Jefferson Lab

FY 2022 ANNUAL LABORATORY PLAN

Thomas Jefferson National Accelerator Facility

Prepared for the U.S. Department of Energy Office of Science

Stuart Henderson, Laboratory Director

August 9, 2022

U.S. DEPARTMENT OF ENERGY JSA

Table of Contents

I. Mission/Overview

Thomas Jefferson National Accelerator Facility (TJNAF) is a world-leading research institution for exploring the nature of matter, providing unprecedented insight into the details of the particles and forces that build our visible universe inside the nucleus of the atom. TJNAF was established in 1984 in Newport News, Virginia, and is operated by Jefferson Science Associates, LLC (JSA), for the Department of Energy's (DOE) Office of Science (SC).

Research at TJNAF reveals the fine details of the constituents of matter, from the familiar protons, neutrons, and electrons in the atom, to the lesser-known quarks and gluons inside the atom's nucleus.

Enabling these studies is TJNAF's world leadership in the development and deployment of large-scale superconducting radiofrequency (SRF) technology. SRF technology powers TJNAF's flagship facility, the Continuous Electron Beam Accelerator Facility (CEBAF). The technical and research successes accomplished with CEBAF as a unique SRF particle accelerator have made possible a wide array of applications, from ever more powerful free-electron lasers for research to detectors that enable life-saving advances in nuclear medicine.

TJNAF strives to attract and retain a diverse and talented workforce to both support its scientific mission and to maintain its core capabilities and expertise in Nuclear Physics; Large-Scale User Facilities/Advanced Instrumentation; Accelerator Science and Technology; and Advanced Computer Science, Visualization, and Data. TJNAF is exploring ways to capitalize on its expertise in the computational sciences to provide large-scale high-performance computing services to an array of research fields for accelerating and maximizing scientific insight in the future.

TJNAF actively partners with industry to advance critical technologies to benefit the nation. The lab also invests in the next-generation Science, Technology, Engineering, and Mathematics (STEM) workforce, training one-third of U.S. PhDs in nuclear physics annually. TJNAF's outreach programs positively impact thousands of students and teachers while helping them build critical knowledge and skills for a brighter future.

II. Lab-at-a-Glance

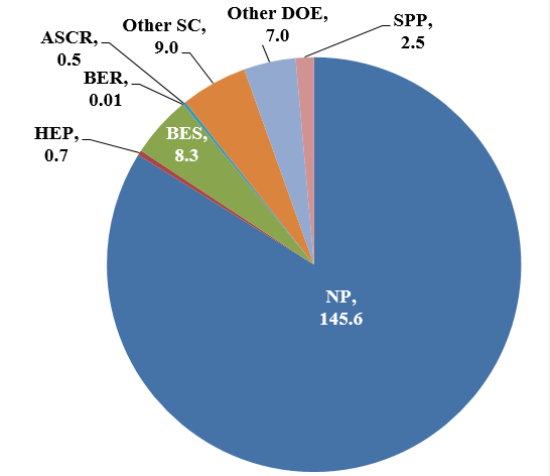
Location: Newport News, Virginia
Type: Program-dedicated, single-purpose lab
Contract Operator: Jefferson Science Associates, LLC
Responsible Site Office: Thomas Jefferson Site Office
Website: http://www.jlab.org
Physical Assets:

- 169 acres and 69 buildings
- 882,900 gross square feet (GSF) in buildings
- Replacement Plant Value: $1,244M
- 0 GSF in excess facilities
- 66,627 GSF in leased facilities

Human Capital (period ending 9/30/2021):

- 758 full-time equivalents
- 25 joint faculty
- 34 postdoctoral researchers
- 26 undergraduate and 55 graduate students
- 1,694 facility users
- 1,559 visiting scientists

FY 2021 Costs by Funding Source: *(Cost Data in $M)*



BES costs ($8.3M) reflect LCLS-II & LCLS-II HE work for SLAC

Lab Operating Costs: $173.6
DOE Costs: $171.1
SPP (Non-DOE/Non-DHS) Costs: $2.5
DHS Costs: $0.0
SPP as % Total Lab Operating Costs: 1.4%

III. Core Capabilities

Nuclear Physics

(Funding: DOE SC Office of Nuclear Physics)

TJNAF is a unique world-leading user facility for discovery studies of the structure of nuclear and hadronic matter using continuous beams of high-energy, polarized electrons. The nuclear physics program at TJNAF spans a broad range of topics in modern nuclear physics. 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. 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.

Excellent synergy exists between the TJNAF experimental, theoretical, and computing 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 HPC to develop new and better tools to help extract the 3D tomography of hadrons from TJNAF data. TJNAF was the first to make use of GPUs for HPC based on heterogeneous architectures (for LQCD calculations) and continues this innovative approach to present needs, including wide embracement of AI/ML in Nuclear Physics techniques.

TJNAF actively partners with BNL to provide important expertise and capability to ensure successful implementation of the EIC, including taking responsibility of scope that benefits from TJNAF's long-time intellectual investment in the EIC, TJNAF's core expertise, and its wide international user community.

Large-Scale User Facilities/Advanced Instrumentation

CEBAF (Funding: DOE SC – Nuclear Physics)

The 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, in close collaboration with a large domestic and international user community of more than 1,700 users annually.

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 to the 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.

Accelerator Science and Technology

(Funding: DOE SC – Nuclear Physics, Basic Energy Sciences, High Energy Physics, Department of Defense (DoD) Office of Naval Research, Commonwealth of Virginia, and Industry)

SRF Accelerators. The SRF accelerator system consists of multiple integrated technologies with expertise spread throughout multiple disciplines and departments. TJNAF maintains collaboration and communication among all associated sub-systems essential to maintaining and enhancing SRF capabilities. System integration essential to an effective SRF system includes cavity fabrication and processing, cryomodules, low-level RF controls, high-power RF, cryogenics, software and hardware controls, and monitoring systems. Ensuring that each of these sub-systems maintains state-of-the-art capabilities is critical to maintaining a world-leading program in SRF accelerator system capabilities. To accomplish the mission, the SRF Institute must maintain a comprehensive set of expertise and facilities to support SRF technologies at TJNAF and be ready to respond to current and future needs of the TJNAF, the DOE complex, and other partners. TJNAF's SRF facilities occupy approximately 60,000 SF of contiguous space all under one roof, which includes 30,000+ SF of new work centers, 25,000 SF of renovated high bay assembly and test work centers, and approximately 5,000 SF for parts inventory and storage. A unique feature of the SRF facility is the ~8600 SF chemroom/cleanroom suite. This state-of-the-art facility is fully engaged to support cryomodule construction and refurbishment needs of CEBAF, LCLS-II HE, SNS PPU, and planning for the EIC project SRF production; strongly contribute to critical fundamental SRF R&D and prepare for future projects such as PERLE, ILC, or FCC-ee.

The ability to use the TJNAF LERF as an accelerator R&D test bed for ERLs and techniques required to establish cooling of proton/ion beams, or other future initiatives, 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 HE.

Cryogenics. Over the last 30 years, 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, including the design of construction projects requiring large-scale cryogenics at SLAC (LCLS-II), Michigan State University (Facility for Rare Isotope Beams), Oak Ridge National Lab (SNS), TJNAF (12 GeV Upgrade), and NASA (James Webb Space Telescope testing), as well as improving the cryogenic efficiency of existing systems (BNL). In the process, several 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. TJNAF provides commissioning support to SLAC and routine operational support to ORNL.

Advanced Computer Science, Visualization, and Data

(Funding: DOE SC – Advanced Scientific Computing Research and Nuclear Physics)

Through our support of the 12 GeV Nuclear Physics program, we have developed software and methodologies that are more broadly applicable. TJNAF has deployed in production AI/ML-based data quality monitoring and automated AI/ML calibration methods for drift chambers. These abilities are accelerating the pace of analysis. We have developed a second-generation multi-threaded framework

(JANA2). We have developed a Geant4 toolkit for EIC simulation studies (eAST) for detector optimization that includes ease of leveraging new and rapidly evolving computing architectures.

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 HPC 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.

TJNAF is leading in the transition from the traditional NP and HEP event-by-event readout model to a streaming model where all detector channels are continuously read in parallel. TJNAF is developing software and hardware to support streaming data acquisition for CEBAF experiments and as a collaborator in the EIC Streaming Readout Consortium. The Environment for Realtime Streaming Acquisition and Processing (ERSAP) is an application environment for Streaming Readout Data Acquisition and online data processing. ERSAP provides a distributed streaming data-oriented framework with support for multiple programming languages**.**

TJNAF is developing core competency and capacity in targeted areas in AI/ML as defined in the Basic Research Needs for Scientific Machine Learning, focusing on integrating uncertainty quantification into deep machine learning models. This work provides better decision support and is in use at the SNS. TJNAF works on various aspects of design and control algorithm and contributed significantly to the scalable reinforcement learning framework, the Easily eXtendable Architecture for Reinforcement Learning. TJNAF data scientists are leading Reinforcement Learning efforts and applications to optimize dynamic workflows and compute power consumption.

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

The TJNAF science strategy for the future involves pursuit of four major initiatives that advance key objectives in the field of Nuclear Physics and also enable TJNAF to more broadly contribute to the programs of the Office of Science. These initiatives allow TJNAF to diversify its scientific mission by building upon our foundation in nuclear physics to pursue new research directions and facility capabilities, particularly in advanced computing.

Strategic Areas	5-7 year goals
Nuclear Physics at CEBAF	• Ensure that TJNAF pursues complementary discovery science in the EIC era. • Realize CEBAF reliability at 12 GeV and develop concepts for future upgrades.
Electron-Ion Collider	• Demonstrate leadership in the EIC scientific program and deliver on TJNAF Project Partnership responsibilities.
Accelerator Science and Technology	• Fully develop and staff cryogenic, SRF, and accelerator research capabilities that enable TJNAF to deliver new accelerator projects at TJNAF and across the DOE complex.
Computational Science and Technology	• Be the first in class High-Performance Data Facility with associated research programs in Data and Computational Science.

The four major initiatives form a compelling and coherent vision for the Jefferson Lab of the future. Centered on our strong heritage in Nuclear Physics, and motivated by grand challenges within the field such as the quest to image the nucleon, our strategy brings together fundamental nuclear physics, computational science and the underlying accelerator technology to drive discovery in nuclear science,

design and build the facilities of the future, and power new methods and facilities to integrate experiment, theory, and computation, enabling a new paradigm of scientific discovery.

The first major initiative is Nuclear Physics at CEBAF. The currently planned program of experiments will require the better part of the next decade to execute. Here, CEBAF will continue to provide unique capabilities to advance our understanding of hadronic matter at high luminosity far beyond what will be available at the future EIC. The planned CEBAF experimental program is launching a new era in three-dimensional imaging of the nucleon to facilitate solutions to long-standing anomalies in nuclear medium modifications, and to provide benchmarks for Quantum Chromodynamic calculations. Furthermore, advances in nuclear theory, particularly first principles calculations in LQCD, provide essential support for future developments at CEBAF and EIC.

TJNAF has established itself as a major partner in the development, construction, and scientific utilization of the new EIC Project, the second major initiative. This effort is both synergistic and complementary to the Nuclear Physics program at CEBAF, and exploits TJNAF's world-leading expertise in utilizing electron scattering in experimental nuclear physics as well as accelerator science and technology. The theory program at TJNAF is well equipped to provide leadership in guiding and interpreting eventual EIC experimental results.

The third major initiative is Accelerator Science and Technology. TJNAF will continue to be a world-leading center for SRF technology research and production, both for fundamental scientific research and for applications to industry, medicine, and national security. In order to reach its full potential, TJNAF will fully develop and staff the SRF, cryogenic, and accelerator research capabilities, thus enabling the lab to deliver on new accelerator projects across the DOE complex. Examples of additional elements of this initiative include machine learning for accelerator operations, development of a polarized positron source, and advanced photocathode development.

TJNAF will continue to advance the role of computation in Nuclear Physics while expanding our horizon beyond Nuclear Physics to other disciplines and research areas. TJNAF has developed a vision for an advanced computational facility – the High-Performance Data Facility -- to accelerate scientific discovery across DOE Office of Science programs by providing large-scale high-performance computing that brings parity between simulated, experimental, and observational data to accelerate and maximize scientific insight. This facility will provide services to Office of Science programs that enable interdisciplinary teams of scientists to attack fundamental problems in science and engineering that require nimble shared access to large data sets, often aggregated from multiple sources.

V. Infrastructure

In Section 5, TJNAF describes plans to maintain and improve its physical infrastructure while minimizing overhead cost to maximize return on S&T investment.

5.1 Overview of Site Facilities and Infrastructure

TJNAF 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, which sub-leases five acres to DOE for TJNAF use. Also adjacent is an 11-acre parcel owned by Newport News that contains the Applied Research Center (ARC) where JSA leases additional office and lab space. SURA owns 37 acres adjacent to TJNAF where it operates a 42-room Residence Facility at no cost to DOE.

TJNAF consists of 69 DOE-owned buildings comprising 882,990 SF of office, shop, technical, and storage space. JSA leases additional office and lab space in the VARC (37,643 SF) and ARC (11,435 SF). JSA also

leases two off-site storage warehouses (17,549 SF). Distribution of space by type is summarized in Table 5.1. There are currently no excess facilities and none are expected within the next 10 years. In addition to real property assets, 42 personal property shipping containers represent 12,920 SF of added storage.

Table 5.1: Distribution of Usable Space by Type

Type of Use	Total Usable Square Feet, 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%)

TJNAF provides office and workspace for approximately 760 JSA contractor, JSA, and federal government employees plus 1,600 transient users and visiting scientists. Facility space is well utilized with a current asset utilization index of 99.6%. The condition of TJNAF facilities is generally good as summarized in Table 5.2.

Table 5.2: 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	30	353,596	36	N/A
	Substandard	0	0	7	249,069	3	N/A
	Inadequate	0	0	1	6,638	0	N/A
	TOTAL	36	339,976	38	609,303	39	N/A
Utilization	Underutilized	0	0	0	0	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/kilowatt-hour (kWh) and water from Newport News at an average rate of $3.69/HCF (HCF=hundred cubic feet), and disposes of wastewater through the HRSD 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 summarized in Enclosure 1. In addition to DOE-owned land, the SURA-owned land, as well as Newport News-owned land reserved for TJNAF interests, preserves expansion opportunities critical to the lab's strategic plan. The Land Use Plan also accommodates a future High-Performance Data Facility strategically placed on the campus.

The SLI-funded CEBAF Renovation and Expansion (CRE) project received CD-1 in March 2020. The project includes the acquisition of the ARC, renovation of CEBAF Center, and a 22K SF building expansion—which will eliminate the VARC lease. The ARC acquisition process is anticipated to be concluded in FY22. An extension of the current 11,435 SF lease is in place until the acquisition is complete. No real estate actions were performed in FY21 and the only additional real estate action planned for FY22 is a 15-20,000 SF off-site warehouse lease, which is required until the completion of the TJII project.

5.2 Campus Strategy

The S&T strategy 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 a continued focus on CEBAF infrastructure reliability. 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 <81 hours of total downtime over a 32-week experimental period. To accomplish this, Facilities Maintenance and Operations completed 5,100 preventative maintenance tasks and 1,717 corrective tasks in FY 2021.

The impact of electrical transients to the operation of high-power electronic equipment remains 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 preventive maintenance of the substations feeding the lab (22, 33, and 40 million watts (MVA)), removing trees near transmission lines, inspecting overhead lines, coordinating utility preventive maintenance tasks with accelerator downtimes, proactively monitoring line voltage variations within tariff limits, and meeting regularly to review power reliability. In FY21 upgrades were also performed to provide remote ground fault relay operation capabilities and replacement of automatic voltage regulators

To support increased accelerator operations during the warm summer months, a project was identified to increase the cooling capacity of the linac service buildings. The scope of the project increases chilled water capacity, improves air flow, reduces infiltration of unconditioned air, and increases air conditioning. The first two phases of the project were completed in FY21 and the final phase is anticipated to be completed by FY25.

Replacement of accelerator fire detection and suppression systems was completed in FY20. This project replaced end-of-service-life components including all fire suppression, detection, and monitoring systems. A nitrogen-filled dry pipe system replaced the existing air-filled system, which will slow corrosion, improve the life of the system, and decrease maintenance costs. Replacement of fire detection systems in the experimental halls was completed in FY21.

Presented in Table 5.3 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, here. This campus strategy reflects a high priority on CEBAF reliability while also giving consideration for infrastructure upgrades needed to support a future High-Performance Data Facility and incorporating US Administration expectations for sustainability, resilience, decarbonization, and net zero initiatives.

Table 5.3: 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 liquid helium to the Test Lab to enable the development, production, and testing of SRF components and cryomodules, both for use by TJNAF in CEBAF and projects for other labs.	The Cryogenics Test Facility (CTF) has experienced heavy utilization due to the CEBAF upgrade and BES multi-lab partnership projects. Approximately $5M of system components have reached end-of-life and others require upgrading to maintain adequate capacity for projected workload.	Complete the **CTF Upgrade.** Funding was provided in FY20 under the SLI-GPP program.
	Provide sufficient high bay, storage, and office space needed to design, produce and test SRF components and systems.	10,000 SF of high bay space in the Test Lab is unavailable for SRF needs due to occupation by Physics' large-scale assembly and testing activities. SRF office space needs in the Test Lab exceed available capacity. 10,000 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.	The **TJII** project will construct a new 45,000 SF Test Lab High Bay Annex for Physics' large-scale assembly and testing activities, thus making existing Test Lab high bay space available for SRF. Physics' engineering office space will be relocated to a modernized EEL to ensure adequate space is available for SRF in the Technology and Engineering Development Facility. A new 15-20,000 SF warehouse will relieve the demand for remote, off-site leased storage. Need date is immediate.

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
	LERF for dedicated cryomodule testing for DOE Projects, and R&D on electron guns and future accelerator concepts	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.	The **LERF Renovation** will ensure the facility can meet its planned operational use. Need date is FY25.
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 grams/second (g/s) of LHe at >96% 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**. This Project was initiated in FY17 as an SLI-GPP project, and is now nearly complete.
	210 tons of cooling capacity are required in each of the two linac service buildings to support CEBAF operations.	Existing cooling system is 36% undersized for current loads. Shortfall is 75 tons in each linac.	The **LINAC Additional Cooling** project increases chilled water capacity, improves air flow, reduces infiltration of unconditioned air, and increases air conditioning. The first two phases are complete and the final phase is needed by FY25.
	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 34 weeks/year.	High bay space in the EEL, Test Lab, and TED buildings is heavily overutilized. Overcrowding increases the safety risk to staff and visiting scientists. Off-site space is currently being leased to meet the demand.	The **TJII** project will construct a new 45,000 SF Test Lab High Bay Annex for Physics' large-scale assembly and testing activities. Need date is immediate.

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
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 the **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 is underway as an FY20 GPP-funded project.
	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 overutilized 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.	The **CRE,** including acquisition of the ARC, renovates the CEBAF Center and provides an additional 144,000 SF of space. The project consolidates staff and vacates leased space. Need date is immediate. Initial project funding was received in FY20.
	The EEL provides 54,800 SF of technical and lab space for Physics, Engineering, and Facilities staff and is integral to our campus plan.	EEL has end-of-life mechanical systems and numerous code deficiencies. Office and technical space is insufficient, poorly distributed, and not integrated with the campus.	The **TJII** project fully renovates and modernizes the EEL facility to meet mission needs. Need date is immediate.
Support Facilities and Infrastructure (SC25)	Provide 100,000 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 70,000 SF of existing laydown	The **Laydown Yard Expansion** roughly doubles an existing, centrally located storage area which is not visible from off-site. Consolidation will improve material management and

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
		area will be lost due to future building construction.	provide an opportunity to eliminate unneeded material. Need date is FY25.
	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.	The **Cooling Tower Water Reuse** project develops a 50M gal/year alternate water source for use in cooling towers by directing and treating water from off-site retention ponds. Need date is FY25.
	Relocate Facilities Maintenance and Operations functions.	Functions are located in two substandard buildings (13 and 19) located in the administrative core of the campus. Critical spares are inefficiently scattered across the campus.	**The TJII** project provides a fully integrated solution and relocates these functions to a new Integrated Maintenance and Logistics Center (IMLC) located in the lab's service corridor. Need date is immediate.
	Relocate logistics functions.	TJNAF logistics functions are primarily located within high bay space within the EEL building, which is already oversubscribed and needed to support research and technical operations.	The **TJII** project provides a fully integrated solution and relocates these functions to a new IMLC located in the lab's service corridor. Need date is immediate.
	Suitable access roads, parking, and pedestrian walkways to facilitate collaboration and meet safety and	Continued expansion of the TJNAF campus as outlined in this plan along with development of property immediately	The site-wide Roads, Parking, and Sidewalks Improvement project rebuilds existing roads and resolves impacts created by both on-site

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
	regulatory requirements.	surrounding TJNAF requires expansion and alteration of campus access and parking to support vehicle loads, and maintain compliance with safety and regulatory requirements.	and adjacent off-site construction. Need date is FY29 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 no longer be available after FY30.	The **Central Utility Plant (CUP) Upgrade** project includes replacing the existing chillers with new chillers to be installed in the CUP. Need date is FY24.
	Suitable potable water distribution to reliably meet need for 120M gal/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 Utility Upgrades** 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 FY29.
	Relocate service entrance road to the TJNAF campus.	TJNAF service vehicle traffic flow and Facilities Maintenance and Operations functions do not support future growth of administrative, research, and technology portions of the TJNAF campus.	The **TJII project will 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 is FY26 or sooner if practical.
	Meet renewable energy goals established by DOE.	TJNAF currently relies on the purchase of renewable energy credits to meet DOE sustainability goals,	The **Renewable Energy Integration** project provides a 3-4 MW photovoltaic and battery storage system on-site,

Core Capability (SC-X)	Infrastructure Requirement	Current Shortfall	Optimum Solution and Need Date
		which require that renewable electric energy account for not less than 7.5% of a total agency electric consumption.	which will assist to meet renewable energy goals and provide a resilient microgrid for the campus. Need date is FY30.
	Meet potable water intensity reduction goals established by DOE.	Potable water intensity is expected to dramatically increase beginning in FY26 due to campus growth and data center cooling demands.	The **Cooling Tower Water Reuse Expansion** project provides an additional 50M gal/year alternate water source for use in cooling towers. Need date is FY31.
Advanced Computer Science, Visualization, and Data (SC02) and Computer Science (SC10)	162,000 SF of data center space and administrative space for 100+ staff to grow core capabilities in computational science.	CEBAF Center data center (6,000 SF) is at capacity, and insufficient administrative space exists in CEBAF Center to support the growth of the CST.	Construct Phase 1 of a new High-Performance Data Facility with sufficient administrative space for 100-165 staff.

The gaps identified above can be closed using a combination of SLI, SLI-GPP, and NP-GPP funding of $280M over a decade. We assume that the Commonwealth of Virginia will provide funding for Phase 1 of the data center. 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 Condition Index is 0.98. However, this could drop over time if Facilities Operations and Maintenance funding continues to be limited to 1.25% of replacement value. Modernization projects and construction of new facilities through SLI and GPP funding have enabled TJNAF to maintain a modest deferred maintenance value ($7.5M in FY21). 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 Data table provided in Enclosure 2.

***Infrastructure Investment Table*:** The TJNAF Infrastructure Investment Table and Campus Plan is provided in Enclosure 2.

***Integrated Facilities and Infrastructure Crosscut Data Table*:** The TJNAF Integrated Facilities and Infrastructure Crosscut Data Table is also provided in Enclosure 2.

5.3 Site Sustainability Plan Summary

TJNAF remains strongly committed to achieving targets established in the DOE Strategic Sustainability Performance Plan. In FY21, significant accomplishments were made in areas such as renewable energy, waste management, electronics stewardship, and sustainable acquisition. Notably, TJNAF was recognized by DOE for its commitment to environmental excellence in procurement, a distinction that earned the lab a GreenBuy Superior Award for having achieved five consecutive Gold level awards. Only three sustainability interim targets were not met in FY21: potable water use intensity, electricity use intensity, and sustainable buildings (by building count).

Given the energy and water requirements for CEBAF operations as well as projected energy and water loads for a future HPDF on campus, achievement of potable water use intensity and electricity use intensity reduction goals represent a significant challenge. However, considerable progress is being made in both of these critical areas.

Several facilities currently utilize clean, renewable geothermal heat pump systems that produce and consume thermal energy. Photovoltaic (PV) systems are currently being considered for several facilities, and energy conservation measures, such as replacement of fluorescent and high intensity discharge (HID) lighting with light emitting diode (LED) fixtures, are completed each year. Additionally, a large PV array capable of producing 3-4 MW is being considered, which could completely offset administrative campus energy loads. On-site renewable efforts are supplemented annually by the purchase of renewable energy credits (RECs) as needed. Increasing the number of RECs purchased annually is a part of TJNAF's strategy to meet carbon pollution-free electricity and emissions reduction goals set in Executive Order 14057.

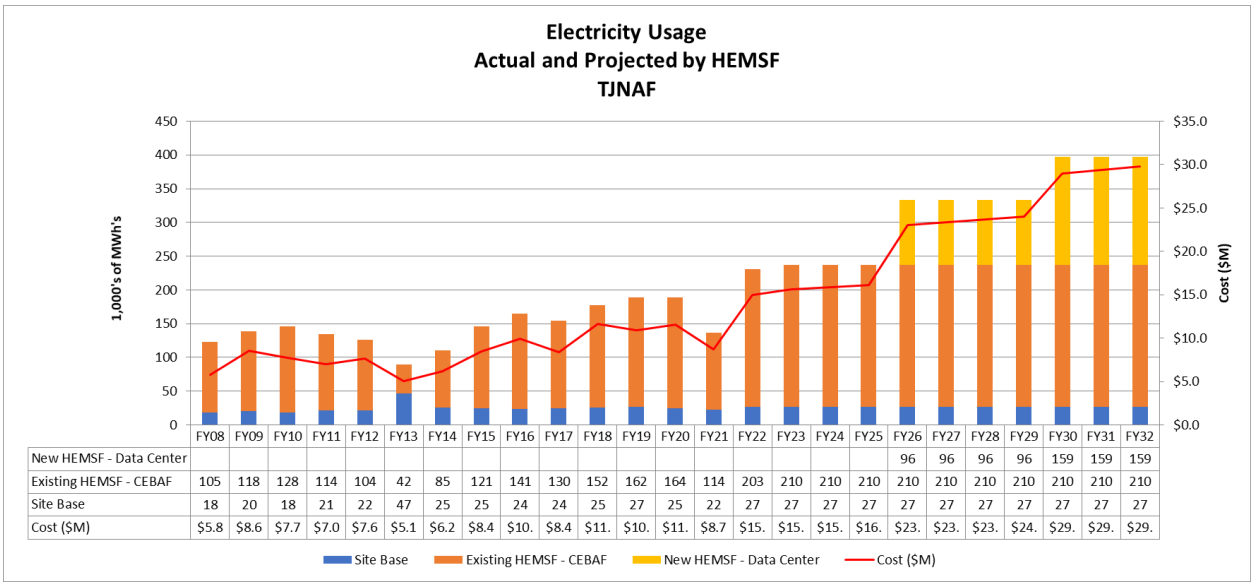
Similar progress is being made in potable water reduction efforts. Approximately 4.9M gal/yr (a savings of $64,000) of potable water is saved annually by reusing discharge water from the Test Lab ultra-pure water system as a make-up water supply source for a nearby cooling tower. A project to provide an additional 50M gal/yr of reuse water from a nearby stormwater lake to evaporative cooling towers has been partially funded and is currently in the conceptual design phase. Expansion of this water system has even been planned to compensate for projected future HPDF water demands.

Recent legislation such as the Energy Act of 2020 and Executive Order 14057 are actively being integrated into TJNAF campus and sustainability planning efforts. In FY22, TJNAF began conversations with the TJSO and Federal Energy Management Program to pursue the establishment of performance contracts that will further assist in reaching energy savings, net-zero, decarbonization, and greenhouse gas reduction goals. A Vulnerability Assessment and Resilience Plan will be completed in FY22, which will enable TJNAF to identify, prepare for, and meet the challenges posed by climate change.

<u>Electricity Usage and Cost Projections</u>

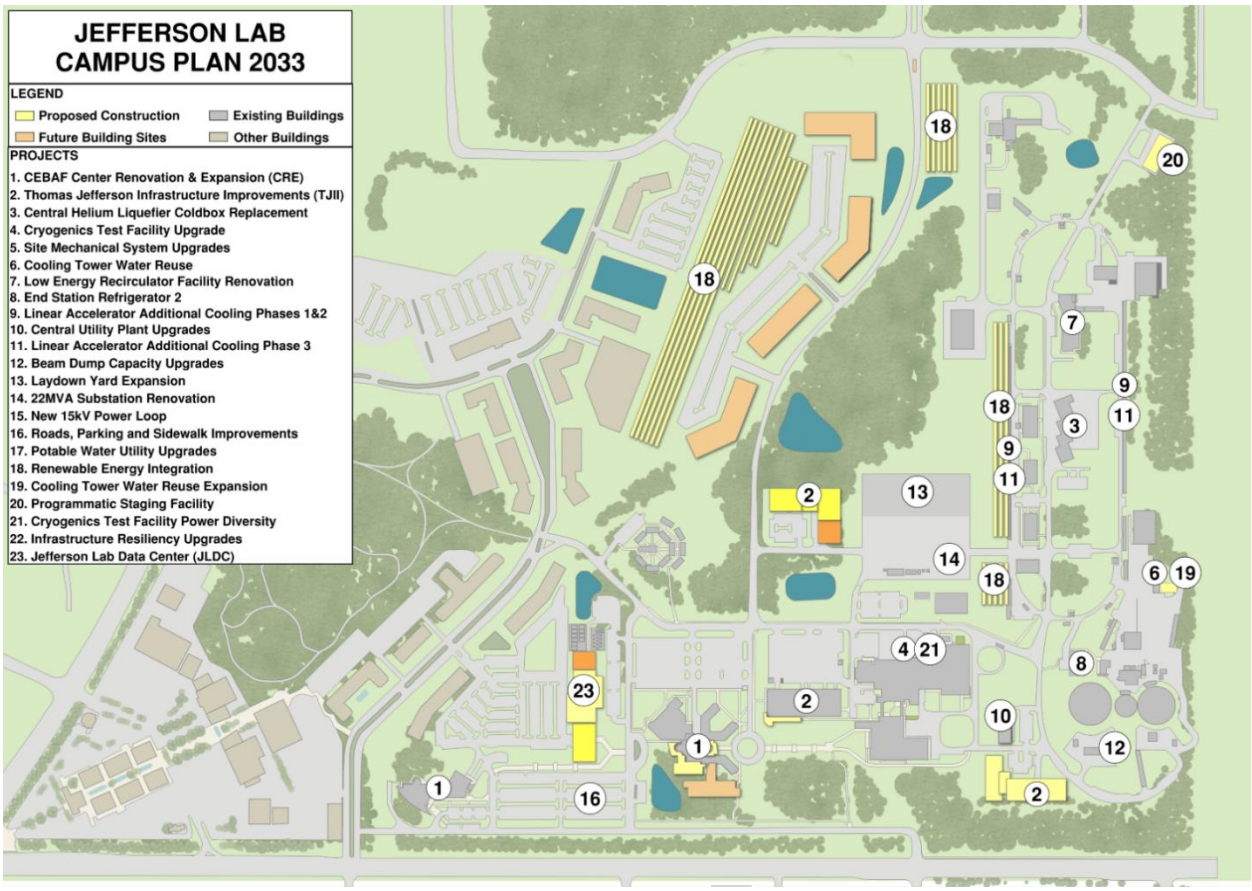
Figure 5.1 shows TJNAF's historical and projected electricity usage and costs. Projections are based on scheduled operations for FY23 of 33 weeks and, for FY24 and beyond, 34 weeks. Additional projections related to a proposed new high-energy, mission-specific facility (HEMSF)—a data center—are also included from FY26 forward.

Figure 5.1: Electricity and Cost Projections



	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
New HEMSF - Data Center																			96	96	96	96	159	159	159
Existing HEMSF - CEBAF	105	118	128	114	104	42	85	121	141	130	152	162	164	114	203	210	210	210	210	210	210	210	210	210	210
Site Base	18	20	18	21	22	47	25	25	24	24	25	27	25	22	27	27	27	27	27	27	27	27	27	27	27
Cost ($M)	$5.8	$8.6	$7.7	$7.0	$7.6	$5.1	$6.2	$8.4	$10.	$8.4	$11.	$10.	$11.	$8.7	$15.	$15.	$15.	$16.	$23.	$23.	$23.	$24.	$29.	$29.	$29.

Enclosure 1 – Land Use Plan



Enclosure 2 – Infrastructure Investment Table

Laboratory Name: Thomas Jefferson National Accelerator Facility

(Dollars in Thousands)

Project Title	Site Project Code *(if applicable)*	Total Estimated Cost ($000)	FY21 Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY32 ($000)	FY33 ($000)	Funding Type *Select from Drop Down Menu*	Funding Program *Select from Drop Down Menu*	Project Type *(Required for for SLI Program) Select from Drop Down Menu*	Main Project Driver *(Required for SLI Program) Select from Drop Down Menu*	Project Urgency *(Required for SLI Program) Select from Drop Down Menu*	Comments
End Station Refrigeration 2 (ESR2)		**9,500**														GPP-Prog	NP	Utility	Mission	Critical	
LINAC Additional Cooling - Phases 1 & 2		**1,500**	1,384													GPP-Prog	NP	Utility	Mission	Critical	
Central Utility Plant (CUP) Upgrades		**4,200**	195	1,579	1,626	800										GPP-Prog	NP	Utility	Mission	Critical	
LINAC Additional Cooling - Phase 3		**1,400**		47	16	1,337										GPP-Prog	NP	Utility	Mission	Critical	
Beam Dump Capacity Upgrades		**3,200**				1,021	2,179									GPP-Prog	NP	Utility	Mission	Critical	
Laydown Yard Expansion		**1,700**				842	858									GPP-Prog	NP	Other	Mission Support	Critical	
22 MVA Substation Renovation		**3,200**					1,083	2,117								GPP-Prog	NP	Utility	Mission Support	Critical	
New 15kV Power Loop		**4,000**						1,100	2,900							GPP-Prog	NP	Utility	Mission Support	Critical	
Roads, Parking, and Sidewalk Improvements		**5,500**						1,027	1,471	2,000	1,002					GPP-Prog	NP	Other	Mission Support	Desired	
Potable Water Utility Upgrades		**3,900**								2,502	1,398					GPP-Prog	NP	Utility	Mission Support	Critical	
Renewable Energy Integration		**5,500**									2,237	3,263				GPP-Prog	NP	Utility	Sustainability	Critical	
Cooling Tower Water Reuse Expansion		**5,900**										1,513	4,387			GPP-Prog	NP	Utility	Sustainability	Critical	
Programmatic Staging Facility		**5,000**											532	4,468		GPP-Prog	NP	New Bldg	Mission Support	Critical	
Cryogenics Test Facility (CTF) Power Diversity		**3,000**												599	2,401	GPP-Prog	NP	Utility	inuity of Operat	Critical	
Infratructure Resiliency Upgrades		**5,000**													2,818	GPP-Prog	NP	Utility	inuity of Operat	Desired	
Central Helium Liquefier (CHL) Cold Box		**8,000**														GPP-SLI	SLI	Utility	Mission	Critical	
Cryogenics Test Facility (CTF) Upgrade		**5,200**														GPP-SLI	SLI	Utility	Mission	Critical	
Site Mechanical System Upgrades		**576**	576													GPP-SLI	SLI	Utility	Sustainability	Desired	
Cooling Tower Water Reuse		**3,900**		3,900												GPP-SLI	SLI	Utility	Sustainability	Critical	
Low Energy Recirculator Facility (LERF)		**7,000**					7,000									GPP-SLI	SLI	Bldg Renov/Modern	Mission	Critical	
CEBAF Renovation and Expansion (CRE)	20-SC-73	**98,000**	2,000	10,000	26,000	30,000	28,000									LI-SLI	SLI	Bldg Renov/Modern	Mission	Critical	
Thomas Jefferson Infrastructure Improvements	22-SC-72	**95,000**		1,000	10,000	30,000	30,000	24,000								LI-SLI	SLI	New Bldg	Mission	Critical	

Enclosure 2 (Cont'd) – SC Integrated Facilities and Infrastructure (IFI) Crosscut Data Table

Laboratory Name: Thomas Jefferson National Accelerator Facility

Data summarized from Investment Table

Capital Investments (summarized from Investment Table)	FY21 Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY33 ($000)	FY34 ($000)
	($000)												
SLI Line Items	2,000	11,000	36,000	60,000	58,000	24,000	0	0	0	0	0	0	0
SLI GPP	576	3,900	0	0	7,000	0	0	0	0	0	0	0	0
GPP - SC Research Programs	1,579	1,626	1,642	4,000	4,120	4,244	4,371	4,502	4,637	4,776	4,919	5,067	5,219
Total DOE Capital Investment	4,155	16,526	37,642	64,000	69,120	28,244	4,371	4,502	4,637	4,776	4,919	5,067	5,219
Lab Minor Construction - IGPP (see Instruction & Tab 1 for details)													
Lab Minor Construction - Other IGPP (see Instruction & Tab 1 for details)													
Total Capital Investment	4,155	16,526	37,642	64,000	69,120	28,244	4,371	4,502	4,637	4,776	4,919	5,067	5,219

Maintenance and Repair (M&R) Predictive, Preventive and Corrective M&R (incl. DM Reduction) (For SC Facilities Only)*	FY21 Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY33 ($000)	FY34 ($000)
	($000)												
Direct Funded	76	78	81	83	86	88	91	93	96	99	102	105	108
Indirect Funded	9,985	10,285	10,593	10,911	11,238	11,575	11,923	12,280	12,649	13,028	13,419	13,822	14,236
Total Predictive, Preventive and Corrective M&R	10,061	10,363	10,674	10,994	11,324	11,663	12,013	12,374	12,745	13,127	13,521	13,927	14,345
Annual Required Maintenance *FY 24 Only (please describe how calculated below)*				10,987									

Operation, Surveillance & Maintenance Costs of Excess Facilities	FY21 Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY33 ($000)	FY34 ($000)
	($000)												
Direct Funded													
Indirect Funded													
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	10,061	10,363	10,674	10,994	11,324	11,663	12,013	12,374	12,745	13,127	13,521	13,927	14,345

Disposal and Demolition Costs	Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY33 ($000)	FY34 ($000)
	($000)												
Direct Funded													
Indirect Funded						400							
Total Disposal and Demolition	0	0	0	0	0	400	0	0	0	0	0	0	0

Assessing Impacts of the Campus Strategy on Key Parameters* *(Assumes Investment Plan fully funded)*	FY21 Actual ($000)	FY22 ($000)	FY23 ($000)	FY24 ($000)	FY25 ($000)	FY26 ($000)	FY27 ($000)	FY28 ($000)	FY29 ($000)	FY30 ($000)	FY31 ($000)	FY33 ($000)	FY34 ($000)
	($000)												
Deferred Maintenance**	7,436	7,659	7,889	8,126	8,369	8,620	8,879	9,145	9,420	9,702	9,993	10,293	10,602
Repair Needs***	20,493	21,108	21,741	22,393	23,065	23,757	24,470	25,204	25,960	26,739	27,541	28,367	29,218
Modernization Costs***	84,660	87,200	89,816	92,510	95,286	98,144	101,088	104,121	107,245	110,462	113,776	117,189	120,705
Replacement Plant Value****	1,615,000	1,690,756	1,741,479	1,793,723	1,869,130	1,938,400	1,999,152	1,999,153	1,999,154	1,999,155	1,999,156	1,999,157	1,999,158
Building Area (GSF)	882,990	1,007,876	1,007,876	1,007,876	1,052,876	1,103,201	1,108,201	1,108,201	1,108,201	1,108,201	1,108,201	1,108,201	1,108,201
Increases		124,886			45,000	56,219	5,000						
Removals						5894							
Maintenance Investment Index (M&R/RPV)	0.62%	0.61%	0.61%	0.61%	0.61%	0.60%	0.60%	0.62%	0.64%	0.66%	0.68%	0.70%	0.72%
Maintenance to Repair Needs Index (M&R/RN)	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%	49.09%
Deferred Maintenance Investment Index (DM/RPV)	0.46%	0.45%	0.45%	0.45%	0.45%	0.44%	0.44%	0.46%	0.47%	0.49%	0.50%	0.51%	0.53%
IGPP Investment Index (IGPP/RPV) (if applicable)													
Planned FY 24 M&R/FY 24 Required Maint (%)					100.06%								

** SC Owned Facilities Only*

*** Projections should take into account inflation of current DM and planned projects/activities that remove DM. DM is total for all property types (Building, Trailers, and OSF's except land and OSF 3000- 3999 assets). Use inflation factors consistent with your area.*

****Exclude any related to OSF's OSF 3000 - 3999 assets*

*****RPV is total RPV for all Property Types (Building, Trailers, and OSF's except land and OSF 3000 - 3999 assets). Projections should take into account inflation of current RPV and planned projects that add or remove assets. Use inflation factors consistent with your area.*

******If not provided in the Investment Table, please provide a list of actual/planned direct and lab funded D&D projects using table below*