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

Title of Requirement	PhD in Non-Canonical Integral Transforms for Multistatic Synthetic Aperture Radar (SAR) and Video SAR (VSAR) for Target Motion
Requisition No.	Redacted under FOI Exemption
SoR Version	**0.1**

1.	**Statement of Requirements**
1.1	**Summary and Background Information**
	This PhD will generate and validate innovative algorithms for the formation of images of dynamic scenes from multistatic Synthetic Aperture Radar (SAR), i.e. VSAR. The PhD will be jointly funded by Redacted under FOI Exemption Redacted under FOI Exemption seeks to drive game-changing and novel Redacted under FOI Exemption Redacted under FOI Exemption within the radar field; it develops novel technologies and techniques that could deliver operational advantage and freedom of action in the future. One particular area of interest is the improvement of radar imagery. The majority of monostatic SAR image formation schemes utilise a line integral approach. However elliptical/ellipsoidal, circular and spherical integral transforms can be utilised to mathematically model bi-static/multi-static systems. This, coupled with iterative reconstruction and novel regularisation schemes, will tackle complex scattering phenomenology, resulting in fine resolution images and providing more information about the scene – such as about anisotropic scatterers. This PhD is required to consider SAR image formation of dynamic scenes. In mono- and bi-static SAR, objects moving at a constant speed in the azimuth direction will appear blurred due to the change in position between each radar pulse, while those moving in the radial direction will be focussed but appear displaced in azimuth. Accelerating and manoeuvring objects further add to the complexity. Both theoretical and practical numerical methods will be developed to understand how multi-static and other high-dimensional data can be used to resolve this otherwise ambiguous inverse

	problem. Iterative reconstruction with novel spatio-temporal regularisation schemes will then be developed to provide "Video SAR" imagery of the dynamic scenes. The resulting images will provide significant benefit for the project stakeholders beyond existing methodology by, for example, helping to locate moving objects which would otherwise be hidden amongst stationary background clutter, retaining fine resolution of moving objects through sub-aperture images, and reducing the need for time-consuming expert operator intervention to understand motion-related artefacts.
1.2	**Requirement**
	Technical Approach A practical solution of an Inverse Problem requires a wide range of mathematical techniques: numerical linear algebra; non-linear, large-scale optimisation; numerical solution of Partial Differential Equations (PDEs); regularization theory; as well as theoretical tools such as microlocal or functional analysis, to understand data sufficiency, stability, and potential solution methods. It requires at least an appreciation of the physical sensing modality (Radar), including the engineering limitations, possibilities and practicalities, to ensure the correct mathematical questions are posed and solved. Experimentation and inter-disciplinary collaboration allows for further testing, refinement and translation of methods to higher TRLs. Firstly, an integral transform taking into account a bistatic/multistatic SAR geometry will have to be determined. In order to do this, similar problems of integrals across curves and surfaces and their inversion procedures will need to be related to the multistatic SAR problem. Specifically, Palamadov type integral transforms and their reconstruction algorithm seem likely to fit multistatic SAR well. In doing so, consistency conditions on the data can be investigated by use of the Singular Value Decomposition (SVD). Moreover, microlocal and functional analysis tools can be employed to explore and examine stability issues in inverting these transforms. Secondly, a fellowship being undertaken by Redacted under FOI Exemption will lay the foundations of new 4D tomographic SAR. As a new paradigm in Radar MASINT processing, this will give rise to further research challenges in processing and exploitation. Beginning a PhD will ensure momentum is maintained in this area. The 4D tomographic method is new to SAR. However, compressive techniques are used in other imaging problems, as well as sub-aperture techniques, so the fundamental building blocks are available. Theoretical techniques such as functional analysis (e.g. microlocal analysis) have appeared in SAR applications, although results have not generally been translated in to developing practical tools, or the meaning of

mathematically complex theoretical results have not been conveyed to the wider radar research community. This PhD focusses on these latter aspects.

The innovation lies in developing and applying compressive joint spatio-temporal regularised reconstruction methods for dynamic SAR, resulting in VSAR imaging retaining fine resolution in sub-apertures, and resolving the effects of not just moving but also manoeuvring targets. This greatly enhances the ability to detect and recognise targets in dynamic scenes - a high impact for intelligence gathering operations. Solving a 4D tomography problem which is mildly non-linear in the temporal component is also novel - nonlinearity is more often driven by the response of different material properties, rather than how they move.

The work carried out in this PhD will not be restricted to a specific frequency band but will attempt to investigate the techniques from UHF/VHF right through to Ku/K band, so that the techniques benefit next-generation SAR systems for several use case scenarios. It is envisaged that the work will comprise of a mixture of numerical and theoretical techniques to benefit a low-TRL high-risk high-reward outcome.

Proposed Supervision Arrangements from University

Redacted under FOI Exemption. The research facilities include one of the finest libraries in the country, the Redacted under FOI Exemption. This library has recently made a very large commitment of resources to providing comprehensive online facilities for the free use of the University's research community. Postgraduate students in the Department benefit from direct access to all the Library electronic resources as well access to all journals from their offices or using VPN connections elsewhere. Many research seminars are held in the Department on a weekly basis and allow staff and research students to stay in touch with the latest developments in their fields.

In terms of software development support, Redacted under provide specialised eResearch capabilities, helping the student to realise their aspirations and support them in conducting world leading, high impact research. Working with the student, the IT support eliminate barriers, increase productivity and continuously expand what's possible. The student will have access to training courses to utilise powerful technology platforms and advanced skills encompassing high performance computing, software and data engineering, data visualisation and analytics and research data storage. The strong governance, support and training complement these technological capabilities and allow the student to focus on research, rather than managing technology.

The PhD programme mandates that 3 taught MSc course units be taken to increase the student's mathematical awareness around the scientific and technological aspects of the PhD. Any other such training required to pursue the challenge will be directed by the PhD supervisor. It is highly

advantageous to create a network and maintain links with experts in the imaging and radar fields, thus the student will be encouraged to submit abstracts/posters to workshops and conferences worldwide. This will not only improve presentation skills but interpersonal skills will be developed as they will have to engage with different people from different cultures as well as scientific disciplines. The student is required to do a mini-viva every year, where they're expected to write up a formal report which shall be made available to [redacted] In the interests of [redacted], progress should be presented to 2/3 members of the imaging team when there is significant progress.

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- Year 1 – Literature review, attend / partake in relevant training pre-allocated to enable transfer of technical know-how in order to complete the tasks in the planned timeframe. Understand integral transforms to formulate theoretical multistatic SAR theory.
- Year 2 – Develop and apply compressive joint spatio-temporal regularised reconstruction methods for dynamic SAR (VSAR).
- Year 3 – Redacted under FOI Exemption in total to validate research against trials data of dynamic urban and rural scenes, work with [redacted] Redacted under FOI Exemption on relevant research, contribute to meetings/conferences with international partners and partake in relevant [redacted] development. It is in the interest of [redacted] that a classified internal technical report be delivered by the end of the secondment, noting that it shouldn't be an essential document for the PhD. Complete implementation of reconstruction algorithms for multistatic SAR integral transforms and VSAR.
- Year 4 – Test the algorithm developed by the end of Year 3. Typeset PhD thesis and allow for mitigation for the programme of work from previous years. Deliver PhD thesis, software, presentation and training to [redacted]

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NOTE: Payment will be annually in arrears, and upon satisfactory completion of all deliverables at the end of each PhD Year.

	Redacted under FOI Exemption [redacted] [redacted] [redacted] [redacted] [redacted]
1.3	**Options or follow on work** *(if none, write 'Not applicable')*
	Further research directions may become apparent during the PhD, but none are anticipated at this stage.
1.4	**Contract Management Activities**
	• **Quarterly Progress Meetings** • **Annual Continuation Reports (Interim PhD Thesis) and Presentations** • **Final PhD thesis and Presentation** • **Software Project Management Plan** • Redacted under FOI Exemption • Redacted under FOI Exemption • **Software Familiarisation Session and Materials** Deliver PhD thesis, software, presentation and training to [redacted]. If reports are not approved and accepted by [redacted] they will need to be resubmitted at no additional cost to [redacted].
1.5	**Health & Safety, Environmental, Social, Ethical, Regulatory or Legislative aspects of the requirement**
	The PhD student must be a Redacted under FOI Exemption or subject to specific agreement with [redacted] a dual national with a [redacted]y. The PhD student needs to be able to obtain a basic Security Clearance (SC); this will allow them to work with Redacted under FOI Exemption The student must sign up to risk assessments for [redacted] office spaces, lab spaces and trials (if attending) when working with [redacted]

1.6	Deliverables & Intellectual Property Rights (IPR)				
Ref.	**Title**	**Due by**	**Format**	**Expected classification (subject to change)**	**What information is r deliverab**
D – 1 Start-up meeting	Start-up meeting	*TO+8weeks*	*Meeting*	Redacted under FOI Exe	Meeting to include but not li following discussions: - PhD plan (to include asp health, safety and qualit schedule - Deliverables list (with ag and "Forecast Delivery D - Payment milestones (wi Date" and "Forecast Del - Risks and issues - Dependencies and assu - Redacted under FOI Exempti (requested) - Redacted under FOI Exemp Future meetings

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D - 2 **Quarterly Progress meeting**	Quarterly Progress meetings	TO+3months and every 3 months thereafter (could be less frequent if deemed appropriate and mutually agreed)	***Meeting***	Redacted under FOI Ex	Meeting to give updates cov project progress, to include minimum: - Actual progress versus - Highlights and lowlights - Risks and issues - Dependencies - Future meetings - Record of actions and d Any changes to the followin reported to the Authority's P - Schedule - Deliverables Forecast D - Redacted under FOI Exempti - Redacted under FOI Exemp
D - 3	Annual Continuation Reports (Interim PhD Thesis) and Presentations	T0+12 months, T0+24 months,	***Report (.pdf) and Presentation (.pptx)***	Redacted under FO	Reports and presentation pa technical findings from the p plan for the next year.

		T0+36 months			
D – 4	Final PhD Thesis and Presentation	T0+48 months	*Report (.pdf) and Presentation (.pptx)*	Redacted under FO	Report and presentation pa technical approach, results, recommendation from the w
D – 5	Software Project Management Plan	T0+12 months and annually thereafter if updated	*Report (.pdf)*	Redacted under FO	A document to describe hov be developed, maintained a updated as necessary durin project).
D – 6	Redacted under FOI Exemption	Life of the Contract (T0 to +48)	*Source Code*	Redacted under FO	Redacted to be given continued a working Git repository throu period.
D – 7	Redacted under FOI Exemption	T0+48 months	Redacted under FOI Exemption	Redacted under FO	Redacted under FOI Exemption

					• Architecture docume flowcharts); • Build instructions inc dependencies (and • V&V log containing i software's purpose, status, and limitation record of code revie activities. A test pla acceptance test (UA by Dstl and the deve contract is let. • Technical Guide: a r physics and mathem the development of (noting any errors, w exceptions agreed w • Software Release N
D – 8	Software Familiarisation Session and Materials	T0+48 months	Report (.pdf) and	Redacted under FO	Redacted under FOI Exemption

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			presentation (.pptx)		and how it can be used and produces, to be given to Redacte

1.7	**Deliverable Acceptance Criteria**
	As per standard PhD T&Cs

2	**Evaluation Criteria**
2.1	Method Explanation
	Redacted under FOI Exemption.
2.2	Technical Evaluation Criteria
	Confirmation that the proposal fully meets the Authority's Statement of Requirement. Pass/Fail
2.3	Commercial Evaluation Criteria
	Tenderer has submitted a commercially compliant bid. Firm priced version submitted within budget of Redacted under FOI Exemption Pass/Fail Labour rates and price as per single source rates uploaded to R Cloud Pass/Fail Completion of Research Workers Form's Pass/Fail Completion of Statement Relating to Good Standing Pass/Fail Completion of SAQ Pass/Fail Confirm acceptance of R Cloud Version 4 Terms and Conditions Pass/Fail Completion of DEFFORM 711 Pass/Fail