Department of Energy Laboratory Plan –TJNAF
July 29, 2016

I. Mission and 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 several decades. The upgraded facility is in the commissioning phase and will begin research operations in the near future. TJNAF's current core capabilities are: experimental, theoretical and computational Nuclear Physics; Accelerator Science and Technology; and Large Scale User Facilities/Advanced Instrumentation.

The Lab has an international scientific user community of 1,510 researchers whose work has resulted in scientific data from 178 full and 10 partial experiments, 380 Physics Letters and Physical Review Letters publications and 1,292 publications in other refereed journals to-date at the end of FY 2015. Collectively, there have been more than 113,000 citations for work done at TJNAF.

Research at TJNAF and CEBAF also contributes to thesis research material for about one-third of all U.S. Ph.D.s awarded annually in Nuclear Physics (27 in FY 2015; 531 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)

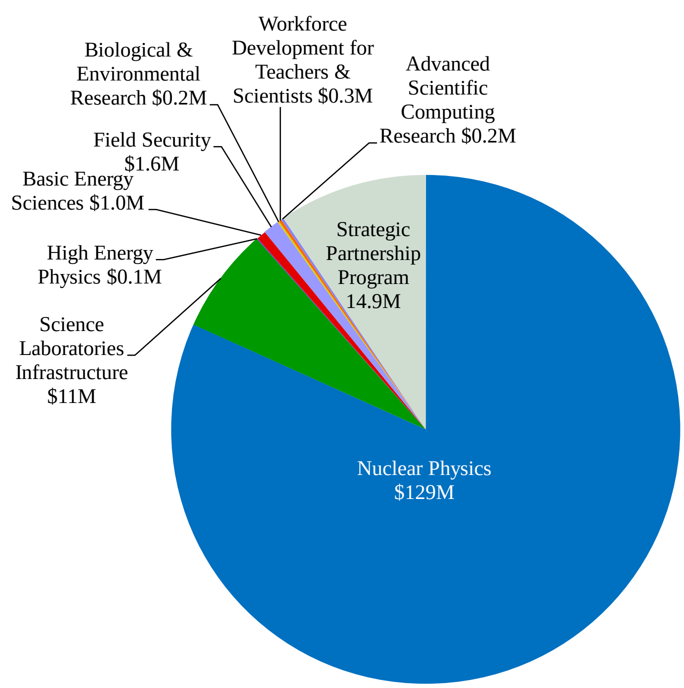
Responsible Site Office: Thomas Jefferson Site Office

Website: http://www.jlab.org

Physical Assets:
- 169 acres and 66 buildings and 4 trailers
- 876,084 GSF in buildings
- Replacement Plant Value (RPV): $397M
- 0 GSF in Excess Facilities
- 74,736 GSF in Leased Facilities

Human Capital (period ending 9/30/15):
- 686 FTEs
- 24 Joint faculty
- 21 Postdoctoral Researchers
- 7 Undergraduate and 37 Graduate students
- 1,510 Facility Users
- 1,346 Visiting Scientists

FY 2015 Funding by Source: *(Cost Data in $M)*



FY 2015 Total Lab Operating Costs (excl. Recov. Act): $157.8
FY 2015 Total DOE Costs: $142.9
FY 2015 SPP (Non-DOE/Non-DHS): $14.9
FY 2015 SPP as % Total Lab Operating Costs: 9.4%
FY 2015 Total DHS costs: $0.0

III. Core Capabilities

The following core capabilities distinguish TJNAF and provide a basis for effective teaming and partnering with other DOE laboratories, universities, and private sector partners in pursuit of the laboratory mission. These distinguishing core capabilities provide a window into the mission focus and unique contributions and strengths of TJNAF and its role within the Office of Science laboratory complex. Descriptions of these facilities can be found at the website noted in the Lab-at-a-Glance section of this Plan.

Each of the laboratory's core capabilities involves a substantial combination of facilities and/or teams of people and/or equipment, has a unique and/or world-leading component, and serves DOE/DHS missions and national needs. Specifically, TJNAF's three major core capabilities meeting these criteria are described below in detail:

1. **Nuclear Physics** (funded by DOE Office of Science (SC)– Nuclear Physics (NP))

   Experimental 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 Continuous Electron Beam Accelerator Facility (CEBAF) electron beam can be simultaneously delivered to the experimental halls at different energies. Up to May 2012, the beam energy delivered was up to 6 GeV, and there were three experimental halls – A, B and C. Each experimental hall was 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 now more than 1,500 users annually, of which roughly 2/3 are domestic, TJNAF supports one of the largest, if not the largest, nuclear physics user communities in the world.

   TJNAF's completed 6 GeV program utilizing CEBAF has given the United States leadership in addressing the structure and interactions of nucleons and nuclei in terms of the quarks and gluons of Quantum Chromo Dynamics (QCD). The Nuclear Physics community in the U.S. has acknowledged this leadership and its potential, and indeed the 2007 NSAC Long Range Plan recommended completion of a doubling of the energy reach of CEBAF, the 12 GeV Upgrade, including construction of a fourth experimental Hall D and equipment upgrades to the existing Halls, as its highest priority. Later NSAC Subcommittees and Decadal Plans reaffirmed this priority. The highest priority of the recent 2015 NSAC Long Range Plan is to capitalize on the investments made, and first and foremost states that "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."

   Recent lattice QCD 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. 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. The 12 GeV Upgrade of CEBAF will enable a worldwide unique new experimental program with substantial discovery potential to capitalize on these developments in nuclear and hadron physics.

The construction of the 12 GeV CEBAF nears completion. The accelerator commissioning has been completed and has been declared ready for operations. Hall A has seen its first continuous wave (CW) beam delivered and initiated its science program. Accelerated beam to Hall D, the newest and fourth experimental hall, was commissioned in the fall of 2014, and also Hall D, is after a stage of detector commissioning, ready for its science program. Accelerator operations sending simultaneous beam to Hall D (at 12 GeV), Hall A (at 11 GeV), and Hall B (at 2.2 GeV) have been established. Construction of experimental facilities in Halls B and C is nearing completion, with their commissioning planned for the upcoming winter period. The increased complexity of the accelerator and experimental equipment, including the introduction of Hall D, represents a substantial expansion of the scale of the operations in FY17.

Theoretical & Computational Nuclear Physics

A comprehensive theoretical effort and leadership across nuclear physics is the mission of the TJNAF Theory Center. The research program is an essential part of the national strategy for understanding the structure of hadronic matter and the worldwide effort to explore the nature of quark and gluon confinement. The broad program encompasses investigations of the hadron spectrum, hadron structure and hadron dynamics using a range of state-of-the art theoretical, phenomenological and computational approaches. These cover *ab initio* calculations, both in the continuum and on the lattice, of the properties of light nuclei, analyses of the nucleon-nucleon interaction, predictions for and analyses of the structure of the nucleon and its excitations, the determination of the spectrum of mesons with emphasis on their underlying quark and gluon structure, and explorations of the internal landscape of hadrons in terms of momentum, spin and spatial distributions. This internal dynamics is investigated in parallel studies using the methods of both lattice and perturbative QCD. A recent emphasis here has been on the issue of how to define and then compute the internal orbital motion of quarks and gluons. A particular strength of the theory group is the capability to meld the appropriate theoretical tools with cutting edge computational technology.

The synthesis of the latest technology with innovative theoretical tools is particularly notable in the area of High Performance Computing. TJNAF deploys cost-optimized computing for Lattice QCD calculations as a national facility for the U.S. lattice gauge theory community. Such computing capitalizes on the DOE's investment in leadership-class computing to facilitate the calculations needed to advance the understanding of nuclear and high-energy physics. To make best use of these facilities, development of a suite of novel software tools (Chroma) has allowed the calculation of observables of direct relevance to the TJNAF experimental program from the spectroscopy of baryons and mesons, including exotics, to form factors and generalized parton distributions. When combined with the power and speed of the dedicated Graphical Processing Unit (GPU) infrastructure, results of unrivaled precision for the hadron spectrum have been produced. Computational techniques in Lattice QCD now promise to provide insightful and quantitative predictions that can be meaningfully confronted with and elucidated by forthcoming experimental data. Moreover, the relation between nuclear structure at short distance scales and the underlying dynamics of quarks can be uncovered. An increasingly important part of this lattice effort is the computation of hadronic scattering amplitudes, with emphasis on providing the decay couplings of well-established mesons as a benchmark for extension to hybrid states, where the decay couplings will aid the experimental search of GlueX and CLAS12. One third of the Theory Center members is also engaged in phenomenological studies of the physics to be accessed at a future Electron Ion Collider, and are major contributors to the whitepaper that sets out its physics case. In all aspects, the Theory Center works closely with the experimental community, whether in performing crucial radiative corrections for parity-violating experiments, or in studies to constrain transverse momentum-dependent and generalized parton distribution functions from the full kinematic range of results that TJNAF will produce.

A key component in support of the 12 GeV experimental program is the Theory Center's *JLab Physics Analysis Center (JPAC)* working particularly closely with the CLAS12 and GlueX Collaborations. The *JPAC* project draws on world theoretical expertise in developing appropriate phenomenological tools and computational framework required for extracting the details of quark and gluon dynamics from experimental data of unprecedented precision and scope. Definitive answers to the basic questions of "do there exist hadrons for which the excitation of gluons is essential to their quantum numbers" and "what is the detailed internal flavor, momentum, angular momentum and spatial distribution of nucleons" require continuing engagement and collaboration between experimentalists and theorists both at TJNAF, at US universities and in the wider hadron physics community.

The Nuclear Physics Core Capability serves DOE Scientific Discovery and Innovation (SC) mission numbers 2, 4, 22, 24, 26, 27, 28, 30, 33, 34, 35 and 36 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

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

The focus of TJNAF's Accelerator Science is on superconducting, high current, continuous wave, multi-pass linear accelerators (linacs), including energy recovering linacs. Past achievements and future plans involve the lab's expertise in low emittance electron injectors, SRF niobium-based accelerating technology, and advanced electron-ion collider design. This broad suite of capabilities is complemented by world-class expertise in accelerator design and modeling.

<u>Injector R&D</u>

TJNAF has extensive expertise in high current photoemission sources, especially polarized sources. Over the past years, the polarization delivered to the CEBAF users has progressed from 35% (bulk gallium arsenide), to 70% (strained gallium arsenide), to 89% (multi-layer strained gallium arsenide). In addition to measurements by the experiment, the polarization is measured at the injector with a Mott polarimeter, whose precision has been pushed to the limit with dedicated R&D. A new, higher voltage DC gun has been built (200kV) anticipating the need for improved beam quality for future parity violation experiments at 12 GeV CEBAF, and a photogun capable of operation at 350 kV is being developed for the Upgraded Injector Test Facility (described in part 4 of this section) and for nuclear physics experiments at the Low Energy Recirculator Facility (LERF). Recent photogun development was partially funded by the International Linear Collider (ILC) and through the DOE program Research and Development for Next Generation Nuclear Physics Accelerator Facilities (LAB 12-632) and (LAB 14-1082). TJNAF electron sources and injectors have produced in continuous wave operation, electron beams with currents of 180 µA and 89% polarization for CEBAF and unpolarized beams of 9 mA for the ERL. For future high-current unpolarized beam applications, photoguns will soon rely on alkali-antimonide photocathodes that exhibit longer operating lifetime compared to gallium arsenide photocathodes.

SRF R&D

The SRF Institute at TJNAF can be a cost-effective R&D partner for all Office of Science projects requiring SRF expertise because of its experience and facilities. Past and current partnerships include jointly funded R&D and production of cavities for the Spallation Neutron Source (SNS) at ORNL, high-current cavities funded by ONR, crab cavities funded by the Advanced Photon Source (APS), and R&D on high Q_0 cavities and new materials for future accelerator technologies funded by BES. The application of this know-how is currently being applied to projects across the DOE-SC complex.

TJNAF also carries out forefront SRF R&D including high gradient research (which led to the development of processing procedures that were applied to the 12 GeV cavities), new materials and thin film research aimed at low frequency cavities where the cost of niobium is high.

More recently, the focus has shifted to high Q_0, which reduces the cryogenic losses in SRF cavities. TJNAF is producing very high Q_0 cavity results with the use of Nitrogen doping of traditional solid niobium cavities. Current work continues exploring process refinements and extending the process to various types of cavities. Additionally, TJNAF is studying the possibility of reacting tin on the internal surfaces of Niobium cavities to create a film of Nb_3Sn. The initial results are encouraging and could lead to superconducting cavities with significantly lower cryogenic losses than the niobium cavities that are the state of the art today. TJNAF is also engaged in understanding the impact of these very high Q_0 cavities on the requirements for cryostat and component designs in cryomodules. This technology has been adopted for the LCLS-II project at SLAC.

TJNAF is also pursuing a program to improve the performance of cryomodules installed in CEBAF by reworking the oldest or weakest cryomodules with new state of the art cavities while reusing most of the cryomodule hardware. This may be the most cost-effective way to maintain the gradient needed for high-energy operations.

TJNAF is studying new materials, notably ingot niobium, which improves the Q_0 while reducing the material costs. Studies of niobium with increased tantalum content (reduced purification) are also demonstrating promise of higher Q_0 at lower cost. These two effects are not mutually exclusive and together provide a low-cost strategy to reach the performance required by CW accelerators at a more affordable cost.

Advanced Electron Ion Collider (EIC) Design

The Accelerator Division, in partnership with the Physics Division and collaborators at other national laboratories, has been developing a design concept for a Jefferson Laboratory Electron Ion Collider (JLEIC). A pre-conceptual design report for JLEIC was published in 2012, which fulfills 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, is now working towards a pre-Conceptual Design Report (pre-CDR) in 2 years with a CDR to follow in ~4 years. A first cost estimate was submitted to the NSAC Subcommittee on EIC cost in January 2015: technical choices and costs were endorsed by the Subcommittee and formed the basis for the NSAC Long Range Plan discussions. The JLEIC is a collider that uses the existing 12 GeV CEBAF as an injector for the electron ring. The ion ring requires a brand new ion complex to produce, accelerate and collide the ions with the electrons. The injector complex consists of a source, ion linac, booster, and collider ring. The electron ring and ion ring are stacked in a common ~2.2 km long figure-8 tunnel. The innovative figure-8 design allows proton and light-ion polarization well above 70%. The optics for the main accelerator components has been designed, and the focus now has turned to studying the correction systems and planning the R&D to validate key needed technologies. The most critical R&D item is high-energy bunched-beam magnetized electron cooling, and we plan to establish feasibility of this novel technology with a series of studies, simulations and targeted experiments that leverage our competence and capabilities and those of our collaborators. Other components of the JLEIC R&D portfolio include innovative superconducting magnets for arcs and interaction regions, and SRF technology for storage and crab cavities. Completing design and R&D towards a conceptual design report consistent with the critical decision timeline for the EIC project and with the requirements for DOE order 413.3 will require appropriate resources to be identified.

The Accelerator Science Core Capability serves DOE Scientific Discovery and Innovation mission numbers 25, 26, and 30 from “Enclosure 1: List of DOE/NNSA/DHS Missions.”

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 7/8 mile racetrack and was built to deliver precise electron beams to three experimental End Stations or Halls simultaneously. Hall A houses two high-resolution magnetic spectrometers of some 100 feet length and a plethora of auxiliary detector systems. Hall B has been the home of the CEBAF large-acceptance spectrometer (CLAS) with multiple detector systems and some 40,000 readout channels. Hall C boasts an 80 feet long high-momentum magnetic spectrometer 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.

The expertise developed in building and operating CEBAF has led to an upgrade that doubled the maximum beam energy (to 12 GeV) and provided a unique facility for nuclear physics research that will ensure continued world leadership in this field for several decades. The $338M project, known as the 12 GeV CEBAF Upgrade, received Critical Decision 0 (CD-0) approval in March 2004 and started construction (CD-3 approval) in September 2008. Approval of CD-4A (Approve Accelerator Project Completion and the Start of Operations) was received in summer 2014, approximately five months ahead of schedule. This upgrade has added one new experimental facility, Hall D, dedicated to the operation of a hermetic large-acceptance detector for photon-beam experiments, known as GlueX. In Hall A, with the existing equipment, and new Hall D the initial 12 GeV science operations have started. The remaining 12 GeV upgrade work, nearing completion, will add a new magnetic spectrometer in Hall C, and convert the Hall B apparatus to allow for the higher-energy and higher luminosity operations. Unique scientific opportunities exist in Hall A with the new Super BigBite Spectrometer (SBS) under construction and with additional dedicated apparatus. This encompasses one-of-a-kind experiments, such as the foreseen MOLLER apparatus to measure the weak charge of the electron and provide a fundamental precision test of the Standard Model. Also foreseen is a general-purpose apparatus such as SoLID, that will allow unprecedented 3D imaging of nucleons in momentum space in the valence quark region, a search to new physics in the 10-20 GeV range complementary to the LHC but unique to a lepto-phobic Z' of 100-200 GeV, and access to the QCD conformal anomaly. Accelerator instrumentation is installed to deliver beams to all four Halls simultaneously.

To enable the experimental program, TJNAF staff is a world leader in the development and operation of high-power cryogenic target systems, and highly-polarized gaseous and solid-state target systems, such as polarized ^{3}He, H and D solid-state polarized target systems, and frozen-spin H and HD-Ice targets. Many of these targets have demonstrated world record performance. In addition, to facilitate a modern and efficient data acquisition system, TJNAF staff have designed and developed an ultra-fast fully pipelined electronics system, with components finding their way into other user facilities such as Brookhaven National Laboratory. This development of advanced data acquisition instrumentation allows for spin-offs such as that described in the bio-medical applications below. TJNAF staff is at present envisioning how with foreseen trends in advanced scientific computing and ultra-fast electronics, we can define the next generation of data readout of large-scale advanced instrumentation, as e.g. relevant for the envisioned SoLID apparatus and a future Electron-Ion Collider.

Nuclear Physics Detector Technology (funded by DOE SC – Nuclear Physics)
Developing and implementing novel detector techniques for the next-generation of nuclear physics experiments supports the main mission of TJNAF. Such techniques allow the development of large-scale particle identification, high-rate tracking and electromagnetic calorimetry systems. Some examples are the Ring-Imaging Cherenkov (RICH) kaon identification detector under construction in collaboration with INFN/Italy, the high-rate Gas Electron Multiplier (GEM)-based tracking systems in collaboration with University of Virginia, and the lead-tungstate (PbW04) based calorimeter development in collaboration with Orsay/France and Catholic University of America. TJNAF is also instrumental in testing position sensitive photomultiplier tubes and the exploration of advance photon detectors such as the silicon photomultipliers (with their first-time ever applicability in a large-scale experiment in GlueX) and a recently initiated collaboration with ANL on development towards an early application of the large area picosecond photon detector. This expertise has contributed to the technology transfer efforts of TJNAF, as described in Section V, such as commercial breast-imaging systems, the development of a new hand-held camera based on silicon photomultipliers and used as an imaging aid to cancer surgeons during surgical procedures, the advance of a SPECT-CT system that has been used in brain studies on awake, unrestrained mice, and development of PhytoPET, a PET imaging methodology for plant research.

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 can support has been increased from three to four. The experimental program is very flexible and dynamic. The simultaneous execution of experiments requires that CEBAF be capable of delivering beam with a large dynamic range in beam currents (nA → 100s of μA) or bunch charge (0.004fC → 0.4pC). Additionally, the experimental user can request beam energies that correspond to 1, 2, 3, 4, 5 or 5.5 pass recirculation. The electron beam is polarized and spin alignment can be optimized for a single user.

Presently, CEBAF is transitioning from the 12 GeV commissioning effort into the "initial years" Physics program. Up to this point, an opportunistic Physics program has been supported during periods when the accelerator commissioning efforts allowed. Extensive superconducting radio frequency (SRF) cavity maintenance was performed during the summer of 2015. Following this maintenance, CEBAF delivered the first 12 GeV to Hall D in December 2015. In addition to achieving the design energy, the beam transverse and longitudinal properties were measured to be within the Physics specification for the initial year's program. Additionally, the 5-th pass RF separator was operated at full design energy simultaneously delivering 50μA of CW beam to Hall A and 100nA CW beam to Hall D. With 418 installed SRF cavities, CEBAF operations represent a significant fraction of the world SRF operating cavity-hour 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.

Additional research and development activities include beam diagnostics, emphasizing non-invasive techniques to monitor and maintain delivery of beams with up to a 1MW of beam power. CEBAF operations also support and enable R&D in Accelerator Physics and efforts from the Engineering and Physics Divisions.

TJNAF staff has developed a substantial ability to conceive and design large accelerator facilities, building upon 6 GeV CEBAF operations and augmented with the ongoing 12 GeV Upgrade. With the completion of the 12 GeV Upgrade, TJNAF will continue its role of the world's premier experimental QCD facility. The ability to use the TJNAF 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 mutual beneficial cross-fertilization between the TJNAF LERF and Nuclear Physics.

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

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.

Using SRF technology based on CEBAF, TJNAF has constructed and operated an advanced Free Electron Laser (FEL). The development of this machine enabled TJNAF to pioneer new Energy Recovery Linac (ERL) technology. In the ERL, the electron beam is re-cycled back through the accelerator out of phase with the accelerating field so the beam energy is returned to the SRF cavities. This power, which would normally be dumped, can represent 90% of the beam power in a high power linear accelerator. TJNAF was the pioneer in developing this technology and the TJNAF FEL remains the highest power system extant. A number of other laboratories are adopting this technology, and ERL technology is likely to become an important contribution to sustainability initiatives at DOE labs.

This IR FEL has demonstrated up to 14 kW of CW average power, making it the most powerful free electron laser in the world. Funds were obtained from the Commonwealth of Virginia to upgrade the beam energy by refurbishing one of the cryomodules. This cryomodule has been completed, met specifications in the test cave, been installed and commissioned in the FEL.

TJNAF is developing a new plan for the future use of this valuable asset. The Lab is using the term LERF (Low Energy Recirculator Facility) to refer to this facility to reflect a broad potential. The present range of the discussion includes future nuclear physics experiments (DarkLight is one example, with construction already partially funded by an NSF MRI grant), characterization of materials using low energy positrons, and R&D on production of medical isotopes using the (gamma, n) reaction. There is also substantial potential for facilitation of commercial development of free electron laser technology, and TJNAF is pursuing this option as well. Overall, TJNAF is developing a plan for future utilization of this facility, which would be of maximum benefit to the mission of the laboratory and of the nation.

TJNAF is also 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). Representing a major upgrade in international X-ray Free Electron Laser capabilities for study of atomic interactions, condensed matter physics, warm dense plasmas, and biological physics, the system will provide intense, coherent 50 fs long photon pulses at up to 5 keV in energy with repetition rates up to 1 MHz. The heart of this facility is a state-of-the-art SRF linac replacing the first 1/3 of the SLAC copper linac providing 4 orders of magnitude improvement in average laser beam intensity. Expertise at TJNAF will facilitate successful construction, installation, and operation of this first SRF-based linac at SLAC. TJNAF will be responsible for construction of half (2 GeV) of the superconducting accelerator as well as the two cryogenic refrigerators. The system will utilize an entirely new nitrogen surface processing to raise the cavity quality factor above 3×10^{10} for substantial savings in electrical power and refrigeration required. Cavities will be fabricated by industry based on the successful XFEL production model but testing and assembly of the cavities into cryomodules, and testing of the cryomodules will be performed by TJNAF and FNAL before installation at SLAC. Once operational, beams from both the existing LCLS accelerator and the new superconducting accelerator will be able to drive two advanced undulators providing exceptional experimental flexibility and doubling the number of users that can utilize the facility simultaneously. The project has obtained CD2/3 approval from DOE.

Another SRF application under consideration is the development of an EUV (Extreme Ultraviolet) FEL for semiconductor lithography. There is increasing industrial interest in this technology, and TJNAF is pursuing the possibility of strategic partnerships with industry to perform the physics and engineering design of an FEL suitable for such an application.

<u>SRF Accelerator Construction (funded by DOE SC, Nuclear Physics)</u>
TJNAF has developed and installed state-of-the-art infrastructure for the design, development, fabrication, chemical processing, and testing of superconducting RF cavities. This complete concept-to-delivery capability is among the best in the world. All of these capabilities have been essential to the development, deployment, commissioning and operation of the 12 GeV CEBAF Upgrade and continue to be essential to refurbish cryomodules from CEBAF which is critical to maintaining the gradient needed to support the Physics programs. The completion of TJNAF's Technology and Engineering Development Facility (TEDF) Project, provided about 40,000 additional square feet of space. This additional space combined with the renovated existing space, also completed as part of the TEDF Project, enhanced and enabled all SRF operational elements to be co-located. The new facility also includes additional experimental assembly space. Integral to the new facility is configurable space that can be adapted to work on different kinds of SRF cavities as TJNAF's portfolio of projects expands. Essential to the SRF program at TJNAF is a five-

year plan to progressively update the SRF processing tools to optimally leverage the building infrastructure to improve processing and achieve a safer and ergonomically better work environment.

The SRF Facility will be used to assemble the cryomodules for the LCLS-II project. Modifications have been made to the configurable space to adapt the Facility for the production of LCLS-II cryomodules. New assembly tooling has been added and integrated with existing tooling to provide a unique and efficient approach to assembling cryomodules for the LCLS-II project. Additionally, new RF capability is being added to the SRF Cryomodule Test Facility (CMTF) to enable acceptance testing of the LCLS-II cryomodules. The new tooling and the upgraded CMTF will first be used to assemble and test the LCLS-II prototype cryomodule in late FY16. Construction of the production cryomodules is planned to start in late FY16 and continue into early FY19.

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 an important resource for the US 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) 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 Masters theses to ensure the continuity of this expertise in the coming decades.

TJNAF's cryogenics group's highly-skilled staff operates and improves the laboratory's three large 2K cryogenic plants (Central Helium Liquefier (CHL) 1 & 2 and the Cryogenic Test Facility (CTF)) that support CEBAF operations and SRF production. Including the existing Endstation Refrigerator (ESR), the overall refrigerator count has increased to five operational plants (adding CHL2 and Hall D) as the 12 GeV Upgrade came on-line. The large 2K plants utilize patented cryogenic cycles developed by TJNAF that increase efficiencies by up to 30% as compared to what has traditionally been available from industry. Extensive operational experience has allowed the group to develop controls technologies and techniques that permit year round, unattended operations that drastically decrease staffing needs required for operations of this magnitude. Additionally, stepwise improvements have been made on the mechanical systems, primarily the warm compressors, which significantly extend their lifetimes between major maintenance cycles and decrease input power needs. The combination of cycle and mechanical improvements has decreased the input power requirements for equivalent refrigeration at 2K by 1.4MW for CHL2 as compared to CHL1.

The 12 GeV Upgrade has benefitted from improvements that were first demonstrated at NASA's Johnson Space Center where both the cycle technology and improvements on the warm compressor system were applied to a 12.5kW refrigerator at 20K for a space effects chamber to test the James Webb telescope. Prior to this, the cycle technologies were applied to other DOE facilities, notably to the Relativistic Heavy Ion Collider (RHIC) at Brookhaven.

The group is presently responsible for designing, specifying, procuring and commissioning the CHL for FRIB, based on the successful CHL2 design for the 12 GeV Upgrade.

Additionally, responsibilities for specifying and procuring the two LCLS-II refrigerators have been undertaken by the group.

Nationally, this group is a premier source of cryogenic engineering and design for large helium refrigerators, filling a void in commercially available services. TJNAF's cryogenics group is consulted when project needs for a large helium refrigerator system arise (>2kW @ 4K or equivalent capacity) to ensure effective design results and highly efficient operation.

The Large Scale User Facilities/Advanced Instrumentation Core Capability serves DOE Scientific Discovery and Innovation mission numbers 24, 26 and 30 from Enclosure 1: List of DOE/DHS Missions.

IV. Science Strategy for the Future/Major Initiatives

With the imminent completion of its 12 GeV upgrade project, TJNAF is well positioned to continue its world leadership in hadronic nuclear physics. The upgraded CEBAF along with the enhancements in experimental equipment offer many opportunities for major advances in our understanding of the substructure of the nucleon, the fundamental theory of the strong force QCD, aspects of nuclear structure relevant to neutron star physics, and the (lack of?) completeness of the standard model of particle physics. The new capabilities will enable unique 3D mapping of the valence quarks and extend the earlier studies to comprehensively describe the valence quark momentum and spin distributions in nucleons and nuclei. New opportunities to discover heretofore unobserved hadron states predicted by quantum chromodynamics will become available. Higher precision measurements of the weak couplings of elementary particles will be accessible through measurements of parity violating asymmetries. Full exploitation of the upgraded facility will require construction of new experimental equipment, and TJNAF has two proposed MIE projects (MOLLER and SoLID) that have received strong endorsement from the nuclear physics community.

The 2015 NSAC Long Range Plan (LRP) strongly supports the robust operation of CEBAF necessary to deliver the long-awaited science program: "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." In addition, the LRP recommends "increasing investment in small-scale and mid-scale projects and initiatives" and we hope this can help realize the new MIE projects at TJNAF.

The 2015 LRP recommends "high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB." TJNAF is well positioned to provide the US nuclear physics community with a highly capable option for an EIC based on the cost-effective use of CEBAF as a source of highly polarized 12 GeV electrons. We continue to develop our novel figure eight collider ring design, known as JLEIC, and believe this represents an excellent opportunity for the US nuclear physics community and for the long-term future of TJNAF.

The LRP identifies a theory initiative, "new investments in computational nuclear theory that exploit the U.S. leadership in high-performance computing", that offers an opportunity to greatly advance progress in Lattice QCD calculations. TJNAF will strive to leverage its unique capabilities in high performance computing to address topics in QCD and other areas of computational science.

TJNAF possesses key capabilities and competencies in accelerator science and in the application of the modern accelerator technologies. Continued development of these capabilities is one of the major initiatives integral to this strategic plan. In addition to providing world leading facilities and expertise to meet the identified needs of the nuclear physics research community, TJNAF has identified collaborative roles that it can play in the provision of facilities elsewhere associated with the Office of Science (e.g., Basic Energy Sciences and High Energy Physics) and other agencies.

TJNAF is continuing to develop expertise in advanced computer science, visualization and data management. TJNAF is a world leading center of Lattice QCD (LQCD) computing, and extending this competency to the experimental program complements the lab's mission to maximize the scientific productivity of the nuclear physics community. TJNAF will continue to build on these developments with the goal of establishing this core capability in the near future.

V. Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

Thomas Jefferson National Accelerator Facility is located on a 169 acre federal reservation. North of the DOE-owned land is an eight acre parcel referred to as the Virginia Associated Research Campus (VARC) which is owned by the Commonwealth of Virginia and leased to SURA which, in turn, sub-leases five acres of this property for $1 dollar per year to DOE for use in support of the Lab. SURA owns 37 acres adjacent to the TJNAF site, where it operates a 42-room Residence Facility at no cost to DOE. At the close of FY 2015, approximately 686 Staff FTEs, 24 Joint Appointments, 21 Postdoctoral Researchers, 7 Undergraduate, and 37 Graduate Students were occupying site facilities. Each day, TJNAF hosts on average, 100 users from the United States and around the world.

As of September 30, 2015, TJNAF consists of 66 DOE-owned buildings (867,028 SF), and four real-property trailers (9,056 SF) totaling 876,084 SF, plus roads and utilities. Additionally, the Lab leases office and shop buildings (37,643 SF) from the Commonwealth of Virginia, office and lab space (26,869 SF) from the City of Newport News located in the Applied Research Center (ARC) adjacent to the TJNAF campus, a temporary office trailer (469 SF), and 9,755 SF of off-site leased storage space totaling 74,267 SF of leased space. The Lab continues efforts to consolidate leased and trailer office space with the elimination of 8,964 SF or leased and owned trailers in FY 2015 and the planned elimination of 6,596 SF of trailers in FY 2017.

Table 1 shows the results of recent Lab Operations Board (LOB) sponsored condition assessment. The Lab has completed the condition assessment of all facilities. A total of 60 of the 70 DOE owned and leased buildings were found to be adequate, 9 substandard, and one (1) inadequate. Of the 5 owned and leased trailers assessed, four were found to be substandard and one (1) inadequate. Of the 36 other structures and facilities (including OSF 3000 series assets) assessed, 30 were found to be adequate, 5 substandard, and one (1) inadequate. A total of 4,920 SF of real property trailers are currently underutilized and plans are being developed to eliminate this space. There are currently no excess facilities at the Lab and none are expected within the next 10 years. Currently, there are 55 aged shipping containers (17,000 SF) used for storage, a reduction of six containers over the last year. An additional 17 shipping containers are scheduled to be removed by the end of FY17.

Table 1: Facility Assessments and Excess Facilities

	Adequate		Substandard		Inadequate	
	Count	SF	Count	SF	Count	SF
Other Structures and Facilities (OSFs)	25	N/A	5	N/A	1	N/A
Mission Unique Facilities	37	328,650	0	0	0	0
Non-Mission Unique Facilities	29	322,183	12	291,673	2	4,157
	Count	SF				
Number and square footage of excess facilities	0	0				
Square footage of underutilized space in non-excess facilities.	2	4,920				

A current copy of the Land Use Plan can be can be found on the TJNAF Facilities Management website. The Lab has leased 9,275 SF of warehouse space in FY16 in support of Lab efforts on the LCLS2 project at SLAC. The lease for the Service Support Center (34,739 SF) and Facilities Shops building (2,904 SF) was extended in FY15 from September 30, 2017 to September 30, 2045. The current lease of 26,869 SF in Applied Research Center expires September 30, 2017 and will be renegotiated in FY16.

Campus Strategy

The objectives for the 2026 TJNAF Lab Campus plan are:

- Construct and upgrade facilities and utilities to fully support mission objectives.
- Replace substandard temporary and leased space with permanent facilities.
- Increase energy efficiency and support DOE sustainability goals and requirements.
- Accommodate a Jefferson Lab Electron Ion Collider (JLEIC)

Infrastructure investments over the last ten years have provided more than 264,000 SF of new facilities (Experimental Hall D, Technology and Engineering Development Building, CEBAF Center Wing F, General Purpose Building, and Experimental Staging Building. This construction includes the Technology and Engineering Development Facility project was completed providing the Lab a new 74,000 SF Technology and Engineering Development (TED) Building, a 47,000 SF Test Lab Addition, as well as a renovated Test Lab, (a 50 year-old previous NASA facility), funded by the Science Lab Infrastructure (SLI) program. In addition the Accelerator Site electrical distribution system primary and secondary feeders and cooling towers have been replaced as part of the SLI funded Utilities Infrastructure Modernization (UIM) project. The remaining portions of the UIM project work will be completed in FY17. Through these projects, the campus has been transformed into a walking-campus, with many sustainability features incorporated. Current critical infrastructure gaps shown in Table 1 below have been identified through the latest Lab condition assessment. These gaps need to be closed to enable a fully mission-capable campus.

Infrastructure Gaps

Infrastructure Component	Gaps and Impacts
Cryogenics	Hall and Cryogenics Test Facility cryogenics are unreliable due to age of equipment
Office and meeting and collaboration space	Temporary / leased office space for scientists, engineers, and support staff is substandard or inadequate Lack of modern meeting capabilities negatively impacts collaboration
High bay fabrication/experimental equipment assembly	High bay fabrication space is over-utilized Layout of existing experimental equipment assembly space is not functional and is not fully utilized for its intended purpose due to storage and other functions occupying the space
Shipping, Receiving, and Warehouse	Permanent warehouse space is over-utilized Temporary / leased storage space is substandard or inadequate Shipping and receiving functions currently occupy space which was intended for experimental equipment assembly
Sustainability	Numerous facilities are currently inefficient and do not meet HPSB or sustainability guiding principles
Site Utilities	Fire protection potable water, sanitary sewer, and storm water systems all lack capacity to support operations

Prioritized Infrastructure Needs

- **Cryogenics** (SLI/SLI-GPP /Lab GPP) - The Lab's highest priority is to upgrade its cryogenic infrastructure to ensure reliability and capacity for future mission needs. Operation of the Cryogenics Test Facility (CTF) is critical to support testing for the cryomodule cavity components produced by the Superconducting Radio Frequency (SRF) Institute for Jefferson Lab, other Labs in the Office of Science complex as well as SPP. Installation of a new 4K cold box and controls under the UIM project will provide additional CTF 4K capacity. The new cold box will arrive in FY16 with installation complete in FY17. Additional investments are needed to increase 2K capacity and overhaul/replace aging equipment related to 2K operations. These investments are planned by the Lab following delivery of LCLS2 cryomodules in support of anticipated future SRF projects for the DOE National Lab complex.

  A separate and unrelated issue of reliability of the 40+ year old End Station Refrigerator (ESR) plant serving three of the four experimental halls exists due to the lack of critical spare parts that are no longer manufactured or available. The replacement of the ESR will consist of a refurbished and installed surplus 4K refrigerator from the Superconducting Super Collider (SSC) project with the associated distribution system, utilities and controls.

- **Communications** (SLI) –Subsurface communications systems have insufficient capacity to meet existing and future needs. The UIM project currently underway will correct both of these identified gaps. Estimated completion is in FY 2016.

- **Computer Center Efficiency Upgrade and Consolidation** (SLI and Lab GPP) – Computer Center cooling and power improvements are now underway under the UIM project and will provide needed data center cooling and uninterruptable power utility capacity to support lab computing needs. This project is scheduled for completion in FY16. HVAC improvements under the UIM project will provide core computing hot and cold aisle configuration to allow consolidation of the Lab computer and data centers. A Lab funded GPP project will provide high performance computing hot and cold aisle configuration to reduce the Power Utilization Efficiency (PUE) to assist in the Lab meeting DOE Computer Center power efficiency goals. Estimated completion is in FY 2017.

- **EHS&Q Offices** (Lab GPP) – Construction of 12,000 SF of energy efficient office and technical space to house the EHS&Q Division will consolidate the staff currently residing throughout the Lab in a combination of overcrowded, aging trailers and leased space. Project will allow elimination of a trailer and reduction of long term leased space. Construction is underway and is scheduled for completion in FY 2017.

- **CEBAF Center Renovation** (SLI-GPP) – The condition of the 1988 original structure has been rated as substandard. The mechanical system in this portion of the building has exceeded its service life and has experienced multiple failures. Replacement of major pieces of HVAC equipment is required in the near future. Replacement of the HVAC system will require vacating the portion of the building under renovation and removal and replacement of the ceilings. Lab staff is currently overflowing into common areas such as corridors, storage rooms, and copy areas creating egress issues and safety concerns. Reconfiguration of the affected spaces is needed to alleviate many of these conditions. Renovation will meet high performance building standards. The renovation will be executed one wing per year plus the atrium/auditorium in the fourth year using a combination of Lab GPP and facility maintenance funds.

- **CEBAF Center Office Expansion & Modernization** (SLI) – The current site at TJNAF accommodates the staff needed for ongoing operations. However, existing office facilities are inadequate, and impede progress. Currently over 22,200 SF of office space and meeting rooms are leased in the Applied Research Center owned by the City of Newport News to accommodate staff. A portion of this leased space is occupied by the Center for Advanced Studies of Accelerators (CASA). It is important for CASA to be co-located with Theory, Physics, and Accelerator divisions. The scientific community is growing and there is limited flexible, reliable, and efficient collaboration space: large meeting rooms have to be rented off-site for large meetings and collaborations. In addition, with the Auditorium and storage space for TJNAF's educational program located in other buildings across the site, work-flow from one building to another is inefficient. The ARC building is also rated as substandard and needs a sustainability renovation to reduce energy consumption towards DOE goals. A long term infrastructure initiative is to house Lab staff and operations within DOE owned space. These functions would fit well within an office addition to CEBAF Center. The Lab also lacks adequate meeting space to host numerous Lab meetings and collaborations. Inclusion of meeting space along with office space is the proposed SLI project. The scope includes 83,000 SF of office and meeting space. Construction will meet high performance building standards. The preliminary cost and time estimate for this element of work is $66M and three years including design. The project could eliminate up to 55,000 SF of leased space while providing the needed meeting space to support ongoing programs.

- **Physics Technical Support Building** (Lab GPP) **-** Currently technical staff and equipment supporting the operations for all four experimental halls are spread among several buildings on the campus and accelerator site. This project will provide 12,000-14,000 SF of technical and high bay space for fabrication and improves efficiency by consolidating these functions and locating them in closer proximity to the experimental halls. Additionally, the project resolves space shortages of Engineering Division technical and high bay fabrication space as well as provides swing space required to conduct the EEL Renovation project. Construction will meet high performance building standards.

- **Water Reuse Capture and Tank** (Lab GPP) – Installation of rain water collection system and storage tank for use in cooling towers and for limited irrigation to reduce potable use to assist in meeting water sustainability goals.

- **Shipping and Receiving/Property Warehouse/Facility Operations** (Lab GPP) - Existing high bay and technical space in the Experimental Equipment Lab (EEL) is not fully utilized due to its required use for storing materials and equipment and for conducting shipping and receiving activities. Construction of a shipping, receiving and modern warehouse would allow improved use of the much needed high bay and technical space and allow elimination of 61 shipping containers for storage. Completion of this project is needed to create necessary swing space for the renovation of the EEL and to provide long term experimental setup and support space. The facility will also house the facilities maintenance shops currently in the (2,904 SF) Forestry Building leased from the Commonwealth of Virginia. This building is in substandard condition and needs to be replaced. The project will be constructed in phases based on Lab annual GPP funding. The facilities operations and maintenance shop will be the first phase. The project will be constructed in phases beginning with expansion of the Central Material Storage Area.

- **Experimental Equipment Lab Renovation** (GPP Cross-cut) - Renovation of the Experimental Equipment Lab building is needed to increase the functionality and utilization of the high bay space as well as to correct inadequate mechanical systems, improve efficiency of the building envelop and correct code deficiencies. The scope of the work will require vacating large portions of the buildings during the periods of construction. Functions will be temporarily relocated to the newly constructed Shipping and Receiving Warehouse to minimize the impact on operations.

- **Road Improvement** (Lab GPP) Reconfiguration and improvements of Lab entrance roads to improve site coordination with adjacent land development.

- **Site Storm Water Management** (Lab GPP) **–** Installation of a storm water retention pond to meet increasing regulatory requirements.

- **Accelerator Storage Building** (Lab GPP) **–** Currently storage to support SRF and other accelerator operations is scattered in numerous storage containers as well as off site in leased space. Onsite efficient storage will improve efficiency in accessing and management of materials. Project provides 6,000 to 8,000 SF of storage space for accelerator specific materials and assemblies and will reduce use of shipping containers and offsite leases.

The $29.9M FY 2014 UIM project will, among other things, resolve the above process cooling gaps with the replacement of aging cooling towers and electrical distribution and communication through the replacement of electric cabling and the installation of additional data cabling and equipment. The UIM project will eliminate more than $2.7M of deferred maintenance. The remaining gaps can be closed through a combination of SLI, SLI-GPP, and NP-GPP funding totaling $85.3M over the next ten years. These projects will eliminate more than $3.7M of deferred maintenance. Additional estimated funding of $2.5M is expected through a Utility Energy Services Contract to implement energy conservation measures.

The Lab's Asset Condition Index is 0.985, a rating of excellent. The Lab has averaged 1.5% maintenance and repair expenditures over the last 5 years. During this period the deferred maintenance has decreased from $15.8M to $5.9M through SLI and GPP capital investment and elimination of temporary facilities. Electrical and mechanical preventative maintenance costs have decreased through the conversion from contract to in-house resources. Enclosure 2 is the Integrated Facilities and Infrastructure Crosscut Data Table showing planned Lab maintenance and deferred maintenance projections. Through the planned investments we project a continued decrease in the values of deferred maintenance.

The Campus Land Use Plan is shown as Enclosure 3. Enclosure 2 shows the investments needed to implement this Campus Plan. The plan consists of a mix of SLI, infrastructure crosscut, NP-GPP, and alternative financing. NP-GPP funding levels shown were based on the annual NP budget guidance. It is not anticipated there will be any inadequate facilities at the end of the period.

The fully executed campus plan supports:

- 4 Experimental Halls fully operational
- 4-Hall multiplicity
- 35 weeks of research
- CEBAF reliability >85%
- Partner/lead on major SRF-based accelerator construction projects
- Ability to exploit/leverage capabilities of the Low Energy Recirculator Facility (LERF) (Isotopes, Dark Light, Industry and University-led research)

<u>Computing Infrastructure</u>

The Chief Information Officer (CIO) is a member of the Laboratory's Leadership Team and is responsible for providing information from the Laboratory's Information Technology (IT) systems to Laboratory management, the overall IT vision, the Information Architecture for computing and IT and oversight for cyber security. Working with Laboratory Leadership and key stakeholders, the CIO defines the governance process for IT at the Laboratory. Further, the CIO chairs the IT Steering Committee, which is comprised of members engaged in IT activities from across the Laboratory. The committee strategically steers the use of IT, evaluates the Laboratory's IT Strategic plans and architectures and reviews priorities. The CIO also meets individually with Division Heads and Laboratory Leadership to receive feedback on IT services and investments and to ensure IT activities and priorities are aligned with the priorities of the Laboratory and individual divisions.

To ensure that all IT acquisitions are in line with the Laboratory's IT Strategic plan and compatible with the Laboratory's IT environment, all IT purchase requisitions require approval of the CIO/IT Division. Additionally, credit card purchases are limited to a list of preapproved software applications and IT supplies. To reduce costs and simplify the desktop computing environment, preapproved desktop and laptop systems are made available for purchase from the Laboratory's stockroom.

Commodity IT at TJNAF is provided and managed by the IT Division under the supervision of the CIO. The Division provides IT services and support for scientific computing, business and central computing, networking, telecommunications and cyber security.

The primary R&D acquisitions have four major components, devices to control and monitor the accelerator complex (1) and experimental halls (2) and scientific computing to support the experimental program (3) and LQCD (4).

Plans for IT acquisitions are vetted by Laboratory management, including the CIO, as part of the annual lab planning process. During budget execution, purchase requisitions above a threshold are reviewed in detail by senior IT managers and recommended for approval to the CIO.

Major acquisitions for the controls systems were part of the 12 GeV Upgrade project and are now in a maintenance phase.

Acquisitions for scientific computing for the experimental program include hardware components (storage, compute facilities and networking), software licenses, and dedicated labor to administer the systems. Hardware is budgeted for in a process that takes into account the accelerator running schedule, an assessment of projected computational and storage requirements and the age and capacity of the installed plant. Every two years, the acquisition plan is reviewed as part of an external review of scientific computing. The yearly acquisitions are approved by the head of the Physics Division, reviewed by IT staff and approved by the CIO.

TJNAF operates high performance computing clusters as part of the national computational infrastructure for lattice quantum chromodynamics (QCD) established by the Department of Energy. The US National Computing Facility for Lattice Gauge Theory manages the acquisition and operation of computer facilities at three labs, including Jefferson Lab. The project is managed by Fermi National Accelerator Laboratory and has a formal project management plan that specifies concurrence by Laboratory CIOs.

Tables 2 and 3 describe existing R&D and Commodity IT systems. Tables 4 and 5 describe planned R&D and Commodity IT system acquisitions.

Table 2: Existing R&D Systems

Component	Description	Primary Funding Source	Costs ($M)	Lifecycle State	Notes
Local and Wide Area Networking	Wide –Area and Site-wide networking to the wall excluding the Accelerator.	Indirect	1.128	Stable	Wide-area networking is achieved in collaboration with local universities and ESnet.
Mass Storage	Mission specific investment for central scientific mass storage systems (tape libraries and high speed tape, disk cache systems).	Direct	0.706	Stable	
Cluster Computing	Mission specific investment for centrally provided scientific compute facilities for experimental data analysis, theory analysis, clusters, interactive analysis services, and all associated software.	Direct	1.453	Stable	
Data Acquisition Systems	Mission specific investment for physics experiment data acquisition systems and development	Direct	0.465	Stable	Costs includes an $250K upgrade for Hall B in FY15
Accelerator Controls	Mission specific investment for providing the controls systems for operating CEBAF (Continuous Electron Beam Accelerator Facility)	Direct	0.520	Stable	

Commodity IT is conventional information technology resources that support the operational business of the laboratory. This includes business systems such as Financial, HR, Procurement, Safety and Health, etc.; end user stations, telecommunications, cyber security. The total Cost of systems includes any licenses, hardware, maintenance or user support associated with system or software.

Table 3: Existing Commodity IT Systems

Component	Description	Primary Funding Source	Costs ($M)	Lifecycle State	Notes
Business Computing Systems	Systems, software, applications, development and support for the Laboratory's business systems, such as Finance, Procurement, Human Resources, Occupational Health, and Training organizations.	Indirect	1.499	Stable	Leverages the central computing environment to minimize costs
Central Computing Systems	Compute servers, central login servers, directory and name services, domain servers, etc. Computing services and systems that make up Jefferson Lab's groupware and collaborative computing environment. Email, calendaring, pda support, video and audio conferencing.	Indirect	2.148	Stable	Central Computing environment makes extensive use of virtual machine technology
Desktop Support	System for help desk, printer support, all related hardware and software.	Indirect	0.500	Stable	
Telecommunications	Telephone, cell phone services, voice mail, cell phones, pagers, and other telecommunications services	Indirect	0.575	Stable	Telephone system is a VoIP system
Cyber Security	Maintain the laboratory's Cyber Security Program reducing SC cyber security vulnerabilities to acceptable levels. Implement FISMA, DOE & government-wide requirements and policies for cyber security.	Mix	1.014	Stable	Contribute Indirect dollars to the Cyber Security budget so that the laboratory can maintain an appropriate program

Table 4: Planned Acquisitions of R&D Systems

Component	Description	FY 2016 Planned Spending	FY 2017 Projected Spending	FY 2018 Projected Spending
Mass Storage	Mission specific investment for central scientific mass storage systems (tape libraries and high speed tape, disk cache systems).	0.300	0.300	0.600
Cluster Computing	Mission specific investment for centrally provided scientific compute facilities for experimental data analysis, theory analysis, clusters, interactive analysis services, and all associated software.	0.650	1.150	0.900
Data Acquisition Systems	Mission specific investment for physics experiment data acquisition systems and development		0.200	

Table 5: Planned Acquisitions of Commodity IT Systems

Component	Description	FY 2016 Planned Spending	FY 2017 Projected Spending	FY 2018 Projected Spending
N/A				

Enclosure 1: List of DOE/NNSA/DHS Missions

Scientific Discovery and Innovation (SC)

ASCR

1. To develop mathematical descriptions, models, methods, and algorithms to accurately describe and understand the behavior of complex systems involving processes that span vastly different time and/or length scales.

2. To develop the underlying understanding and software to make effective use of computers at extreme scales.

3. To transform extreme scale data from experiments and simulations into scientific insight.

4. To advance key areas of computational science and discovery that further advance the missions of the Office of Science through mutually beneficial partnerships.

5. To deliver the forefront computational and networking capabilities to extend the frontiers of science.

6. To develop networking and collaboration tools and facilities that enable scientists worldwide to work together.

BES

7. Discover and design new materials and molecular assemblies with novel structures, functions, and properties, and to create a new paradigm for the deterministic design of materials through achievement of atom-by-atom and molecule-by-molecule control

8. Conceptualize, calculate, and predict processes underlying physical and chemical transformations, tackling challenging real-world systems – for example, materials with many atomic constituents, with complex architectures, or that contain defects; systems that exhibit correlated emergent behavior; systems that are far from equilibrium; and chemistry in complex heterogeneous environments such as those occurring in combustion or the subsurface

9. Probe, understand, and control the interactions of phonons, photons, electrons, and ions with matter to direct and control energy flow in materials and chemical systems

10. Conceive, plan, design, construct, and operate scientific user facilities to probe the most fundamental electronic and atomic properties of materials at extreme limits of time, space, and energy resolution through x-ray, neutron, and electron beam scattering and through coherent x-ray scattering. Properties of anticipated new x-ray sources include the ability to reach to the frontier of ultrafast timescales of electron motion around an atom, the spatial scale of the atomic bond, and the energy scale of the bond that holds electrons in correlated motion with near neighbors

11. Foster integration of the basic research conducted in the program with research in NNSA and the DOE technology programs, the latter particularly in areas addressed by Basic Research Needs workshops supported by BES in the areas of the hydrogen economy, solar energy utilization, superconductivity, solid-state lighting, advanced nuclear energy systems, combustion of 21st century transportation fuels, electrical-energy storage, geosciences as it relates to the storage of energy wastes (the long-term storage of both nuclear waste and carbon dioxide), materials under extreme environments, and catalysis for energy applications.

BER

12. Obtain new molecular-level insight into the functioning and regulation of plants, microbes, and biological communities to provide the science base for cost-effective production of next generation biofuels as a major secure national energy resource
13. Understand the relationships between climate change and Earth's ecosystems, develop and assess options for carbon sequestration, and provide science to underpin a fully predictive understanding of the complex Earth system and the potential impacts of climate change on ecosystems
14. Understand the molecular behavior of contaminants in subsurface environments, enabling prediction of their fate and transport in support of long term environmental stewardship and development of new, science-based remediation strategies Understanding the role that biogeochemical processes play in controlling the cycling and mobility of materials in the subsurface and across key surface-subsurface interfaces in the environment enabling the prediction of their fate and transport.
15. Make fundamental discoveries at the interface of biology and physics by developing and using new, enabling technologies and resources for DOE's needs in climate, bioenergy, and subsurface science
16. Operate scientific user facilities that provide high-throughput genomic sequencing and analysis; provide experimental and computational resources for the environmental molecular sciences; and resolve critical uncertainties about the role of clouds and aerosols in the prediction of climatic process

FES

17. Advance the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source

18. Support the development of the scientific understanding required to design and deploy the materials needed to support a burning plasma environment

19. Pursue scientific opportunities and grand challenges in high energy density plasma science to explore the feasibility of the inertial confinement approach as a fusion energy source, to better understand our universe, and to enhance national security and economic competitiveness

20. Increase the fundamental understanding of basic plasma science, including both burning plasma and low temperature plasma science and engineering, to enhance economic competitiveness, and to create opportunities for a broader range of science-based applications

HEP

21. Understand the properties and interactions of the elementary particles and fundamental forces of nature from studies at the highest energies available with particle accelerators

22. Understand the fundamental symmetries that govern the interactions of elementary particles from studies of rare or very subtle processes, requiring high intensity particle beams, and/or high precision, ultra-sensitive detectors.

23. Obtain new insight and new information about elementary particles and fundamental forces from observations of naturally occurring processes -- those which do not require particle accelerators

24. Conceive, plan, design, construct, and operate forefront scientific user facilities to advance the mission of the program and deliver significant results.

25. Steward a national accelerator science program with a strategy that is drawn from an inclusive perspective of the field; involves stakeholders in industry, medicine and other branches of science; aims to maintain core competencies and a trained workforce in this field; and meets the science needs of the SC community

26. Foster integration of the research with the work of other organizations in DOE, in other agencies and in other nations to optimize the use of the resources available in achieving scientific goals

NP

27. To search for yet undiscovered forms of nuclear matter and to understand the existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe

28. Understand how protons and neutrons combine to form atomic nuclei and how these nuclei have emerged during the 13.7 billion years since the origin of the cosmos.

29. Understand the fundamental properties of the neutron and the neutrino, and how these illuminate the matter-antimatter asymmetry of the universe and physics beyond the Standard Model.

30. Conceive, plan, design, construct, and operate forefront national scientific user facilities for scientific and technical advances which advance the understanding of nuclear matter and result in new competencies and innovation. To develop new detector and accelerator technologies that will advance NP mission priorities

31. Provide stewardship of isotope production and technologies to advance important applications, research and tools for the nation.

32. Foster integration of the research with the work of other organizations in DOE, such as in next generation nuclear reactors and nuclear forensics, and in other agencies and nations to optimize the use of the resources available in achieving scientific goals.

WDTS

33. Increase the pipeline of talent pursuing research important to the Office of Science

34. Leveraging the unique opportunities at DOE national laboratories to provide mentored research experiences to undergraduate students and faculty)

35. Increase participation of under-represented students and faculty in STEM programs

36. Improve methods of evaluation of effectiveness of programs and impact on STEM workforce

Energy Security (ES)

1. Supply - Solar

2. Supply - Nuclear

3. Supply - Hydro

4. Supply - Wind
5. Supply - Geothermal
6. Supply - Natural gas
7. Supply - Coal
8. Supply - Bioenergy/Biofuels
9. Supply - Carbon capture and storage
10. Distribution - Electric Grid
11. Distribution - Hydrogen and Gas Infrastructure
12. Distribution - Liquid Fuels
13. Use - Industrial Technologies (including efficiency and conservation)
14. Use - Advanced Building Systems (including efficiency and conservation)
15. Use - Vehicle Technologies (including efficiency and conservation)
16. Energy Systems Assessment/Optimization

Environmental Management (EM)

1. Facility D&D
2. Groundwater and Soil Remediation
3. Waste Processing

National Security (NNSA)

1. Stockpile Stewardship and Nuclear Weapons Infrastructure
2. Nonproliferation
3. Nuclear Propulsion

Homeland Security (HS)

1. Border Security
2. Cargo Security
3. Chemical/Biological Defense
4. Cyber Security
5. Transportation Security
6. Counter-IED
7. Incident Management
8. Information Sharing
9. Infrastructure Protection
10. Interoperability
11. Maritime Security
12. Human Factors

Enclosure 2 – Integrated Facilities and Infrastructure Crosscut Data Table

Thomas Jefferson National Accelerator Facility (Jefferson Lab)

Integrated Facilities and Infrastructure (IFI) Crosscut Data Table:

(Dollars in Thousands)

Maintenance and Repair (For Federally Owned Facilities)	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Predictive, Preventive and Corrective M&R (incl. DM Reduction)													
Direct Funded	114	71	73	75	78	80	82	85	87	90	93	95	98
Indirect Funded	5,963	5,900	6,360	6,550	6,750	6,950	7,200	7,700	8,000	8,250	8,520	8,780	9,050
Total Predictive, Preventive and Corrective M&R	**6,077**	**5,971**	**6,433**	**6,625**	**6,828**	**7,030**	**7,282**	**7,785**	**8,087**	**8,340**	**8,613**	**8,875**	**9,148**
Operation, Surveillance & Maintenance (OS&M) of Excess and Unutilized Facilities													
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 and Unutilized Facilities	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Maintenance and Repair	**6,077**	**5,971**	**6,433**	**6,625**	**6,828**	**7,030**	**7,282**	**7,785**	**8,087**	**8,340**	**8,613**	**8,875**	**9,148**
Deferred Maintenance Projection	5,891	6,141	6,196	6,027	6,277	6,527	6,777	4,784	4,424	4,674	4,924	5,174	5,424

Other	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Replacement Plant Value Projection ($000)	397,343	411,416	423,759	436,472	449,566	463,053	480,270	513,887	531,528	549,698	567,689	584,719	603,218
Building Area (Thousands GSF)	876	876	888	888	888	888	900	970	977	984	984	984	1,000
Excess and Unutilized Facilities (Thousands GSF)	0	0	0	0	0	0	0	0	0	0	0	0	0

Enclosure 2 (cont'd) - Laboratory Investments

Thomas Jefferson National Accelerator Facility (Jefferson Lab)

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Objectives:

Objective 1	Construct and upgrade facilities and utilities to fully support mission objectives
Objective 2	Replace substandard temporary and leased space with permanent facilities
Objective 3	Increase energy efficiency and support DOE sustainability goals and requirements

Planned Capital Investments: (Asterisk denotes infrastructure crosscut proposed project)

(Dollars in Thousands)

Project	Total	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Activity Type	Funding Program	Core Capability
EHS&Q Building	**2,150**	2,000		150											GPP	NP	EI
Core Computing Sustainability	**2,250**		2,000	250											GPP	NP	EI
Cryogenics Equipment Upgrade	**5,650**			1,600	2,250	1,800									GPP	NP	LSUF
Physics Technical Support Building	**5,000**					1,450	3,300	250							GPP	NP	LSUF
Central Material Storage Area Expansion	**1,800**							1,800							GPP	NP	LSUF
Shipping & Receiving Building	**2,120**							950	1,170						GPP	NP	EI
Facilities Operations Building	**4,000**								1,150	2,000	850				GPP	NP	EI
Water Reuse Capture & Tank	**2,000**									390	1,610				GPP	NP	EI
Lab Road Improvements	**2,000**											2,000			GPP	NP	EI
Property Storage Building	**2,535**											535	2,000		GPP	NP	LSUF
Site Stormwater Management	**2,000**												610	1,390	GPP	NP	EI
Accelerator Storage Building	**1,300**													1,300	GPP	NP	AST
Cryogenics Infrastructure Modernization – Exp. Halls *	**8,000**			8,000											GPP	SLI	LSUF
CEBAF Center Renovation - Wings A, B, C *	**9,800**				9,800										GPP	SLI	NP
EEL Modernization *	**9,900**								9,900						GPP	SLI	LSUF
CEBAF Center Office Expansion &	**62,000**				4,700	30,000	27,300								--	SLI	NP
UESC	**2,500**		2,500												--	--	EI

Core Capabilities

EI Enabling Infrastructure

LSUF Large Scale User Facilities/Advanced Instrumentation

AST Accelerator Science and Technology

NP Nuclear Physics

Enclosure 3 – Campus Land Use Plan