Department of Energy Laboratory Plan –TJNAF
August 3, 2020

I. Mission/Overview

The Thomas Jefferson National Accelerator Facility (TJNAF), located in Newport News, Virginia, is a laboratory operated by Jefferson Science Associates, LLC, for the Department of Energy's (DOE) Office of Science (SC). The primary mission of the laboratory is to explore the fundamental nature of confined states of quarks and gluons, including the nucleons that comprise the mass of the visible universe. TJNAF also is a world-leader in the development of the superconducting radio-frequency (SRF) technology utilized for the Continuous Electron Beam Accelerator Facility (CEBAF). This technology is the basis for an increasing array of applications at TJNAF, other DOE labs, and in the international scientific community. The expertise developed in building and operating CEBAF and its experimental equipment has facilitated an upgrade that doubled the maximum beam energy (to 12 GeV (billion electron volts)) and provided a unique facility for nuclear physics research that will ensure continued world leadership in this field for decades. TJNAF's current core capabilities are: Nuclear Physics; Accelerator Science and Technology; and Large Scale User Facilities/Advanced Instrumentation.

The lab supports an international scientific user community of 1,691 researchers whose work has resulted in scientific data from 192 full and 21 partial experiments (including 14 full and 21 partial in the 12 GeV era), 476 Physics Letters and Physical Review Letters publications and 1,618 publications in other refereed journals to-date at the end of fiscal year (FY) 2019. Collectively, there have been more than 182,000 citations for work done at TJNAF.

Research at TJNAF and CEBAF also typically contributes to thesis research material for about one-third of all U.S. Ph.D.s awarded annually in Nuclear Physics (28 in FY 2019; 658 to-date; and 195 more in progress). The lab's outstanding science education programs for K-12 students, undergraduates and teachers build critical knowledge and skills in the physical sciences that are needed to solve many of the nation's future challenges.

II. Lab-at-a-Glance

Location: Newport News, Virginia

Type: Program-dedicated, single-purpose lab

Contract Operator: Jefferson Science Associates, LLC (JSA)

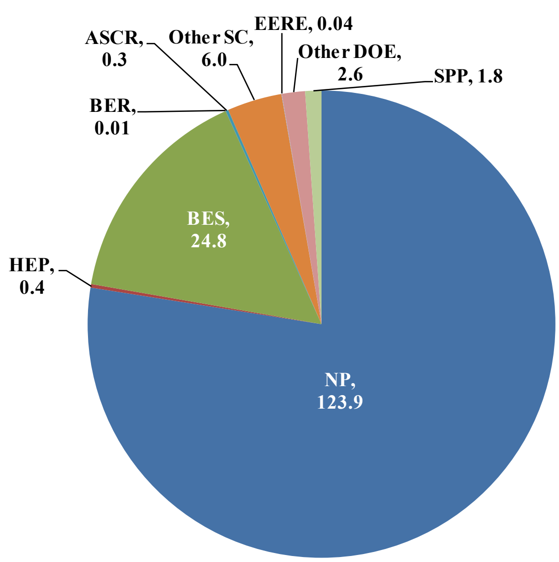
Responsible Site Office: Thomas Jefferson Site Office

Website: http://www.jlab.org

Physical Assets:
- 169 acres and 69 buildings
- 882,900 GSF in buildings
- Replacement Plant Value (RPV): $509M
- 0 GSF in Excess Facilities
- 66,289 GSF in Leased Facilities

Human Capital (period ending 9/30/19):
- 714 FTEs
- 24 Joint faculty
- 30 Postdoctoral Researchers
- 33 Undergraduate and 40 Graduate students
- 1,691 Facility Users
- 1,552 Visiting Scientists

FY19 Costs by Funding Source: *(Cost Data in $M)*



BES costs ($24.8M) reflect LCLS-II & LCLS-II HE work for SLAC

Lab Operating Costs: $159.9
DOE Costs: $158.1
SPP (Non-DOE/Non-DHS) Costs: $1.8
DHS Costs: $0.0
SPP as % Total Lab Operating Costs: 1.1%

III. Core Capabilities

1. **Nuclear Physics** (funded by DOE SC – Nuclear Physics)

   TJNAF is a unique world-leading user facility for studies of the structure of nuclear and hadronic matter using continuous beams of high-energy, polarized electrons. The completion of the 12 GeV Upgrade project enables many outstanding new scientific opportunities. The 2015 NSAC (Nuclear Science Advisory Committee) Long Range Plan clearly stated that its highest priority was to capitalize on this investment: "With the imminent completion of the CEBAF 12 GeV upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized."

   The Continuous Electron Beam Accelerator Facility (CEBAF) electron beam can be simultaneously delivered to the experimental halls at different energies. With the completion of the 12 GeV Upgrade the beam energy can be up to 12 GeV, converted to 9 GeV photons for experimental Hall D, and up to 11 GeV to Halls A, B and C. Each experimental hall is instrumented with specialized experimental equipment designed to exploit the CEBAF beam. The detector and data acquisition capabilities at TJNAF, when coupled with the high-energy electron beams, provide the highest luminosity (10^{39}/eN/cm^2/s) capability in the world. The TJNAF staff designs, constructs and operates the complete set of equipment to enable this world-class experimental nuclear physics program. With nearly 1,700 users annually, of which roughly two-thirds are domestic, TJNAF supports what is generally considered the largest nuclear physics user community in the world.

   The CEBAF science program spans a broad range of topics in modern nuclear physics. Recent lattice Quantum Chromodynamics (LQCD) calculations predict the existence of new exotic hybrid mesons that can be discovered with the new 12 GeV experiments, and elucidate the nature of confinement. New phenomenological tools have been developed that produce multidimensional images of hadrons with great promise to reveal the dynamics of the key underlying degrees of freedom – a new science program termed Nuclear Femtography. A surprising connection between the role of nucleon-nucleon interactions and the quark structure of many nucleon systems discovered at TJNAF earlier, needs to be understood. Development of measurements of exceptionally small parity-violating asymmetries with high precision has enabled major advances in hadronic structure, the structure of heavy nuclei (through measurement of the neutron distribution radius), and precision tests of the standard model of particle physics, including a measurement of the electron's weak charge.

   A comprehensive theoretical effort provides leadership across nuclear physics by pulling together state-of-the art theoretical, phenomenological and computational approaches, including effective field theory techniques, QCD global analyses, and non-perturbative LQCD calculations. TJNAF deploys cost-optimized High Performance Computing for LQCD calculations as a national facility for the USQCD (a U.S. lattice gauge theory community) that complements DOE's investment in leadership-class computing. Computational techniques in LQCD now promise to provide insightful and quantitative predictions that can be meaningfully confronted with and elucidated by forthcoming experimental data. Those techniques also promise to calculate the structure of hadrons that are hard, if not impossible, to do scattering experiments with.

   Excellent synergy exists between the TJNAF experimental and theoretical programs. The Joint Physics Analysis Center (JPAC) develops theoretical and phenomenological understanding of production and decays of hadron resonances, which helps bridge the analyses and interpretation of experimental data from TJNAF with the results of LQCD calculations. The Jefferson Lab Angular Momentum (JAM) collaboration pulls expertise in QCD theory, phenomenology and high performance computing to develop new and better tools to help extract the 3D tomography of hadrons from TJNAF data. TJNAF scientists are heavily engaged in the community effort and its phenomenological studies to help develop the strong science case and unique detection capabilities for a future Electron-Ion Collider (EIC). TJNAF has consolidated its efforts in the development of the science program by forming an Electron Ion Collider Center (EIC^2). Seminars, visiting fellows, and workshops will be among the components of this new center.

2. **Accelerator Science and Technology** (funded by DOE SC – Nuclear Physics, High Energy Physics)

TJNAF has world-leading capabilities in technologies required for superconducting linacs; notably, as follows:

- Complete concept-to-delivery of superconducting linear accelerators and associated technologies
- State-of-the-art SRF fabrication and assembly capabilities
- Unrivaled design, commissioning and operations experience in large cryogenic plants
- World-leading polarized electron injector capabilities
- Low-level RF and controls
- Accelerator and large-scale control systems
- Accelerator operation and design

These world-leading capabilities are evidenced by the production of more than 100 cryomodules produced and in continuous operation today. The ability to deliver large projects on time and on budget is evidenced by our involvement in major superconducting projects for SRF and cryogenics, including SNS and LCLS-II, for which TJNAF is responsible for construction of half of the superconducting cryomodules, as well as the two cryogenic refrigerators, and the FRIB helium refrigerator.

Construction of the Upgraded Injector Test Facility (UITF) at building 58 is complete. The UITF provides a means to test important devices for CEBAF, like photocathode guns, the new SRF "booster" cryomodule and the HDice polarized target for Hall B. It is a testbed to evaluate new accelerator technologies, like Nb_3Sn-coated accelerating cavities operating at 4K, and with a new beamline being prepared using LDRD funds, potential accelerator applications of e-beams, like wastewater treatment with electron beams. And although providing only low-energy electron beams (< 10 MeV), the UITF could be used to conduct PAC-approved experiments like the bubble chamber astrophysics experiment to study photodisintegration of oxygen.

In addition, TJNAF has pioneered Energy Recovery Linac (ERL) concepts and technologies, holds the record for recirculated beam power (1.4 MW), and has been a world leader in high-power free electron lasers (FELs) based on ERL technology. TJNAF, through its Center for Advanced Studies of Accelerators, possesses world-leading capabilities in beam dynamics aspects of linear accelerators, ERLs, FELs, and colliders.

Electron Ion Collider (EIC) Design

The Accelerator Division, in partnership with the Physics Division and collaborators at other national laboratories, developed a design concept for a Jefferson Lab Electron Ion Collider (JLEIC). A design report for JLEIC was published in 2012, to respond to the energy and luminosity requirements of the EIC physics White Paper. The JLEIC design team, composed of TJNAF personnel and strategic national and international collaborators, developed a pre-Conceptual Design Report (pre-CDR) in FY 2018 and FY 2019. These design efforts influenced and continue to influence the EIC project that started in FY20, with TJNAF as a major partner in the overall facility design and performance objectives.

3. Large Scale User Facilities/Advanced Instrumentation

Experimental Nuclear Physics (funded by DOE SC – Nuclear Physics)

TJNAF is the world's leading user facility for studies of the quark structure of matter using continuous beams of high-energy, polarized electrons. CEBAF is housed in a seven-eighths mile racetrack and was built to deliver precise electron beams to three experimental end stations or halls. The electron beam can be converted into a precise photon beam for delivery to a fourth experimental Hall D. Accelerator instrumentation is installed to deliver beams to all four halls simultaneously.

CEBAF provides a set of unique experimental capabilities unmatched in the world, as follows:

- Highest energy electron probes of nuclear matter
- Highest average current
- Highest polarization
- Ability to deliver a range of beam energies and currents to multiple experimental halls simultaneously
- Highest-intensity tagged photon beam at 9 GeV for exotic meson searches
- Unprecedented stability and control of beam properties under helicity reversal for high-precision parity violation studies

Hall D is dedicated to the operation of a hermetic large-acceptance detector for photon-beam experiments, known as GlueX. Hall A houses two high-resolution magnetic spectrometers of some 100 feet in length and a plethora of auxiliary detector systems, including the large-acceptance Super BigBite Spectrometer. Hall B is home of the CEBAF large-acceptance spectrometer (CLAS12) with multiple detector systems and some 100,000 readout channels. Hall C boasts two roughly 80-foot-long, high-momentum magnetic spectrometers that allow for precision scattering experiments, and has housed many unique large-installation experiments. Maintenance, operations and improvements of the accelerator beam enclosure and beam quality, and the cavernous experimental halls and the multiple devices in them, are conducted by the TJNAF staff to facilitate user experiments. Important capabilities related to the experimental program include state-of-the-art particle detection systems, high-power cryogenic targets, polarized targets, high-speed readout electronics and advanced data acquisition technology.

CEBAF Operations (funded by DOE SC – Nuclear Physics)

As mentioned above, CEBAF has been recently upgraded to provide an electron beam with energy up to 12 GeV, a factor three over the original 4 GeV CEBAF design. In addition to the increase in beam energy, the maximum number of simultaneous experiments that CEBAF is now four, with the completion of a four-laser injector upgrade and the addition of Hall D. With the completion of the 12 GeV Upgrade, TJNAF will continue to be the world's premier experimental QCD facility.

With 418 installed SRF cavities, CEBAF operations provide an important contribution to the worldwide SRF performance data set. Some of the CEBAF SRF cavities have been operating for more than 20 years. The CEBAF data set and operational experience is a valued resource for new or existing SRF-based accelerators. TJNAF has the ability to conceive and design large accelerator facilities, building upon 6 GeV CEBAF operations and augmented with the ongoing 12 GeV Upgrade.

Accelerator Technology (funded by DOE SC – Nuclear Physics, Basic Energy Sciences, High Energy Physics, DOD ONR, Commonwealth of Virginia, and Industry)

The ability to use the TJNAF Low Energy Recirculator Facility (LERF) as an accelerator R&D test bed for Energy Recovery Linacs and techniques required to establish cooling of proton/ion beams, for example, provides a mutually beneficial cross-fertilization between the TJNAF LERF and Nuclear Physics. The LERF vault has recently been configured to enable higher throughput of cryomodule testing for LCLS-II. In addition, the LERF is supporting an R&D program to develop an accelerator-based concept to make Cu-67, a potentially useful radioisotope for medical imaging and radiotherapy.

As a result of the development, construction and operation of CEBAF, TJNAF has developed world-leading expertise in superconducting RF linear accelerators, high-intensity electron sources, beam dynamics and instrumentation, and other related technologies. These capabilities have been leveraged to develop new technologies relevant to other disciplines beyond nuclear physics, as well as applications to areas of national security.

TJNAF is applying its accelerator technology to collaborate with four other national laboratories to realize the Linac Coherent Light Source II, at the Stanford Linear Accelerator Center (LCLS-II at SLAC). TJNAF is responsible for construction of half of the superconducting cryomodules as well as the two cryogenic refrigerators. An LCLS-II upgrade, LCLS-II-HE, is also underway to double the energy of LCLS-II from 4 to 8 GeV and extend the X-ray energy limit from 5 keV to 12.8 keV. TJNAF will build 10 cryomodules for the LCLS-II-HE project.

TJNAF has been selected to produce cryomodules for the Spallation Neutron Source Proton Power Upgrade (SNS PPU). The scope of the project is to build seven new high beta cryomodules with 28 new SRF cavities to increase the SNS linac beam energy to 1.3 GeV.

Cryogenics (funded by DOE SC – Nuclear Physics)

Over the last two decades, TJNAF has developed a unique capability in large-scale cryogenic system design and operation that is a critical resource for the U.S. national laboratory complex. The TJNAF cryogenics group has been instrumental in the design of many construction projects requiring large-scale cryogenics: SLAC (LCLS-II), Michigan State University (FRIB), Oak Ridge National Lab (SNS), TJNAF (12 GeV Upgrade), and NASA (James Webb Space Telescope), as well as improving the cryogenic efficiency of existing systems (Brookhaven National Laboratory). In the process, many inventions have been patented, and one has been licensed by Linde (one of two companies that build cryogenic systems) for worldwide applications on new and existing cryogenic plants. This work has also resulted in many master's and Ph.D. theses, to ensure the continuity of this expertise in the coming decades.

The group is presently responsible for designing, specifying, procuring, and commissioning the helium refrigerators for LCLS-II, based on the successful CHL2 design for the 12 GeV Upgrade and designs developed for FRIB. The FRIB refrigerator is complete and commissioning for the

LCLS-II refrigerators has begun. Significant CEBAF upgrades in progress include the completion of in-house fabrication of a replacement 2K cold box for CEBAF operations using the latest cold compressor technology. Installation and commissioning of this cold box is to be completed by the end of CY 2020. Work continues on the modification and installation of a surplus SSC refrigerator, ESR-2, to support future CEBAF end station operations. Additionally, project planning is underway to utilize funding received to upgrade the 2K capacity of the Cryogenic Test Facility that supports super conducting cavity and magnet testing at the Test Lab. The combination of ongoing operations of five refrigerators supporting the TJNAF experimental program, the upgrading of those refrigerators, and the work outside the lab has enabled the training of the next generation of cryogenic engineers in the newest technology as well as the details of plant operations supporting a dynamic experimental program.

IV. Science and Technology Strategy for the Future/Major Initiatives

The TJNAF science strategy for the future has a strong foundation based on the advancement of the U.S. nuclear physics program (as embodied in the 2015 Nuclear Science Advisory Committee (NSAC) Long Range Plan) and the support of other initiatives and thrusts in the Office of Science. TJNAF has developed the FY 2020 Laboratory Agenda to delineate major initiatives associated with strategic objectives in Science and Technology as well as Operations. The Agenda was constructed around a set of four Strategic Outcomes that deliver on the mission of the laboratory, and three of these Strategic Outcomes are related to TJNAF's science and technology activities.

V. Infrastructure

Starting in Section 6 and continuing through Sections 7 and 8, TJNAF describes plans to maintain and improve its physical infrastructure and human capital resources while minimizing overhead cost to maximize return on science and technology investment. These plans are aligned with the FY 2020 Laboratory Agenda and its four strategic objectives. In the previous sections of this plan, the three strategic objectives that encompass the S&T mission of the Laboratory were addressed. The remainder of this plan reflects the actions required to achieve the fourth and final strategic outcome related to Laboratory operations that provide a strong foundation for sustained research and development excellence at TJNAF.

Strategic Outcome 4: Provide, protect, and improve the human, physical, and information resources that enable world-class science.

Overview of Site Facilities and Infrastructure

Thomas Jefferson National Accelerator Facility is located on a 169-acre DOE-owned federal reservation within the City of Newport News in southeast Virginia. Adjacent to the federal reservation is the Virginia Associated Research Campus (VARC), a five-acre parcel owned by the Commonwealth of Virginia and leased by SURA, the managing member of the JSA joint venture, which sub-leases five acres to DOE for use by TJNAF. Also adjacent to the federal reservation is an 11-acre parcel owned by Newport News that contains the Applied Research Center (ARC), within which JSA leases additional office and lab space. SURA owns 37 acres adjacent to the TJNAF site, where it operates a 42-room Residence Facility at no cost to DOE.

The TJNAF complex consists of 69 DOE-owned buildings comprising 882,990 square feet (SF) of office, shop, technical, and storage space. JSA leases an additional 37,643 SF of office and shop space from the Commonwealth of Virginia in the VARC and 11,097 SF of office and lab space from the City of Newport News in the ARC. JSA also leases 17,549 SF of storage space in two offsite storage warehouses within 12 miles of TJNAF. These areas are gross, usable space as summarized in Table 1.

The TJNAF complex provides office and workspace for approximately 760 JSA contractor, JSA, and federal government employees along with a transient population of 1,600 users and visiting scientists. Facility space is well utilized with a current asset utilization index of 98.6%. Distribution of space by use is summarized in Table 1.

Table 1: Distribution of Usable Space by Type of Use

Type of Use	Total Square Feet, Usable Space, Owned and Leased
Technical and Laboratory	258,768 (39%)
High Bay	150,198 (23%)
Office	101,420 (16%)
Storage	92,847 (14%)
Common	54,579 (8%)
TOTAL	657,812 (100%)

The condition of TJNAF facilities is generally good (Table 5). Of the 74 DOE-owned or -leased buildings, 65 are rated adequate, eight substandard, and one inadequate. Of the 36 other structures and facilities (including OSF 3000 series assets) assessed, 33 were rated adequate and three substandard. Only 2,783 SF of space is currently rated as underutilized. There are currently no excess facilities at the Lab and none are expected within the next ten years. In addition to real property assets, there are 49 personal property shipping containers representing 15,160 SF of storage space in use at TJNAF.

Table 2: TJNAF Facility Rating and Utilization Assessment

Condition		Mission-Unique Facilities		Non-Mission-Unique Facilities		Other Structures and Facilities	
		Number	SF	Number	SF	Number	SF
Rating	Adequate	36	339,976	29	343,444	33	N/A
	Substandard	0	0	8	259,221	3	N/A
	Inadequate	0	0	1	6,638	0	N/A
	TOTAL	36	339,976	38	609,303	36	N/A
Utilization	Underutilized	2	3,240	0	2,873	0	N/A
	Excess	0	0	0	0	0	N/A

TJNAF is entirely dependent on public utility service. JSA sources power from Dominion Energy at an average rate of $0.06/kWh and water from Newport News at an average rate of $3.69/HCF, and disposes of wastewater through the Hampton Roads Sanitary District at an average rate of $8.77/HCF. Utility service meets mission requirements although occasional, unplanned commercial-power outages periodically disrupt accelerator operation.

The TJNAF Land Use Plan is maintained on the TJNAF website and is summarized in Enclosure 1. With the decision not to site the EIC at TJNAF, the Campus Plan and Land Use Plans have been updated to align with this decision. The SURA owned land, as well as Newport News owned land which is reserved for TJNAF interests, adjacent to the Lab site will still play a critical role for preserving expansion opportunities critical to the Lab's strategic plan. This involves constructing a new service road entrance directly connecting the campus with a major public road which will facilitate the future relocation of maintenance and logistics functions. Additionally, it locates a future High Performance Computer Center that is ideally located on the campus. Discussions with SURA are ongoing related to the transfer of the land to DOE to enable development of projects included in the Campus Plan.

The SLI funded CEBAF Renovation and Expansion (CRE project received CD-1 in March 2020. The project includes the acquisition of the Applied Research Center (ARC), renovation of CEBAF Center and 82K to 144K SF building expansion which will eliminate an existing ARC building lease from the City of Newport News Economic Development Authority as well as the lease of the Virginia Applied Research Center (VARC) from the College of William and Mary. The ARC acquisition process is ongoing and is anticipated to be concluded in early FY 2021. An extension of the current 11,097 SF lease in planned until the acquisition is complete.

Campus Strategy

The S&T strategy described in Section 4 of this plan dictates the campus investment plan. Working with the Chief Research Officer, the facilities planning team reviews the capabilities of the current infrastructure against the S&T strategy to identify current and projected gaps. TJNAF then performs an analysis of alternatives (AOA) to select the optimum solutions to close the gaps between mission needs and infrastructure capability. The selection of solution and time phasing is driven by mission priority and constrained by the projected levels of indirect, GPP and SLI program funding.

This plan reflects the heightened urgency to improve infrastructure reliability given the recent trend of increasingly disruptive failures impacting experimental schedules. Accelerator reliability is the product of the joint availability of all component systems (cavities, magnets, controls, infrastructure, and so forth). To meet the CEBAF 85% availability goal, the Accelerator Division has allocated to facilities infrastructure an availability requirement of >98.5%, which translates to <1079.5 hours of total downtime over a 32-week experimental period. To accomplish this Facilities Operations and Maintenance completed 5,206 preventative maintenance tasks and 1,715 corrective tasks in 2019.

The recent failure history suggests continued substantial improvement in infrastructure reliability and high power electronic equipment design is needed to reach this availability requirement. The impact of electrical transients to the operation of high power electronic equipment remain the greatest cause of impact to accelerator operations and the area of major concentration. JSA continues to work with Dominion Energy to improve power quality including removal of trees near transmission lines, inspecting overhead lines, coordination of utility PM tasks with Accelerator downtimes, proactively monitoring line voltage variations within tariff limits and meeting regularly to review power reliability. In the third quarter of 2019, Facilities Operations and Maintenance performed Preventative Maintenance (PM) on 46, 15 kV transformers. The tests included oil tests and electrical tests and. Of the 46 transformers serviced, 17 transformers either failed or had less than satisfactory test results. Transformers failing the test were repaired or replaced. In 2019, Facilities Operations and Maintenance completed a major PM of the 40 MVA switchgear.

Belt-driven rack fans cooling the RF power supply racks have been in service since the original accelerator start-up and are failing at an increasing rate with parts obsolescence making it extremely difficult to maintain. An alternate design is being evaluated with plans for replacement in 2021.

Heat detection in the tunnel failed due to higher radiation levels during 12 GeV beam operations. A project was completed in FY 2019 with a more robust fire heat detection system capable of withstanding higher radiation levels. Replacement of accelerator fire detection and suppression systems is scheduled to start in FY 2020 due to its poor service condition

Presented in Table 3 is the correlation between S&T mission requirements, required infrastructure capability, current shortfall in this capability, and optimum solution, which then becomes the basis for the infrastructure plan detailed in Enclosure 2.

Table 3: Campus Strategy Reflecting Realistic Solutions to Address Infrastructure-Capability Shortfalls to Meet TJNAF S&T Strategic Objectives

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
Accelerator Science and Technology (SC01)	Provide LHe to the Test Lab to enable the development, production and testing of SRF components and cryomodules, both for use by TJNAF in CEBAF and under WFO projects for other labs.	The Cryogenics Test Facility (CTF) has experienced heavy utilization due to the CEBAF upgrade and large WFO projects. Approximately $4M of system components have reached end-of-life and others require upgrading to maintain adequate capacity for projected workload.	Complete the **Cryogenics Test Facility (CTF) Upgrade.** Funding was provided in FY20 under the SLI-GPP program.
	Provide sufficient storage space for material and tooling needed to design, produce and test SRF components and systems.	18,000 SF of technical storage is leased in warehouse space remote from TJNAF. This introduces additional labor and time requirements to control and access this high-value material.	Construct a 15,000 –20,000 SF of Equipment Storage as part of the Large Scale Assemble and testing (LSAT) project to relieve the demand for remote, off-site leased storage for SRF components, tooling, and work in process. Need date is FY24 or sooner if practical.
	Low Energy Recirculator Facility (LERF) for R&D on magnetized high-current beams, characterization of materials using low-energy positrons, and production of medical isotopes	Mechanical systems are at end of service life and electrical systems are at or past capacity. Finishes are well worn and need to be renewed.	Execute a **LERF Renovation** to ensure the facility can meet its planned operational use. Need date is FY26 or sooner if practical.

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
Large Scale User Facilities/R&D Facilities/Advanced Instrumentation (SC16)	Central Helium Liquefier (CHL) capable of supplying CEBAF with 9400W of 2K cooling and 22 g/s of LHe at >85% reliability	Two plants, CHL1 and 2, must operate to meet the 2K cooling requirements, but CHL1 is unable to meet the up-time requirements due to an aging cold box.	Complete the **CHL1 2K Cold Box Replacement**. Need is immediate and project is underway as a FY 2017 SLI-GPP project scheduled for completion in 2021.
	Provide 10,152 SF of suitable office and workspace for Cryogenics Engineering staff adjacent to CHL plant.	Current facility is substandard due to aging mechanical systems and worn finishes. Office space is over utilized due to expanding cryogenics staffing.	**Cryogenics Engineering Office Renovation (Building 89)** replaces worn systems and finishes and increases office space capacity. Project is under construction with expected completion in July 2020.
	45,000 SF of environmentally controlled high bay and technical space to support SRF production, cryogenics fabrication, and equipment assembly and staging for four experimental halls operating at 32 weeks/year.	High bay space in the EEL, Test Lab and TED buildings is heavily over utilized. Overcrowding increases the safety risk to staff and visiting scientists. Off-site space is currently being leased to meet the demand.	Construct 45,000 SF of environmentally controlled high bay and technical work space as part of the **LSAT** project. Need date is FY 2024 if practical.
Nuclear Physics (SC20)	End station refrigeration capable of supplying Halls A, B, and C with 4000W of 4K cooling and 40 g/s of LHe at >85% reliability	Current End Station Refrigerator serving Halls A, B, and C only has 1500W of 4K cooling and 11 g/s of LHe, has been operating nearly continuously for 20 years and is near end-of-life.	Complete installation of the SSC Cold Box to activate **End Station Refrigerator 2 (ESR2)**. This will close the capability gap and provide a long-term solution to meet the experiment plan. Need date is immediate. Project funded was provided in FY20.
	Up to 210,000 SF of office and collaborative space that meets DOE high-performance, sustainable building standards to house staff, students and visiting users	CEBAF Center (127,000 SF) is over utilized and substandard due to aging mechanical systems that require immediate replacement. An additional 45,000 SF of office space is leased in adjacent buildings at disadvantageous rates.	**CEBAF Center Renovation and Expansion (CRE),** possibly including the acquisition of the ARC, renovates CEBAF Center and provides an additional 82K-144K SF of space. The project consolidates staff and vacates leased space. Need date is FY 2026 or sooner is practical Initial project funding was received in FY20

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
	The Experimental Equipment Lab (EEL) provides 54,800 SF of technical and lab space for physics, engineering, and facilities staff and is integral to our campus plan.	The EEL mechanical systems are at the end of their service life. Portions of the building need to be brought within code. Exterior cladding is approaching the end of its serviceable life and requires replacement within the next 8-10 years to maintain effective use of this facility.	The **LSAT** project provides a midlife renovation of the EEL facility. . Need date is FY 2024 or sooner if practical.
Support Facilities and Infrastructure (SC25)	Relocate service entrance road to the TJNAF campus	TJNAF service vehicle traffic flow and facilities maintenance operations and logistics functions do not support future growth of administrative, research and technology portions of the TJNAF campus	Construct a new **Service Entrance Road** to directly connect the TJNAF campus to a major public road which will facilitate the future relocation of the facility maintenance and logistics functions. Need date if FY31 or sooner if practical.
	Relocate facilities maintenance & operations functions.	Facilities maintenance and operations functions are primarily located in two substandard (Buildings 13 and 19) located in the administrative core of the campus. Due to insufficient space in these facilities storage of critical spares are inefficiently scattered among numerous service buildings across the campus	**The Integrated Maintenance and Logistics Center (IMLC) Phase 1** provides a fully integrated solution and relocates these functions to the Lab's service corridor. Need date is FY23 or sooner if practical.
	Relocate logistics functions	TJNAF logistics functions are primarily located within high bay space within the Experimental Equipment Laboratory (EEL) building which is already oversubscribed and needed to support research and technical operations	The **Integrated Maintenance and Logistics Center (IMLC) Phase 2** provides a fully integrated solution and relocates these functions to the Lab's service corridor. Need date is FY24 or sooner if practical.
	Suitable access roads and parking to meet safety and regulatory requirements	Continued expansion of the TJNAF campus as outlined in this plan along with development of property immediately surrounding TJNAF requires expansion and alteration of campus access and parking to	Site-wide **Road, Parking, and Sidewalk Improvements** rebuild existing roads and resolve impacts created by both on-site and adjacent off-site construction. Need to align solution with selected option for this project. Need

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
		support vehicle loads and maintain compliance with safety and regulatory requirements.	date is FY26 or sooner is practical.
	To meet DOE sustainability goals for 2025, TJNAF must reduce potable water consumption by 36% relative to 2007 baseline.	Must reduce potable water consumption from current intensity of 63.5 gal/GSF to 41 gal/GSF.	**Cooling Tower Reuse Water** project develops a 40 Mgal/year alternate water source for use in cooling towers. Project would direct and treat water from off-site retention ponds for use in cooling towers. Need date is FY21.
	Main entrance sign appropriate for a DOE national laboratory and adequate wayfinding signage to safely direct users and visitors	Existing entrance sign was designed and built when TJNAF was first opened and no longer reflects the scope and capabilities of the site or its important technology anchor role in the community	The **Main Entrance and Site Signage** project will replace the main entrance sign and provide needed wayfinding signage across the site. The site circulation plan will be impacted with the CRE project. Need to align solution with selected option for this project. Need date is FY27 or sooner if practical.
	Provide 1,900 gal/hr of chilled water to cool R&D equipment in the Test Lab, EEL, CEBAF Center, and Accelerator service buildings.	Existing Test Lab chillers are approaching the end of their service life and use refrigerant that will be no longer available after FY 30.	**Test Lab Chiller Replacement** includes replacing the existing chillers with a new chiller to be installed in the Central Utility Plant (CUP). Need date is FY27 or sooner if practical.
	Provide 165,000 SF of outside storage to accommodate large experimental assemblies, support structures, and equipment for future experiments and operations	Current laydown space is scattered in multiple locations around site. Stored material in some of these sites is visible from off site and creates an eyesore. Some 700,000 SF of existing laydown area will be lost due to future building construction.	The **Laydown Area Expansion** roughly doubles an existing, centrally located storage area which is not visible from off site. Consolidation will improve material management and provide an opportunity to eliminate unneeded material. Need date is FY21 or sooner if practical.
	Provide an isolated and secure facility to calibrate radiological instruments and house rad waste processing equipment and work in process	Campus growth is encroaching on the existing calibration lab and making it more susceptible to storm water flooding. Further, rad waste processing equipment and work in process are currently located in part of the Equipment Storage Building assigned to Physics Division.	Construct a new **RadCon Calibration Lab and Waste Processing** work center in a more remote area adjacent to the Central Material Storage Area (CMSA). Need date is FY30 or sooner if practical

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
	Suitable potable water distribution to reliably meet need for 120 Mgal. per year use	Portions of the water system exceed 50 years and have experienced severe corrosion. The site lacks a full water loop with isolation valves to allow for normal maintenance without severely affecting operations.	The **Potable Water Improvements** project replaces aging sections of piping and provides for completion of the site water distribution loop with adequate isolation valves for system operations and maintenance. Need date is FY28 or sooner if practical.
	Suitable sanitary sewer system to meet the service needs of the site	Portions of the system have insufficient slope and have experienced breaks or surface water infiltration. The capacity is marginal to meet future needs.	The **Sanitary Sewer Improvements** project will correct existing deficiencies and add additional capacity to meet expected growth requirements. Need date is FY29 or sooner if practical.

The gaps identified above can be closed using a combination of SLI, SLI-GPP, and NP-GPP funding of $205M. In addition to providing essential capabilities for mission performance, these investments will eliminate $5M of deferred maintenance.

The primary focus of our facilities operations and maintenance program is to increase the mean time between failure of facility systems through accelerated replacement of end-of-life systems and adding redundancy for critical systems to eliminate downtime from single-point failures. Similarly, when failures occur TJNAF will reduce the mean time to repair by making sure sufficient stock of critical spares is on hand to immediately restore operation rather than accept lengthy downtimes to source replacements.

The most recent TJNAF Asset Condition Index is 0.95. However, this could drop over time if Facilities Operations and Maintenance funding continues to be limited to 1.4% of replacement value. Modernization projects and construction of new facilities through SLI and GPP funding has enabled TJNAF to maintain a modest deferred maintenance value ($7.2M in FY 2019). Over the next decade, no significant increase in deferred maintenance is expected as JSA implements the capital spending plan reflected in the Integrated Facilities and Infrastructure Crosscut table provided in Enclosure 2.

Infrastructure Investment Table

The TJNAF Infrastructure Investment Table and Campus Plan is provided in Enclosure 2, at the end of this plan.

Integrated Facilities and Infrastructure Crosscut Data Table

The TJNAF Integrated Facilities and Infrastructure Crosscut Data Table is provided in Enclosure 2, at the end of this plan.

Site Sustainability Plan Summary

Table 4 shows Sustainability Project funding for planned actions to meet DOE Sustainability goals.

Table 4: Summary of Sustainability Project Funding ($k)

Category	FY 2019 Actual	FY 2020 Planned/ Request	FY 2021 Projected
Sustainability Projects	153,331	321,229	0
Sustainability Activities other than projects	0	0	0
SPO Funded Projects (SPO funding portion only)	0	0	0
Site Contribution to SPO Funded Project	0	0	0
ESPC/UESC Contract Payments	0	0	0
Renewable Energy Credits (REC) Purchase Costs	23,700	27,000	32,000
Total	177,031	348,229	32,000

The lab received a 2018 Federal Energy and Water Management Award in the Lab and Data Center category for energy and water cost savings, optimized energy and water use, and/or the use of advanced and distributed energy technologies under the Computer Center Modernization project achieving a PUE of 1.3.

JSA decided against awarding a UESC project totaling about $3.48M addressing lighting, domestic water conservation, Ultra-Pure Water Reuse, and mechanical upgrades, due to operation risk. These elements are being implemented separately by the Lab as part of operations and maintenance efforts or incorporated into planned recapitalization projects. This approach is expected to reduce the risk while delivering the same or better outcome at a lower cost.

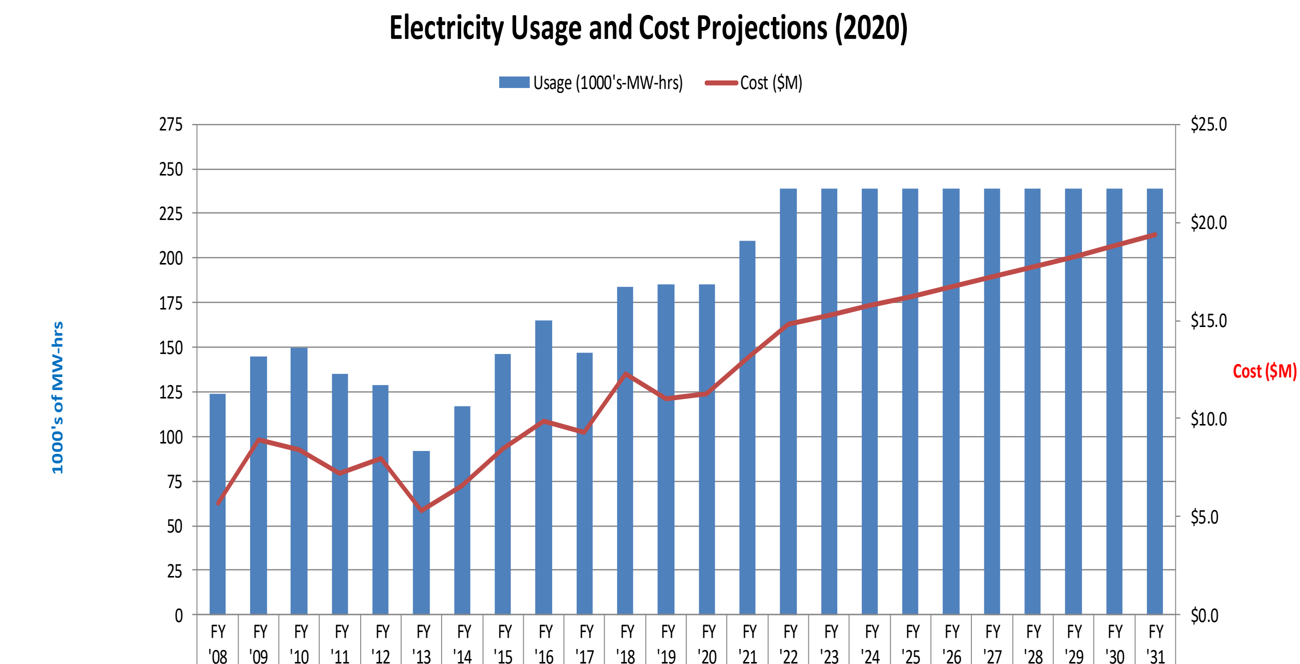
All but two sustainability interim target goals were met this year: potable water intensity and sustainable buildings (by building count). While achievement of the water intensity goal remains the most significant challenge for TJNAF due to the large amounts of potable water required for evaporative cooling of high energy mission specific facilities, a water conservation project was completed in FY 2019 which reuses discharged ultra-pure water (UPW) from the Test Lab as a make-up water supply source for a nearby cooling tower. The project is on track to reduce water consumption by 4.5 million gallons per year and reduce water and sewer utility cost by over $60,000 annually. Additional water conservation strategies have been identified and will be implemented in time to meet the sustainability target goal of a 36% reduction in water intensity by FY 2025 relative to the FY 2007 baseline.

Projects and strategies to achieve target goals in other categories have been identified and incorporated into building renovation plans. Energy intensity (BTU/GSF) should realize significant reduction through high-efficiency lighting upgrade in subject buildings. Reduction of domestic water consumption strategies are also included in building renovation plans. The building level energy and water reductions will also contribute to achievement of High Performance Sustainability Building (HPSB) compliance for several additional facilities.

Electricity Usage and Cost Projections

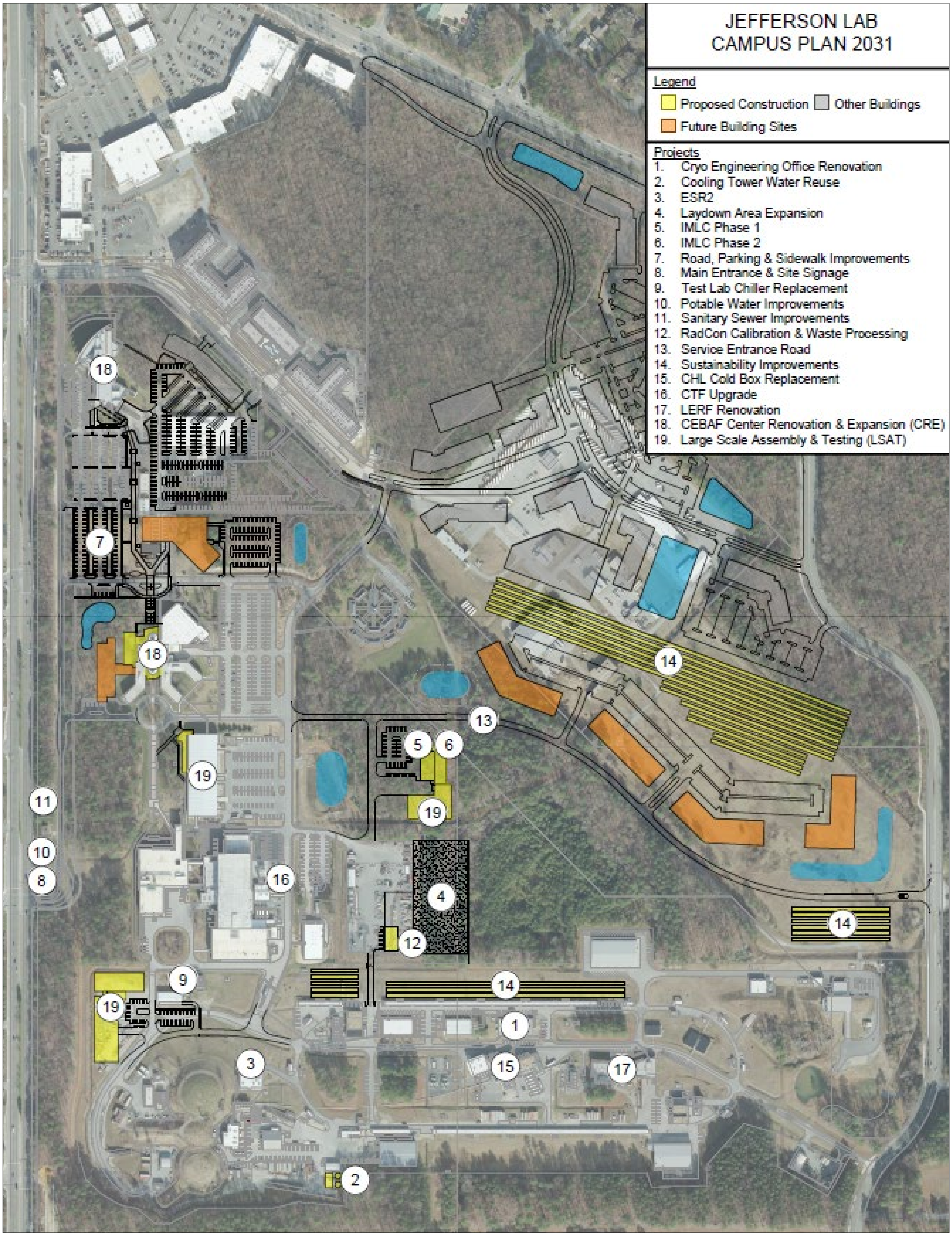
Figure 1 shows TJNAF's historical electricity usage in 1000's of Megawatt Hours and costs (actual year $M), including future projected electricity usage and costs. Projections are based on scheduled operations for FY 2020 of 22.5 weeks and FY 2021 of 26 weeks. FY 2022 onward include summertime runs at the highest achievable beam energy. From FY 2022 forward, 34 weeks of operations are projected for each year.

Figure 1: Electricity and Cost Projections



	FY '08	FY '09	FY '10	FY '11	FY '12	FY '13	FY '14	FY '15	FY '16	FY '17	FY '18	FY '19	FY '20	FY '21	FY '22	FY '23	FY '24	FY '25	FY '26	FY '27	FY '28	FY '29	FY '30	FY '31
Usage (1000's-MW-hrs)	124	145	150	135	129	92	117	146	165	147	184	185	185	210	239	239	239	239	239	239	239	239	239	239
Cost ($M)	$5.7	$8.9	$8.4	$7.2	$8.0	$5.3	$6.6	$8.5	$9.9	$9.3	$12.3	$11.0	$11.3	$13.1	$14.8	$15.3	$15.7	$16.2	$16.7	$17.2	$17.7	$18.3	$18.8	$19.4

Enclosure 1 – Land Use Plan



Enclosure 2 – Infrastructure Investment Table

Laboratory Name: Thomas Jefferson National Accelerator Facility

Infrastructure Objectives:

Objective 1 - Provide sufficient high bay space to build and test experimental equipment, for SRF production, and for cryogenics fabrication
Objective 2 - Enhance office and collaborative space for Laboratory staff and users
Objective 3 - Increase reliability and resiliency of utilities for CEBAF operations and advanced R&D
Objective 4 - Provide, protect, and improve infrastructure that enables world class science

Project Title	Site Project Code (if applicable)	Total Estimated Cost ($000)	FY19 ($000)	FY20 ($000)	FY21 ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	Infra-structure Objective *(use number from above)*	Funding Type *Select from Drop Down Menu*	Funding Program *Select from Drop Down Menu*	Primary Core Capability *Select from Drop Down Menu*	SC Program(s) supported *Use initials like BES, BER, NP, HEP, etc. or All for Site-wide*	Project Type for SLI Projects *Select from Drop Down Menu*	Gap Being Addressed
Cryogenics Engineering Office Renovation		**1,900**	1,100													2	GPP-Prog	NP	SC01	All		modernizes substandard office space
Cooling Tower Water Reuse		**821**	705	116												3	GPP-Prog	NP	SC25	All		reduces operating costs; meets sustainability goals
End Station Refrigeration 2 (ESR2)		**9,500**		9,500												3	GPP-Prog	NP	SC01	All		increases utility capacity and reliability
Laydown Yard Expansion		**1,000**			1,000											4	GPP-Prog	NP	SC25	All		relocates operations functions to service corridor
Integrated Maintenance and Logistics Center (IMLC) Phase 1		**4,900**			1,122	2,186	1,592									4	GPP-Prog	NP	SC25	All		relocates operations functions to service corridor
Integrated Maintenance and Logistics Center (IMLC) Phase 2		**2,978**					659	2,319								4	GPP-Prog	NP	SC25	All		relocates operations functions to service corridor
Road, Parking and Sidewalk Improvements		**4,848**							2,388	2,460						4	GPP-Prog	NP	SC25	All		enhances and extends pedestrian corridor
Main Entrance and Site Signage		**1,000**									1,000					4	GPP-Prog	NP	SC25	All		enhances main entrance and improves wayfinding
Test Lab Chiller Replacement		**1,200**									1,200					3	GPP-Prog	NP	SC25	All		increases utility capacity and reliability
Potable Water Improvements		**2,100**									334	1,766				3	GPP-Prog	NP	SC25	All		increases utility capacity and reliability
Sanitary Sewer Improvements		**1,500**										844	656			3	GPP-Prog	NP	SC25	All		increases utility capacity and reliability
RadCon Calibration Lab and Waste Processing		**3,700**											2,032	1,668		4	GPP-Prog	NP	SC25	All		increases safety and security
Service Entrance Road		**2,000**												1,101	899	4	GPP-Prog	NP	SC25	All		extends service corridor and improves service traffic flow
Sustainability Improvements		**1,953**													1,953	3	GPP-Prog	NP	SC25	All		reduces operating costs; meets sustainability goals
Central Helium Liquefier (CHL) Cold Box Replacement		**8,000**														3	GPP-SLI	SLI	SC01	All		increases utility capacity and reliability
Cryogenics Test Facility (CTF) Upgrade		**5,200**		5,200												3	GPP-SLI	SLI	SC01	All		increases utility capacity and reliability
Low Energy Recirculator Facility (LERF) Renovation		**5,000**							5,000							4	GPP-SLI	Other	SC01	All		modernizes substandard technical space
CEBAF Renovation and Expansion (CRE)	20-SC-73	**87,000**		2,000	2,000	37,000	46,000									2	LI-SLI	SLI	SC20	All	Bldg Renov/Mod	modernizes substandard office space
Large Scale Assembly and Testing (LSAT)		**60,000**				8,000	30,000	22,000								1	LI-SLI	SLI	SC16	All	Bldg Renov/Mod	modernizes substandard highbay and technical space

Enclosure 2 (cont'd) Integrated Facilities Infrastructure (IFI) Crosscut Data Table

Laboratory Name: Thomas Jefferson National Accelerator Facility

SC Integrated Facilities and Infrastructure (IFI) Crosscut Data Table

Data summarized from Investment Table

Capital Investments (summarized from Investment Table)	FY 19 Actual	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
SLI Line Items	0	2,000	2,000	45,000	76,000	22,000	0	0	0	0	0	0	0
SLI GPP	0	5,200	0	0	0	0	5,000	0	0	0	0	0	0
GPP - SC Research Programs	1,805	9,616	2,122	2,186	2,251	2,319	2,388	2,460	2,534	2,610	2,688	2,769	2,852
Total DOE Capital Investment	1,805	16,816	4,122	47,186	78,251	24,319	7,388	2,460	2,534	2,610	2,688	2,769	2,852
Lab Minor Construction - IGPP	0	0	0	0	0	0	0	0	0	0	0	0	0
Lab Minor Construction - Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Investment	1,805	16,816	4,122	47,186	78,251	24,319	7,388	2,460	2,534	2,610	2,688	2,769	2,852

Maintenance and Repair Predictive, Preventive and Corrective M&R (incl. DM Reduction) (For Federally Owned Facilities)	FY 19 Actual	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Direct Funded	122	126	129	133	137	141	146	150	155	159	164	169	174
Indirect Funded	6,986	7,196	7,411	7,634	7,863	8,099	8,342	8,592	8,850	9,115	9,389	9,670	9,960
Total Predictive, Preventive and Corrective M&R	7,108	7,321	7,541	7,767	8,000	8,240	8,487	8,742	9,004	9,274	9,553	9,839	10,134
Annual Required Maintenance *(see FIMS Data Dictionary)*				11,137									

Operation, Surveillance & Maintenance (OS&M) of Excess Facilities	FY 19 Actual	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Direct Funded	0	0	0	0	0	0	0	0	0	0	0	0	0
Indirect Funded	0	0	0	0	0	0	0	0	0	0	0	0	0
Total OS&M of Excess Facilities	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Maintenance and Repair & OS&M	7,108	7,321	7,541	7,767	8,000	8,240	8,487	8,742	9,004	9,274	9,553	9,839	10,134

Disposal and Demolition	FY 19 Actual	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Direct Funded	0	0	0	0	0	0	0	0	0	0	0	0	0
Indirect Funded	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Disposal and Demolition	0	0	0	0	0	0	0	0	0	0	0	0	0

Assessing Impacts of the Campus Strategy on Key Performance Indicators *(Assumes Investment Plan fully funded)*	FY 19 Actual	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31
Deferred Maintenance ($000)	7,304	7,196	7,628	8,086	8,571	9,085	8,703	5,620	5,958	6,315	6,694	7,096	7,521
Repair Needs ($000)	27,754	28,698	20,985	22,244	23,579	24,994	24,927	22,501	23,851	25,282	26,799	28,407	30,111
Modernization Needs ($000)	115,447	117,120	120,634	114,640	118,079	121,622	102,507	39,808	41,003	42,233	43,500	44,805	46,149
Replacement Plant Value ($000)	508,861	524,127	566,992	584,001	602,853	621,775	666,452	694,194	715,020	736,470	758,564	781,321	804,761
Building Area (GSF)	882,990	882,990	1,004,972	1,004,972	1,016,914	1,024,191	1,089,191	1,111,191	1,111,191	1,111,191	1,111,191	1,115,266	1,115,266
Increases	0	0	121,982	0	11,942	7,277	65,000	22,000	0	0	0	5,000	0
Removals	0	0	0	0	0	0	0	0	0	0	0	925	0