and Commercial proposal, including all price detail been submitted?		Pass/Fail
Has a completed Cyber Risk profile form been completed and submitted?		Pass/Fail
Completed DEFFORM 711		Pass/Fail