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

Title of Requirement	Development of a 'super-resolution' bi-static radar concept for the detection, localisation and recognition of concealed knives.
Requisition No.	**1000165336**
SoR Version	**0.1**

1.	**Statement of Requirements**
1.1	**Summary and Background Information**

RCloud Broad and Narrow Capability Areas:

- Mathematical and computer sciences:
    - Computing hardware and software research
    - Data and signal processing technology
    - Mathematical techniques
    - Statistical methods and techniques
- Navigation & detection systems research:
    - Radar systems research
    - Radio frequency detection and antenna research
    - Target direction range and position finding research
- Physics:
    - Radio frequency wave propagation.

Research and development is required on 'super-resolution' inversion techniques applied to bi-static (and eventually multi-static) radar signals to deliver a radio-frequency (RF) tomographic capability. The requirement is to develop algorithms capable of taking the frequency, amplitude, phase and temporal signals from a bi-static radar and reconstruct the 3D spatial distribution of any targets (above a certain Radar Cross Section threshold) in the field-of-view – with a spatial resolution better than that defined by the antenna diffraction limit and the RF bandwidth.

As a first phase of R&D, these algorithms should be demonstrated on computer simulated data of a bi-static radar concept comprising the necessary minimum level of spatial encoding e.g. a single transmit antenna with a multi-element receive antenna. Future phases of R&D will require the simulation to be expanded to dynamic, multi-static radar concepts, and then eventually experimental demonstration of the algorithms and concepts using suitable COTS software defined radar components. The main target objects of interest are knives concealed on people below their clothing.

One key challenge for see-through imaging is the trade-off between signal penetration and imaging resolution. More specifically, to allow good signal penetration, relatively low frequency EM signals are needed. On the other hand, high resolution imaging requires large signal bandwidth for range resolution and/or large antenna arrays (angular aperture) for angular resolution. The difficulties in meeting both requirements at the same time are:

- Lower carrier frequency means smaller signal bandwidth, i.e., poorer range resolution.
- Lower carrier frequency means longer wavelength and hence a larger physical size for antenna arrays.

	Due to the physical size of the sensor platform, cost, and mobility requirements, large size antenna arrays may not be feasible. Other challenges for see-through imaging include scene complexity (confounding reflectors), sources of in-band noise, and interference created by obstacles along the signal paths. Super-resolution inversion frameworks are based on optimisation formulations using structured matrices (Toeplitz and Hankel matrices). These frameworks are relatively new being established only in the last decade [1, 2], but have already been used for various applications and their benefits have been widely accepted (e.g. [3] for a review paper in magnetic resonance imaging, [4] for a general review paper, [5] for a review of 'direction of arrival' estimation).
1.2	**Requirement**
	Aim: The aim of the proposed R&D is to fully and systematically explore modern super-resolution frameworks as applied to stand-off, see-through RF tomography using distributed radar transmit / receive elements. **Scope:** The scope of the proposed R&D should include the following initial work packages: **Work Package 1: Computer simulation of basic sensing concept:** Using existing super-resolution frameworks and algorithms, develop a computer simulation of a simple imaging scenario comprising: a. A bi-static radar sensing system with just a single transmit antenna and a single receive antenna, operating at a relevant frequency band e.g., 10 to 10.4 GHz. b. A representative distribution of RF-reflecting target objects. c. A relevant radar signal modulation e.g., Orthogonal Frequency-Division Multiplexing (OFDM). d. An example super-resolution algorithm. e. A range reconstruction of the target object scene, showing that once the super-resolution algorithm is applied, range resolution is improved beyond the bandwidth defined resolution limit. For this initial simulation, complex scene features such as multiple clutter objects and target obscurants, are not expected to be included. **Work Package 2: Extension of computer simulation to more complex sensing configurations:** Extend the WP 1 simulation to include: a. Sufficient spatial encoding on the receive antenna (e.g., a multi-element receive antenna) to enable 2D range-angle measurements to be made. b. An increase in scene complexity so that the number of RF-reflecting target objects exceeds the number of antenna elements. c. An example 2D range-angle super-resolution algorithm. d. A standard 2D back-projection reconstruction algorithm. e. Varying the scene signal-to-noise levels to show the benefits of super-resolution reconstruction. f. A 2D range-angle reconstruction of the target object scene, for both the super-resolution algorithm and the back-projection algorithm, showing that once the super-resolution algorithm is applied, range and angular resolution is improved beyond the bandwidth / diffraction resolution limits.

	Monitor the number of processing steps in both the radar signal modulation technique and the super-resolution reconstruction process, so that first estimates of real-world sensing speed can be made in terms of: a. Radar data acquisition speed: Investigation of software define radar components to understand whether the required radar signal modulation can be delivered at a speed compatible with operational use. b. Image reconstruction speed: Testing whether super-resolution algorithms can be made to operate at speeds compatible with operational use. **The purpose:** The purpose of the proposed R&D is to understand whether body-worn, multi-element, multi-static (i.e., multi-element transceiver units worn by more than one person), software defined radar, when coupled with super-resolution reconstruction techniques, could deliver a covert, real-time people screening capability for knives. **Expected expertise:** An academic team is sought with expertise on the theoretical side of multi-dimensional super-resolution frameworks along with a good track record of conference publications and journal submissions in the field. The team will be actively involved in translating the theory of super-resolution frameworks into practical applications which must include an interest in RF tomography. In addition, the team must also have an interest in implementing the inversion algorithms onto low size, weight and power (SWaP) wearable processing hardware for fast image reconstruction
1.3	**Options or follow on work** *(if none, write 'Not applicable')*

	If the computer simulation phase gathers sufficient evidence to warrant further investigation of the concept, the following areas of R&D are of interest (to be refined once the implications of the computer simulation phase are fully understood):
	
	1. Computer simulation extension:
	    a. To understand how well `point clusters' can be used to approximate object shapes (similar practices exist in the automotive radar literature for modelling autonomous driving scenes).
	    b. To understand how Machine Learning techniques can be used to model complex scenes.
	    c. To include 2D receiver arrays to allow range and 2D angle to be reconstructed (i.e. volumetric 'images').
	    d. To then include multi-static receivers e.g. several 2D receiver arrays worn by different people in the vicinity of the subject being screened.
	2. Sensing speed:
	    a. Radar data acquisition speed: Investigation of software define radar components to understand whether the required radar signal modulation can be delivered at a speed compatible with operational use.
	    b. Image reconstruction speed: Testing whether super-resolution algorithms can be made to operate at speeds compatible with operational use.
	3. Laboratory demonstration:
	    a. Based on suitable COTS software defined radar and processing components, design the most basic laboratory demonstrator necessary to verify:
	        i. The potential of super-resolution reconstruction algorithms from an image resolution perspective.

	ii. The potential for achieving operationally useful image reconstruction speeds. iii. The potential for achieving operationally useful field-of-view scanning speeds. b. Build the laboratory demonstrator. c. Test (is it working as designed?) and evaluate (does it deliver the performance expected?) the laboratory demonstrator.
1.4	**Contract Management Activities**
	No specific requirements identified.
1.5	**Health & Safety, Environmental, Social, Ethical, Regulatory or Legislative aspects of the requirement**
	No specific requirements identified.

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	Monthly progress meetings (*6)	End of Month	PowerPoint Presentation (.pptx)	OFFICIAL	Slides to include but not be limited to: • Update on technical progress • Progress against project schedule. • Review of risks / issues.	Default RCloud Agreement Terms and Conditions shall apply Full rights version, noting the Full rights are required to enable the deliverable to be shared with the Home Office, and potentially Other Government Departments.
D-2	Interim Report – Computer simulation of radar range profiling with super resolution reconstruction	T0 +3 months	MS Word Document (.doc)	OFFICIAL	Report to include but not be limited to: • Description of target scene being simulated. • Description of radar system being simulated. • Description of super-resolution algorithm being implemented. • An electronic copy of the simulation software and super-resolution algorithm software. • An electronic copy of documentation that explains how to install the software on a suitable	Default RCloud Agreement Terms and Conditions shall apply Full rights version, noting the Full rights are required to enable the deliverable to be shared with the Home Office, and potentially Other Government Departments.

					PC/laptop, and how to run the software to generate super-resolution images. • Conclusions on gain in range profile resolution achieved with super-resolution algorithms (compared with bandwidth limited range resolution).	
D-3	Final report – computer simulation of radar range-angle imaging with super-resolution reconstruction	T0 +6 months	MS Word Document (.doc)	OFFICIAL	Report to include but not be limited to: • Description of target scene being simulated. • Description of radar system being simulated. • Description of super-resolution algorithm being implemented. • An electronic copy of the simulation software and super-resolution algorithm software. • An electronic copy of documentation that explains how to install the software on a suitable PC/laptop, and how to run the software to generate super-resolution images.• Description of standard back-projection algorithm being implemented. • Conclusions on gain in (range-angle) image resolution achieved with super-resolution algorithms (compared with bandwidth / diffraction limited back-projection algorithms). • Conclusions on feasibility of achieving radar data acquisition and image reconstruction	Default RCloud Agreement Terms and Conditions shall apply Full rights version, noting the Full rights are required to enable the deliverable to be shared with the Home Office, and potentially Other Government Departments.

1.7	**Deliverable Acceptance Criteria**
	Both the Interim and Final Report will be reviewed (including clarification questions to supplier) over a 2 week period following delivery, to allow corrections / changes to be identified and a final version to be released for Acceptance at the end of the 2 week window.

2	**Evaluation Criteria**
2.1	Method Explanation
	The evaluation shall be based on a Value for Money (VFM) Index, whereby the Technical Score will be dived by the Cost. Bidders should note that to be considered for evaluation and task award they must pass the identified commercial compliance questions which are assessed as Pass / Fail.
2.2	Technical Evaluation Criteria

The technical assessment will be based on the following questions:

Serial	Question	Weighting	Score
1	The proposal provides a clear statement demonstrating an understanding of the requirement, and the context in which the work is to be delivered	1	0 - 10
2	The proposal provides demonstrable evidence that the proposed project team are Suitably Qualified and Experienced Personnel (SQEP) in the context of super-resolution image reconstruction frameworks and their implementation on dynamic, multi-static radar imaging applications. This can be demonstrated though, but isn’t limited to, evidence including CVs, Qualifications, and previous project / task experience	2	0 - 10
3	The proposal contains a credible plan, demonstrating that work will be done in a timely fashion. Evidence includes but is not limited to, a project management and resource management plan, which shows how the proposer plans to deliver the project.	1	0 - 10
4	The proposal clearly explains the sensing concepts (and their concept-of-use) that will be used at each stage of the investigation, including how the sensing geometries are relevant to knife detection use cases	2	0 - 10
5	The proposal clearly explains how the super-resolution image reconstruction approach will be applied to each defined sensing concept	2	0 - 10
6	The proposal provides a clear road-map for the future stages of concept development.	1	0 - 10

The technical questions shall be assed using the following scoring range:

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 commercial assessment shall consider the following questions: 1. Has the proposal been submitted as a Firm price? Pass / Fail 2. Has One (1) copy of the full technical proposal been submitted, excluding all pricing detail? Pass / Fail 3. Has One (1) copy of the full technical and commercial proposal been submitted, including all pricing detail? Pass / Fail 4. Has a completed copy of the RCloud Part C Task Response Form been submitted? Pass / Fail