



Attachment A
Definition: Scalable Storage System Technical Specification
Solicitation Number: 6400011050

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1 Program Background

1.1 Conventions

Attributes of the Scalable Storage System (SSS) are ranked according to their relative contribution to functionality, productivity, and usability. As appropriate, each section/paragraph of the technical specification is followed by a letter in brackets that ranks that particular attribute of the SSS according to its relative contribution to functionality, productivity, and usability. The following conventions are used:

Attribute Priority	Description
Critical [C]	Items considered the most important, or critical to the SSS. Offeror shall describe any exceptions to items considered critical, and describe proposed methods for mitigating the impact of an offer that does not provide this item. Sections that include these items are marked with [C].
Significant [S]	Items that are of sufficient significance that the effectiveness of the SSS would suffer if not provided. Offeror is encouraged to provide as many such items as possible. Sections that include these items are marked with [S].
Enhancing [E]	Items that enhance the utility of, and are desirable for, the SSS. Offeror is encouraged to provide as many such items as possible. Sections that include these items are marked with [E].
Information [I]	Items that are provided as additional information to an Offeror regarding information about the ORNL Leadership Computing Facility (OLCF) that may aid an Offeror in determining the most suitable system configuration. Sections that include these items are marked with [I].

Conventions

1.2 Purpose [I]

The SSS acquisition will support Company requirements to provide a scalable storage system for the OLCF-3 multi-petaflop computer system. The SSS shall be a high-performance, resilient storage system for the parallel I/O environment. This acquisition is for the storage system hardware for this parallel I/O environment, in particular the storage media, storage enclosures, storage controllers, and associated hardware including racks, and electrical distribution.

The Company seeks either a block storage solution or an integrated Lustre solution.

Offerors may propose either a “block storage solution” consisting of storage media and controllers or an “integrated Lustre solution” consisting of storage media and controllers, Lustre infrastructure servers, network infrastructure, Lustre software, and Lustre support. For funding details, refer to the Solicitation Section J.

Company will provide any additional components that may be required to integrate the proposed solution with the larger computational environment.

A single Offeror may submit more than one proposal. However, any single proposal must stand on its own merit.



1.3 Company's Existing Scalable Storage System and Infrastructure [I]

The Company has deployed and manages a number of large-scale storage systems used in our leadership computing facility for simulation, data-analysis, and visualization workloads. These provide center-wide parallel Lustre file systems that are available to multiple compute resources. The center-wide interconnect is based on InfiniBand.

2 Procurement Goals and Scope [I]

Regardless of whether Offeror proposes a block storage solution or an integrated Lustre solution, the solution shall provide a SSS that balances the capacity, bandwidth, reliability, and scalability requirements set forth in this Technical Specification.

3 Responsibilities of the Selected Offeror and Interface with Company [I]

The SSS will reside at Oak Ridge National Laboratory (ORNL). The selected Offeror will work directly with Company to install, deploy and integrate the SSS within our operating environment. Company will execute the Acceptance Test. After successful completion of the Acceptance Test, Company will provide all system administration of the SSS.

Offerors of block-level storage solutions shall provide the storage controllers, disks, and the racks in which they are housed, as detailed in their proposal, subject to the requirements provided in this document. Offerors of block-level solutions are not responsible for the host servers, host-side network infrastructure, Lustre software or Lustre support.

Offerors of integrated solutions shall provide the storage controllers, disks, racks, metadata and object storage servers, network infrastructure, metadata servers and storage, Lustre support, and other infrastructure as detailed in their proposal, subject to the requirements provided in this document.

4 Scalable Storage System (SSS) Requirements

4.1 System Composition

The overall design of the SSS shall balance the operational requirement for highly reliable, available and resilient system(s) with the need for a high-performance scalable solution. [S]

The Offeror is encouraged to propose novel approaches to system design, system installation, and maintenance activities that will best meet all of these goals. [I]

The Offeror shall provide a scalable design in which scalable storage unit building blocks shall allow for modular expansion and deployment of the SSS. The most basic building block will be referred to as the scalable storage unit (SSU). SSUs shall consist of a basic set of independent storage controller(s) (SCs), their associated storage media, and peripheral systems (such as network switches) needed for host connectivity. [S]

SSUs shall be grouped into scalable storage clusters (SSCs). SSCs shall consist of one or more SSUs such that one or more industry-standard equipment racks are filled. A single SSC shall be self-sustaining, i.e. containing all necessary hardware, firmware, and software to support creation of a file system on that SSC. The Offeror shall reserve space within each SSC for host servers or recommend a layout for host system racks provided by the Company. The Offeror may assume that the Company requires a minimum



of 1 rack unit (1U) for each host system, and host server configurations that can saturate the proposed bandwidth of the SSC. The final SSC configuration will be negotiated between the Offeror and Company. [S]

The Offeror shall propose configurations with sufficient quantities of SSCs to meet the capacity and performance requirements set forth in this Technical Specification. In the event that the Offeror's solution fails to meet either the capacity or the performance requirement, Offeror shall provide a description of the additional equipment necessary to meet these requirements, and will describe the pricing for this additional equipment separately. [S]

For each SSC configuration proposed, Offeror shall include pricing options for additional equivalent SSCs priced per-SSC. [C]

The Offeror shall include a Test and Development System (TDS) of one or more SSUs, preferably a full SSC. The size of the TDS shall be sufficiently large that all architectural features of the larger system are replicated. [C]

The TDS will support a wide variety of activities, including validation and regression testing. [I]

The TDS shall be independent of the SSS. [S]

Extended warranty and maintenance of the TDS shall be included in the SSS warranty and maintenance plan. [C]

4.2 System Delivery

The test and development system (TDS) shall be delivered, installed, and configured as soon as possible after subcontract execution. It is preferable that the TDS is delivered prior to the SSS. The Company will evaluate the TDS delivery schedule for risk. [S]

The SSS delivery shall be completed by the dates specified in Section B of the Solicitation. The Company will evaluate the SSS delivery schedule for risk. [S]

4.3 Storage Controllers

The Storage Controller is considered the critical component of any solution. [I]

4.3.1 Common Requirements for Block Storage and Integrated Lustre Solutions

The Offeror shall describe the per-SC and aggregate SSS host-side network requirements in terms of number of ports, port types, protocols, and any other technical specification. Company will provide the infrastructure to connect the SSS to the OLCF environment. [C]

Each SC shall provide full RAID services, supporting RAID level 6 (or equivalent). Offeror shall describe the RAID mechanism (or equivalent) proposed. [C]

If the SC uses write-back caching, cache mirroring between controllers is required. Offeror shall describe how either the cached data is written to disk upon SC failure or how the client is notified of an I/O error. [C]

Offeror shall describe how cached data is saved to persistent media in the event of power loss. If batteries are used for this purpose, Offeror shall describe the capacity, recharge time, warranty, and expected lifetime of such batteries and whether integrated monitoring/diagnostic capabilities of batteries are included. [C]



Each SC shall be configurable via a command line interface suitable for scripting in a Linux environment. Configurations using encrypted transport mechanisms such as SSL v.2 or later are preferred. Offeror shall describe the security characteristics of the command line interface. [C]

Each SC shall provide monitoring information (performance, configuration settings, and faults) via a command line interface suitable for scripting in a Linux environment. [C]

Offeror shall provide mechanisms to support fast rebuilds of the LUNs controlled by an SC, such as parity declustering. Offeror shall describe these mechanisms in detail. [S]

Each SC shall support, and be configured with parity check on read (or equivalent). Parity check on read is defined as all components of a RAID stripe are read and the parity data is confirmed to be consistent. Mismatches shall result in a failed read operation and shall be reported via a logging mechanism. Timeouts for slow disks may still be employed in conjunction with parity check on read but shall also be reported via a logging mechanism. Offeror shall describe mechanisms for parity check on read (or equivalent) in detail. [S]

Each SC shall support dynamic sector repair (or equivalent) and background RAID verification (or equivalent) and must be configured with these features enabled. [S]

Each SC shall support both automatic and manual failover. Controller level caching must either support mirroring or be disabled such that automatic failover via DM multipath (or equivalent) shall not result in data corruption. [S]

The Offeror shall provide a uniform power distribution design for all storage systems. Power distribution design shall be based on no less than two independent inputs. The preference is for a power distribution design that can load balance among the independent inputs and respond automatically to power quality events that impact one or more inputs. The SSS shall be able to run in the presence of a failure of a single input. [S]

The Offeror may provide a data integrity mechanism within the SC for enhanced reliability. Features including T10-DIF Protection Information (T10-PI) are preferred. Offeror shall describe these mechanisms in detail if included in the offer. [E]

The SSS and its authentication-protected components shall support complex passwords. The complex compliant passwords are defined as passwords with longer than 8 characters; and requiring digits, special characters, and numbers to be included. [C]

The Company shall have sufficient access to change default passwords on all authentication-protected SSS components to compliant complex passwords, without requiring the assistance of the Offeror, during the Acceptance Test. [C]

The Company shall have sufficient access to periodically change default passwords on all authentication-protected SSS components to compliant complex passwords, without requiring the assistance of the Offeror, after the Acceptance Test. [C]

The SSS shall be resilient to SC failure. [C]

The SSS shall be configured to maintain 70% of the required bandwidth in the presence of concurrent rebuilds or recovery operations (such as rebalancing data after replacing a failed disk) across up to 10% of the available redundancy groups. In no case shall these concurrent rebuild or recovery operations require greater than 12 hours to complete (even in the presence of active I/O operations from the file system). [S]

The SSS shall not possess any single points of failure including controllers, enclosure bays, power distribution units, and disks. [S]

The SSS shall support "hot-swapping" of all components including power supplies, fans, controllers, disks, cabling, host adapters, and drive enclosure bays. [S]



4.3.2 Block Storage Solution Requirements

The SSS shall include storage controller(s) (SC) that provide block level access to the storage arrays via 6 gigabit SAS-2 or InfiniBand (IB) quad data rate (QDR) or greater connectivity. Other host interconnect technologies such as Fibre Channel (FC) may be considered. The impact of the host interconnect adapters on the host purchase price will be evaluated. [S]

For IB connectivity the SC shall support the SCSI RDMA Protocol (SRP). [C]

SRP implementations should fully support the current SRP standard. [E]

4.3.3 Integrated Lustre Solution Requirements

An integrated Lustre solution shall support all block-level requirements listed in Section 4.3.2. [C]

Company shall have authority to install, modify, and reconfigure any version of the Lustre file system software. [C]

Integrated Lustre solutions shall conform to the site security plan and configuration management policy. Offeror shall provide Company administrative access to the integrated solution. [C]

Offeror shall describe in detail the performance capability of its metadata server (MDS) appliances and the number of MDS units it provides. Offeror shall allow integration of a Company-provided MDS if Company deems Offeror's MDS is insufficient. [C]

Any modifications made by Offeror to the Lustre file system software shall be made available by an open source license. [C]

Offer shall describe how the integrated Lustre solution could be used as a standard RAID-SC for risk mitigation purposes. [S]

Offeror shall propose a method for doing full-scale tests of new client and server software features provided by the Lustre community without disturbing data on the production file system. [C]

4.4 Storage Media

Offeror shall provide Company multiple options for backend storage media that may include 2.5 inch, 10,000 RPM SAS, 3.5 inch near line SAS, 7,200 RPM SATA, flash, and other technologies. [S]

The warranty period (including year 4 and year 5 options) shall cover any wear issues related to flash storage. [C]

4.5 Storage Capacity

Offeror shall provide a minimum of 18 PB of usable block level storage. This capacity must account for any overhead for RAID 6 (8+2) (or equivalent data protection), and shall not include any spare drives (or equivalent space for hot-sparing). In the event that the Offeror solution meets both the performance and capacity requirements within budget, increased capacity is desired. [S]



4.6 Performance

The Lustre file system-level performance goal for the SSS is 1.0 TB/s, aggregate write, as measured via file-system benchmarks defined in this Solicitation. Offers of Lustre integrated solution shall meet this requirement. [S]

The block-level performance goal for the SSS is 1.2 TB/s of aggregate write storage system bandwidth for sequential workloads and 240 GB/s for random workloads. Both workloads will be composed of 1 MB I/O requests. This performance shall be measured between the storage servers and the storage controllers across the Offeror's supported host interconnect. Offers of block-level storage solutions shall satisfy this requirement using Company-provided storage servers. [S]

Performance goals must be met with sufficient features enabled to prevent corrupted data from being returned to the host. [C]

Offeror shall describe the aggregate system bandwidth of each proposed SSS configuration as well as the aggregate bandwidth for single SSUs. [C]

Benchmark codes will be employed to assist Company in assessing performance of Offeror's solution. These benchmark codes include both block level and Lustre level tests. Reference the Benchmark Instructions for additional information. [I]

5 Resiliency, Reliability, Availability, Serviceability

5.1 System Mean Time Between Interrupt Requirements

The Offeror shall calculate the System Mean Time Between Interrupt (SMTBI) for each proposed SSS configuration. [C]

A system interrupt is defined as any hardware or system software error or failure, or cumulative errors or failures over time that result in loss of access to any data within the SSS or the ability to store data within the SSS. [S]

The Offeror shall describe the SMTBI of the SSS along with the basis for computing or estimating this value. [S]

5.2 Mean Time To Data Loss Requirements

The Offeror shall calculate the Mean Time To Data Loss for a redundancy group of each SSS configuration. [S]

The Offeror shall describe the process used for estimating the MTTDL for a redundancy group of the SSS. [S]

5.3 Resiliency

The SSS shall possess resiliency features such that attached compute systems can continue to use the SSS despite system faults. The underlying hardware/software/infrastructure shall be able to recover gracefully from faults and failures by rapid re-provisioning of resources or similar mechanism(s). [S]

The Offeror shall describe features of the SSS that improve its resiliency and support rapid recovery from hardware failures. [S]

The Offeror shall provide estimates of the time required to recover from various SSS faults due to hardware and/or software faults. These calculations shall include, at a minimum, analysis of the time to recover from the loss of individual disks, disk arrays, storage controllers, and disk enclosures. [S]



The Offeror shall describe the resiliency features of the proposed SSS that ensure the accuracy of read/write operations, guard against single point of failure, and protect data integrity. [S]

The Offeror shall identify any single points of failure in the SSS. [S]

The Offeror shall describe the features of the proposed solution that enhance resiliency. [S]

5.4 Reliability

The SSS shall be comprised of components, hardware and software, of a design selected to maximize reliability. [S]

System resources shall support continuous monitoring and a mechanism whereby errors are reported for analysis and subsequent action. Reliability shall be examined during Acceptance via tests of data integrity and failover. [S]

The SSS shall have data integrity that no more than one bit in every 10^{18} bits shall be impacted by silent data corruption. Company desires a higher level of data integrity. Offeror shall describe how each component of the SSS contributes to the undetectable bit error rate (UDBER) of these systems. [S]

The Offeror shall describe the features of the proposed solution that enhance reliability. [S]

5.5 Availability

5.5.1 System Effectiveness Level

The SSS shall demonstrate a scheduled availability level of not less than 99.5% (measured monthly).

T	=	Total time in the period of measure
D	=	Total duration of all unscheduled downtimes in the period of measure
S _A	=	Scheduled availability

$$S_A = \frac{(T - D)}{T}$$

Unscheduled downtimes are defined as any period in which any data stored within the SSS is inaccessible or any period in which new data cannot be stored within the SSS. [S]

The Offeror shall describe features of the proposed solution that enhance system availability. [S]

5.6 Serviceability

A high level of serviceability is required to meet Company's availability needs. The SSS design shall incorporate features supporting individual component service leaving the remainder of the resource available to perform work. Design features that permit work to continue in a degraded mode while service is underway are significantly preferable to outages. [S]

Features that support scheduled maintenance rather than time-critical repairs are desired. [E]

The SSS shall support hot swap of field replaceable components without impacting the operating state of the system. The Offeror shall describe the features of the proposed solution that enhance serviceability. [S]

The use of serviceable replacement parts that are warranted as new is acceptable. [I]

Company shall have sufficient systems access to benchmark the system's link-level network internal and external network performance. [C]



6 Warranty, Maintenance, and Support Services

6.1 Warranty/Maintenance

The Offeror shall provide an extended warranty, or combination of warranty and maintenance, for a period of no less than one year from the date of system acceptance that includes all hardware, software, and firmware. The Offeror shall provide priced options to extend this warranty and maintenance for 1-5 additional years. [C]

6.2 Hardware

The Offeror shall provide (at a minimum) 24x7, 4-hour response, and on-site hardware maintenance for critical system components (as recommended by Offeror and defined by Company). The Offeror shall describe their hardware maintenance plan for this project. [C]

The Offeror shall provide (at a minimum) 8x5, next business day, on-site hardware maintenance for non-critical system components (as recommended by Offeror and defined by Company). The Company's business hours are 8AM-5PM local time. Company's business days are Monday through Friday excluding Company holidays. The Offeror shall describe what system components they consider non-critical, and their maintenance plan for these items. [S]

The Offeror shall provide an on-site spare part inventory for commonly failing components (as recommended by Offeror and defined by Company), with expedited replacement of parts removed from inventory. The Offeror shall describe their spare parts/inventory plan. [S]

Offeror shall identify all parts in the proposed solution that can persistently hold Company data. Devices with persistent storage that potentially contains Company data will not be returned to the Offeror. Instead, persistent storage devices that have potentially contained Company data can be certified as destroyed by Company and shall be replaced by Offeror under the hardware maintenance plan. [C]

Failed parts, excluding persistent storage media, may be returned to the selected Offeror or original equipment manufacturer (OEM). [I]

6.3 Lustre File System Support

For purposes of Lustre file system support, the Company identifies three levels of support. Level 1 includes call logging and validation, reviewing system documentation for errors/problems, reviewing a database for symptoms and known resolutions, filing a complete report on any errors/problem, and working with Company to install new software releases furnished by Offeror. Level 2 includes reproducing errors, attempting to eliminate errors/problems via workarounds, and validation of any patches, new revisions, or workarounds provided by Offeror or the Company's contracted Level 3 support provider. Level 3 includes issues significant enough to require Lustre software troubleshooting, engineering, development, or subsequent releases. [I]

The warranty for integrated Lustre solutions shall include Level 1, 2, and 3 Lustre file system support with availability during Company's business hours (8AM-5PM local time Monday through Friday). Offeror may provide Level 3 support through a third party. [C]

The Company currently obtains Lustre Level 3 support from Intel (formerly Whamcloud, Inc.) The Offeror shall provide Level 3 Lustre support equal to or greater than the service the Company currently obtains through Intel (formerly Whamcloud, Inc.) [C]

Block level only storage solutions do not require Lustre support. [I]



6.4 Facilities Engineering Support

The Offeror shall provide facilities engineering support to Company relative to the power, cooling and space requirements of the proposed systems. The Offeror shall install the proposed systems. Company will provide the modifications to the facilities that are necessary to support the proposed systems, including installation and termination of branch circuits, installation and minor modifications to the supplemental air systems that accommodate waste heat ejected to air. [C]

6.5 Training

The Offeror shall deliver a comprehensive training program for SSS administrators. The program shall include periodic refresher training for new releases. Classes for administrators shall be on-site at ORNL. Pertinent topics including but not limited to advanced system administration, resource management, performance tuning, system troubleshooting and failure analysis should be offered. Online training materials may supplement more traditional training methods. [S]

6.6 Documentation [S]

The Offeror shall make electronic versions of documentation available to SSS administrators. Company and the Offeror will identify items that may require authorization and authentication for access, and the method for that authentication. Documentation shall include but should not be limited to:

- Site preparation and installation guides
- System hardware manuals
- System operations manuals
- System administrator's manuals
- Electronic knowledge base

A low level user's guide and a problem reporting procedure are required. Advanced level documentation, in support of training activities is required.

7 Facilities

7.1 Basis

The ORNL National Center for Computational Sciences (NCCS) will provide the base facilities and infrastructure associated with the SSS. [I]

7.2 Facilities Description

7.2.1 General Facilities Description [I]

The SSS and all supporting equipment will be installed within a computing facility at ORNL. This facility will contain sufficient raised floor space to support up to 64 cabinets for the SSS.

This facility will include substantial utility, physical security, building automation systems, and fire protection systems. In addition, the facility will be staffed 24x7x365 by operations, security, electrical systems, and mechanical systems personnel.



7.2.2 Electrical Infrastructure and Electrical Conditions Affecting the Offeror

480V 3 phase branch circuits can be supplied from switchboards to cabinets. These switchboards supply additional transformers that reduce voltage to 208Y/120V for equipment that requires 208Y/120V. [I]

Subject to the total program facility restrictions for this system, Company will provide the electrical distribution system for the SSS including transformers, switchboards, vertical sections, power distribution units, remote distribution units, and breakers. Company will provide the branch circuits from the switchboards, power distribution units, or remote distribution units to the individual cabinets of the SSS. Connection of supply circuits to SSS equipment shall be via direct connection or via plug and receptacle, in which case Offeror shall provide the receptacles to be installed by Company. [S]

In addition to the prescribed 480Y/277V 3-phase power, there will be 208Y/120V, 3-phase electrical circuits available. Offeror shall provide a SSS that utilizes either 480Y/277V 3-phase power or 208Y/120V 3-phase. Offeror may use Rack PDUs within the SSS for power conversion. [S]

Rack PDUs that provide remote on/off switching control of individual outlets via a well-known API are desired. [S]

Rack PDUs that provide load monitoring are desired [E]

The total peak power consumption for the SSS shall not exceed 0.5 MW. The total peak power calculation shall be based on the realistic upper bound for worst-case power consumption for short durations. Offeror shall specify power requirements of the SSS. [S]

Power supplies for all equipment associated with the SSS shall be designed to tolerate power quality events. Offeror shall describe the range and duration of voltage anomalies tolerated by all included power supplies. [S]

Power configuration shall be configured so that the system components are dual-fed, and load-balanced. This configuration must support utility feeds from separate sources such that the power supplies shall manage the failure of one source automatically, with total load from the remaining power supplies keeping the system stable. [S]

The power factor (pf) for all equipment shall be greater than 95%. [S]

7.2.3 Mechanical Infrastructure and Mechanical Conditions Affecting the Offeror

Chilled water is available from a local Central Energy Plant (CEP). This is provided by a 10"-12" chilled water loop with crossover and splitter lines located under the raised access floor. The loop is supplied from four 12" feeders connected to 16" and 18" main lines. The chilled water loop services both liquid cooled computer heat exchangers directly and precision Computer Room air-conditioning Units (CRUs). Conditioned air from CRUs is distributed thru access floor tiles with perforations. Air is returned under the ceiling tiles to the top of the CRUs. A leak detection system is provided on the concrete subfloor. [I]

Automatic flow control valves limit the maximum chilled water flow through all connected components.. A condensate removal system employing gravity drains is provided. The gravity drains are located in the concrete floor supporting the access floor. [I]

Air is supplied from CRUs with the following characteristics [I]:

- Air supply dry temperature is 57F at access floor level
- Air supply dew point temperature is 46F at access floor level
- Air is filtered with ASHRAE 30% filters



Offeror may utilize air or chilled-water cooling. Offeror shall specify all requirements for cooling the SSS. [S]

Optional enhanced cooling features (such as water-chilled doors) are desired. If enhanced cooling features are available Offeror shall provide separate option pricing for these features. [E]

Offeror shall specify all operating environment constraints of the SSS to include upper and lower operating temperatures and upper and lower relative humidity. [S]

Automatic shutdown features based on operating environment constraint limits are desired. [E]

Temperature monitoring capabilities that are accessible via an administrative API such as SNMP or REST/SOAP are desired [E].

7.2.4 Site Visits

The selected Offeror shall conduct a site visit prior to installation of their initial system. [S]