Science & Technology Facilities Council

National Space Test Facility (NSTF)

Statement of work and requirements for the Large Space Test Chamber (LSTC)

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RAL Space

CHANGE RECORD

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1	11/12/2017	All	Initial Issue
2	20/12/2017	All	Update to FAT, background sections and RD/AD
3	09/01/2018	AD Annex A	• Added AD6 NSTF-LSC-RAL-PR-002. • Included comments from internal review • Included patch panel connector details LSTC266/267 • Paint type and additional RDs

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1 INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

This document describes the activity to be executed and the deliverables required by STFC-RAL in relation to the design, manufacture and installation of the LSTC, a new satellite test facility in the NSTF building in Harwell. This statement of work will be part of the contract and shall serve as an applicable document throughout the execution of the work. The technical requirements for the facility are presented in Annex A of this document.

1.2 APPLICABLE AND REFERENCE DOCUMENT

1.2.1 Applicable Documents (ADs)

The following documents contain requirements applicable to the activity:

AD-1	NSTF facilities top level requirements	NSTF-MAN-RAL-RS-002
AD-2	LSTC route survey – Southampton to Harwell	NSTF-LSC-RAL-RP-001
AD-3	LSTC hard Point location diagram	NSTF-LSC-RAL-DW-003
AD-4	LSTC thermal zone concept	NSTF-LSC-RAL-TN-001
AD-5	LSTC Conceptual Space Allocations for LSTC	NSTF-LSC-RAL-DW-004
AD-6	LSTC Safety of Pressure And Vacuum Systems SHE Code 33	NSTF-LSC-RAL-PR-002

1.2.2 Reference Documents (RDs)

The following documents can be consulted by the Supplier as they contain relevant information:

RD-1	Thermal vacuum outgassing test for screening of space materials	ECSS-Q-ST-70-02c
RD-2	Unfired pressure vessels	EN13445
RD-3	Machinery Directive	2006/42/EC
RD-4	Working at Height Regulations	http://www.hse.gov.uk/work-at-height/the-law.htm
RD-5	Telemetry and Telecommand Packet Utilisation	ECSS-E-ST-70-41C
RD-6	Graphical symbols for measurement and control functions in diagrams	ISO14617-6:2002
RD-7	Space Product Assurance: Failure Modes, Effects (and critically) Analysis	ECSS-Q-ST-30-02c Section 8
RD-8	Pressure Equipment Directive – European Commission	PED 2014/68/EU

1.3 ACRONYMS AND ABBREVIATIONS

AD	Applicable Document
AIT	Assembly Integration and Test
AIV	Assembly Integration and Verification
CAD	Computer Aided Design
CCN	Contract Change Notice
CCP	Contamination Control Panel
CDR	Critical Design Review
CE	Conformité Européenne (European conformity)
CVCM	Collected Volatile Condensable Materials
C&I	Control and Instrumentation
EMC	Electromagnetic Compatibility
FAR	Factory Acceptance Review
FAT	Factory Acceptance Test
FEM	Finite Element Model
FMECA	Failure Mode, Effect and Criticality Analysis
GNSS	Global Navigation Satellite System
GN2	Gaseous Nitrogen
HVV	High Vacuum Valve
HMI	Human Machine Interface
ICD	Interface Control Document

IUT	Instrument Under Test
KIPS	Key Inspection Points
LED	Light Emitting Diode
LN2	Liquid Nitrogen
LLIs	Long Lead Items
LSTC	Large Satellite Test Chamber
MGSE	Mechanical Ground Support Equipment
MIP	Mandatory Inspection Point
MS	Milestone
MLI	Multi Layer Insulation
NDT	Non Destructive Testing
NSTF	National Satellite Test Facility
PA	Product Assurance
PAR	Provisional Acceptance Review
PT	Platinum Resistance Thermometer
PLC	Programmable Logic Control
PDR	Preliminary Design Review
P&ID	Piping and Instrumentation Diagram
QA	Quality Assurance
QCM	Quartz Cristal Microbalance
RAL	Rutherford Appleton Laboratory
RD	Reference Document

RF	Radio Frequency
RGA	Residual Gas Analyser
RID	Review Item Discrepancy
SAR	Site Acceptance Review
SAT	Site Acceptance Test
SCADA	Supervising Control and Data Acquisition
SMS	Short Message Service
SoW	Statement of Work
SSD	Solid State Disk
STFC	Science and Technology Facilities Council
SWL	Safe Working Load
TQCM	Thermoelectric QCM
TBA	To Be Agreed
TCU	Thermal Conditioning Unit
TML	Total Mass Loss
TMP	Turbo molecular Pump
TRR	Test Readiness Review
STFC-RAL	Science & Technology Facilities Council – Rutherford Appleton Laboratory
tbc/tbd	to be confirmed / to be defined
UKSA	UK Space Agency
WBS	Work Breakdown Structure

WP	Work Package

2 BACKGROUD AND OBJECTIVES

2.1 BACKGROUND

The National Satellite Test Facility (NSTF) is a new national facility for the environmental testing of complete satellites (up to 7 tonnes mass). It is being funded by the UK Government in response to a study commissioned by UKSA into the status of existing space test facilities in the UK. The study report concluded that there are increasing numbers of small and large organisations requiring access to comprehensive space AIV/AIT facilities who currently have no facilities of their own. It goes on to say that the evidence suggests there is a case to establish a national AIV hub on the Harwell campus, as this location is becoming a centre of attraction for new and existing space companies.
STFC, through its RAL Space Department, submitted a final proposal to the Department for Business, Energy & Industrial Strategy (BEIS) in April 2017, and later the same month the Business Secretary Greg Clarke announced that, subject to business case approval, £99M from the Industrial Strategy Challenge Fund (ISCF) has been allocated to building the NSTF (ref https://www.gov.uk/government/news/business-secretary-announces-industrial-strategy-challenge-fund-investments). The business case was approved in full by HM Treasury on 22nd June 2017.

2.2 NSTF ENVIRONMENTAL FACILITIES OVERVIEW

The top level requirements for the environmental test facilities can be found in AD1, but to summarise the following facilities will be included

- two large high-ceiling satellite integration and preparation cleanroom areas,
- spacecraft centre of gravity and moments of inertia measurement facility,
- large test facilities for vibration, pyro-shock and acoustic environmental testing,
- large thermal vacuum chamber (minimum 8m external diameter x 12m long to support spacecraft thermal vacuum testing and sensor calibration activities,
- a suitably clean electro-magnetic-compatibility (EMC) facility for spacecraft level EMC testing,
- a near-field radio frequency (RF) test range for testing of communication and RF payloads and satellites.

All facilities will be sized to take the spectrum of satellite sizes up to a mass limit of 7 tonnes.

This statement of work defines the activities to be performed by each facility Supplier for the supply of the test facility equipment and associated services. The activities are broken down into work packages as detailed in §3 of this document.

3 WORK TO BE PERFORMED

3.1 WORK LOGIC

The work to be undertaken consists of:

- Design and develop a thermal vacuum test facility satisfying the requirements outlined in this SOW and Annex A (technical requirements),
- Design, manufacture, assemble and test the facility according to agreed requirements,
- Develop control and measurement software,
- Transport and delivery to Harwell Campus near Didcot, UK,
- Re-assemble the facility in the NSTF building,
- Verify the facility's functional and performance requirements with a site acceptance test campaign,
- Deliver relevant documentation, e.g. technical file in-line with CE marking requirements.

The work is broken down into eight work packages as described in §3.2.

- WP 1000: Project management and product assurance,
- WP 2000: Design and development,
- WP 3000: Procurement, manufacture, assembly and factory acceptance,
- WP 4000: Development of commissioning plan,
- WP 5000: Transport, installation and site acceptance,
- WP 6000: Commissioning,
- WP 7000: Development of control and measurement software (if applicable),
- WP 8000: Software validation (if applicable).

The following major reviews shall be held:

- Preliminary Design Review (PDR): 4 months into WP2000
- Critical Design Review (CDR): at completion of WP2000.
- Facility Acceptance Review (FAR) at completion of WP3000
- Test Readiness Review (TRR) at start of WP5000
- Site acceptance review (SAR): at completion of WP5000
- Provisional Acceptance Review (PAR): at completion of WP6000

The final, formal acceptance of the system will take place at the end of PAR.

3.2 WORK PACKAGE DESCRIPTIONS

3.2.1 Work Package 1000: Project Management & Product Assurance

- Input:
  - Contract.

- Requirements as stipulated in Annex A.
- UK and European regulations and standards.

- Task description:
  - Nominate a Project Manager responsible for the management and execution of the work to be performed, and the effective and economical management of the project.
  - Compile a quality assurance (QA) plan describing the overall approach to accomplish the required tasks with respect to reliability, maintainability and safety.
  - Nominate a QA representative responsible for the quality and product assurance.
  - Organise and document incoming inspections of procurements and manufactured parts.
  - Manage all relevant certification of the system and its individual sub-components e.g. CE marking and sub-components and deliver a technical construction file.
  - Organise inspection of the installed system and all related electrical equipment by a qualified inspector.
  - Implement a configuration management programme in accordance with standard procedures to be reviewed at the kick-off of the activity.
  - Establish a documentation control programme in accordance with standard procedures to be reviewed at the kick-off of the activity.
  - Compile a health and safety plan to be reviewed at kick-off of the activity
  - Compile project related reporting as required in the list of deliverables and establish and maintain a master documentation list.
  - Report any deviation from the specified requirements throughout the project and ask STFC-RAL for approval by a formal request for deviation.
  - Report and control non- conformities encountered throughout the project.
- Output / Approval conditions:
  - Nominated project manager.
  - Nominated QA representative.
  - Monthly status reports detailing the project progress and schedule – D2, D3. Section 4.4.1
  - Reports on deviations and non-conformities –D6.
  - Specific product and quality assurance plan – D4.
  - Health and safety plan for the installation and verification activities – D5.
  - Photographic documentation of manufacturing, assembly and test.

- Final Report
- Master documentation list
- CE related certificates / Declarations of conformity – D7.
- Inspection report

3.2.2 Work Package 2000: Design and Development

- Input:
  - Contract
  - Requirements of facility as stipulated in Annex A

- Task description:
  - Develop a system including all hardware and software components as well as the layout auxiliaries and components to meet the requirements and objectives as defined in Annex A of this document compliant to European regulations and the stipulated standards.
  - Perform a requirements analysis and make a trade-off analysis of candidate solutions.
  - Propose concept for approval (at PDR) by STFC-RAL before the start of the detailed design phase.
  - Identify the building dependencies and work with the building main contractor to define interface details to the NSTF building and implement infrastruture at an early stage
  - Detail the design to component level and assess the consistency between system, subsystem and component design.
  - Define all mechanical and electrical layouts required to operate the facility.
  - Define all other services layout required to operate the facility. For example, compressed air and gaseous and liquid nitrogen lines.
  - Compile a design justification file demonstrating the compliance of the design with the technical requirements as stipulated in Annex A.
  - Compile a document describing all external interfaces. External interfaces are defined as those having an interface to the building, and the item under test.
  - Perform detailed analysis of the proposed design using mathematical models to confirm the compliance to requirements, where needed.
  - Identify all items to be manufactured or procured together with their potential suppliers and lead-time.

- Generate all relevant drawings and documentation as required to start the manufacturing and procurement phase.
- Prepare a list of all the material to be used in the design, listing their outgassing properties if they will be used in a vacuum environment.
- Define a factory acceptance plan to verify the performance and compliance of the design at the Supplier's premises prior to shipment.
- Conduct a failure mode, effects and criticality analysis. (Pro forma templates can be supplied for this if required).
- Prepare and compile the data package for the preliminary design review allowing the status and the suitability of the system design to be assessed.
- Prepare and compile the data package for the final design review allowing the detailed system design readiness for manufacturing and predicted performances to be assessed.
- Support design reviews at STFC-RAL and update designs according to the findings.

➢ Output / Approval conditions:

- Mathematical model including the used boundary and load cases. –SW2
- As designed native format 3D CAD models and step files.-SW1
- Validated numerical simulation model for as-built performance.-SW3
- Description and user manual of numerical simulation model (if applicable). –D20
- Data package for the preliminary design review, including:
  - Concept trade-off analysis, concept description and justification document including overall functional block diagram and principle layout of the equipment units –D14
  - Preliminary definition of interfaces.-D16
  - List of critical items (long lead item, etc.)–D12
  - Report on preliminary performance prediction –D22
  - Preliminary description of FEM and CAD models –D19
  - Report on preliminary numerical analyses –D21
  - Preliminary bill of materials -D31 (preliminary)
  - Preliminary compliance matrix –D10
  - Preliminary FMECA –D11
  - Detailed product tree (PT) and work breakdown structure (WBS) - D9

- Data package for the critical design review, including:
  - List of items to be procured or manufactured incl. supplier–D23
  - List of critical items (long lead items, etc.) –D12
  - List of drawings (as designed) –D26
  - Mechanical drawings as required for manufacturing, procurement and assembly stating dimensions, weights (as designed) –D27
  - Electrical drawings as required for manufacturing, procurement and assembly (as designed) –D28
  - Detailed design description and justification document including all interface definitions and details on system architecture covering functional and performance, electrical, mechanical and thermal layout–D15, D29, D30
  - Definition of interfaces.-D16
  - Description of numerical simulation model –D20
  - Report on performance prediction –D22
  - Description of FEM and CAD models–D19
  - Report on numerical analyses –D21
  - Bill of materials, i.e. declared material list-D31
  - Compliance matrix –D10
  - FMECA –D11
  - Factory acceptance plan –D34, D35, D36

3.2.3 Work Package 3000: Procurement, manufacturing, assembly and factory acceptance

- Input
  - Contract.
  - Agreed and approved design.
  - Agreed factory acceptance plan.

- Task description
  - Compile a manufacturing, assembly and inspection plan.
  - Perform and manage all required procurement activities.
  - Prepare and implement related manufacturing, assembly and inspection/validation processes for hardware and software.

- Generate a manufacturing report describing major steps including pictures.
- Conduct and record inspections of all welds (if applicable).
- Compile user and maintenance manual covering the different application scenarios
- Establish and document installation/de-installation procedures for the different configurations (if applicable).
- Update drawings and models to as-built status.
- Compile an exhaustive list of the equipment to be delivered to STFC-RAL including serial numbers and type identification.
- Compile a list of all safety devices with their identification and including their validity.
- Compile a list of drawings.
- Compile a list of KIPs and MIPs
- Conduct a factory acceptance campaign as agreed.
- Compile a summary report on the results of the factory acceptance campaign.
- Compile an on-site acceptance plan taking into account tests of the factory acceptance which have to be re-performed after the installation at STFC-RAL. The on-site acceptance campaign shall include standard test procedures and customer specific tests as documented in Annex A
- Compile a list of recommended spare parts covering a period of 10 years of operation including identification of parts with a limited lifetime
- Prepare the data package for the Factory Acceptance Review
- Organise and convene the Factory Acceptance Review at Supplier's premises
- Implement findings identified during work acceptance review and update documentation accordingly

➢ Output / Approval conditions:

- All equipment and software ready to be shipped to STFC-RAL
- List of as-built drawings.
- Complete set of as-built drawings.
- As-built models i.e. CAD, FEM and other simulation models.
- Recommended list of spare parts.
- Source codes of any developed software in final and validated version.
- Factory Acceptance Review data package which includes:

- Health and Safety plan for the installation
- System operation and maintenance manuals
- System installation / de-installation procedures
- List of items to be delivered –D25
- List of safety devices implemented
- List of recommended spare parts
- List of drawings (as-built)
- Mechanical drawings (as-built)
- Electrical drawings (as-built)
- Equipment drawings (as-built)
- Equipment documentation (as-built)
- Manufacturing report including filled manufacturing/assembly inspection plans and reports
- Welding inspection protocols and welders certification (if applicable)
- Factory acceptance test procedures as-run
- Factory acceptance plan as-run
- Factory acceptance reports and protocols
- On-site acceptance plan
- Final declared material list and material certificates

3.2.4 Work Package 4000: Commissioning Plan

- Input
  - Facility requirements as define in Annex A
  - Verification plan

- Task Description
  - Generate verification matrix showing which requirements will be verified during commissioning
  - Identify the test equipment needed for the commissioning tests, including simulators of typical items under test, e.g. satellite structural thermal model
  - Define the tests needed to verify the facility meets its requirements
  - Write the commissioning plan

- Output / Approval conditions
  - Commissioning plan

3.2.5 Work Package 5000: Transport, installation and site acceptance

- Input
  - Contract
  - Completed and approved Factory Acceptance Review
  - All equipment and software ready to be shipped to STFC-RAL
  - Agreed on-site acceptance plan
- Task description
  - Plan and conduct the transport and delivery of all hardware and software to STFC-RAL including all special tools required for installation, operation and maintenance.
  - Produce a detailed installation plan to include a Method Statement and Risk Assessment.
  - Perform all relevant export/import formalities.
  - Perform adequate packing at Supplier's site before shipping.
  - Unpack equipment at STFC-RAL and perform incoming inspection.
  - Support solving of interfaces issues if required.
  - Establish proper electrical grounding of the complete setup.
  - Route cables and hoses as required properly in cable ducts.
  - Perform thorough functional check out of the system.
  - Train and instruct STFC-RAL staff on effective operation and maintenance of the system including reconfiguration to different applications scenarios
  - Plan and implement an on-site acceptance test campaign at STFC-RAL.
  - Compile a summary report on the results of the site acceptance campaign.
  - Convene on-site acceptance review at STFC-RAL.
  - Compile the on-site acceptance review data package.

- Output / Approval conditions:
  - Documentation related to transport.
  - Import/Export clearance documentation.

- Installation plan, including a Method Statement
- Hardware and software delivered and unpacked at STFC-RAL.
- Trained and instructed STFC staff and their Suppliers.
- Provisional Site Acceptance Review data package which includes:
  - List of items delivered
  - Certificates supporting the compliance to requirements and regulations
  - As-run on-site acceptance plan
  - On-site acceptance reports and protocols
  - Final compliance matrix including test results
  - Master documentation list
  - Technical file
  - Method Statement
  - Risk Assessment

3.2.6 Work Package 6000: Commissioning

- Input:
  - Commissioning Plan
  - Test equipment and simulators
  - Installed test facility in NSTF
  - Detailed test procedures
  - Test Readiness Review minutes of meeting
  - Contractors commissioning team

- Task description:
  - Execute the commissioning tests
  - Resolve problems or anomalies occurring during the testing
  - Document test results
  - Update verification matrix to show compliance, or otherwise, to the test facility requirements
  - Support Test Review Board (TRB)
  - Carry out any remedial work on test facility equipment to ameliorate any non-compliances, and repeat test(s)

- Output / Approval conditions:
  - Verification reports
  - Updated verification matrix
  - NCRs
  - TRB minutes of meeting
  - Confirmation by STFC-RAL that all tests were successful

3.2.7 Work Package 7000: Development of Control and Measurement Software (if applicable)

- Input:
  - Contract.
  - Requirements as stipulated in Annex A

- Task description:
  - Establish and document software requirements, including the software quality requirements.
  - Construct a logical model of the functional requirements of the software product. The logical model shall include a behavioural view.
  - Perform detailed software architectural design and development to transform the requirements for the software into an architecture that:
  - Perform a detailed software design for each component of the software and document it to produce the static and dynamic architecture including:
  - Analyse the potential reusability of existing software components.
  - Develop and document the coding of each software and establish procedures to compile and link software units;
  - Code or procure software to meet the applicable requirements.
  - Perform development tests, analysis and simulations (if needed)
  - Identify components and development tools to be procured or manufactured and identify potential suppliers.
  - Develop and document the software user and maintenance manual.
  - Define and document, control procedures, testing approach, test design and test case specification for testing software.

- Output / Approval conditions:
  - Control and measurement software including firmware, source codes and licenses (if any).
  - Software user and functional requirements specification.
  - Software architectural and detailed design document including logical model.
  - Software build procedure.
  - Software user and maintenance manual.
  - Software test plan.
  - List of re-used S/W components including manufacturer/supplier.

3.2.8 Work Package 8000: Software Validation (if applicable)

- Input:
  - Contract.
  - Requirements as stipulated in Annex A
  - Output of previous work packages.
  - All software required for the operation and control of the test facility.

- Task description:
  - Propose and establish a validation process to validate all software required for the operation and control of the test facility.
  - Produce a software validation plan.
  - Produce software test procedures.
  - Compile a software validation report with respect to the specified software requirements as established in previous work packages.
  - Update the software and software documentation in accordance with the results of the validation activities.

- Output / Approval conditions:
  - Validated control and measurement software. –SW1
  - Software validation plan. –D40
  - Software validation report. –D41
  - Software test procedures as-run. –D42

- Updated, final software documentation as required.-SW1

4 MANAGEMENT REPORTING MEETINGS AND DELIVERABLES

The standard requirements for management, reporting and meetings are as follows;

4.1 MANAGEMENT

The Supplier shall nominate a project manager, who will then act as the main interface for all matters covered by the contract. STFC-RAL shall be notified in writing if the nominated project manager changes during the course of the contract. Changes to the management structure should be communicated to STFC-RAL at the earliest opportunity.

4.2 REPORTING

The Supplier shall produce a status report every month and hold a face to face meeting every two months at either the Supplier's premises or STFC-RAL. The status report should contain the following information;

- Progress made since the last report – D2
- Updated risk register
- Updated list of major non-conformances
- Updated schedule showing key milestones, such as review dates and hardware delivery dates – D3
- Any delays to the agreed schedule shall be explained, and where feasible, a plan to recover schedule shall be presented
- Updated milestone payment plan showing payments made to date
- Updated action list showing the status of each action

4.3 MEETINGS

In addition to the reviews identified in §5.3 of this document, the following meetings shall also be held.

4.3.1 Kick-Off Meeting

A kick-off meeting shall take place at the Supplier’s premises prior to the commencment of any work. This meeting shall be used to agree a baseline scheulde, clarify any outstanding issues and agree dates for deliverable documents, meetings and the first major review.

4.3.2 Progress Meetings

Progress meetings shall be held at the Supplier’s premises every 4 weeks to review progress against the baseline schedule. STFC-RAL may choose to waive some of these meetings if progress is deemed to be satisfactory. Similarly, STFC-RAL may choose to hold these meetings more frequently if progress is not maintained at the required rate.

4.4 DELIVERABLES

4.4.1 Documentation

The following table lists all specific documents to be delivered and the milestones (section 5.2), when they should be delivered by (electronically and hard copy). Note, not all documents all applicable to all the facilities, e.g. D8 is not applicable for any facility that does not contain a pressure vessel. The list of deliverable documents for each facility is to be agreed at the kick off meeting.

ID	Title	Milestone MS
D1	Master documentation list	1-4
D2	Monthly status reports	1-4
D3	Master Schedule	1-4
D4	Specific product and quality assurance plan	1
D5	Health and Safety Plan for the installation and verification activities	2
D6	Non-conformance reports and requests for waiver	1,2,3
D7	CE certification / Statement of conformity	3
D8	PED certification / Statement of conformity	3
D9	Product tree and work breakdown structure	3
D10	Compliance matrix towards SoW requirements	1
D11	Failure Mode and Criticality Analysis - FMECA	2
D12	List of critical items (long lead time etc.)	1
D13	List of recommended spare parts.	3
D14	System concept description and justification	1
D15	Detailed design description and justification	1

ID	Title	Milestone MS
D16	Detailed internal and external interfaces description	1
D17	Operation and maintenance manuals	2
D18	System installation / de-installation procedures	2
D19	Description of FEM and CAD models	1
D20	Description and user manual of numerical simulation model	1
D21	Report on numerical analyses	1
D22	Report on performance prediction	1
D23	List of items to be procured or manufactured	1
D24	List of implemented safety devices	1
D25	List of delivered items	3
D26	List of delivered drawings	3
D27	Mechanical drawings as designed / as-built	1 / 3
D28	Electrical drawings as designed / as-built	1 / 3
D29	Equipment documentation	1
D30	Equipment drawings as-built	3
D31	Declared Material List as-built	3
D32	Manufacturing report including filled manufacturing inspection plans and reports	3
D33	Welder certification, welding procedures and welding inspection protocols (if applicable)	3
D34	Software user and functional requirements specification	3
D35	Software architectural and detailed design document	3

ID	Title	Milestone MS
D36	Software build procedure	3
D37	Software user and maintenance manual	3
D38	Software test plan	3
D39	List of re-used S/W components including manufacturer/supplier	3
D40	Software validation plan	3
D41	Software validation report	3
D42	Software test procedures as-run	3
D43	Standard test procedures for factory acceptance campaign	1
D44	Factory acceptance plan, reports and protocols	1
D45	Factory Acceptance summary report	3
D46	Site acceptance plan, including Method Statement and Risk Assessment.	2
D47	Site Acceptance summary reports and protocols as run	3
D48	Transport documentation and Import/Export clearance documentation	3
D49	Final Report	4
D50	Summary Report	4
D51	Photographic Documentation	3 / 4
D52	P&ID for over pressurisation	2
D53	P&ID for and thermal systems	2
D54	Staff training plan	4
D55	Resilience plan	2

4.4.2 Hardware

The hardware necessary to fulfil the requirements as stipulated in Annex A is to be agreed during the negotiation phase, and prior to the kick-off meeting. All specific tools and equipment to configure, operate and maintain the relevant facility shall be part of the deliverables. Hardware needed for installation of any equipment that is then no longer required for operation of the facility, does not need to be part of the deliverable hardware. Examples of this non-deliverable hardware include lifting equipment and jigs.

4.4.3 Software

Software necessary to fulfil the requirements as stipulated in Annex A to be agreed during negotiation.

ID	Description	Milestone
SW-1	Validated control and measurement software including firmware, source codes and licenses (if any).	3
SW-2	Native 3D CAD model, as built and validated	2/3
SW-3	FEM in compatible MSC Nastran or ANSYS format	2/3
SW-4	Validated numerical simulation model for as-built performance.	2
SW-5	All other developed and/or commercial software purchased under this contract: source code, executable code, all files, documentation and libraries required to build and install the delivered software items	3
SW-6	PI&D in SEE compatible format (applicable to the large thermal vacuum chamber facility only).	2

4.4.1 Commercial Evaluation

Not applicable.

5 SCHEDULE AND MILESTONES

5.1 DURATION

The duration of the work shall not exceed 24 months from kick-off to end of the activity (delivery of final report or hardware or software).

5.2 MILESTONES

The following milestones shall apply:

MS 1 - PDR	Upon successful completion of WP 2000 and/or successful review and acceptance of all related deliverables
MS 2 - CDR	Upon successful completion of the Critical Design review
MS 3 – FAT	Upon successful completion of the Factory Acceptance Test
MS 4 – SAR	Upon the STFC-RAL's provisional acceptance of all deliverable items due under the Contract and the Supplier's fulfilment of all other contractual obligations
MS 5 – Contract Completion	Upon the STFC-RAL's final acceptance of all deliverable items due under the Contract and end of the Warranty Period.

Factory Acceptance Tests (FAT)
A Factory Acceptance Test (FAT) on vessel shall be conducted. A minimum of 4 stages to demonstrating the following Stage 1. After fabrication is complete but prior to any machining, other than weld dressing. Stage 2. After machining but prior to electro-polishing. At this stage the Contractor shall demonstrate that the roundness of the vessels is within tolerance and that the position of the ports and the machining of the flanges comply to the drawings. Stage 3. After electro-polishing. The Supplier shall demonstrate the cleanliness of the internal surfaces of the vessel by means of a water test. (Distilled water shall be sprayed onto the internal surfaces of the vessel. The water shall spread evenly and not form beads). Stage 4. After the vessel is complete but prior to despatch. At this stage the Contractor shall demonstrate a) that the vessel meets all the drawing tolerances and specification and b) that the ultimate vacuum is achieved. The manufacturer shall provide STFC at least 7 days' notice for all key stages indicated and any manufacturer required hold points
A FAT on the pumping system shall be performed to demonstrate one pumping chain and a functioning control and interlock system. The pumping system does not have to be connected to the actual vacuum vessel for this test. The manufacturer shall provide STFC at least 7 days' notice for all key stages indicated and any manufacturer required hold points
A FAT on one of each size TCU shall be performed to demonstrate the overall functionality of the system and controls, and to check the thermal performance can be achieved (including parasitic, test item and indicated 25% spare load capacity). The manufacturer shall provide STFC at least 7 days' notice for all key stages indicated and any manufacturer required hold points
A FAT on one shroud panel shall be performed to demonstrate its compliance. The test shall include thermal cycling, leak testing, metrology, pressure test, cleanliness and general finish. The scope of the FAT shall be defined during the design phase. The manufacturer shall provide STFC at least 7 days' notice for all key stages indicated and any manufacturer required hold points
A FAT on the door operation shall be performed (subject to door mechanism design).

Site Acceptance Tests (SAT)
To be performed on the control and monitoring system to demonstrate the resilience, redundancy, interlocking and other functional requirements as defined in this requirements specification. This will include all aspects of operation including power failure simulations.
Door operation, including all safety interlocks, shall be demonstrated after installation on site.
A pump down test shall be performed to demonstrate that the required pump down times and conditions can be met.
Bake out and cleanliness validation tests shall be performed to demonstrate that the system can reach bake out temperatures, and that the pumping system is able to cope with the increased outgassing load. It shall also serve to validate the outgassing level of the vessel at elevated temperatures and shall be monitored by TQCM at -20C. The pass criteria is f'/f'' < 100.
A shroud thermal performance test shall be performed to demonstrate that the system can achieve the required rates of change, temperature gradients and thermal stability. This will require the Supplier to provide a suitable thermal load to be installed inside the facility that provides the 50kW+25%, 50kW and 20kW load cases in a representative way. This will also allow validation of the predicted LN2 and electrical consumption. It may require additional temperature sensors to be installed (from the payload monitoring system) to be able to assess the thermal performance fully.
A typical thermal cycle shall be performed in both manual and automatic (profile) modes. The thermal cycle profile is to be agreed at the test readiness review (TRR).
A validation of the overall cleanliness of the facility during a typical simulated test shall be performed. This shall demonstrate that the overall contamination rates achieved can be documented and that the average 24 hour rate that is obtained is less than 1E-7g/cm2/24Hours as per ECSS-Q-ST-20-02C Section 5.3.2

In addition to the above milestones, the Supplier may recommend additional milestones in their offers. Additional milestones shall be defined in such a way that clear evidence can be provided to demonstrate the milestone has been reached. For example, if equipment or materials procured by the Supplier is delivered to their premises, then photographic evidence must clearly show the goods marked as “Property of STFC-RAL”. Milestones shall only be accepted for work that has been completed and not for the start of a particular activity, e.g. placement of orders.

5.3 REVIEWS

The following design reviews shall be held during the course of the contract.

5.3.1 Preliminary Design Review (PDR)

- Date: Kick off + 4 months (TBA)
- Location: Supplier's premises
- Input:
  - Contract.
  - Preliminary Design Review Data Package.
- Objectives
  - Show that the proposed design is expected to meet the functional and performance requirements
  - Show sufficient maturity in the proposed design approach to proceed to final design
  - Show that the design is verifiable and that the risks have been identified, characterized, and mitigated where appropriate
  - Identify long lead items (LLIs) that will need procuring before CDR
- Output:
  - Review Item Discrepancies
  - Minutes of meeting, including actions
  - Authorization to proceed with detailed design
  - List of LLIs

5.3.2 Critical Design Review (CDR)

- Date: Kick off +10 months
- Location: Supplier's premises
- Input:
  - Contract and related CCNs
  - Disposition to PDR RIDs
  - Critical Design Review Data Package
- Objectives:
  - The design fully meets the requirements, supported by analysis and/or tests
  - The facility design is robust and shows acceptable margins and is compliant with all requirements
  - External interfaces are defined and documented in configuration controlled Interface Control Documents
  - All engineering documentation necessary to procure and/or manufacture the deliverable hardware is complete

- The facility acceptance plans are well defined
- The schedule for the next phases are realistic
- The risk is fully assessed and are all deemed acceptable

- Output:
  - Review Item Discrepancies
  - Minutes of meeting, including actions
  - Authorization to proceed to manufacture and procurement

5.3.3 Factory Acceptance Review (FAR)

- Date: Kick off +22 months
- Location: Supplier's premises
- Input:
  - All deliverable hardware fully assembled in its final configuration, or as close to its final configuration as possible (TBA), during kick off
  - Factory acceptance test procedures
  - Preliminary test results

- Objectives:
  - To witness the testing of the deliverable hardware prior to its delivery to STFC-RAL
  - To verify the deliverable hardware meets those requirements that are demonstrable by system (facility) level tests
  - To verify the deliverable hardware meets those requirements that are demonstrable by system (facility) level inspection
- Outputs:
  - Factory acceptance test report
  - Approval to ship hardware to STFC-RAL, or where necessary, provide a list of remedial actions to be completed before delivery.

5.3.4 Site acceptance review (SAR)

- Date: Kick off + 24 months
- Location: STFC-RAL
- Input:
  - Contract and related CCN
  - Site Acceptance Review Data Package.
  - Health and Safety Plan
- Description:

  Successful Site Acceptance Review shall be performed to review the results of the implementation of the on-site Acceptance Plan. A Board composed of

STFC-RAL representatives, including PA representatives and other member to be agreed shall perform the Site Acceptance Review. This board shall review and confirm that all the functional and performance requirements are compliant to specified requirements.

- Output:
  - Site Acceptance Review minutes of meeting.
  - List of remedial actions (if needed)

5.3.5 Provisional Acceptance Review (PAR)

- Date: Kick off + 24 months
- Location: STFC-RAL
- Input:
  - Contract and related CCNs
  - Complete Data Package.
- Description:
  - A Provisional Acceptance Review shall be performed to check the completeness of all deliverables and to assess the adequacy of the operational procedures and tools generated under this contract.
- Output:
  - Provisional Acceptance Review minutes of meeting.

6 STFC-RAL UNDERTAKINGS

6.1 CUSTOMER FURNISHED ITEMS

There are no customer furnished items.

6.2 OTHER STFC-RAL UNDERTAKINGS

STFC-RAL will, where feasible, provide the following support. All activities requiring STFC-RAL support must be discussed and agreed in advance (> 2 weeks) of the activities taking place.

- Truck unloading via forklift for items weighing less than 1000kg
- Access to existing overhead cranes, lifting eyes and lifting slings
- Pallet trucks or similar trolleys for moving equipment into position
- Electrical power outlets (requirements to be defined in the course of the contract)
- Pneumatic air supply outlets (requirements to be defined)
- Liquid and gaseous Nitrogen (requirements to be defined in the course of the contract)
- Chilled water supply (requirements to be defined in the course of the contract)
- Disposal facilities for water and non-hazardous consumables
- Support to on-site acceptance test activities (scope to be agreed during course of contract)
- Access to NSTF building

Annex A - LSTC Technical Requirements

ID	Requirement description
LSTC1	**Vessel Configuration**
LSTC2	The LSTC shall be a cylindrical vessel with the axis of symmetry horizontal.
LSTC3	The LSTC body shall be manufactured from AISI 304L or equivalent and all other parts exposed to high vacuum shall preferably be of AISI 304L or equivalent unless justified by functionality.
LSTC4	Material for gaskets at sealing interfaces: Viton O-rings of suitable grade and OFHC copper gaskets shall be used.
LSTC6	All Stainless Steel parts within the vacuum environment of the vessel shall be electro polished. Mechanical polishing methods will not be accepted.
LSTC7	The LSTC vessel design shall conform to the applicable requirements of EN13445 Unfired pressure vessels (latest version). The design shall be supported by a stress analysis of the vessel and other critical structures using industry standard FEA software, or other analysis codes. The analysis shall take into account the effects of thermal & mechanical fatigue induced for the full operating temperature range. The supplier shall provide a preliminary vessel design in their tender return to include vessel shell and dished end thicknesses, main sealing flange details, sealing strategy, stiffening ring sizes and locations. No. of vacuum cycles for analysis shall be 3000 over the 30 year facility life.

LSTC8	The LSTC shall have an outer diameter of no greater than 8m including flanges, stiffeners and packaging (observing any UK and country of manufacture transporting restrictions) unless an alternate assembly or transportation plan can be supplied by the Supplier to demonstrate how the structure will be delivered to the customer's site. NOTE: Independent transport survey provided RD1 (NSTF-LSC-RAL-RP-001, for reference only). The Supplier must appraise and provide a transport strategy with the tender pack.
LSTC9	The LSTC shall have an inner usable diameter (with thermal shrouds installed) of greater than or equal to 7.0m.
LSTC188	The LSTC shall have an internal working length (with thermal shrouds installed and doors closed) of at least 12.0m. NOTE: This excludes the depth of the any dished ends.
LSTC10	The front dished end shall be removable from the vessel body using a sliding electromechanical mechanism that allows clear and unobstructed access to the front of the vessel. The front dished end shall move in a horizontal direction rather than vertically up or down. Pivoting of the dished end about one side of the vessel is not preferred due to the need to keep the swept path clear during operation. The design of this opening shall be discussed and agreed during the preliminary design phase. NOTE: This includes all door supports and mounting structures required for operation.
LSTC11	The rear dished end shall be non-opening.
LSTC237	An access hatch shall be located in the rear dished end of the vessel. It shall be sized to allow a standard person access. The final dimensions and location are to be discussed and agreed during the preliminary design phase.
LSTC12	The opening dished end positioning and locking system shall be fully automatic and comply with Machinery Directive 2006/42/EC.
LSTC13	All service door seals shall be double 'O' ring with interspace pumping. A dedicated oil-free clean evacuation system shall be used to create a vacuum between the 'O' rings. The inter-seal evacuation system shall be independent of the main vessel vacuum system. NOTE: User ports are excluded from this requirements.
LSTC14	Two guide rails shall be mounted inside the body of the vessel to allow wheeled trolleys to be rolled inside. The rails shall be high vacuum compatible. The pair shall be designed for a SWL of 20000kg (10000kg per rail).
LSTC189	The Supplier shall propose a location for these rails based on their previous experience.

LSTC191	The rails shall be capable of carrying a maximum point load of 3000kg applied anywhere along their length. The maximum deflection of the rail under this point load shall be less than 3mm.
LSTC256	The rails shall be electrically isolated from other metallic parts of the vessel and thermal subsystems. A separate earth path shall be provided through appropriately rated cables and feedthrough to allow the rails to either be connected to different earthing systems as required.
LSTC257	The electrical resistance between rails and the external earth termination point shall be < 0.1Ω
LSTC15	Two removable walkways internal to the vessel, one on either side, shall be provided to access test specimen during test set-up / removal. The walkways and safety rails as required shall be in accordance to the Working at Height regulation 2005 (http://www.hse.gov.uk/work-at-height/the-law.htm), and run along the full length of the vessel on each side. The exact location and size the walkways shall be agreed and finalised during the detailed design phase. Note: Their top surface shall be anti-slip (and cleanable) for safety.
LSTC16	The Supplier shall be responsible for defining the size and location of ports for the following; • Vacuum system • Thermal system • Instrumentation & controls • RGA • TQCM Details for each of these ports will be agreed during the design phase. NOTE: For all such system defined ports, the Supplier shall provide one set of compatible blank flanges to blank the ports for leak testing and/or shipping. The blank flanges shall also include O-rings, clamps etc. to be able to seal the ports.

LSTC17	The vessel shall incorporate the user ports as defined in requirements LSTC18, LSTC19, LSTC20, LSTC21 and LSTC22. These ports shall have support guides to allow each flange to be removed for connection of ancillary equipment without additional support (to be discussed during the design phase)
LSTC192	The user ports shall be complemented with a cable support system external to the vessel such as stainless steel cable trays, or baskets, to allow the routing and support of any connected cables. These cable trays shall be attached to the vessel.
LSTC18	The front dished end shall have 8 off DN 500 ISO-K ports.
LSTC19	The rear dished end shall have 8 off DN 500 ISO-K ports.
LSTC20	The vessel shell shall have 8 off DN 500 ISO-K ports.
LSTC21	The front dished end shall have 1 off DN 1500 ISO-F port.
LSTC22	The vessel shell shall have 16 off DN 250 ISO-K ports.
LSTC23	All trapped volumes exposed to vacuum shall be vented.
LSTC24	All weld joints and metal gasket joints subjected to vacuum on one side and high pressure or atmospheric pressure (vessel or shroud panels/piping etc.) on the other side shall have leak tightness of better than $1x10^{-9}$ mbar-l/sec (Helium). All O-ring joints shall have leak tightness of better than $1x10^{-8}$ mbar-l/sec (Helium) after exposure to helium for typically 5 minutes.
LSTC25	The sum of all leaks shall not exceed 1×10^{-7} mbar-l/sec (this does not include outgassing/virtual leaks). This shall include all leaks into the vessel from atmosphere, shroud segments, piping, feed-through and all interfaces on the vessel from other subsystems. NOTE: A methodology to ensure and demonstrate the overall leak tightness of the vessel as specified above shall be clearly documented in the tender submission.
LSTC26	Leak detector connection points shall be included in the backing lines of each turbo molecular pump to facilitate detection of leaks into the vessel space using a helium leak detector. These connection points shall have a manual regulation valve to connect the leak detector to the backing line with all essential hardware.

LSTC27	All external structures like vessel supports, walkways, cat walks, ladders, standing platforms etc. shall be built around the vessel during installation and commissioning to allow access for operation and maintenance. These shall be fabricated out of high grade structural steel finished and painted to maintain high level of cleanliness. The top surface of all such platforms shall be chequered stainless steel, or aluminium, tread plate. Weld inspections shall be conducted in accordance to EN13445 for items directly in contact with the vessel.
LSTC28	The LSTC system shall include multilevel external walkways around the main vacuum vessel to provide access to equipment mounted on the ports. NOTE: The external access requirements and the interfaces between the LSTC and building will be developed during the design phase, and frozen at CDR.
LSTC29	Inspection of the vessel shall be carried out by an Independent Inspecting Authority nominated by the Supplier in accordance with EN13445:2009: part 5, table 6.6.1.1 group 2b. In addition to the group 2b requirements the Supplier shall ultrasonically test all internal welds and radiographically test random samples of the external welds, as prescribed by the code. The Supplier shall agree an inspection schedule with the nominated Independent Inspecting Authority prior to manufacture.
LSTC30	All materials exposed to the vessel vacuum shall comply have a TML<1% and CVCM <0.1% when tested in accordance with ECSS-Q-ST-70-02C. Materials that cannot meet these requirements may be used only with prior approval.
LSTC31	The LSTC shall have 15 hard mounting points at locations shown in drawing RD2 (NSTF-LSC-RAL-DW-003). The final locations will be discussed and agreed during the design phase. These hard points shall be designed to support 250 kg each (vertical).
LSTC32	The body and rear fixed end of the LSTC vessel, vacuum equipment, thermal control plant and all other supplier provided equipment shall be contained within a space of 17m wide by 17m long by 14m high. Further details of this space can be found in document NSTF-LSC-RAL-DW-004

LSTC33	**Vacuum Subsystems**
LSTC209	**Main vessel Vacuum System**
LSTC34	Vacuum system shall be configured to obtain oil free clean vacuum and shall have adequate pumping capacity to last for 500 hours of uninterrupted testing (at maximum allowable leak and outgassing rates) without performing regeneration of connected cryopumps.
LSTC193	The vacuum system shall contain a full layer of redundancy and therefore be resilient to any single failure or malfunction. This shall be demonstrated in a documented FMECA delivered by the Supplier. See requirement LSTC151.
LSTC35	The primary vacuum system shall consist of two independent, identical parallel chains to pump the system as specified in LSTC36.
LSTC194	The primary vacuum system shall use soft start (inverter controlled) pumps.
LSTC36	The total capacity of the primary pumping system shall be sized so the pump down time from atmospheric pressure (1013 mbar) to less than $5x10^{-2}$ mbar is less than or equal to 150 minutes under the following conditions: • All pumps (both prime and redundant sets) shall be used • Cold trap shall not be used • All Supplier supplied system elements/cables etc. are installed inside the vacuum vessel and all at ambient temperature • The vessel shall be exposed to the connected cleanroom conditions for a minimum of 48 hours prior to the test (22°C +/-3°C, 55%RH +/- 10%).
LSTC37	The vessel roughing system shall be equipped with machine operated conductance control valves to achieve a variable pump down rate. The pump down rate shall be adjustable with a lower limit of 5mbar/minute. The maximum shall be greater than or equal to that required by the minimum pump down time in LSTC36.
LSTC38	The primary pumping system isolation valves shall be interlocked to a user specified pressure inside the vessel.
LSTC251	All isolation valves shall have user defined differential pressure monitoring.
LSTC39	The high vacuum pumping system shall comprise of a suitable combination of turbo molecular pumps (TMP) and cryopumps as required.

LSTC195	The system shall allow for one high vacuum pumping chain to be taken off-line for cryopump regeneration or maintenance of TMPs, whilst still maintaining the vessel pressure below $5x10^{-5}$ mbar.
LSTC196	TMPs shall be of magnetic bearing type, and the cryopumps shall be driven by two stage cold heads.
LSTC197	Pumps shall be isolated from the vacuum vessel by means of high vacuum valves (HVVs).
LSTC40	The high vacuum system shall provide the transition from 5.0×10^{-2} mbar to less than 5.0×10^{-5} mbar in less than 8 hours. The following conditions will be applicable: • High vacuum pumping immediately follows primary pumping, with the initial environmental conditions for primary pumping start conditions observed. • Contamination control cold trap shall not be used. • Specified passive gas load given in requirement LSTC42 shall be applied. • All Supplier supplied system elements/cables etc. are installed inside the vacuum vessel and all at ambient temperature. • Thermal shrouds all maintained at 293K +/- 2K.
LSTC42	A passive gas load of 0.3 mbar-l/sec shall be considered (composed of 80% H_2O and 20% N_2) after one hour exposure in high vacuum from various test specimen surfaces like MLI, harnesses, mounting structures etc. This gas load shall decrease with exposure time as per prevailing decay rates for different materials. Supplier shall consider such decay rates from their past experience. These estimates shall be used in arriving at N_2 and H_2O pumping speed required to achieve high vacuum. Exact procedure to simulate decaying passive gas load during final acceptance test shall be evolved realistically during detailed design. The procedure for simulating these gas loads shall be agreed at CDR.

LSTC210	**Vacuum Pressure Control**
LSTC41	During a thermal transition from a long duration cold soak on the shrouds (maintained at <90 K) to ambient temperature 293K, the average vacuum pressure level inside the vessel must not increase above $5x10^{-5}$ mbar. NOTE: The Supplier is to provide any required control logic and provisions to ensure this, including incorporation of automatic software controls in thermal system (such as hold and move forward features dependant on the monitored pressure values) to meet this requirement. This logic shall allow slow and controlled warm up of thermal shroud panels while maintaining high vacuum pressure level below $5x10^{-5}$ mbar. This threshold vacuum level shall be configurable through the user control interface.
LSTC198	During a thermal transition from ambient temperature 293K to 400K, the average vacuum pressure level inside the vessel must not increase above $5x10^{-5}$ mbar. NOTE: The Supplier is to provide any required control logic and provisions to ensure this requirement is met, including incorporation of automatic software controls in the thermal system (such as hold and move forward features dependant on the monitored pressure values). This logic shall allow slow and controlled warm up of the thermal shroud panels while maintaining high vacuum pressure level below $5x10^{-5}$ mbar. This threshold vacuum level shall be configurable through the user control interface.
LSTC211	**Contamination Control**
LSTC43	There shall be an adequately sized contamination control panel (CCP) with a low thermal emissivity surface. The CCP surface shall be flat and easily cleanable.
LSTC241	The surface area (in m^2) of the contamination control panel shall be calculated according to the following: Volume of vessel (m^3) divided by the cold trap area (m^2) < 50 m
LSTC240	The system shall be able to maintain the CCP at a temperature of < 123K (-150°C) over at least 90% of its surface.
LSTC239	The CCP shall maintain temperature < 123K in the event of an interruption to its electrical power for 10 mins or interruption of LN_2 for 30 mins.
LSTC238	The CCP shall have a vacuum compatible collection tray below the panel to collect the condensed material.

LSTC244	The CCP shall remain active and at temperature until the vacuum vessel is repressurised to 100mbar (user definable) to protect test specimen from any contamination threat.
LSTC243	The CCP can be made up from multiple panels, if required.
LSTC242	The final location of the panel, or panels, will be defined during the design phase.
LSTC248	The CCP shall be compatible for worst-case service temperature of 77K and 400K
LSTC247	The CCP shall be designed according to applicable safety codes.
LSTC246	The CCP shall cool down from ambient to <123K in less than 4 hours.
LSTC245	The CCP shall be capable of heating to 400K for bake out purposes.
LSTC249	A minimum of 6 (T type thermocouple) temperature sensors shall be provided on each CCP, for temperature monitoring purposes. These sensors shall be integrated into the control and monitoring system.
LSTC212	**Vacuum Gauging**
LSTC44	The Supplier shall ensure that an adequate number of vacuum gauges is provided in the roughing chains, TMP backing, and cryopumps evacuation lines, as well as in the inter-seal evacuation system (if used). Gauges for system monitoring requirements shall also be provided.
LSTC45	The main vessel shall be equipped with 4 off full range vacuum gauges uniformly distributed.
LSTC200	The Supplier shall provide full details of the proposed vacuum gauges including make, model numbers and quantity. These gauges should be clearly indicated on the P&ID/schematic for the complete vacuum system.
LSTC201	Readings of all vacuum measurement and control channels shall be displayed appropriately on the Supervisory Control And Data Acquisition (SCADA) interface, and shall be logged as part of the overall data acquisition system.
LSTC202	All vacuum gauging shall be included in the FMECA. Any gauges identified as being critical to the operational continuity of the LSTC shall have adequate backup or redundancy fitted.
LSTC213	**Vessel Repressurisation**
LSTC46	A fully automatic vessel repressurisation/venting system shall be provided to backfill the vessel using dry GN_2 and/or compressed air. It shall be possible to switch between GN2 and compressed air. Additional filtration is required at points of entry into the vessel to remove all particles >0.2µm

LSTC205	The pressure at which the system switches over from dry GN2 to dry compressed air shall be user defined via the SCADA interface.
LSTC206	The venting system shall allow the rate of re-pressurisation to be controlled to a minimum of 1mbar/minute using machine controlled valves and a PID controller. The maximum rate of repressurisation shall recover the vessel to 1013mbar in two hours. NOTE: This requirement can be implemented with fixed orifices and valves or a variable conductance valve.
LSTC207	Safety interlocks shall be incorporated into the vessel venting system to prevent accidental re-pressurisation of the vessel.
LSTC208	Safety interlocks shall be fitted to all doors (including the person access door) to prevent them from opening whilst the oxygen concentration inside the vessel is lower than 19.5%.
LSTC214	**Vessel Overpressure Relief**
LSTC47	The vessel shall be fitted with a pressure relief system to prevent the pressure inside from exceeding 0.5bar above ambient pressure. As a minimum the system shall consist of two independent systems to suitably protect against system failure modes as identified in the FMECA, see requirement LSTC151 Exact sizing of various components, with detailed calculations, will need to be performed during the detailed design phase and shall satisfy the requirements in STFC code 33 (NSTF-LSC-RAL-PR-001)
LSTC204	**Vacuum Leak Detection**
LSTC217	The vacuum system shall have provision (with proper branching & hand operated vacuum isolation valves) for connecting a helium leak detector for conducting in-situ leak testing of the vessel and its vacuum components.
LSTC48	A leak detector capable of measuring to better than $1x\ 10^{-11}$ mbar l/s shall be supplied.

LSTC49	Thermal Subsystems
LSTC215	**Thermal Shroud Configuration**
LSTC50	The shroud internal useable space shall be at least 12m long and 7m diameter.
LSTC51	The thermal shroud shall be split into 10 thermal zones, each independently controlled and adjustable in temperature.
LSTC52	The shroud shall be configured as follows: One circular, or dished, zone in each vessel dished end. Eight zones within the main body section of the vessel arranged as two groups of four. Each panel in the group of four shall cover one quadrant of the vessel body along half of its length. The four panels shall be oriented so they meet at the cardinal points assuming north is at the top of the vessel (see RD 2 NSTF-LSC-RAL-RAL-TN-001 for more details).
LSTC54	The shroud working range in GN_2 adjustable mode shall be 93K to 400K.
LSTC55	Each shroud zone shall be able to operate with a set point that is 50K above or below any other zone in the vessel, without affecting the homogeneity (as per LSTC67 and LSTC68) of the other panels. NOTE: This requirement is a goal and shall be discussed during the detailed design phase.
LSTC57	The overall thermal system shall carry 25% spare thermal capacity for payload dissipation (see LSTC67 and LSTC68). This is only applicable to the load from the test item and not the parasitic loads from the rest of the system.
LSTC255	For any thermal system designs where historic performance data is not available an additional analysis margin of 25% shall be held during the design phase.
LSTC179	All TCUs shall be designed to be serviceable in its installed location without affecting the operation of adjacent equipment. Any user replaceable items shall be removable using supplied jigs and fixtures, and without the use of an overhead crane.
LSTC58	For future expansion and to support a future LN_2 flooded shroud option, each TCU shall have the ability to be easily modified to operate in LN_2 mode without modification to its footprint or internal layout. All required connection or supply/take-off points required for LN_2 mode operation shall be fitted with either a spool piece, a cap, or a suitably rated valve. All of these additions should not affect the operation of the system in GN_2 mode.
LSTC60	The installed shroud shall have no gaps or views to the vessel body when viewed from anywhere on the centre line of the vessel.

LSTC62	The shroud and thermal subsystems shall be designed to operate for continuous periods for up to 100 days with no damage or degradation of performance.
LSTC63	The shroud working medium shall be gaseous nitrogen.
LSTC64	The shroud rate of warmup shall be controllable between 60K/hour and 10K/hour with no test item installed. NOTE: The maximum rate of change shall be stated in the Supplier's tender.
LSTC65	The shroud rate of cool down shall be controllable between 60K/hour and 10K/hour with a 50kW test item load uniformly distributed over the shroud.
LSTC67	The shroud temperature homogeneity at steady state shall be ±5K about the set-point at any temperature between 93K and 400K. This is with an evenly distributed thermal load (radiative) from the Item Under Test (IUT) of 50 kW. Loads from other parasitic sources, such as radiative and conductive links to the vessel and supply subsystems are not included in the heat load number, but must be accounted for in the analysis and demonstration of the shroud uniformity. See requirement LSTC69 for a definition of the area to which this requirement applies.
LSTC68	Shroud temperature homogeneity at steady state shall be ±2.5K about the set-point at any temperature between 93K and 400K. This is with an evenly distributed thermal load (radiative) from the Item Under Test (IUT) of 20 kW. Loads from other parasitic sources, such as radiative and conductive links to the vessel and supply subsystems are not included in the heat load number, but must be accounted for in the analysis and demonstration of the shroud uniformity. See requirement LSTC69 for a definition of the area to which this requirement applies.
LSTC69	Temperature homogeneity is applicable over the central 95% of the inward facing surface of each thermal shroud panel. This is to allow shroud edges and cover strips to be discounted in the requirement. Thermal bonding of these areas is still required to minimise the temperature difference between these areas and the main portion of each shroud panel. The supplier should quote the expected temperature gradients in these areas under the 50kW and 20kW cases.
LSTC70	The shroud thermal stability averaged over the panel sensors, under steady state conditions, shall be <1K/Hour.
LSTC93	Each shroud zone shall control to ±1K of its set point using feedback from the installed temperature sensors.
LSTC221	Control points shall be selectable for any installed shroud sensor using a single/min/max/average algorithm.

LSTC72	The shroud internal face shall have a hemispherical emissivity at ambient temperature of >0.89. NOTE: MAP PU1/PUK or Aeroglaze Z306/307 will meet this requirement.
LSTC73	All aluminium components of the shroud or its pipework must have a surface finish applied such as alochrom/alodine 1200 to ensure no oxide layer is able to form.
LSTC74	All stainless steel components of the shroud and its pipework shall be electro-polished unless this would make it unfit for purpose.
LSTC252	The vessel outer surface shall not go below 285K when the shrouds are at their minimum working temperature of 93K.
LSTC76	All metal components facing the vessel outer surface shall have a hemispherical emissivity within specified working temperature range of <0.15
LSTC77	Each shroud zone and TCU shall have sealable connections located outside of the vessel to enable each thermal circuit to be evacuated. This is to allow it to be isolated in the event of a leak to vacuum occurring inside the vessel, or to connect a helium leak tester for in-situ leak testing of the shroud.
LSTC78	Each shroud zone shall be fitted with the necessary valves and ports to allow it to be back filled with helium gas for leak testing.
LSTC79	The global shroud leak tightness for helium shall be $<1E^{-9}$mbar/l/s
LSTC91	Each shroud zone shall have a minimum of one temperature sensor per square meter integrated into the SCADA system.
LSTC92	The location and mounting method of the temperature sensors shall ensure that repeatable and representative temperatures are measured on the shroud. The details of this interface shall be agreed during the design phase.
LSTC261	Due to the total volume and pressures of the thermal shrouds, the Pressure Equipment directive shall apply to the design of the thermal shroud and its ancillaries (Pressure Equipment Directive 2014/68/EU)
LSTC216	**Shroud Feedthroughs and Access Panels**
LSTC61	The shroud shall have removable cable feedthroughs adjacent to each blank user port. These feedthrough shall be baffled so that there is no view factor to the vessel wall. A suitable method would be via a labyrinth.
LSTC80	The cable feedthrough baffles shall be removable from the inner face of the shroud for future modification.

LSTC82	The cable feedthrough baffles shall be sized to create an aperture with dimensions of 75mm by 300mm for cables and connectors to pass through. Any hardware shall protrude no more than 100mm.
LSTC83	The shroud cable feedthroughs shall be rolled or radiused to minimise the stress and risk of damage to the cables passing through. Minimum radius shall be 1mm.
LSTC84	The appropriate shroud zone shall have a removable centre section corresponding to the location of the ISO DN1500 port and equal in diameter. This section shall be removable independently of the main thermal shroud.
LSTC85	Any removable section of the shroud shall be supplied with all MGSE needed for its removal and re-fitting. This only applies to removable panels with a mass greater than 15kg.
LSTC220	The shroud shall be fitted with a door opposite the personnel access door of the same size, or larger.
LSTC86	The access door within the shroud situated in the rear of the vessel shall be openable without disconnecting pipes or the use of additional MGSE.
LSTC81	Any hard mounts or mounting bosses that are accessed through the shroud shall have removable blanking plates fitted to the shroud.
LSTC87	The thermal gradient requirements are applicable to all opening, removable or cable feedthrough parts of the shroud. (Reference LSTC61, LSTC84, LSTC86, LSTC220).
LSTC219	**General Thermal System Requirements**
LSTC178	The vessel shall have a system for illuminating the inside of the vessel consisting of LED lights mounted at regular intervals. These LED lights shall be compatible with the vacuum environment and operating temperature range of the shroud. The lights shall be operable from the SCADA interface.
LSTC88	All external pipework feeding the thermal shrouds, including feedthroughs and any exhausts and LN_2 feed pipes shall be of super insulated vacuum type.
LSTC89	All super insulated vacuum lines shall be rigid wherever possible. Flexible lines shall only be used where thermal movement compensation or vibration decoupling is required.
LSTC90	All user serviceable parts between the shroud and vessel wall shall be accessible without removing the shroud. Examples of user serviceable parts are flexible bellows or mechanical joints.

LSTC218	**Additional Thermal Requirements**
LSTC53	A TCU shall be provided for an additional thermal zone within the payload support system at a later date. This TCU shall have a thermal capacity of 10kW, and have connection points within the vacuum space. The location of the connection points shall be agreed during the design phase and frozen at CDR.
LSTC59	Nine additional thermal control loops shall be provided. These loops shall be fed with LN_2 via proportional valves. Each LN_2 fed loop shall have PID control for heaters and valves. The control interface shall be through the SCADA system and shall be configurable in its control sensors and operation. Location of feedthrough and connections within the vessel will be defined during the design phase.

LSTC95	**Control and Instrumentation Subsystem**
LSTC222	**Control System Architecture**
LSTC223	The control and instrumentation (C&I) system shall be able to connect to the NSTF data IP network for maintenance and data archival purposes. Details of this network, including available address spaces, shall be provided during the preliminary design phase.
LSTC224	The C&I system shall operate in a fully self-contained mode when disconnected from the NSTF network.
LSTC97	The C&I system shall consist of PLC/Server/SCADA hardware and software (in a server-client configuration) with 100% hot redundancy, including connectivity.
LSTC98	The control PLC shall have multiple processors with an internal watchdog for high speed detection of a processor fault and automated swap over to a redundant processor.
LSTC99	The data storage shall be fault tolerant, using a RAID system of minimum level 5 configuration.
LSTC102	Any monitored parameter shall be logged to disk at an adjustable rate between once per 10 seconds and once per 60 seconds.
LSTC185	The C&I system shall allow control of the thermal environment both manually (using set points) and automatically (through a pre-set thermal profile).
LSTC186	The C&I system shall allow each thermal zone to be controlled individually or in groups.
LSTC187	The C&I system shall make selected data available through a separate IP data link in a packetised format according to ECSS-E-ST-70-41C. Details of this interface are to be finalised during the initial design phase. The overall C&I system shall additionally allow remote control of thermal set points through this interface if the user is authorised to do so.
LSTC96	The C&I system shall monitor and log the value and consumption rate of all incoming services to the LSTC facility such as power, compressed air, water, LN_2, GN_2 etc. This data shall be acquired at a sufficiently large number of points that it can be used for both the control system operation (identifying failures and switching to redundant systems) and for performance and cost modelling.
LSTC258	The data acquisition system shall be able to accept a signal from a GNSS antenna for timestamping and synchronisation of data.
LSTC267	All control and instrumentation signals passing through the vacuum vessel walls shall use plugs and sockets at this interface appropriate to the signal type being carried.

LSTC228	**Data Visualisation**
LSTC100	The data visualisation system shall have a graphical SCADA visualisation window for each major subsystem (e.g. Vacuum, Thermal Control, TCU, power distribution, etc.) Additional windows shall be available as sub-windows for diagnostic and maintenance functions.
LSTC101	All SCADA windows and human machine interfaces (HMI) shall allow setting of access control levels (such as viewer, user, administrator) to restrict the modification and visualisation of displayed parameters to authorised users only.
LSTC103	All monitored parameters shall be replayable/recallable from the time history from any test, either in a tabulated or graphical form depending on the parameter type.
LSTC104	All monitored parameters shall be configurable for visual, audible, email and SMS text message based alarms.
LSTC105	Alarms should have upper and lower warning and hard limits, each independently configurable using a script-based file import (format to be discussed during design phase).
LSTC106	A HMI shall be provided in the cleanroom for the operation, monitoring and diagnostics of the door system, in accordance with the door operating procedure.
LSTC107	A HMI shall be provided in the plant room for operation, monitoring and diagnostics of the vacuum and repressurisation systems.
LSTC108	A HMI shall be provided in the plant room for operation, monitoring and diagnostics of the thermal system.
LSTC111	Any SCADA window/parameter should be available on a portable display device.
LSTC109	The SCADA systems shall be available in the LSTC Control Room, customer EGSE area and office.
LSTC227	The SCADA systems shall run under a MS windows operating system.
LSTC226	Master (Server) PCs with display screens shall be situated in the control room and shall consist of multiple large format displays capable of displaying any monitored parameter via the SCADA interface. Screen sizes will be defined during the detail design phase.
LSTC110	Customer (Client) PCs' and display screens shall be situated in both the customer EGSE room and customer office space and consist of multiple large format displays capable of displaying any monitored parameter via the SCADA interface. Screen sizes will be defined during the detail design phase.

LSTC225	**Additional Instrumentation**
LSTC112	The vessel shall be fitted with two Residual Gas Analyser (RGA) systems of 200amu range with both faraday and multiple detectors (MKS Microvision 2 - to maintain heritage).
LSTC262	The operation of the RGA's shall be interlocked to the vessel vacuum status to ensure operation only when the vacuum level is sufficiently good.
LSTC113	RGAs shall be isolated from the vessel by manually operated high conductance vacuum valves.
LSTC114	RGAs shall be fitted in a location accessible for maintenance without additional access equipment.
LSTC115	The vessel shall be fitted with two 15MHz TQCM systems for contamination monitoring (one set equals CrystalTek 66TR, 56S/T, 46E/T, 106CA + cable and feedthrough).
LSTC116	The Supplier shall provide all QCM heatsinking and cabling. Data from the QCMs shall be readable by the main SCADA system.
LSTC265	**Additional Payload Acquisition System**
LSTC117	A data acquisition system shall be supplied to condition and acquire the following additional payload sensors and signals.
LSTC264	The data acquisition system shall allow the logging and visualisation of acquired data using the requirements as defined for the main facility control system.
LSTC229	The data acquisition system shall be capable of acquiring data from 1000 off T type thermocouples.
LSTC230	The system shall be capable of acquiring data from 100 4-wire PT100 PRT sensors.
LSTC231	The system shall be capable of acquiring 50 analogue voltage channels with a range of 0-60V
LSTC232	The system shall be capable of acquiring 50 analogue current channels with a range of 0-20mA
LSTC118	The measurement accuracy for the payload thermocouple chain (ie. from the interface patch panel in the chamber to the digitised signal) shall be better than +/- 0.5 °C between 80K and 400K. The accuracy of the TCs that will form the last part of the measurement system shall not contribute to this requirement. The supplier shall provide overall temperature measurement uncertainties based on a 20m long Class 1 thermocouple being connected to the patch panel in the chamber.
LSTC233	The measurement accuracy for 4-wire Platinum Resistance Thermometer (PRT) chain shall be better than +/- 0.1 °C between 80K and 400K. The sensor's accuracy shall not form part of this figure. The Supplier shall provide measurement uncertainties based on a Class A PT100 PRT.

LSTC253	The measurement accuracy for the voltage channels shall be better than +/- 10mV. The supplier shall provide a measurement uncertainty calculation.
LSTC254	The measurement accuracy for the current channels shall be better than +/- 0.1mA. The supplier shall provide a measurement uncertainty calculation.
LSTC181	The Supplier is responsible for all feedthroughs and cabling associated with the payload acquisition system.
LSTC182	The payload monitoring system shall terminate on patch panels within the vessel's vacuum space. The location of these panels are to be proposed according to the Supplier's previous experience and to be agreed during the design phase and fixed at CDR.
LSTC266	All payload acquisition signals passing through the vacuum vessel walls shall use plugs and sockets at this interface appropriate to the signal type being carried.
LSTC183	The connector type for the payload monitoring system is to be agreed during the design phase, but will as a minimum require compensating connectors for the thermocouples. The final connector types shall be agreed during the design phase and fixed at CDR.

LSTC119	**Exclusions**
LSTC120	All services listed in this section will be provided in the plant area adjacent to the vacuum vessel with suitable termination points (format to be agreed during the design phase). It is the Suppliers' responsibility to connect to these systems as part of the scope of supply.
LSTC263	All electrical power systems will be 'as distributed', no filtration shall be provided by the building and as such the supplier shall provide any necessary specialised filtration required to prevent interference on the electrical distribution network influencing the LSTC facility and any interference generated by the LSTC Facility appearing on the electrical distribution network.
LSTC121	UPS systems are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in kVA, including maximum expected duration to safely recover test facility to ambient).
LSTC122	Backup electrical generation systems are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in kVA, including maximum expected duration to safely recover test facility to ambient).
LSTC123	Compressed air generation systems are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in cfm, including required pressure and dew point).
LSTC124	GN_2 generation systems are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in cfm, including required pressure and purity in ppm).
LSTC125	Bulk liquid nitrogen (LN_2) storage and transfer of stored LN_2 into the plant room are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in kg per hour, including required pressure and liquid quality).
LSTC126	Chilled water generation systems are not within the scope of supply; however the supplier shall document in their bid (and subsequent design data packs) the capacity required and interfaces to such a system to ensure uninterrupted operation (in kW, including flow rates, pressure drops, temperatures and water quality).

LSTC127	Oxygen depletion monitoring equipment within the building and plant areas is not within the scope of supply, however, in-vessel oxygen depletion monitors are to be provided by the Supplier.
LSTC128	Cleanroom panelling or cleanroom air filtration systems are not within the scope of supply.
LSTC129	Cleanroom contamination monitoring is not within the scope of supply.
LSTC130	IP Network infrastructure (fixed cabling) is not within the scope of supply except between supplied vessel subsystems. The NSTF will provide the links between major areas such as the control room, Customer's rooms and offices. However, the supplier should provide the number required and capacity of such systems to ensure connectivity to other NSTF systems (such as backup servers) and to the supplied hardware.

LSTC147	**Documentation required with tender response**
LSTC145	The Supplier shall provide with their tender a preliminary ICD (Interface Control Document), to show mechanical, electrical and structural dependencies for installation and operational modes i.e. required power supplies, building interfaces (loading floor pads, walkways etc.), and consumable supplies such as LN2, GN2, water, compressed air etc. This will be iterated and updated at the LSTC PDR and frozen at the LSTC CDR.
LSTC146	The formal ICD(s) for the LSTC shall be maintained by the NSTF team, combining information from the LSTC supplier and the building contractor.
LSTC157	Detailed technical submission showing how all the requirements are to be met, including any supporting calculations and electronic information such as CAD or FEA models.
LSTC180	A compliance matrix against requirements indicating compliance as Yes, No or Partial. If a Yes answer is given it must be supported by information within the main proposal. If a Partial response is given the main proposal must clearly indicate the level of compliance that is achievable and any possible solutions to achieve full compliance.
LSTC148	Proposed method for measuring helium leak rates of the vessel and other subsystems using a helium leak detector during manufacturing, FAT and SAT.
LSTC149	Proposed Process and Instrument Diagram (P&ID) to ISO14617-6:2002 for the pressure system.
LSTC150	Proposed Process and Instrument Diagram (P&ID) to ISO14617-6:2002 for the thermal system.
LSTC151	Initial Failure modes, effects (and criticality) analysis (FMEA/FMECA) to ECSS-Q-ST-30-02c Section 8.
LSTC152	LN_2 and energy consumption analysis for 50kW, 20kW and 10kW cases.
LSTC259	Energy consumption analysis for vessel evacuation and transfer to high vacuum pumping.
LSTC260	Energy consumption analysis for TCU maximum heater power cases.
LSTC153	Proposed LSTC staff training plan, to provide key STFC staff working knowledge of the operation, maintenance and safety of the supplied equipment.
LSTC154	Deleted.
LSTC155	Thermal gradient estimations for the thermal shroud for all load cases.

LSTC156	Details of vessel support, anchoring scheme, levelling and foundation requirements.
LSTC158	Details of scheme to protect fabricated component from contamination during project execution.
LSTC159	Manufacturing, NDT & QA plan to be followed for this project.
LSTC162	Proposed component location on and around the vessel, including TCU's, vacuum system, controls, LN_2 and power distribution. This should clearly demonstrate compliance with the allocated space.
LSTC163	Preliminary pump down calculations for sizing the rough vacuum pumping system and high vacuum systems.
LSTC164	List of key components comprising the vacuum system with quantity, models, make, capacity , etc.