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

Title of Requirement	UAV-GPSAR Demonstrator Build & Project Ghostly
Requisition No.	RQ0000012034
SoR Version	**0.1**

1.	**Statement of Requirements**
1.1	**Summary and Background Information**
	The concept of ground-penetrating synthetic aperture radar (GPSAR) mounted on an unmanned aerial vehicle (UAV) has been presented in open literature. Dstl seeks to explore the capabilities and limitations of the concept via field trials. To undertake such trials the build of a synthetic aperture radar (SAR) demonstrator is required. The final demonstrator system shall be mounted to a UAV and be capable of collecting radar, positional and attitude measurements whilst in flight. Intermediate stages towards the development of such a system are presented herein. The UAV-GPSAR concept is based on a radar looking sideways and scanning a swath of ground as the UAV is flown to the side of the area of interest. The data collected during flight shall allow the production of SAR images of the ground surface/sub-surface. It should be noted that the required performance criteria sought are threshold values and for each the Contractor is required to use his best endeavours to exceed the requested specifications, i.e. to build a radar that can be flown as fast as possible. The build of a UAV-GPSAR demonstrator follows a study by the Contractor under Purchase Order - **Redacted under FOIA Section 26 – Defence** for the design of a test-bed system. The Contractor's design report [1] shall be taken as the foundation for the build of a UAV-GPSAR demonstrator. The design study ended with the production of two candidate radar architectures **Redacted under FOIA Section 26 – Defence**). These radars have been constructed as breadboard assemblies and provide the basis for continuation of the development and onwards development.. Reference [1] 'Ground penetrating SAR design report', **Redacted under FOIA Section 26 – Defence**.
1.2	**Requirement**

The Development towards trials of a UAV-GPSAR system will be pursued by Dstl with the Contractor in Stages. At the end of each Stage of the development the performance of the developing system will be assessed by Dstl to decide whether to continue, revise or cease the work.

The threshold radar requirements are based on Table 1 of the design report [1].
Redacted under FOIA Section 26 – Defence
Subject to satisfactory performance of each of the Stages detailed below the Dstl intends, but is not obligated, to complete all the work outlined in this Statement of Requirements dependent on satisfactory performance of each Stage. Dstl's decision as to whether to complete the work shall be final and conclusive and not capable of challenge by the Contractor.

On completion of the first two Stages the work package details, timescales and costs can be more accurately predicted for the remaining tasks. These later Stages (3 and 4) are outlined in this document as Options in Section 1.3 below.

In the event that performance criteria are met at the end of a Stage and this enables continuation on a technical basis, it should be noted that financial constraints may delay or halt progression to the next step. Dstl shall therefore have the right, at its absolute discretion, to determine which stages of development are undertaken.

The stages are outlined below where 'W' refers to 'work package' and 'D' marks a 'deliverable'.

Stage 1 - Radar candidates and static tests

The objective of this Stage is to assess the suitability of the radar architectures produced under the previous contract, and shown in the design report [1], for the requirements of a GPSAR demonstrator. Stage 1 consists of the following work packages some of which (as indicted) have been completed under previous contracts and therefore do not form part of this Contract:

W1.1 Breadboard FMCW radar build
Completed as part of the work under previous **Redacted under FOIA Section 26 – Defence***.*

W1.2 Breadboard SFCW radar build
Completed as part of the work under previous **Redacted under FOIA Section 26 – Defence***.*

D1.1 FMCW and SFCW breadboard radars
Build completed as part of the work under previous **Redacted under FOIA Section 26 – Defence***.*

W1.3 Waveform development SFCW & FMCW

Redacted under FOIA Section 26 – Defence

W1.4 Data collection (static)

The Contractor shall undertake data collection from the two breadboard radars (W1.1 and W1.2) and waveforms (W1.3) using various length cable loopback configurations. **Redacted under FOIA Section 26 – Defence** The captured data will be processed to determine the achieved sweep time, receiver sensitivity, receiver dynamic range and detection bandwidth.

Stage 1 – Decision/Break Point

At the completion of Stage 1 if one or both radar architectures meet the key required performance criteria thresholds (above) Dstl will inform the Contractor in writing and request that Stage 2

commences with the design(s) that have proven satisfactory. The Firm Prices provided for Stage 2 (with the exception of W2.5A) shall apply unless Optional requirement W2.5 is exercised at this time.

However, should both of the radar architectures fail to meet the required performance, Dstl Commercial Services will request the Contractor to submit a proposal to explain whether/how one or both of the designs may be improved with the objective of meeting these values. Dstl shall cancel the contract if no credible options for improvement are identified.

Stage 2 - Synthetic aperture radar imaging - with controlled motion

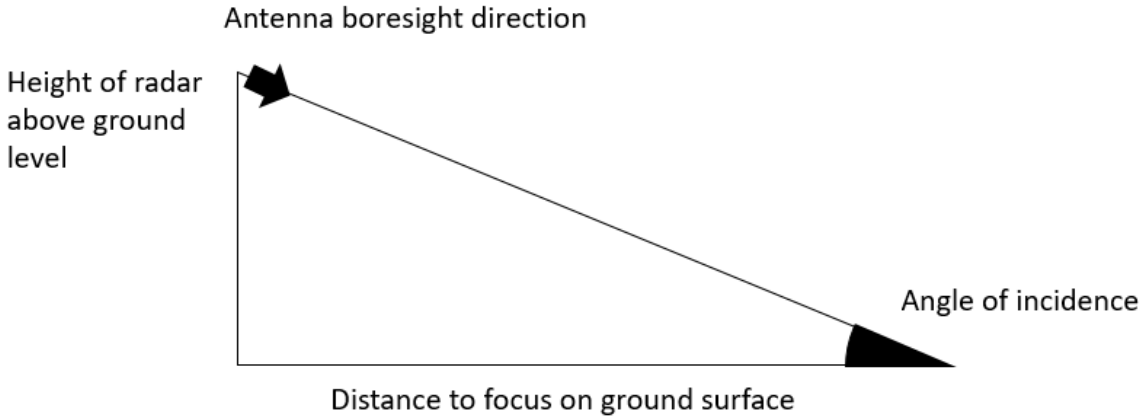
The Contractor shall assess the suitability of the produced radar architectures as the basis of a SAR imaging system.

Redacted under FOIA Section 26 – Defence

W2.1 Breadboard radars with Xenint sourced scanning system integration

Dstl will provide the Contractor with commercial-off-the-shelf (COTS) antennas.

The Contractor shall obtain a scanning system, possibly based on a track and trolley, and shall setup at a suitable indoor facility. **Redacted under FOIA Section 26 – Defence**



The scanning system shall allow the collection of radar data, and the associated transmit/receive antenna position, with horizontal movement, to allow the formation of SAR images. The system shall enable data collection in two modes; whilst the antennas are held stationary at different positions and whilst the antennas are moved by the scanning frame.

The Contractor shall also provide the hardware to operate the breadboard radars with the scanning frame and to enable communication between the radar and scanning frame.

W2.2 Data collection (in motion) – to be undertaken by the Contractor with Dstl as an observer

The collection of data from both the FMCW and SFCW radars, assuming both meet the required performance criteria of Stage 1, shall be carried out in turn with the scanning system.

Measurements shall be taken by the Contractor for test targets of different radar cross-section (RCS) placed at varying spacing in range and azimuth on the floor surface in-front of the scanning system. The targets shall be of differing RCS to assess detection capability, and of varying spacing to assess resolution limits. **Redacted under FOIA Section 26 – Defence**

(a) The Contractor shall capture data from multiple static positions, to form a horizontal synthetic aperture of at least 5 m length, to validate expected operation and the decoding of phase information from multiple points. Repeated tests shall be recorded by the Contractor to understand any systematic variabilities. The Contractor shall conduct tests to determine calibration parameters such as the electrical delay to achieve accurate range information.

	(b) The Contractor shall capture data during continuous motion, along a horizontal synthetic aperture of at least 5 m length, starting at low speeds and steadily progressing to higher speeds. If the motion system is limited on speed, a change of the GPSAR sweeping rate could be modified to simulate faster motion and so test image quality against platform speed. **Redacted under FOIA Section 26 – Defence** W2.3 Data processing and range profile analysis (SFCW & FMCW) The Contractor shall develop signal processing and data visualisation scripts to enable performance comparisons to be made between the FMCW and SFCW radar derived range profiles. The Contractor shall also develop performance metrics based on range resolution and signal-to-noise ratio, additional analysis schemes should also be considered. This is to provide evidence to identify the optimum radar technique as the foundation for future development. W2.4 Offline SAR image generation (SFCW & FMCW) The Contractor shall provide algorithms suitable for the use of SFCW and/or FMCW raw data as input, as required by the design(s) taken forwards to Stage 2. **Redacted under FOIA Section 26 – Defence** Additionally the algorithms shall be capable of compensating for refraction at the ground surface to form images of subsurface objects, however, this capability shall not be tested as part of the Contract. Images shall then be generated by the Contractor using data collected during W2.2. The images derived from either radar architecture shall be compared by the Contractor using metrics of range resolution and azimuth resolution **Redacted under FOIA Section 26 – Defence** together with target signal-to-noise ratio, additional analysis schemes should be considered. If more than one SAR algorithm has been used a comparison shall be undertaken by the Contractor using the derived metrics to advise on the optimal scheme for imaging. Stage 2 – Decision/Break Point Based on the performance of the radars a decision will be taken by Dstl on which design to proceed with to Stage 3. The radars will be assessed on their overall performance and will proceed only if one of the designs is judged to have performed satisfactorily. Dstl Commercial Services shall inform the Contractor in writing and in accordance with the provisions in section 1.4 below, request the Contractor to provide Firm Prices for Stage 3 in lieu of the ROM costs previously submitted. No work is to be undertaken against Stage 3 until the Firm Prices have been submitted and agreed by Dstl Commercial Services and the Tasking Order amended accordingly. Should both of the radar architectures fail to achieve satisfactory performance a proposal shall be requested by Dstl to explain whether/how one or both of the designs may be improved with the objective of meeting the criteria. At this point the Contract would cease if no enhanced scheme is foreseen.
1.3	**Options or follow on work**
	In addition to the requirements detailed in Section 1.2 above the Contractor hereby grants Dstl the following irrevocable options for potential follow on work to be taken up singularly or collectively at the Firm Prices agreed or to be agreed in accordance with the provisions below, it being agreed that Dstl has no obligation to exercise such options. Optional Work Packages W2.5A Breadboard radars and Dstl scanning frame integration study

To be conducted by the Contractor with support from Dstl to facilitate access to a government furnished scanning frame facility. Dstl shall also provide COTS antennas.

The Contractor shall undertake a study to investigate the feasibility of producing a software application (LabView or similar), source code and executable, to control the collection of radar data and the transmit/receive antenna position on the Dstl scanning frame with movement horizontally and vertically. The application shall be designed by the Contractor to allow the capture of radar and position data to allow the formation of SAR images. The application shall be designed by the Contractor to enable data to be collected in two modes; whilst the antennas are held stationary and whilst the antennas are moved by the scanning frame. As part of the study the Contractor shall offer Dstl a Firm Price for undertaking Optional Work Package W2.5B (below). The Firm Price should be submitted to the Dstl Project Manager but copied to Dstl Commercial Services cdwarren@dstl.gov.uk,

W2.5B Breadboard radars and Dstl scanning frame integration

In the event that work package W2.5A has been undertaken and completed the integration of the breadboard radars and Dstl scanning frame shall be carried out.

D2.3 Breadboard radar, scanning frame and SAR imaging user manual

User manual to enable operation of the breadboard radars mounted to the scanning frame (Contractor and Dstl system, if W2.5A and 2.5B completed) for the collection of synthetic aperture radar data. User manual for image formation using the SAR algorithm(s).

Stage 3 - Synthetic aperture radar imaging – ground vehicle mounted field experiments

The objective of this stage is to provide the capability to undertake GPSAR experiments in the field. A guide to the potential content of the constituent work packages is given below although these are subject to revision on completion of Stage 1 and 2.

W3.1 GNSS/INS & LiDAR positioning systems evaluation

The procurement and evaluation of global navigation satellite systems and inertial navigation shall be carried out. A series of outdoor experiments shall be conducted to capture data from these modules and the results documented. Experiments shall include static measurements to capture the positional noise floor and motion measurements performed against a known grid with markers accurately placed on the ground surface.

D3.1 Summary note on positional accuracy

The Contractor shall produce a summary note reporting on the positional accuracy achievable while the units are stationary and moving. The purpose of this deliverable is to confirm the achievable accuracy is acceptable to produce focussed SAR images.

W3.2 GPSAR demonstrator radar design

The demonstrator radar will build on from the breadboard radar. At this stage the development shall continue solely with the optimum radar architecture (FMCW or SFCW) and optimum SAR processing framework specified in D2.1.

The demonstrator radar shall be designed by the Contractor to include the following:

Redacted under FOIA Section 26 – Defence

- Integration of all positioning systems, GNSS/INS & LiDAR;
- Embedded operation using an on-board processor to perform control, and management of the system;

- Swap out of connectorised components with drop-in replacements for size and weight reduction, paving the way towards UAV integration; and

- Custom PCB's for size and weight reduction, paving the way towards UAV integration.

W3.3 Ground vehicle GPSAR mounted mechanical design, development and interoperability

Redacted under FOIA Section 26 – Defence
The Contractor shall design, develop and build the mechanical design for the ground vehicle mounted GPSAR. The mechanical aspects shall be designed for providing effective RF screening and for creating RF isolation, especially between the transmitter and receiver sub-systems.

D3.2 Ground vehicle mounted GPSAR demonstrator

The hardware/software output of this development stage shall be a GPSAR system that can be easily mounted onto a ground vehicle.

W3.4 Ground vehicle mounted imaging trials

This work packages shall be undertaken by the Contractor in collaboration with Dstl.

The Contractor shall carry out a programme of field trials of the GPSAR system to assess SAR imaging performance from a moving ground vehicle. These trials shall be undertaken in collaboration with Dstl. SAR imaging of metal trihedrals surface lain at varying distances shall be carried out whilst the GPSAR system is moved past the target area.

D3.3 Trials Report

The Contractor shall provide a written report on the performance of the ground vehicle mounted GPSAR for imaging surface trihedral targets

D3.4 Design Report - Stage 3 Update

Update of the GPSAR design following Stage 3 output.

D3.5 Ground vehicle mounted GPSAR user manual

User manual to enable operation of the ground vehicle mounted GPSAR.

Stage 3 – Decision/Break Point

If the ground vehicle GPSAR system meets the imaging requirements of D2.1 the development shall be carried forwards to Stage 4. Dstl Commercial Services shall inform the Contractor in writing and in accordance with the provisions in section 1.4 below, request the Contractor to provide Firm Prices for Stage 4 in lieu of the ROM costs previously submitted. No work is to be undertaken against Stage 4 until the Firm Prices have been submitted and agreed by Dstl Commercial Services and the Tasking Order amended accordingly.

Should the system fail to meet the required performance, Dstl shall request a proposal to explain whether/how the design may be improved with the objective of meeting the criteria The Contract shall cease the contract if no enhanced scheme is foreseen.

Stage 4 - Synthetic aperture radar imaging - UAV mounted field experiments

The objective of this stage is to produce a UAV-GPSAR system with the capability to collect SAR data during field trials.

W4.1 Bespoke antenna build

This work package will be informed by knowledge from Dstl research.

Using existing knowledge of suitable antenna designs from the design report [1] in conjunction with Dstl reviews of literature and internal research findings the Contractor shall deliver the bespoke build of antennas suitable for use with a UAV mounted radar. **Redacted under FOIA Section 26 – Defence**

W4.2 Mechanical design, development and interoperability

This work package is a repeat of work package (W3.3) but focusing on the integration of the GPSAR with a UAV instead of the UGV.

W4.3 Ground station/UAV GPSAR communication link

The Contractor shall upgrade the GPSAR radar demonstrator system to include a data communication link between the UAV and a ground station. This will enable control and the monitoring of the UAV mounted GPSAR demonstrator during flight.

D4.1 UAV mounted GPSAR demonstrator

The hardware/software output of this development stage shall be a UAV mounted GPSAR demonstrator system.

W4.4 UAV-GPSAR imaging flight trials

The Contractor shall undertake flight trials to assess performance of UAV-GPSAR demonstrator to form SAR images of the ground surface. These trials shall be undertaken in collaboration with Dstl. SAR imaging of metal trihedrals surface lain shall be carried out whilst the UAV-GPSAR is flown past the target area.

D4.2 Trials Report

Report on the performance of the UAV mounted GPSAR for imaging surface and buried trihedral targets.

D4.3 Design report - Phase 4 Update

Final update of the GPSAR design following Stage 4 output.

D4.4 UAV mounted GPSAR user manual

User manual to enable operation of the UAV mounted GPSAR.

Should Dstl wish to exercise any or all of the Options above, Dstl Commercial Services will:

- Where a Firm Price for the Option has been agreed, inform the Contractor in writing of its intention to exercise the Option and agree with the Contractor the programme to completion, before formally exercising the option through the provision of a written Contract Amendment and the issue of a Purchase Order seeking the Contractor's formal acceptance.

- Where a Firm Price for the Option does not exist, inform the Contractor in writing of its intention to exercise the Option and seek as a minimum a detailed Technical Proposal, a Firm Price and a programme to completion of the option for agreement, before formally exercising the option through the provision of a Contract Amendment and the issue of a Purchase Order.

	No work should be undertaken on any of the Optional requirements without the issue of such a Contract Amendment and Purchase Order. Any work undertaken without such a Contract Amendment and Purchase Order being issued will be entirely at the Contractor's own risk. **<u>Tasking Order Arrangement – Project Ghostly</u>** In addition to the Options above Dstl wishes to include in this RCloud Task the provisions for a Tasking Arrangement whereby Tasks relating to **Redacted under FOIA Section 43 – Commercial Interest** may be ordered from the Contractor up to and including 31st March 2023. If DSTL wishes to raise Tasks under the Tasking Order Arrangement it will do on a Tasking Order Form (to be agreed prior to award of this RCloud Task) against which the Contractor will be requested to submit his Technical and Commercial Proposals for consideration by Dstl. No work is to be undertaken without receipt of an approved Tasking Order Form and Purchase Order. Any such work will be at the Contractor's risk. Firm Prices for any requirements raised under the Tasking Order Arrangement shall be submitted by the Contractor to DSTL Commercial Services if/when requested and shall utilise rates within the allowable rates detailed on the RCloud rate card. The Limit of Liability under this Tasking Order Arrangement for FY 22022/23 shall be £425,000 Excluding VAT although no guarantee is provided that such a level of funding will be available or that Tasks up to this value will be awarded.
1.4	**Contract Management Activities**
1.5	**Health & Safety, Environmental, Social, Ethical, Regulatory or Legislative aspects of the requirement**
	The contracted work shall consider radiation hazards and provide calculations of safe working distances, as set by the Health and Safety Executive, from the transmitting radar antenna(s). **The systems shall meet the relevant electrical safety standards.** **Trials plans and risk assessments shall be produced for all tests and trials outside of regular day-to-day working practices.**

1.6	Deliverables & Intellectual Property Rights (IPR)						
Ref.	**Title**	**Due by**	**Format**	**TRL***	**Expected classification (subject to change)**	**What information is required in the deliverable**	**IPR DEFCON/ Condition**
D1.2	Static Test Analysis Report and Data	T0+1 month	Report (.pdf)	3	**Redacted under FOIA Section 43 – Commercial Interest**	Report providing SFCW/FMCW sweep time, receiver sensitivity, receiver dynamic range and detection bandwidth. The results shall be assessed against the thresholds stated in 'Requirements' Section 1.2 above. This report shall include an explanation of the limits on data capture rate (sweep time) for both architectures, with regards to current technology and inference to future technologies and performance. The collected data, in a readable format, shall also be part of this deliverable	Default RCloud Agreement Terms and Conditions shall apply Full Rights Version
D1.3	Design Report - Stage 1 Update	T0+1 month	Report (.pdf)	3	**Redacted under FOIA Section 43 – Commercial Interest**	Following Stage 1, update the GPSAR design report [1] Section 7.3.4. 'Estimated Data Acquisition Rates' with the static test results and highlight the implications for the design of the GPSAR demonstrator output.	Default RCloud Agreement Terms and Conditions shall apply Full Rights Version

D1.4	User Manuals for Breadboard Radars	T0+1 month	Report (.pdf)	3	**Redacted under FOIA Section 43 – Commercial Interest**	User manual to enable control and data collection using the breadboard radars including e details on how to configure the radars for the cable loopback tests.	Default RCloud Agreement Terms and Conditions shall apply Full Rights Version
D2.1	Analysis Report - Radar architecture and SAR imaging - Results and conclusion	T0+9 months	Report (.pdf)	4	**Redacted under FOIA Section 43 – Commercial Interest**	The report shall detail the outcomes of the Stage 2 work packages and include a recommendation on the optimal radar architecture (SFCW or FMCW) and SAR algorithm for use with moving antennas. The recommendation shall be based on the above SAR imaging performance criteria. The collected data, in a readable format, shall also be part of this deliverable.	Default RCloud Agreement Terms and Conditions shall apply Full Rights Version
D2.2	Design Report - Stage 2 Update	T0+9 months	Report (.pdf)	4	**Redacted under FOIA Section 43 – Commercial Interest**	Update of the GPSAR design report [1] following Stage 2 output. The use of the radars on a scanning frame will provide a better understanding of the SAR performance, i.e. azimuth resolution, range resolution and dependency of aperture length. Therefore, Section 4 'Synthetic aperture array (SAR) processing' of report [1] shall be updated with experimental results.	Default RCloud Agreement Terms and Conditions shall apply Full Rights Version

1.7	Deliverable Acceptance Criteria
	☒ **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 below)** The deliverables specified in Section 1.6 shall be delivered to an acceptable quality outlining the findings clearly and including technical detail to an appropriate level.

1.8 Government Furnished Assets (GFA)

GFA to be Issued - YesYes

If 'yes' – add details below. If 'supplier to specify' or 'no,' delete all cells below.

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		**Redacted under FOIA Section 43 – Commercial Interest**	TBA	Dstl	N/A
GFA-2		**Redacted under FOIA Section 43 – Commercial Interest**	TBA	Dstl	Return at end of contract
GFA-3		**Redacted under FOIA Section 43 – Commercial Interest**	TBA	Dstl	Return at end of contract
GFA-4		**Redacted under FOIA Section 43 – Commercial Interest**	TBA	Dstl	Return at end of contract