February 2024

Specification for the

Electron Bio-Imaging Facility @ Diamond Light Source

CryoEM Sample Handling and Storage Robot

This document and any associated Annexes is classified as "**COMMERCIAL IN CONFIDENCE**". Information provided herein should be used solely for the purposes of the tender exercise and any subsequent contract with Instruct-ERIC for the supply of goods and/or services at Diamond Light Source Ltd. Information should not be disclosed to third parties, other than for strictly related purposes, without the prior written consent of Instruct-ERIC.

This specification will be an integral part of any subsequent contract. The tenderer must indicate whether each individual clause is accepted, and if not give a full explanation. Where alternative design features or manufacturing procedures are proposed by the tenderer, this must always be in addition to a bid that fully meets the existing specification.

Section 7 of this specification lists the information required with the tender. It is essential that this accompanies the tender reply. In the absence of this information the bid may be rejected as non-compliant.

Written by: Jason van Rooyen

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1. INTRODUCTION

Located on the Harwell Science and Innovation Campus in Oxfordshire, UK, Diamond Light Source Ltd. (DLS) is a leading-edge facility for science, engineering and innovation. It is the largest science facility to be built in the UK for 40 years and produces infra-red, ultraviolet and X-ray beams of exceptional brightness. Diamond allows researchers from academia and industry to investigate the structure and behavior of the world around us at the atomic and molecular level. Areas of investigation include fields such as medicine, the environment, materials and engineering science, physics, chemistry and heritage science. The research undertaken at DLSbrings economic, health and quality of life benefits to the UK and further afield.

Instruct-ERIC is a distributed European Research Infrastructure for structural biology composed of a number of Instruct Centres across Europe. Diamond Light Source (DLS) is part of one of these Instruct Centres: Instruct Centre UK. Together, Instruct-ERIC and DLS participate in the Horizon Europe funded project Fragment-Screen which aims to develop new instrumentation, experimental and software methodologies for Fragment-Based Drug Design (FBDD).

This project aims to push the limits of what's currently possible by bringing together instrumentation manufacturers and beamline scientists to design and deliver solutions to increase automation and overcome existing barriers to higher throughput FBDD. The envisaged solutions will immediately benefit the wider European research community accessing structural services through large user facilities but also hopefully result in the dissemination of the solutions to the global academic and industrial community via commercialisation of successful designs.

DLS is leading the work package tasked with overcoming the hurdles preventing electron cryo-microscopy (cryo-EM) from being deployed in FBDD campaigns through innovations in sample handling and AI-based workflow improvements in data collection. This tender covers the development of a technical solution for automatically handling and storing cryo-EM samples akin to the automated sample changers present on current generation macromolecular X-ray crystallography (MX) beamlines. Instruct-ERIC has designated funding for the procurement of this technical solution, a CryoEM Sample handling and storage robot, to be installed at DLS.

2. DELIVERABLES

2.1 Scope

The current state of the art represents very thin and fragile perforated 3 mm copper foils called “grids” being housed in slightly larger brass holders, manufactured by Thermo Fisher Scientific (TFS), called “cartridges”, and retained with a wire c-clip. This 3.5x04 mm cassette is currently handled throughout the cryo-EM workflow, including submersion into cryogens, by hand using tweezers and stored in simple polymer boxes with screw lids, holding several cartridges. Multiple boxes are shipped to research facilities for imaging in dry-shippers cooled to LN2 temperatures. In order to image the samples, cartridges are loaded into TFS cassettes (holding 12) and then returned to boxes for storage in large LN2-filled Dewars. Multiple rearrangements and disposal of cartridges occurs over the duration of a visit.

The scope of the contract is to design, manufacture, commission, and deliver a standalone robotics system to ingest sample carriers shipped from home labs, identify their origins and contents, permit their reorganisation, and load the microscope automatically, all the while keeping samples contamination free at cryogenic temperatures not exceeding 120K. The innovations envisaged to result from this contract aim to replace as much of the current manual handling as possible and introduce sample tracking at all levels and steps in the cryo-EM workflow. Changes to the cartridge, taken as the starting point of the workflow, and the loaded cassette, taken as the end-point, are considered out of scope in this project as compatibility with and warranties on exiting equipment precludes their redesign. To be useful, the workflow needs to be reversible such that samples can be recovered after imaging and reorganised for longer term storage.

The storage robot must be sufficiently compact to fit within an existing microscope laboratory and present a user-friendly Graphic User Interface (GUI) for tracking sample ID’s and permitting rearrangements and loading. Software workflows, such as an Application Programming Interface (API), will be required to permit ingestion of shipping manifests and export of inventories. This is an essential starting point for wider integration of the proposed solution into the multi-user synchrotron environment where EPICS-based control and LIMS databases work together to coordinate user’s sample and experimental visit parameters prior, during, and after their visits.

Notwithstanding the period of validity for the acceptance of tenders, tenderers should confirm that the price quoted in their tender is valid for the duration of the project (until 31st January 2026).

If the required performance can be met or exceeded using alternative designs, technologies or materials, then these will not be excluded from consideration as long as sufficient information is supplied to justify the proposed solution. If some of the technical specifications cannot be met then this should be made clear. While it is strongly preferred that all technical specifications be achieved or exceeded, proposals that do not meet every technical specification will not necessarily be rejected.

The tenderers could be required to enter into a written confidentiality agreement covering confidential information provided by Instruct prior to the contract award or during the project.

2.2 Equipment

The main items to be delivered are:

- Sample carriers with built-in tracking IDs.
- Robotic sample handling and storage system.

- Ancillary equipment for cooling and maintaining sample integrity e.g., vacuum systems if deployed.
- Any software and hardware (PC) to control the system and interface with shipping manifests (ingest and egress).
- All control and monitoring electronics.
- Commissioning, functional/performance testing, after installation at DLS.
- Training of DLS eBIC staff
- Sufficient spare parts with long delivery times to guarantee operation of the system with minimum down-time for a period of at least 2 years from the date of final acceptance.

2.3 Reports and Documentation

- Kick-off meeting documentation and minutes
- Preliminary Design Review documentation and minutes
- Initial quality assurance assessment
- Final Design Review documentation and minutes
- Full set of drawings for all supplied equipment including 'as built' optics, mechanical and electrical drawings
- Full support documentation for all items of equipment, including all installation, operation and maintenance manuals, including components supplied by a third party
- A list of any further recommend spare parts not included in the contract to guarantee long-term operation
- Safety reports
- C.E. Declarations of Conformity / Incorporation, as appropriate;
- Quality assurance documents for the completed device with copies of all specified material certificates, details of all quality control checks, intermediate tests and results and Factory and Final On-Site Acceptance Tests procedures and results (see section 9).

All documentation is to be supplied in English.

2.5 Delivery Timescales

The project started on 1st February 2023 and will end on 31st Jan 2026.

Following the award of the contract, the design stage shall not exceed 9 calendar months in length unless mutually agreed in writing. A full design review must take place within this time period. In the event of the design being incomplete after 11 calendar months and extension is not mutually agreed, the contract shall terminate.

Instruct-ERIC requires that Factory Acceptance Tests will commence no later than 12 calendar months. Following delivery and installation at DLS, the system will be installed complete and commissioned on site within 14 months of the date of placement of the order.

Instruct-ERIC requires the following timescales to be met:

Milestone Number	Months after contract

Kick-off meeting	0.5
1. Preliminary design review (PDR)	4
2. Final design review (FDR)	9
3. Site Acceptance Test (SAT)	12
4. Receipt of Delivery at DLS	13
5. On-Site Acceptance	14

In the event that the Supplier cannot meet these timescales, the best alternative offer should be put forward.

3. GENERAL CONDITIONS OF CONTRACT

3.1 Basis of the contract

Any eventual contract will be based on the following documents:

1. This specification
2. All other documents issued with this Invitation to Tender.
3. Instruct-ERIC's Conditions of Contract
4. Any amendments to item 1 issued by Instruct-ERIC during the tender period
5. The Supplier's tender proposal
6. Any post-tender clarifications between the Supplier and Instruct-ERIC

Strict compliance with these contract documents is required unless otherwise specifically agreed in writing.

3.2 Supplier's Responsibilities

The Supplier is responsible for meeting all the requirements of this specification.

Where reference is made, within the specification or any associated document, either to a standard, a trade name or product, Instruct-ERIC will consider a demonstrably compatible alternative or equivalent. The Supplier is responsible for providing evidence of equivalent performance if their tender offers a compatible alternative or equivalent.

3.2.1 Technical and Progress Meetings

Instruct-ERIC and the Supplier must agree the final design at the final design review (FDR) meeting. At the FDR, the Supplier must present to Instruct-ERIC and any representatives the detailed final design, including:

- An outline of maintenance, operating and hazard management documents
- A list of components
- A detailed manufacturing, installation and testing programme
- Full details of factory, site and final acceptance testing

The Supplier must issue the final design report detailing the proposed design, as well as a set of computer-aided-design (CAD) drawings, five working days in advance of the meeting to enable inspection by Instruct-ERIC.

Moreover, Instruct-ERIC are to receive progress report for delivered Milestones along with receipt of invoice.

An agreed set of minutes will be produced following the FDR, accurately recording whether all aspects of the design listed above have been completed, as well as listing all agreements and actions.

3.2.2 Approval Prior to Manufacture

Unless otherwise agreed in writing, Instruct-ERIC must approve the final design presented at the FDR before the Supplier proceeds to ordering of any materials, components or equipment required to fulfil this contract.

3.2.3 Approval before Delivery

Delivery to DLS shall not commence until successful completion of all factory acceptance tests and after written authorisation by Instruct-ERIC.

3.2.4 Final Acceptance

The final acceptance will be complete when the goods have been delivered to DLS and have satisfactorily completed the testing procedures demonstrating full compliance with this specification (section 4). It is a condition of final acceptance that all supporting documentation, hazard management, maintenance and operating manuals, quality assurance documents, and mechanical and electrical drawings have been received and accepted by Instruct-ERIC.

3.3 Norms and Standards

The goods should comply with all current relevant regulations regarding pressurised gases, cryogens, and electrical systems.

3.4 Guarantee

The goods shall be guaranteed for 18 months following the date of delivery, or 12 months from the date of final acceptance, whichever is the later.

3.5 Safety and Hazard Management

The Supplier shall carry out a safety assessment of the goods and their operation to reduce the risk of personnel becoming injured as a result of interaction with the goods. This shall be fully documented in the corresponding manuals. Any safety and risk assessments carried out as part of the CE marking shall be supplied to DLS.

The supplier should pay particular attention to the hazards arising from components internal to the system being installed or connected in the wrong orientation during assembly, as well as errors to the whole system during installation and connection at DLS. This applies to mechanical and electrical components upon both the original build and installation and on subsequent repair and service. Where practicable this should take the form of mechanical features that restrict assembly to the correct orientation and/or marking. The results of this study and the mitigation steps taken to reduce this risk to an acceptable level will be presented to Instruct-ERIC during design review.

3.6 Manuals

Detailed installation, operation and maintenance manuals shall be supplied with the goods.

3.7 Delivery

The Supplier shall ensure that all equipment within the extent of this supply is fully and satisfactorily protected during handling and transportation. Packing cases must be robust and suitable for lifting and transportation without damage. Internal packing must be adequate to prevent movement or vibration during transportation.

All packages should be fully labelled with the full address of Diamond Light Source Limited, and the DLS contact name shall be clearly displayed. All packages must be marked and delivered as directed by DLS.

Individual items weighing more than 30 kg shall be provided with sufficient lifting hooks and/or be compatible with lifting by a fork-lift truck.

4. DETAILED FUNCTIONAL SPECIFICATIONS

4.1 Overview

An end-to-endsp solution is sought for a complete stand-alone sample management and storage system for automatically handling cryo-EM cartridges, for the purposes of reorganising samples before and after imaging experiments and directly loading TFS Transmission Electron Microscopes (TEMs). As the desired aim is to replace and simplify the maximum number of manual handling steps, it is envisaged that novel machine friendly sample carriers will need to be developed to permit their automated handling, whilst permitting their identification under cryogenic and contamination-free conditions. The complete system will therefore comprise both these carriers and the robotic storage system to handle and store them before loading TFS cassettes and then TEMs.

Special attention should be focussed on the robustness and positional accuracy of the robot's loading function to avoid any damage to TFS microscopes from incorrectly loaded cassettes. This is all the more challenging due to the large temperature changes associated with the requirements of being able to warm and dry the system frequently to maintain precise functioning. The end-user will interact with the system via a simple GUI and should be able to upload and retrieve carrier content manifests and manually intervene to rescue samples if required.

4.2 Traceable sample carriers

It is envisaged that new format grid carriers will be required to enable robust, contamination-free (un)loading and re-organisation of cartridges under cryogenic conditions. These need to fit in with existing and widely-adopted shipping carrier standards and allow manual loading by home labs without access to the planned robotic manipulators. Considerations of cost, durability, contamination rates, and integration with tracking ID systems need to be made. Integration with the cartridge manipulators, the main focus of this tender (see below), are expected to be the principal design priority as recovering cassettes from the carriers needs to be automated too.

Current storage and shipping capacities:	
Cassette	holds 12 cartridges
Current grid boxes	hold 4 cartridges
Current pucks	4*12 boxes per puck = 48
Current storage capacity	4800 cartridges in 1200 boxes in 480 pucks in 10 canes in 35L Dewar
Shipments typically	currently 1 cane or 10 pucks or 480 grids

Essential requirements:

- Sealed to avoid contamination during long term storage under LN2 of several months to years
- Reasonable storage density comparable with current values
- Capable of automated handling by robotic system to present cartridges for organisation and loading
- Capable of manual loading in home labs and adhere to current storage and shipping conventions
- Cost effective, robust (reusable) and simple machining for sharing with the community/commercialisation partners
- Traceable via barcoding or other technology

4.3 Storage robot functionality

4.3.1 Loading of sample carriers from home labs

After removal from shipping Dewars, carriers need to be easily loaded by hand into the storage robot and tracking IDs need to be read and sample inventories within carriers need to be cross-checked with records. Currently, rearrangements are not envisaged to occur between more than 48 samples positions or several carriers, but this is envisaged to scale with improvements in data collection rates.

Current loading frequency and imaging experiment durations:	
Microscope loads/unloads:	
screening	12 cassettes in 1 cartridge every 4 hours
data collection	1 cartridge every 48 hrs
Experiment durations:	
manual loading of cassettes from boxes	20 – 40 min
longest imaging session	80 hrs

Essential requirements:

- Ingestion of no more than 5-10 sample carriers (depending on storage density) via simply manual operation
- An API or other upload service allowing the ingestion of shipping manifests.
- Simple instructions and feedback, with error-checking, via a GUI to instruct the user on successful loading of sample carriers. Sample information should be queryable or presented upon upload immediately.
- Any discrepancies in storage manifests need to be identified immediately and solutions presented to the user i.e., visual inspection of carrier positions may be necessary to confirm a missing cartridge.
- Unloading sample carriers needs to be as simple as the ingestion process with associated ability to download storage manifests via the API.

Desirable requirements:

- Modularity to permit scaling of sample carrier ingestion (see storage function below)

4.3.2 Storage of samples

Samples need to be stored free of contamination for several days (at least 80 hrs) within the robotic handling system. The ability to manually recover samples without losing temperature integrity is essential and so are rapid reset/cycle times to allow thawing and drying of all components. Subsequent system start-up should not require lengthy calibrations and the cooling needs to be compatible with automatic LN2 filling systems or alternative non-cryogenic cooling options. Avoidance of LN2 would be a great safety benefit. Vacuum systems greatly reduce contamination rates and cryogen requirements but are not necessary as current manipulations are done manually under LN2 at atmospheric pressure. The system will need to present users with an opportunity to intervene to manually rescue samples if sample integrity is at risk due to power or cooling failures.

Essential requirements:

- Cassettes containing sensitive samples on grids should be maintained below 120K to avoid devitrification for several days
- Contamination of sample surfaces by ice crystals present in LN2 cryogenic systems should be kept to an absolute minimum
- Sample recovery and rescue, whilst maintaining temperature integrity is essential in the event of system failure.
- Stable performance during operation and minimal regeneration (thaw, dry, and re-cooling) durations are important to be able to deploy the system in support of the daily operation of the beamline.
- Handling and presentation of carriers for identification via RFID, optical, or other readers whilst maintaining the integrity of the cartridges contain therein

Desirable requirements:

- Achieving cryogenic temperatures without LN2 or liquid cryogens would greatly enhance the safety of the system
- Modular design of the storage facility to permit scaling of the volume of samples
- Long term storage (months to years) would be a massive benefit if achievable at sufficiently dense capacities. Current LN2 Dewar storage systems hold 4800 cassettes for months – years
- Sufficient modularity to permit presentation of cartridges to optics-based or other inspection instruments via ports or incorporation of reading heads would be a major future benefit

4.3.3 Rearrangement of samples

Central to the delivery of this project is the development of a micromanipulator with sufficient dexterity to handle the cartridges under cryogenic conditions with the main aims of reorganising cassettes in their storage carriers and loading of the TFS cassette (see 4.3.6). A significant challenge to overcome is the maintenance of positional targeting precision for loading of carriers or cassettes over the experiment duration covering the sample storage at cryogenic temperatures. The gripping geometry will also need to allow presentation of sample carriers and ideally cartridges, in a contamination-free manner, for ID tracking (see 4.3.4).

Gripper actuation performance should ideally be similar at room temperature permitting future integrations with upstream cryo-EM workflows through integrations with sample preparation and imaging modules. Similarly, reconfigurability and flexibility of function are important consideration for the same reason.

Essential requirements:

- Manipulation and handling of sample carriers to access cartridges
- Damage free loading, transfer, and unloading of cartridges to and from sample carriers to and from TFS cassettes
- Error detection, resolution, and manual intervention for damaged or miss-positioned cartridges including handling the presence of solid ethane on cartridge surfaces from upstream sample preparation (this usually sublimates in the microscope vacuum or under prolonged storage in the vapour phase of LN2 storage Dewars)
- Disposal of samples into 96% ethanol solution or a removable vessel which permits the introduction of 96% EtOH before opening to atmosphere.

Desirable requirements:

- Presentation of cartridges to optical or haptic readers for sample identification
- Invariance of precision of movement at room and cryogenic temperatures will allow future integration with upstream workflows

4.3.4 Sample tracking

Identifying samples at all stages of the experiment from preparation in the home lab to unloading of the microscope, is essential to enabling higher throughput FBDD imaging experiments. The increased volumes of cartridges, their fragile nature combined with often erroneous handling, requires close monitoring of sample logistics at the multiple transfer steps in the cryo-EM workflow. Without constant error checking, cartridges, with no visible markings can no longer be linked to the samples or experimental conditions that generated them. Therefore, the robotics system designed to manipulate samples in this tender also needs to be able to handle identification of sample carriers and ideally individual cartridges via novel optical, RFID, haptic, or other readers. Software interfaces and databases for ingesting, tracking cartridge IDs, resolving conflicts, and exporting manifest will also be needed to allow future integration of the system into working labs. Special attention will be required to identify and resolve cartridge losses caused by handling issues, both within the envisaged system and within the TFS microscope.

Essential requirements:

- Sample carrier identification, validation of ingested manifests, and tracking of cartridge rearrangements
- Error checking and conflict resolution for miss-handled cartridges or data entry errors

- Chosen methods of carrier identification should maintain performance over the duration of an experiment and be reliable enough to cope with expected ice-contamination levels
- The GUI should present cartridge location and identities

Desirable requirements:

- Cartridge level identification at cryogenic temperatures
- Ideally, metadata, which helps identify samples should be queryable from the GUI

4.3.5 Loading of grids into TFS cassettes

The most critical function of the robot is to load cartridges into a TFS cassette with sufficient positional accuracy to not damage the delicate springs but enough to ensure correct seating. Incorrectly positioned cartridges can result in extremely expensive downtime on £10m microscopes. The accuracy therefore needs to match that of manual handling at a minimum and sufficient error checking is required to identify positional errors. Furthermore, as the cartridge assembly is done by home labs under cryogenic conditions, decoupling of clip rings during loading and operation of the microscope can occur and this needs to be accounted for, and present the operator with a chance to manually rescue samples. Error checking need to be of sufficient quality to avoid damage to TFS cassettes or downstream components like TFS autoloader.

An additional desired feature is that the actuator should ideally permit rotational alignment of cartridges for tomographic workflows i.e., be able to rotate a cartridge in-plane to any arbitrary angle before insertion into a cassette.

Essential requirements:

- Loading of TFS cassettes with comparable accuracy to human handling without damaging fragile grids held within cartridges
- Error checking of cartridge integrity and loading success is paramount. Errors can occur in home labs (loading of cassettes) and in the microscope (unloading of cassettes).
- Manual recovery of cartridges, at cryogenic temperatures, should be possible so that grids can be reclipped if possible

Desirable requirements:

- Ideally, cassettes should be stored without contamination within the robot for use when loading or a rapid exchange function will be necessary to allow the operator to present a clean and dry cassette for (un)loading.
- Rotational positioning of cartridges within TFS cassettes would be highly desirable for tomography workflows

4.3.6 Loading of microscope autoloader system

A hands-free transfer mechanism is sought to load cassettes into the TFS microscope autoloader system either through manipulation of the existing “nanocab” docking system or a custom housing. Cryogenic temperatures need to be maintained from the storage robot to the microscope autoloader but the docking interface is not high-precision and sufficient clearance is present for a deviation from the existing nanocab interface.

Essential requirements:

- Automated pre-cooling of a hand-presented nanocab and docking of the loaded cassette under cryogenic conditions.
- Undocking/reingestion of the cassette from a cold nanocab for cartridge recovery, rearrangements, and storage in carriers.

Desirable requirements:

- Hands-free "docking" of loaded cassettes directly into the TFS TEM autoloader interface or mock-up to prove the concept (success in this step requires direct positioning next to microscopes)
- Collision detection/prevention as this manipulation would transverse considerable distance from the storage robot and possible in an area with human traffic.
- Custom cassette housings/transporters/housings would minimize potential lengthy recycle times when using existing TFS nanocabs

5. QUALITY ASSURANCE AND TESTING

5.1 Factory Acceptance Tests

Factory Acceptance Tests are carried out to demonstrate to Instruct-ERIC that the system is fully functioning and complies with this specification and DLS standards.

The complete system to be supplied must be fully assembled and tested at the Factory and all Factory Acceptance Tests must be completed successfully before shipment. For third-party components (e.g. optics or RFID modules) these must be installed at the Factory and included in the Factory Acceptance Tests, unless agreed otherwise with Instruct-ERIC.

Before the Final Design Review, the supplier shall provide a complete and detailed schedule of all Factory Acceptance Tests to be performed, including the proposed acceptance criteria and a list of any components to be used to demonstrate the performances.

The proposed time plan and all acceptance criteria must be agreed with Instruct-ERIC at the latest at the Final Design Review and must be satisfactory to Instruct-ERIC.

FATs should include, but not be limited to the following key elements:

Repeated error-free loading and unloading of TFS cassettes and then a TFS autoloader docking interface mock-up, either directly or via nanocabs, over the duration of a normal imaging experiment will be taken as acceptable system performance and can be broken down into the following sub-tests:

5.1.1 Carrier (un)loading:

It needs to be demonstrated that sample carriers can be ingested into the storage robot easily and quickly by an operator along with their prepopulated loading inventories. Manifests need to be confirmed during inventory steps, through non-damaging presentation to ID devices/read-heads, and error scenarios including the following dealt with:

- A cartridge listed as present being found missing in the actual sample carrier
- Conflicts in sample carriers IDs as supplied
- Resilience to frosting and the consequences of ice contamination on reading IDs and handling carriers needs to be demonstrated over several days of operation (>80hrs)
- Misplaced or mishandled carriers need to be detected or handled as to prevent damage/jamming of the system

The process should be demonstrated to be equivalent for unloading with manifests and carriers easily recovered within sufficient time to maintain temperature integrity.

5.1.2 Cartridge manipulation:

Gripper handling needs to be shown to be sufficiently precise to reliably move cartridges between carrier positions (or into disposal receptacles) without damage to samples, whilst maintaining temperature integrity and keeping contamination to an absolute minimum. It will need to be shown that the GUI is sufficiently simple to permit intuitive sample rearrangements by an operator. Equivalently, rearrangements triggered through the API need to be shown as possible. If incorporated, cartridge-level identification needs to be demonstrated as reliable. Performance needs to be shown to be stable over the duration of storage (>80hrs), at high usage loads, and the following error scenarios need to be dealt with:

- An empty cartridge (no grid)
- A weakly clipped cartridge (with c-clip only partially held in place)
- A stuck carrier housing or stuck cartridge inside the carrier slot
- Provision of impossible instructions via the API or GUI e.g., co-locating cartridges in the same slot of a carrier

Recovery of critical system states needs to be demonstrated, including recovery of cold samples, return of the system to an operational state, and error logging features must be demonstrated.

5.1.3 Cassette loading:

Repeated successful loadings of cartridges into TFS cassettes with similar positional accuracy to that achieved by a human operator, and without damage sufficient to cause long-term deterioration of the operation of cassettes, need to be demonstrated and evaluated by inspection or ideally by internal error checking features. As above, the usefulness of the GUI and API for controlling the (un)loading instructions needs to be demonstrated and performance of the manipulator function must be reproducible over the course of an experiment (>80hrs). The following error scenarios need to be dealt with:

- Cartridge disassembly in the cassette (either due to microscope operation or assembly issues from human error)
- Missing or empty cartridges upon return from the microscope
- Insufficient free space to permit execution of given instructions e.g., the user requests 11 new grids to be placed into a cassette already housing 4 after discarding the remaining 5

5.1.4 Microscope loading

It must be shown that the robot is capable of presenting cassettes to a mock-up of a TFS autoloader docking interface directly or loading TFS nanocabs successfully without damage to either component. The following error states will need to be tested:

- User takes too long to dock the cassette into the microscope
- Instructions are given to undock samples from a microscope which already has a nanocab in place. Similarly, instructions are given to load samples when there is a nanocab present or docking it interlocked
- Safety interlocks need to be demonstrated in the event of a human accessing the same autoloader during loading operations
- Rescue from failure modes including jamming by the TEM autoloader need to be demonstrated

5.2 On-Site Acceptance Tests

After delivery to DLS the following tests to confirm the specifications listed in Section 4 will be carried out by the Supplier in the presence of DLS staff:

- Functional tests of all aspects of the complete system listed in section 5.1
- Tests agreed during the final design review
- Effectiveness of safety interlock systems
- Accessibility for operational and maintenance purposes
- Failure Modes, Effects and Criticality Analysis (see BS 5760-5 1991).

It will be dition of final acceptance that the Supplier must have provided to Instruct-ERIC's satisfaction, full documentation as noted throughout this specification, to cover all systems embodied within this contract.

5.3 Visual Checks

DLS will check for damage during transport.

5.4 General arrangements for tests

The tests at the factory and on-site must together establish that all items of the manufactured equipment completely meet the performance requirements described in this specification.

Testing shall conform at all times to the local safety codes. DLS reserves the right to require additional or more extensive tests to be conducted, in the event of marginal design or performance.

The acceptance test procedures must include, but not be limited to all of the testing procedures specifically outlined in this document, but also those necessary to prove compliance with this specification and with DLS standards, as specified in the list of annexes. These test procedures are subject to DLS review and acceptance. DLS will reserve the right to witness all tests and will be the sole arbiter as to their being satisfactory.

Review and acceptance by Instruct-ERIC does not release the Supplier from its responsibility to correct errors, oversights and omissions to ensure conformance to the specifications in this document and to DLS standards as specified in the list of annexes.

All tests must be properly recorded on test certificates, and results submitted to DLS.

Instruct-ERIC reserves the right to reject any material or component not completely fulfilling the conditions laid down in this specification.

No component failing any specified test may be used in manufacture except with the written permission of DLS.

In the event of any test failure and subsequent rectification work, DLS reserves the right to repeat any previously unsuccessful tests.

6. INSTALLATION REQUIREMENTS

6.1 Layout and Location

The storage robot will be installed in a TEM microscope room with vibration level specifications below VC-F and minimal AC/DC fields (130 nT p-p).

- The lab temperature is 22 +/- 0.3 ºC
- The lab humidity is between 30% 40%
- Please refer to the annex document B for electrical standards.
- Central compressed air supplied at via 6 mm hose
- Central dry nitrogen supplied via 8.5 mm hose
- Central liquid nitrogen supplied via flexible braided hoses with CGA 295 fitting (female) to either SIVL or mobile 200 L tank

6.2 Access Restrictions

The assembly must be able to be transported through a doorway opening 1.5 m wide by 2.8 m high and manoeuvred into place without disturbance to other installed equipment. Roughly 1.4 m X 2.5 m is available for locating the robot and facility connections are no more than 1.5 m away on vertical walls and 2 m from the floor.

6.3 General Requirements

The Supplier shall supply all necessary tooling and equipment and all fixtures and fittings for the installation.

The site must be kept tidy at all times during installation and testing.

6.4 Health and Safety Considerations

6.4.1 General

Before installation commences the Supplier shall supply Instruct-ERIC with a full risk register for the design and installation and method statements for the installation. There will be obligatory safety training for all personnel coming to work site, typically this takes half an hour to complete.

The Supplier is responsible for supplying all necessary safety equipment such as safety glasses, gloves, visors etc.

During installation the Supplier shall erect barriers and notices to define the installation area.

Operation, maintenance and installation instructions must be supplied with the equipment. These instructions must, if followed, ensure compliance with all the relevant DLS site regulations and guidelines.

6.4.2 Site Preliminaries

The Supplier shall identify to DLS engineer's representative, in advance, the names of all the Suppliers' staff who will be employed on-site. This information shall be provided at least five working days before Supplier's personnel arrive on-site.

The Supplier shall comply with the Health and Safety at Work Act 1974 in completeness. This includes compliance with COSHH regulations, method statements and risk assessment etc.

6.4.3 Cryogen Safety

The Supplier will design the system to allow the users to operate within the safe guidelines of the DLS "Liquid Nitrogen and Liquid Helium Code of Practice for Handling (HAS-PRC-0024)", which is included in the annexed documents. The room wherein the robot will be located has oxygen depletion monitoring sensors and auto-shutoffs for the SIVL LN2 auto-filling lines.

7. TENDERING

7.1 Pre-tender Clarifications

If interested Suppliers do not fully understand the requirements and implications of the specification, or if some doubt exists as to its interpretation then they should contact Instruct-ERIC to obtain clarification.

Technical enquiries or commercial/contractual issues may be made at any reasonable time during the tender period via:

Instruct-ERIC Finance Department
Email: finance@instruct-eric.org
Telephone: +44 (0) 1865 988639

Postal address:

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Oxford, OX4 2JY
UK.

If such a clarification results in a modification of the specification or other tender documents then this information will be distributed to all interested Suppliers.

7.2 Tender Evaluation

Instruct-ERIC will evaluate the bids taking into consideration the cost, delivery time, the technical aspects, including desirable options, as well as the Supplier's quality assurance procedures and relevant experience, e.g. familiarity with TFS TEM autoloader systems and other synchrotron beamline projects. Full details of the evaluation criteria and their weightings can be found in the tender notice.

Regarding the technical information, particular attention will be paid to the ease of operation, reliability, and compactness of the robot's design. Specific areas of particular concern are the duration of stable operation and sample storage as well as ensuring no damage to downstream microscopes.

7.3 Information Required with the Tender

NB. At least one copy (hard copy or email) must reach Instruct-ERIC by midnight on the day of the deadline. Any tender received after this time will be deemed late and as such not receivable.

The Supplier shall provide with the tender documents sufficient information to allow an informed choice of Supplier, as detailed below. It is essential that this information accompanies the tender response; otherwise, the bid may be rejected as non-compliant.

7.3.1 Forms to be completed

- Supplier Evaluation Questionnaire

7.3.2 Acceptance of Instruct documents

A clear statement of acceptance of all articles of the following documents:

- Instruct Specification
- DLS Standards, as specified in the list of annexes.
- Instruct-ERIC Terms and Conditions
- Instruct-ERIC Payment Schedule

If full acceptance of these documents is not possible, a list of exceptions with full details and alternative proposals must be provided.

7.3.3 Cost Breakdown

Please submit a firm price in Euros for the total project.

Unless otherwise indicated prices should include delivery to DLS site under incoterms DDP (Delivered Duty Paid).

A breakdown of costs with details and options as requested:

- Robot
- Service contract/warranty
- Cryo-cooling requirements
- Temperature, humidity and cleanliness requirements
- Site installation and commissioning
- Design, manufacture and installation of all necessary electronic and controls systems
- Cost of essential spares to be supplied as part of the contract

7.3.4 Services and Running Costs

- Estimates of heat-to-air power dissipation for all components
- Additional equipment or facilities required
- A breakdown of electrical power requirements, including UPS
- Estimates of gas and cooling requirements during normal operation
- A maintenance schedule
- Hardware and software maintenance
- Service contract options

Please include the cost and lead times of standard replacement parts and any costs associated with installing them.

7.3.5 Delivery and Installation

Please include details of the proposed delivery arrangements, covering:

- Description of any handling requirements during installation, testing and commissioning

- Details of the largest dimensions and weights of individual components to be installed

LIST OF ANNEXES

Annex A	Visual glossary	Illustrative explanation of component terminology
Annex B	MENG-GEN-STD-0002	Standards to which all Electrical and Mechanical Equipment supplied to DLS must comply
Annex C	HAS-PRC-0061	DLS Oxygen Depletion Policy and Guidance
Annex D	HAS-PRC-0024	DLS Liquid Nitrogen and Liquid Helium – Code of Practice for Handling
Annex E	HAS-PRC-0030	DLS Compressed Gas Cylinders Code of Practice for Handling