

JOULE REFRESH STATEMENT OF WORK

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Department of Energy

National Energy Technology Laboratory

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# Introduction

The National Energy Technology Laboratory (NETL) is seeking to enter into a 3-year lease for the design, fabrication, installation, deployment, and integration of a High Performance Computing (HPC) system, a Prefabricated Data Center (PDC) or Modular Data Center (MDC) infrastructure unit, including necessary software, warranty/maintenance/service, with an option to purchase at the end of the 3-year lease.

NETL has an existing HPC housed in a MDC located at the NETL Morgantown, WV site. The existing HPC is a Linux-based cluster. Additional information on the existing equipment is identified in the Trade-in section of this Statement of Work (SOW). The contractor shall be responsible for: the removal and replacement of the existing HPC; providing a bid to re-use the existing PDC/MDC, either as-is or refurbished/retrograded, certifying with an engineering analysis that it can maintain the proper operating environment for the HPC; providing a bid (optional) for a replacement PDC/MDC certifying through engineering analysis that it is capable of maintaining the proper operating environment for the HPC; and, ensuring all drives are wiped completely prior to their removal from the NETL site.

The contractor will include an option to refresh the equipment through a follow-on 3-year lease for updated equipment or to purchase the replacement HPC equipment at the end of the lease for the residual value of the computer. Due to constantly evolving technology, the follow-on lease option will be an un-priced option. The purchase option will be proposed as a fixed-price and included as a pre-priced option. The Government will have the unilateral right to exercise the appropriate option that best fits its current funding profile.

**The following table contains a description of the CLINs included in this solicitation.**

|  |  |  |
| --- | --- | --- |
| **CLIN** | **Description** | **Budget / Contract Information** |
| **1** | Joule High Performance Computing (HPC) System Requirements | $5M/yrLease CLIN 1 & 3Procure CLIN 2 |
| **2** | Backup Storage Requirements |
| **3** | Warranty/Maintenance/Service Agreement – Joule HPC and Backup Storage |
| **Option Items** |
| **4** | Prefabricated Data Center/Modular Data Center Infrastructure (Optional CLIN) | Lease to purchase |
| **4 SubCLIN** | Viewing/Visualization Requirements (SubCLIN Option) | Lease to purchase |
| **5** | Warranty/Maintenance/Service Agreement – PDC/MDC  | Lease |
| **6** | Application Software Support (Optional CLIN) | Annual license/subscription |
| **7** | Data Destruction / Wiping | Procure |

**NETL anticipates having $5 Million available per year for the 3-year lease, inclusive of HPC items, Backup Storage, and Warranty (CLIN 1, CLIN 2, and CLIN 3). CLINs 1 & 3 are to be leased; CLIN 2 is to be procured.**

**CLINs 4 – 7 will be considered based on the availability of funding. The viewing/visualization area (SubCLIN) is to be priced as a separate item within CLIN 4.**

**Items under CLIN 6 will be incorporated into this Statement of Work as a bulletized listing with individual pricing.**

**Alternative approaches**:

NETL anticipates receipt of alternative approaches for the HPC with the intent to achieve the greatest computing capability and storage above the minimum stated requirements. The objective is to achieve the best available computation unit for the available funding limitation stated above.

NETL requires contractors to bid the re-use of the existing PDC/MDC, either as-is or refurbished/retrograded to meet the operational efficiency and environmental requirements of the new HPC. Contractors may also bid replacement of the existing PDC/MDC as an option to meet the environmental requirements of the new HPC. Each alternative approach will be evaluated separately to determine the best value to the Government. Each alternative approach must be clearly stated and priced as identified in the above table.

Any alternative(s) will be incorporated into this Statement of Work via a summary addition to the appropriate CLIN area.

**Applicable Industry Codes:**

The listing below is not an all-inclusive listing of codes and regulations as each specific configuration must consider all industry codes applicable to the proposed design. The listing below are overarching codes and regulations that are known to apply regardless of specific design.

* NFPA 70, 2008, National Electric Code
* NFPA 72, National Fire Codes
* NFPA 75, Gaseous Total Flooding Extinguishing Systems
* NFPA 101, Life Safety Code
* ISO 14119, Safety of Machinery – Interlocking Devices Associated with Guards – Principles for Design and Selection
* ISO 14119/AMD1, Safety and Machinery – Amendment 1: Design to Minimize Defeat Possibilities
* ANSI A13.1, Scheme for the Identification of Piping Systems
* ANSI/AIHA Z9.2, Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems
* City of Morgantown, WV Article 527, “Noise Ordinance” <http://www.morgantown.com/noiseord.htm>

**Transition Plan:**

Contractors shall provide a transition plan to include activities contained in their bid (e.g. final design, testing and burn-in, equipment delivery, removal and replacement of HPC, refurbishment and/or replacement of PDC/MDC, addition of viewing vestibule, startup and commissioning activities, etc.). The plan can take any form but will at least contain a GANTT chart highlighting the activities.

The Joule supercomputer is vital to the research conducted at NETL. Contractors shall make every effort to limit downtime during transition from the existing to the new HPC (e.g. staged installation so portions of the HPC can be running while construction and remaining refresh systems are installed).

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# Background

## 2.1 National Energy Technology Laboratory (NETL)

NETL is a U.S. Department of Energy (DOE) national laboratory owned and operated by the DOE’s Office of Fossil Energy.

NETL’s mission and vision is to lead the nation and world in the discovery, integration, and demonstration of the science and technologies that will continue to ensure the nation’s energy security, while protecting the environment for future generations. NETL will achieve this mission by:

* Maintaining nationally-recognized technical competencies in areas critical to the discovery, development, and deployment of affordable, sustainable fossil energy technologies and systems;
* Collaborating with partners in industry, academia, and other national and international research organizations to nurture emerging fossil energy technologies across the full breadth of the maturation cycle, from discovery, through development, to commercial-scale demonstration and deployment; and
* Continuing active engagement in the national and international clean energy conversation to be poised to recognize, and react to, emerging opportunities to enable transformational clean energy ideas.

A particular challenge is leveraging the potential of emerging computing systems and other novel computing architectures to fulfill the scientific mission, which will require numerous significant modifications to today's tools and techniques to deliver on NETL’s mission.

## 2.2 Objective and Mission Needs

NETL is the home to JOULE – a high-performance computing system integrated with visualization centers, which provides the foundation of NETL’s research efforts on behalf of DOE. Supercomputing allows NETL researchers to simulate phenomena that are difficult or impossible to otherwise measure and observe. The ever evolving technology environment continues to produce faster and more efficient high-performance computing equipment. The existing JOULE equipment is approximately 5-years old.

The objective of this contract is to refresh this equipment and obtain higher productivity from newer technology, with the ultimate goal of reducing the cost and time associated with technology development.

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##

## 2.3 Definitions

* Core – A physical portion of CPU that contains execution units (e.g. instruction dispatch, integer, branch, load/store, floating-point, etc.), registers, and typically at least L1 data and instruction caches. Virtual or hyper-threaded cores are not considered as separately enumerated cores for the purpose of this RFP.
* CPU – The central processing unit(s) of a computational node. The CPU is responsible for running the node’s operating system, interfacing with storage and network resources, and accessing primary node memory. A typical computational node will integrate one or more CPUs into a single system. The CPU will incorporate one or more cores and will provide communication among its internal cores and with cores on any other CPU within the same computational node. All cores within all CPUs will address system memory and other resources via a shared address space.
* EPEAT – Electronic Product Environmental Assessment Tool is a method for Government purchasers to evaluate the environmental impact of a product. It assigns a Gold, Silver, or Bronze rating based on a predefined set of performance criteria.
* FLOPS – Double-precision floating point operations per second. For the purpose of this RFP, FLOPS shall be a raw calculated value based on maximum theoretical floating point operations per cycle. (e.g., Intel Skylake processor delivers 32 double-precision floating point operations per cycle per core. With a rated clock speed of 2.4 GHz, it would achieve 76.8 GFLOPS per core. With 16 cores per CPU and two CPUs per node, it would achieve 2.458 TFLOPS per node.)
* GB – A gigabyte is a billion (109) bytes in the context of hard drive and flash storage quantities. A GB is 230 (1,073,741,824) bytes in the context of RAM quantities.
* Gbps – Gigabits per second, used as the transfer rate metric for Ethernet, Infiniband, and Omni-Path networks.
* GFLOPS – A billion (109) double-precision floating point operations per second. (See FLOPS above.)
* GPU – A high-throughput graphic processing unit typically integrated into an accelerator card and used to improve the performance of both graphical and high-throughput computing tasks. The GPU is not a CPU in that it does not run the node’s primary operating system and functions solely as an accelerator with control of the GPU dispatched by the node’s CPU.
* HPC – High-performance computing system which generally uses fast commodity server hardware and high bandwidth, low-latency networking equipment and, optionally, high-throughput GPU accelerator cards to provide a platform for shared-memory, distributed-memory, and GPU-accelerated workloads.
* IPMI – Intelligent Platform Management Interface; a low-level control protocol for remote booting, resetting, power cycling, and monitoring of all computational and support systems using out-of-band communication on the Ethernet physical layer.
* JBOD – Just a Bunch Of Drives refers to an off-board chassis with multiple removable drive bays serviced by external SAS connections. These chassis power the storage drives, but storage devices are controlled by another system via the SAS connections.
* Node– Shared-memory Multi-CPU system. A set of cores sharing random access memory within the same memory address space. The cores are connected via a high speed, low latency mechanism to the set of hierarchical memory components. The memory hierarchy consists of at least core processor registers, cache and memory. The cache will also be hierarchical. If there are multiple caches, they will be kept coherent automatically by the hardware. The access mechanism to every memory element will be the same from every core. More specifically, all memory operations are done with load/store instructions issued by the core to move data to/from registers from/to the memory.
* PB – A petabyte is a quadrillion (1015) bytes in the context of hard drive and flash storage quantities.
* PCIe — PCI Express interface, the standard internal interfaces for the connection of expansion boards to the node motherboard. These may include HCAs for network connectivity, HBA or RAID cards for storage attachment, or PCIe-based SSDs for high-speed, low-latency burst buffering.
* PDU — Power Distribution Unit, refers to the rack-level power supply system that converts high current power distribution sources to server-level power inputs. Also, these commonly may provide surge suppression and some power conditioning.
* PFLOPS– A quadrillion (1015) double-precision floating point operations per second. (See FLOPS above.)
* PDC/MDC – Pre-fabricated data center or modular data center refers to the self-contained data center infrastructure and its supporting hardware (e.g. cooling unit, de-humidifier unit, power infrastructure, etc.)
* PUE – Power Usage Effectiveness is the ratio of the total power consumed by the entire data center (including cooling loads) divided by the power used only by the computational, storage, and network equipment. The PUE determination is made on an annual average basis.
* RAID – Redundant Array of Independent Drives, a technique to merge multiple storage drives into a single block device to increase overall capacity, performance, and reliability.
* RAID1 – RAID level that mirrors two or more storage devices. This RAID level will be used for on-board computational node storage using Linux Multi-Device (md) or Software RAID capabilities.
* RAID6 – RAID level that integrates four or more storage devices into single block device, using (effectively) two of the storage devices to store redundant parity information to help guard against data loss due to storage device failure. This RAID level will be used for all storage node arrays using hardware-accelerated RAID controllers.
* TB - A terabyte is a trillion (1012) bytes in the context of hard drive and flash storage quantities. A TB is 240 (1,099,511,627,776) bytes in the context of RAM quantities.
* TFLOPS – A trillion (1012) double-precision floating point operations. (See FLOPS above.)

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# CLIN 1 - JOULE High Performance Computing (HPC) System Requirements

**NOTE:** The following sections describing requirements for compute nodes, login nodes, maintenance nodes, firewalls, computational network, access network, maintenance network, and storage requirements are a minimum notional requirement. Vendors may incorporate alternatives of their own design in their bid as long as performance and capability are comparable or better. Vendors must explain/justify how their alternative’s performance and capability is comparable or better as part of their bid.

## 3.1 Description of the JOULE HPC

The current JOULE HPC system includes: .50 PFLOPS, 1,512 Nodes, 24,192 CPU cores (16 cores/node), 0 CUDA cores, 73 TB total memory (32-64 GB per node – DDR3 type), 102.4 GB memory bandwidth per node (8 channels), Sandy Bridge CPU (2.6 GHz clock speed), QDR Infiniband Interconnect (40 Gbps bandwidth, 90 ns latency), 8 FLOPS/core/clock cycle, 450 power consumption (kW).

The minimum goal is to have the refreshed system include: 5.25 PFLOPS, 1,912 Nodes, 61,184 CPU cores (32 cores/node), 716,800 CUDA cores, 396 TB total memory (96-192 GB per node – DDR4 type), 256 GB memory bandwidth per node (12 channels), Skylake (or equivalent) CPU (2.6 GHz clock speed), Omni-Path Intel Interconnect (100 Gbps bandwidth, 110 ns latency), 32 FLOPS/core/clock cycle, 675 power consumption (kW).

A complete, concise description of its proposed JOULE system architecture, including all major system components plus any unique features that should be considered in the design is required to be provided. At a minimum the description shall include:

* An overall system architectural diagram showing all node types and their quantity, interconnect(s), and bandwidths of data pathways between components.
* An architectural diagram of each node type showing all elements of the node.

## 3.2 Compute NODE Requirements

The compute nodes make up the largest portion of the systems contained within the enclosure. The compute nodes are split into three configurations that differ in RAM quantity and in the addition of GPU accelerator cards. A node refers to an individual non-virtualized commodity computing system (server). Typically, this is an individual server (there may be multiple nodes per 1 or 2 U commodity chassis unit). The number of compute nodes will be maximized for best fit within their enclosure while maximizing compute performance within the bounds of the project magnitude. Node count, CPU speed, and core count should be maximized to provide the highest HPC compute performance within the budget range provided. This would equate to maximizing HPC FLOPs per dollar. The functional requirements outlined below for a conceptual reference system must be met as a minimum.

The compute cluster will contain a minimum of 61,184 (Intel Skylake or equivalent) cores, 2.6 GHz or faster base clock frequency with power consumption of or under 150 watts per processor at the rated speed. Half of the compute cluster nodes will have at least 3 GB of main memory per core. The other half will have at least 6 GB of main memory per core. Of these large memory nodes, one-hundred ***only*** will be fitted with a pair of NVIDIA Pascal P100 12GB GPU accelerator cards.

*Node Configuration Requirements*

* Dual CPU Intel system
* Current generation 150 watt (or less) at rated speed 16-core Intel Xeon CPUs
* 96 GB DDR4 RAM per node for 50% of the compute nodes
* 192 GB DDR4 RAM per node for 50% of the compute nodes
* 2 NVIDIA Pascal P100 12GB GPU cards in 100 of the 192 GB nodes.
* 4 TB RAID 1 local disk storage per node
* All hardware must be compatible and supported on CentOS 7 Linux
* IPMI support for all computational nodes with connection to the Gigabit Ethernet Management Network
* Motherboard- or CPU-integrated Mellanox EDR Infiniband or Omni-Path 100 Gbps HCA or equivalent with connection to the 100 Gbps Compute Network
* All systems shall be capable of supporting IPV6 addressing

*Preferred Items*

* Maximize computational node count per available budget
* CPU speed can be adjusted to maximize computational performance value

## 3.3 Login NODE Requirements

There will be 24 login nodes that provide access into the HPC environment. These login nodes shall be networked to the 100 Gbps Compute Network (with 2:1 blocking) and the Access Network (10Gbps Ethernet). Configuration will be a light-weight version of the compute nodes with fewer cores, but the same generation of Xeon CPU to allow binary compatibility and compiler optimization across the login and compute nodes. Login nodes do integrate a workstation-class GPU accelerator to provide resources for VirtualGL applications.

*Node Configuration Requirements*

* Dual CPU Intel system
* Same Intel Xeon generation as used in Compute Nodes, minimum of 8 cores per CPU
* 96 GB RAM DDR4 ECC memory
* 4 TB local disk space configured in RAID 1 (boot/OS)
* One NVIDIA M2000 family GPU Card w/ 4 GB or higher
* All hardware must be compatible and supported on CentOS 7 Linux
* IPMI support for all login nodes with connection to the Gigabit Ethernet Management Network
* Redundant power supplies
* Motherboard- or CPU-integrated Mellanox EDR Infiniband or Omni-Path 100 Gbps HCA or equivalent with connection to the 100Gbps Compute Network
* 10G Ethernet NIC with connection to the 10Gb Access Network
* All systems shall be capable of supporting IPV6 addressing

*Preferred Items*

* Current generation Intel CPUs
* 1U rack space or less per node
* SSDs RAID 1 for local storage

## 3.4 Maintenance NODE Requirements

There will be 8 maintenance nodes that run batch queues, monitor performance, and provide support to the backend of the HPC. These maintenance nodes shall be networked to the Compute Network (Infiniband or Omni-Path).

*Node Configuration Requirements*

* Dual Intel CPU system
* Same Intel Xeon generation as used in Compute Nodes, minimum of 8 cores per CPU
* 96 GB DDR4 ECC memory
* 4 TB local disk space configured in RAID 1 (boot/OS)
* All hardware must be compatible and supported on CentOS 7 Linux
* IPMI support for all maintenance nodes with connection to the Gigabit Ethernet Management Network
* Redundant power supplies
* Motherboard- or CPU-integrated Mellanox EDR Infiniband or Omni-Path 100 Gbps HCA or equivalent with connection to the 100Gbps Compute Network
* 10G Ethernet NIC with connection to the 10Gb Access Network
* All systems shall be capable of supporting IPV6 addressing

*Preferred Items*

* Lowest cost current generation CPU

## 3.5 Firewall System Requirements

There will be four CentOS 7 server-based firewall systems that control access from the external network(s) to the internal HPC access network. These systems shall be networked to the Access Network and the external HPC network connection. The configuration of the firewall systems is the responsibility of the Contractor.

*System Configuration Requirements*

* Dual Intel CPU system, current generation CPU
* Two 10 Gb Ethernet ports
* 96 GB DDR4 ECC memory
* 1 TB local disk space configured in RAID 1 (boot/OS)
* All hardware must be compatible and supported on CentOS 7 Linux
* IPMI support for all firewall systems
* Short-depth form-factor 1U chassis
* Redundant power supplies
* All systems shall be capable of supporting IPV6 addressing

*Preferred Items*

* Dual SSDs to replace boot/OS SATA hard drives

## 3.6 Compute Network Requirements

The Compute Network interconnects all compute, storage, and login nodes (1800+ ports). This is a physically segregated network. Note that routing and management of large numbers of Infiniband or Omni-Path cables is non-trivial. A comprehensive cable routing plan accounting for the thickness and limited bending radius of cables is required as part of the contract deliverables.

*Configuration Requirements*

* 100Gbps low-latency network
* Mixed-blocking configuration with a maximum of two inter-switch hops among all nodes

2:1 Blocking factor to all compute, login, and maintenance nodes

1:1 Blocking factor to all storage nodes

* Total network size determined by final compute node count

*Preferred Items*

* *None.*

## 3.7 Access Network Requirements

The Access Network connects all login and storage nodes to the firewall. This is a physically segregated network.

*Configuration Requirements*

* 10 Gbps Ethernet switch
* Eight uplink modules to permit connection via campus fiber infrastructure to campus computer room
* 10 Gbps connections to all storage, login, and firewall nodes
* 10 Gbps bridge to Maintenance Network

## 3.8 Maintenance Network Requirements

The Maintenance Network connects to all nodes via 1Gbps Ethernet and uses 10G uplink ports to flatten access.

*Configuration Requirements*

* 1 Gbps Ethernet switches as needed in all racks with at least one 10G uplink
* 10 Gbps top level switch(es) to aggregate all rack level connections
* 10 Gbps bridge to Access Network
* Must support both IPMI access and Gigabit IP access to all nodes

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**FIGURE 1 –Diagram for Access, Management, and Compute Network Connections**



## 3.9 HPC Storage Requirements

*Required Items*

* Total primary storage of at least 3.5 PB (1015 bytes) to be located inside the PDC/MDC.
* Primary storage spread across at least 24 storage servers

Using 1:1 Blocking connections to the 100 Gbps Compute Network

10G Ethernet connections to the Access Network

1G Ethernet connection to the Maintenance Network

2 TBs of PCIe NAND (or equivalent) burst buffer cache

192 GB DDR4 ECC RAM or more

Redundant power supplies

IPMI support for all login nodes with connection to the Gigabit Ethernet Management Network

Hardware RAID controller with battery backup, fully supported by CentOS 7 Linux

Integrated into a parallel file system including at least two redundant meta-data servers

Primary storage will be located inside the MDC

*Preferred Items*

* Twenty-four 16-drive storage server nodes
	+ 10GB HGST Enterprise-class SAS drives
	+ LSI MegaRAID 9361-8i SAS RAID Controller
	+ Two 1TB PCIe NAND or 3D X-Point SSDs
	+ 192 GB DDR4 ECC RAM
* Two 16-drive metadata server nodes
	+ 10GB HGST Enterprise-class SAS drives
	+ 192 GB DDR4 ECC RAM
	+ Two 1TB PCIe NAND or 3D X-Point SSDs

## 3.10 Development Hardware Requirements

The contractor shall deliver an early evaluation system 10 working days after the award of the contract consisting of the following equipment:

* 8 Computational Nodes
* 4 Storage Nodes
* 1 Backup Node with JBOD enclosure and drives
* 1 Login Node
* 1 Maintenance Node
* 1 Firewall System
* 1 Gigabit switch with cables to connect all systems
* 1 Infiniband/Omni-Path Switch with cables to connect all systems

The early evaluation system shall meet the following requirements:

* (1) 42U Rack Enclosure with Power Distribution Units
* PDU voltage will be 208/240V and use the NEMA L6-30P plug

NETL will provide operating system images, BIOS settings, and any hardware configuration notes for each node type within 10 working days of receipt of the early evaluation system. The Contractor will use these images and information in the construction/configuration of the remaining systems.

## 3.11 HPC Operating Software Requirements

* Within 10 working days of receipt of the early evaluation system, NETL will provide operating system images, BIOS settings, and any hardware configuration notes for each node type. The Contractor will use these images and information in the construction/configuration of the remaining systems.
* NETL typically supplies software necessary to configure, test and maintain the described HPC system. If required, the contractor shall provide any proprietary software that is necessary or recommended for the use of the HPC system. This shall include any special compilers, libraries or drivers required.
	+ If any proprietary software is to be supplied, then contractor must provide updates and upgrades during the term of the lease.
* Proprietary software for switchgear, power management and security utilities are not covered by this requirement; OEM software shall be supplied as required as needed for operation of these systems.

## 3.12 PDC/MDC (HPC Enclosure)

It is the intent of NETL to re-use its existing PDC/MDC for the duration of the 3-year lease being solicited by this RFP. Contractors shall provide a bid with fully engineered supporting documentation, as described below, to re-use the existing PDC/MDC even if they intend upon bidding a new one of a different design (see CLIN 4-Optional). NETL will determine whether to continue use of the existing PDC/MDC or exercise CLIN 4 based upon merits of the bid and availability of funding.

The NETL PDC/MDC was built by Savier company (Italy) for Silicon Graphics, Inc. (SGI) in 2012 and is designed for a 20-year life cycle. The contractor shall determine whether the MDC power distribution and cooling is adequate, requires updating, or needs to be replaced. Updates can be in the form of retrograding the MDC to replace/remove the transformer, upgrade/replace power distribution components, installing additional cooling such as a DX chilled water plant for supplemental air drying and cooling, adding water cooling and adiabatic cooling or fan farms, adding chilled water cooling, or any other change that is required as long as it is fully supported in the bid.

Use of the existing PDC/MDC as-is, or any modifications/replacement thereto, shall be fully justified with appropriate engineering calculations and shown as part of the bid. The Contractor shall provide engineering documentation of the complete cooling solution based on ambient temperature data for the Morgantown, WV area (ZIP CODE 26505) and provide an estimated PUE for the system.

Maximum acceptable PUE is 1.4, with a target PUE of less than 1.2. EPEAT compliance in energy efficiency shall be identified in the proposal.

As part of the justification, the contractor will provide drawings detailing at minimum:

* Air Flow
* Cooling and cooling calculations
* Electrical circuit routing
* Network cable routing and management
* Fire detection and suppression
* Access system
* Phone/communications
* Floor Plan showing server locations

*Current PDC/MDC Description*

NETL supplies the current PDC/MDC with a 2MW 4160-480VAC transformer. The current PDC/MDC has a 1.125MW 480-415VAC transformer in the vestibule with bus bars capable of approximately 500KW per side, or a total of 1MW. A Circuit Breaker Plug, or stab box, is attached to the bus bars which powers PDUs at the back side of the racks (in the hot aisle). There is a total of 40 racks available at 25KW each. There are two sides, north and south, each which contain 20 racks. Racks contain 50U of useable space, are of standard width at 19 inches, and are deeper than standard racks at 31 ½ inches.

The PDC/MDC has 48 variable speed fans that pull ambient air from the outside through moisture separators, a set of movable louvres, and roughing filters into a mixing chamber. From there air is drawn through HEPA filters, evaporative media, and additional moisture separators to the fans, which then push air into the cold aisles and through the computer racks. The two cold aisle/computer racks discharge heated air into a common hot aisle which is exhausted to the outside. During the cold months some of the hot aisle air is recirculated into the mixing chamber to heat incoming air. Hot aisle air is also sometimes drawn into the mixing chamber during humid months to dry the incoming air.

A PLC uses a programmed stoichiometric set of curves along with measurements of inside and outside temperature and humidity levels to control cooling scenarios, louvre position, hot air recirculation, the use of water on evaporative media, and fan speed. Ambient air cooling is augmented by water flow over evaporative media to cool the unit. The PDC/MDC uses filtered city water for cooling.

See the below schematic and attached drawings/specifications for further description of the existing unit.



## 3.13 Site Information

The site where the current PDC/MDC resides has the following characteristics:

* Grade level concrete pad (approximately 40’ X 100’);
* 2MW 4160-480VAC transformer;
	+ Electricity is provided to the site by a 4160 VAC line with a 2MW step down transformer with 480VAC 3 Phase output as a single point feed for the PDC/MDC;
* Single point feed for domestic, potable water (city water) at 50 GPM on the site;
* Siemens Firefinder XLS System fire alarm monitoring system that the PDC/MDC needs to interface with; and
* Single point feed of 10G optical fiber

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# CLIN 2 – Backup Storage Requirements

The Backup Storage equipment will be purchased rather than leased. The backup system will provide a minimum capacity of 3.5 PB and will be located in B39 Datacenter.

*Required Items*

* Backup servers and JBOD enclosures

Dual 10G Ethernet ports

IPMI support for all login nodes with connection to the Gigabit Ethernet Management Network

Hardware RAID controller with battery backup, fully supported by CentOS 7 Linux

Redundant power supplies

Not more than two 40- to 50-drive JBOD enclosures per backup server

Free-standing rack to hold backup servers and JBODs along with PDUs

Backup storage will be located in B39; Backup storage racks and PDUs will meet the following:

42U Rack Enclosure with Power Distribution Units

PDU voltage will be 208/240V and use the NEMA L6-30P plug

*Preferred Items*

* Eight backup server nodes

LSI MegaRAID 9380-8e SAS RAID Controller

96 GB DDR4 ECC RAM

* Eight backup JBOD arrays

10GB HGST Enterprise-class SAS drives

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# CLIN 3 – Warranty/Maintenance/Service Agreement – JOULE HPC and Backup Storage

All delivered equipment shall be warranted for a period of three (3) years (length of lease). The warranty in this CLIN covers items specified in CLINs 1 and 2.

Contractor shall provide a warranty inclusive of a maintenance and service agreement for all of the equipment. This shall include computational equipment troubleshooting, to be physically performed by qualified NETL staff (through guidance of qualified off-site help-desk personnel); with part replacement provided by the contractor.

The contractor shall provide the following additional hardware as a cache to allow for on-site troubleshooting and replacement of failed components:

* Four (4) spare motherboards for computational nodes (no CPU, RAM)
* Twelve (12) spare memory modules for computational nodes
* Four (4) spare power supplies for computational nodes
* Eight (8) spare computation node hard drives
* Twenty-four (24) spare case fans for computational nodes
* Eight (8) spare hard drives for JBOD enclosures and storage server nodes
* Four (4) spare Node-to-Edge Switch 100Gbps cables

All bids will be provided with the above warranty requirements. In addition, the contractor may provide alternative maintenance/service plans for consideration that include full support for all service calls and describe the on-call resource including response times for troubleshooting and repair. All alternative approaches must be clearly described and priced separately.

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# CLIN 4 - Prefabricated Data Center/Modular Data Center Infrastructure

This is an optional CLIN; Contractors may provide a bid for a replacement PDC/MDC as part of the response to this RFP.

The Contractor shall provide engineering documentation of the complete cooling solution based on ambient temperature data for the Morgantown, WV area (ZIP CODE 26505) and provide an estimated PUE for the system.

Maximum acceptable PUE is 1.4, with a target PUE of less than 1.2. EPEAT compliance in energy efficiency shall be identified in the proposal.

As part of the justification, the contractor will provide fully engineered drawings detailing at minimum:

* Air Flow
* Cooling and cooling calculations
* Electrical circuit routing
* Network cable routing and management
* Fire detection and suppression
* Access system
* Phone/communications
* Floor Plan showing server locations

## 6.1 Site Information

The site where the current PDC/MDC resides has the following characteristics:

* Grade level concrete pad (approximately 40’ X 100’);
* 2MW 4160-480VAC transformer;
	+ Electricity is provided to the site by a 4160 VAC line with a 2MW step down transformer with 480VAC 3 Phase output as a single point feed for the PDC/MDC;
* Single point feed for domestic, potable water (city water) at 50 GPM on the site;
* Siemens Firefinder XLS System fire alarm monitoring system that the PDC/MDC needs to interface with; and
* Single point feed of 10G optical fiber

## 6.2 PDC/MDC Requirements

If Vendors choose to bid a replacement PDC/MDC, the enclosure must meet the following requirements:

Any enclosure(s) shall be furnished and installed upon the pre-existing concrete pad (approximately 40’ X 100’) with a minimum of four (4) inches clearance for water run-off. The pad is grade level and is for use of the PDC/MDC and all infrastructure units external to the PDC/MDC. Contractor will provide a means of water collection and diversion to a drain system. The PDC/MDC will have a skirt system to improve aesthetics and as a guard against wildlife.

All leveling or height above grade requirements will be met by the Contractor through use of enclosure build out and leveling blocks. The Contractor shall provide specifications if caisson anchor points are required and for electrical requirements for the HPC, the enclosure, and supporting cooling hardware. In addition, the Contractor shall provide engineering documentation of the complete cooling solution based on ambient temperature data for the Morgantown, WV area (ZIP CODE 26505) and provide an estimated PUE for the system.

Maximum acceptable PUE is 1.4, with a target PUE of less than 1.2. EPEAT compliance in energy efficiency shall be identified in the proposal.

Water (non-chilled), power, and network connectivity are present at the pad. All connections to the power, water, and network are the responsibility of the contractor.

*Enclosure Required Items*

* External, fully enclosed weather-proof storage enclosure(s). The enclosure will be certified to withstand environmental conditions present at USA zip code: 26505.
* Rack space to accommodate the computing, networking, and storage equipment of the HPC. Racks will accommodate industry standard width and depth commodity servers.
* Power distribution to support enclosure and all equipment contained within configured to connect to the enclosure. Cable support and termination is to be performed by contractor in an electrical distribution panel which will be provided by NETL as part of the power distribution system at the PDC/MDC location.
* UPS capacity to supply a nominal 5 minutes of planned shutdown time for the storage array, login, and maintenance nodes and associated maintenance network equipment (all other equipment will be allowed to shutdown with loss of power).
* Enclosure heating and cooling system with capacity to maintain air temperature and humidity conditions meeting contractor requirements for enclosure and all equipment contained within.
* High-efficiency cooling system (e.g. in-loop open-air economizer system or equivalent/better) that automatically leverages external environmental conditions to minimize enclosure environmental conditioning power requirements.
* The cooling solution including the HPC, enclosure, power distribution, UPS, and environmental conditioning will achieve a maximum Power Usage Effectiveness (PUE) of 1.4, with a target PUE of 1.2 or less.
* Fully stationary racks and integrated structured wiring plant.
* Ability to rack/de-rack and cable full depth servers without leaving the enclosure.
* Power distribution system must be metered to allow continuous monitoring of PDC/MDC PUE.
* Gas-based fire mitigation system including positive, hardware lock-out mechanism when unit is occupied capable of interfacing with contractor site’s Siemens Firefinder XLS System fire alarm monitoring system.
	+ The fire suppression system shall provide indication that the fire suppression system is inactive while locked out.
* The fire suppression system will have provisions for employees to positively lock-out the fire suppression system so it cannot inadvertently activate while they are performing maintenance inside the enclosure.
* The contractor shall provide keyed access to all entry points.
* Airlock entry to prevent inclement weather intrusion into the equipment spaces.
* Secondary emergency egress.
* Adequate area for storage cabinets for spare parts and tools.
* External lighting as required to maintain a safe working environment in the installation area.

*Preferred Items*

* Double-width MDC-type enclosure allowing two parallel racks of equipment with hot/cold aisle configuration.

## 6.3 Viewing/Visualization Requirements (SubCLIN Option)

NETL requests contractors provide separately priced options for a viewing/visualization kiosk/building at the PDC/MDC site:

*Re-use / refurbishment of the current PDC/MDC*

Contractors will provide a bid for attaching an enclosed walkthrough viewing and visualization vestibule to the east end of the existing PDC/MDC. This viewing and visualization area is for the purpose of touring and demonstrating the capabilities of the JOULE HPC.

The contractor is required to provide the design and installation of the infrastructure to accommodate the viewing and visualization area. The requirements for such are to be capable of allowing space for a minimum of 10 individuals within the viewing and visualization area along with space for a minimum of three remote login user workstations. NETL will be responsible for the equipment located in the viewing and visualization area.

This shall include replacing the current, solid, fire rated doors with either a door with a window, or a full glass door to allow viewing the HPC. The replacement doors shall have crash bars for exit. The vestibule shall have exit doors with crash bars on the north and south end and shall be clearly marked as exit doors. The vestibule shall be powered and climate controlled separately from the HPC equipment to prevent interference with the climate control of the equipment and so it is not included in the PUE calculation.

*Replacement PDC/MDC*

If the contractor is suggesting a replacement PDC/MDC, NETL desires to have an enclosed walkthrough viewing and visualization area connected to, or enclosed within, the PDC/MDC infrastructure unit. This viewing and visualization area is for the purpose of touring and demonstrating the capabilities of the JOULE HPC.

The contractor is required to provide the design and installation of the infrastructure to accommodate the viewing and visualization area. The requirements for such are to be capable of allowing space for a minimum of 10 individuals within the viewing and visualization area along with space for a minimum of three remote login user workstations. NETL will be responsible for the equipment located in the viewing and visualization area.

This shall include window viewing sections to the HPC equipment but shall be separate from the HPC equipment to prevent interference with the climate control of the equipment and so it is not included in the PUE calculation..

Expectation – At a minimum, the viewing/visualization area should have two 4ft-high by 5ft-wide viewing panes to observe the HPC equipment in operation. Other alternatives (e.g. glass wall) would be acceptable provided that the area can also accommodate the remote login user workstations.

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# CLIN 5 - Warranty/Maintenance/Service Agreement – PDC/MDC

The PDC/MDC and support/cooling equipment shall be warranted for a period of 3-years (length of the lease). Contractor’s bids shall price routine MDC troubleshooting to be performed by qualified NETL staff with part replacement by the Vendor.

As part of the bid to use the existing PDC/MDC, contractors shall provide the following additional hardware as a cache to allow for on-site troubleshooting and replacement of failed components:

* Two spare variable speed ventilation/cooling fans of the same design as those installed in the PDC/MDC
* Two spare fan controllers

If the contractor is going to bid a replacement PDC/MDC, or make significant changes to the cooling or power distribution systems, they shall provide additional hardware to allow on-site testing and replacement of failed components as follows (at a minimum) and any other items that may be required by the contractor’s engineering group. A complete list of spares, ID numbers, part numbers, quantity that should be maintained, and pricing shall be provided:

* Two each spare variable speed ventilation/cooling fans of the same design as those installed in the PDC/MDC and cooling systems
* Two spare fan controllers for each type of fan
* Operating valves for cooling system (e.g. solenoids, isolation valves, expansion valves)
* One set of air filters
* One set of evaporative filters (if required)
* Spare PLC
* Spare louvre operator
* Spare PLC data cable connectors
* Spare lights and switches
* Spare relays
* Spare door hardware
* Spare hoses (if required)
* Spare pump (if required)
* Spare sensors (e.g. temperature, humidity, water, flow, pressure, differential pressure)
* Spare fan farm fan (if required)
* Two spare PDUs
* Spare fuses

All bids will be provided with the above warranty requirements. In addition, the contractor may provide alternative maintenance/service plans that include full support for all service calls and describe the on-call resource including response times for troubleshooting and repair.

# Quality Assurance Requirements

*Pre-Ship Burn-In Testing*

Racks of assembled equipment shall be made available for NETL inspection and testing via remote login after performing the two (2) following burn-in demonstrations:

* The contractor shall assemble racks of HPC nodes at their facility and perform a minimum of 24-hour burn-in at the maximum rated temperature that will be found inside the PDC/MDC using MEMTEST86+ and provide results to NETL within 72 hours of burn-in procedure completion.
* Additionally, the Vendor shall perform a minimum 24-hour burn-in of all systems using stress applications provided by NETL and provide results to NETL within 72 hours of burn-in procedure completion.

Systems shall be fully re-tested as described above after any component replacement during this testing period.

*Quality Requirements*

The contractor shall have a Quality Assurance Program (Quality Management System) that complies with DOE Order 414.1C through the application of ISO 9001-2008 or other equivalent national consensus standard. The Quality Assurance Program is subject to review and approval by NETL.

The contractor shall maintain quality records for 3-years unless otherwise approved by NETL. NETL representatives shall have access to review quality records as they pertain to this contract. NETL reserves the right to review the contractor’s control methods, operational processes, and inspection or test data resulting from contract and may elect to do so at the contractor’s site/facility (including any manufacturing facility). Access rights shall be extended to NETL representatives and/or regulatory agency personnel.

Work performed on-site at NETL is subject to the terms and conditions set forth in this contract for on-site performance.

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# Period of Performance

|  |  |
| --- | --- |
| **Deadline** | **Deliverable** |
| 4 wks after award | Pre-Fabrication design |
| 14 working days after award | Delivery of Evaluation Systems |
| 19 wks after award | Complete burn-in testing and provide results to NETL |
| 20 wks afteraward | Delivery of PDC/MDC Enclosure Upgrade Materials or New Enclosure, Computational Equipment, and Supporting Systems |
| 26 wks afteraward | * Removal of old computational equipment
* Upgrade of current MDC or replacement
* Installation of computational and support systems
* Integration of all Computing, Storage, Network Equipment
* MDC and support equipment operating procedure
 |
| 28 wks after award | * Full set of drawings and cut sheets
* Removal of old equipment and construction debris
 |

* Pre-Fabrication Design – A full-system design prior to fabrication. These designs will address site planning, cooling system design, equipment locations inside and outside of the PDC/MDC enclosure(s), power and network cable routing. At 50% and 95% completion, the contractor shall submit a draft design for review and comment. The contractor shall provide a comprehensive floor plan with the pre-fabrication design.
* Early Evaluation System – The contractor shall provide an early evaluation system consisting of at least the following equipment:
	+ 8 Computational Nodes
	+ 4 Storage Nodes
	+ 1 Backup Node with JBOD enclosure and drives
	+ 1 Login Node
	+ 1 Maintenance Node
	+ 1 Firewall System
	+ 1 Gigabit switch with cables to connect all systems
	+ 1 Infiniband/Omni-Path Switch with cables to connect all systems
* The early evaluation system shall meet the following requirements:
	+ - (1) 42U Rack Enclosure with Power Distribution Units
		- PDU voltage will be 208/240V and use the NEMA L6-30P plug
	+ Upon completion of testing and evaluation, the contractor will be provided system images, BIOS settings, and any hardware configuration notes for each node type. The contractor shall use these images and information in the fabrication of the remaining systems.
* Preliminary acceptance testing
	+ During computational equipment assembly, the contractor shall make completed systems available on a rack-by-rack basis for testing and benchmarking by NETL personnel via remote login.
	+ Individual racks will be approved via these remote tests prior to delivery to the NETL site for installation and integration.
* Installation of equipment
	+ The contractor shall complete all installation of equipment (including any PDC/MDC) and all connections to cooling, electrical distribution, security, and fire suppression systems. This includes attachment to NETL supplied 480VAC, water, and network resources.
	+ Backup storage systems shall be installed in B39 using the following criteria:
		- 42U Rack Enclosure with Power Distribution Units
		- PDU voltage will be 208/240V and use the NEMA L6-30P plug

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# Installation and Training

The contractor shall provide installation and training as required for all items in this contract.

## 10.1 Installation

The installation shall include delivery, unpacking, set-up, clean-up and all necessary connections and integration. Upon completion of installation, the contractor shall complete a full-power up of all systems to an idle state for a minimum of 24 hours followed by :

* High-performance LINPACK (HPL) benchmark using all computing cores for at least 24 hours (with additional GPU High-Performance LINPACK for nodes connected to the GPU enclosures);
* Storage stress testing of all storage, and backup nodes using Bonnie++ for at least 24 hours
* Demonstration of full function and operability of PDC/MDC components and control systems
* Perform commissioning activities by demonstrating:
(1) all nodes boot and shutdown via IPMI control.
(2) all nodes are accessible via the 1g/10g Ethernet network and Infiniband/Omni-Path network.

(3) all compute nodes are used to complete a single HPL run and provide results.

(4) all storage nodes demonstrate capacity and error-free status of RAID arrays.

(5) all storage nodes complete a disk benchmark run against each RAID array and provide results.

In the event of equipment failure, the equipment will be replaced by the contractor and the testing will be redone from the beginning.

## 10.2 Training

The contractor will provide training on all controls and functions of the MDC and HPC systems including:

* Environmental controls
* PLC operations
* Maintenance activities
* HPC startup and shutdown
* HPC system administration
* Network switches and configuration
* Storage nodes configuration, startup and shutdown

At least two training sessions will be held to accommodate separate HPC and PDC/MDC systems. Training shall be provided for up to 10 individuals.

# Required Documents

***The following items shall be delivered as part of the bid:***

## 11.1 Transition Plan

* Plan with GANTT chart showing activities contained in the bid (e.g. final design, testing and burn-in, equipment delivery, removal and replacement of HPC, refurbishment and/or replacement of PDC/MDC, addition of viewing vestibule, startup and commissioning activities, etc.).
	+ The Joule supercomputer is vital to the research conducted at NETL. Contractors shall make every effort to limit downtime during transition from the existing to the new HPC (e.g. staged installation so portions of the HPC can be running while construction and remaining refresh systems are installed).

## 11.2 Data Destruction / Wiping Process Plan

* A detailed description of the proposed data wiping process to be used on hard drives

***The following items are to be delivered upon completion of the installation of the units/systems:***

## 11.3 Operating Manuals

* Operating manuals for the HPC and PDC/MDC
* Operating manuals for support equipment
* User level documents for all delivered computational components
* Maintenance schedules for equipment

## 11.4 As-built Drawings and Cut Sheets

* Cut sheets for all major components
* As-built drawings showing all mechanical and electrical connections
* Building drawings showing all mechanical structures and connection points, air flow/other cooling, and all support equipment

## 11.5 Data Destruction / Wiping

* Upon data destruction
	+ Report detailing the wiped hard drive serial numbers and evidence that all data has been destroyed

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# Trade-In of Existing System



NETL is retaining the existing primary and backup storage nodes and maintenance nodes. NETL will remove these items. This entails the following:

* Eight Primary Storage Servers
* Eight Primary Storage JBOD Drive Enclosures
* Eight Secondary Storage Servers
* Eight Secondary Storage JBOD Drive Enclosures
* Six Maintenance Nodes (maint1-maint4, app1-app2)
* Two Login Nodes (login1, login2)
* Two 2U Quad-node Compute Nodes

Additional detail can be found in the description of the current system attached to this RFP.

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# CLIN 6 - Application Software Support

This CLIN is optional; the contractor may provide a price for annual cost of the following list of software applications that NETL currently procures and deploys on the Joule. Contractors may also provide a bid for a subset of the following table if applicable.

| **Name** | **Features** |
| --- | --- |
| Allinea | Network Floating |
| Allinea Forge DDT |
| Allinea Forge MAP |
| Accelerator Add-On for NVIDIA CUDA |
| 136 Max Processes |
| Fluent (ANSYS) | Network Floating |
| 4 DesignModeler |
| 9 HPC Packs |
| 29 Fluent Solvers |
| 4 Prepost |
| 448 Parallel Processes |
| Barracuda | Network Floating |
| 1 Barracuda-15 |
| 1 Barracuda-15-setup |
| 1 Barracuda-15-chem |
| 1 Barracuda-15-setup-chem |
| 1 Barracuda-gpu |
| ComSol | Network Floating |
| Uncounted SERIAL |
| 1 ACDC |
| 1 ACDCBATCH |
| 1 BATTERIESANDFUELCELLS |
| 1 BATTERIESANDFUELCELLSBATCH |
| 1 CHEM |
| 1 CHEMBATCH |
| 4 COMSOL |
| 4 COMSOLBATCH |
| 2 HEATTRANSFER |
| 2 HEATTRANSFERBATCH |
| 1 LLMATLAB |
| 1 LLMATLABBATCH |
| 2 MATLIB |
| 2 MATLIBBATCH |
| 1 RF |
| 1 RFBATCH |
| 2 STRUCTURALMECHANICS |
| 2 STRUCTURALMECHANICSBATCH |
| 1 SUBSURFACEFLOW |
| 1 SUBSURFACEFLOWBATCH |
| 1 WAVEOPTICS |
| 1 WAVEOPTICSBATCH |
| 1 DESIGN |
| 1 DESIGNBATCH |
| 1 NONLINEARSTRUCTMATERIALS |
| 1 NONLINEARSTRUCTMATERIALSBATCH |
| 1 OPTIMIZATION |
| 1 OPTIMIZATIONBATCH |
| 1 RAYOPTICS |
| 1 RAYOPTICSBATCH |
| 4 COMSOLGUI |
| 4 CLIENTSERVER |
| 1 CLUSTERNODE |
| 1 CADIMPORT |
| 1 CADIMPORTBATCH |
| 1 CADREADER |
| 1 CADREADERBATCH |
| 1 BFC |
| 2 HT |
| 2 SME |
| 1 ES |
| 1 OPTLAB |
| EnSight | Network Floating |
| 150 CEI |
| 2 ENSIGHTGOLD |
| Gaussian | Site License |
| Intel Parallel Studio Cluster Edition | 5 Seats Network Floating |
| 5 AdvXEl |
| 5 ArBBL |
| 5 CCompL |
| 5 Comp-CL |
| 5 Comp-DCAF |
| 5 Comp-FL |
| 5 Comp-OpenMP |
| 5 Comp-PointerChecker |
| 5 DAAL-L |
| 5 DbgL |
| 5 FCompL |
| 5 IClsTktL |
| 5 IClsValL |
| 5 ITrAnlL |
| 5 ITrAnlW |
| 5 ITrColL |
| 5 MKernL |
| 5 MPassL |
| 5 PerfAnl |
| 5 PerfPrimL |
| 5 StaticAnlL |
| 5 ThreadAnlGui |
| 5 ThreadBB |
| Mathematica | Network Floating |
| 2 Controlling |
| 16 Computing |
| MatLab | 1 Seat Network Floating |
| 1 MATLAB |
| 1 Curve\_Fitting\_Toolbox |
| 1 Signal\_Toolbox |
| 1 Statistics\_Toolbox |
| 1 Wavelet\_Toolbox |
| MolPro  | S0a |
| QChem | Unlimited Single Research Group |
| TurboMole  | Maintenance, Support, Updates |
| VASP | Unlimited Single Research Group |

# CLIN 7 - Data Destruction / Wiping

As part of the Joule removal, the contractor shall be required to wipe all data from hard drives using a process compliant with the DoD 5220.22-M protocol and provide documentation of the successful wipe, by hard drive serial number.

The following items are included in the listing of 3,198 drives that will require data destruction:

* + Compute – there are 378 compute chassis, 8 bays and 8 drives per chassis; total of 3,024 compute drives;
	+ Visualization – there are 6 visualization servers, 2 drives per chassis, each chassis connected to a JBOD. There are 16 drives per visualization system; total of 96 visualization drives;
	+ Scratch – there are 3 scratch servers, 2 drives per chassis, each chassis connected to a JBOD. There are 16 drives per scratch system; total of 48 scratch drives;
	+ Login – there are 8 logins, 2 drives per chassis; total of 16 login drives; and
	+ Development/KNC – these are varying densities; total of 14 drives.

NETL is retaining the primary and backup storage nodes and maintenance nodes. NETL will remove these items. This entails the following:

* Eight Primary Storage Servers
* Eight Primary Storage JBOD Drive Enclosures
* Eight Secondary Storage Servers
* Eight Secondary Storage JBOD Drive Enclosures
* Six Maintenance Nodes (maint1-maint4, app1-app2)
* Two Login Nodes (login1, login2)
* Two 2U Quad-node Compute Nodes

At any time the new HPC is to leave the site (e.g. at the conclusion of lease or at time of refresh) the same requirement for wiping hard drives will apply.

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# Appendix A Glossary

|  |  |
| --- | --- |
| CLIN | Contract Line Item Number |
| CPU | Central Processing Unit |
| CUDA | Compute Unified Device Architecture |
| DX | Direct eXpansion |
| EPEAT | Electronic Product Environmental Assessment Tool |
| FLOPS | Floating Point Operations per Second |
| GB | GigaBytes |
| Gbps | Gigabits Per Second |
| GFLOPS | Giga Floating Point Operations per Second |
| GPM | US Gallons Per Minute  |
| GPU | Graphics Processing Unit |
| HEPA | High-Efficiency Particulate Air |
| HPC | High-Performance Computing |
| HPL | High-Performance LINPACK |
| IPMI | Intelligent Platform Management Interface |
| JBOD | Just a Bunch Of Drives |
| MB | MegaBytes |
| MDC | Modular Data Center |
| NEMA | National Electrical Manufactures Association |
| PB | PetaBytes |
| PCIe | PCI Express |
| PDC | Pre-fabricated Data Center |
| PDU | Power Distribution Unit |
| PLC | Programmable Logic Controller |
| RAID | Redundant Array of Independent Drives |
| RAM | Random Access Memory |
| SSD | Solid State Drive |
| TB | TeraBytes |
| TFLOPS | Tera Floating Point Operations per Second |
| VAC | Volts Alternating Current |

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