Department of Energy Laboratory Plan –TJNAF

June 6, 2011

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 utilize its unique Continuous Electron-Beam Accelerator Facility (CEBAF) 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 further development of the superconducting radio-frequency (SRF) technology utilized for CEBAF. This technology is the basis for an increasing array of applications at TJNAF, other DOE labs, and in the international scientific community. At TJNAF, the advancement of SRF technology has enabled the 12 GeV upgrade project to double the energy of CEBAF which is presently underway. In addition, it facilitated the development of TJNAF's Free Electron Laser (FEL) and Energy Recovery Linac (ERL), key technologies for future state-of–the–art light sources. TJNAF's present core capabilities are: experimental, theoretical and computational Nuclear Physics; Accelerator Science; Applied Nuclear Science and Technology; and Large Scale User Facilities/Advanced Instrumentation.

The Lab has an international user community of 1,356 researchers whose work has resulted in scientific data from 172 experiments to date, 289 Physics Letters and Physical Review Letters publications and 889 publications in other refereed journals at the end of FY 2010. Collectively, there have been over 30,000 citations for work done at Jefferson Lab.

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 (25 in FY 2010; 419 to date, 204 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, VA

Type: Program-Dedicated Lab

Contract Operator: Jefferson Science Associates, LLC (JSA)

Responsible Site Office: Thomas Jefferson Site Office

Website: http://www.jlab.org

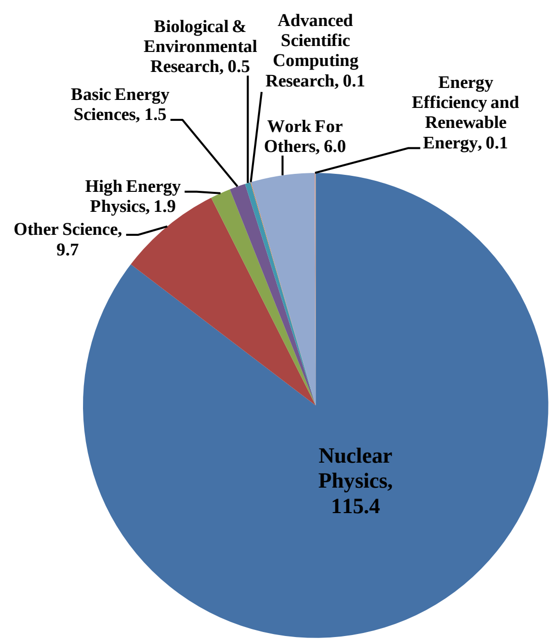
Physical Assets:

- 169 acres and 79 buildings and trailers
- 703,582 GSF in buildings and trailers
- Replacement Plant Value (RPV): $316.9M
- Deferred Maintenance: $15.6M
- Asset Condition Index (ACI):
  - Mission Critical 0.96 (Good)
  - Mission Dependent 0.84 (Fair)
  - Asset Utilization Index: 97.4

Human Capital:

- 763 FTEs (at 3/15/11)
- 23 Joint faculty
- 25 Postdoctoral Researchers
- 14 Undergraduate and 30 Graduate students
- 1,356 Facility Users
- 1,188 Visiting Scientists

FY 2010 Funding by Source: *(Cost Data in $M)*



FY 2010 Total Lab Operating Costs: $ 135M
FY 2010 Total DOE Costs: $ 129M
FY 2010 WFO (Non-DOE/Non-DHS): $6M
FY 2010 WFO as % Total Lab Operating Costs: 4.4%
FY 2010 DHS Costs: $ 0
Recovery Act Obligated from DOE Sources in FY 2010: $0
Recovery Act Costs from DOE Sources in FY 2010: 43.5M

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 four major core capabilities meeting these criteria are described below in detail:

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

   <u>Experimental Nuclear Physics</u>
   TJNAF is unique in the world as a user facility for studies of the quark structure of matter using continuous beams of high-energy, polarized electrons. Its detector and data acquisition capabilities, when coupled with the high-energy electron beams, provide the highest luminosity (10^{39}/eN/cm^2/s) capability in the world. TJNAF supports one of the largest nuclear physics user communities in the world. The scientific program aims for excellence and pre-eminence in a number of key areas of nuclear physics. These include:

   a) the structure of hadrons – especially the nucleon's charge and magnetization distributions including the separation in individual quark contributions, the exploration of the degrees-of-freedom governing baryon excitation, the momentum and spin distributions of valence quarks, and the experimental and theoretical tools necessary to carry out a program of nucleon tomography;
   b) the structure of nuclei – including that due to the short-range component of the nucleon-nucleon interaction, the neutron radius of ^{208}Pb, and the underlying quark-gluon structure of the nucleus; and
   c) Tests of fundamental symmetries in nuclear and particle physics, such as the determination of the weak charges of the proton and the electron, tests of the predictions of the Standard Model and the search for its possible extensions.

   <u>Theoretical & Computational Nuclear Physics</u>
   The program aims to provide comprehensive theoretical effort and leadership across nuclear physics. Support for the experimental program ranges from phenomenological analyses of the nucleon-nucleon interaction, and precise low-energy studies of the Standard Model, to the structure of the nucleon and its excitations, 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, and through the EBAC (Excited Baryon Analysis Center) project exploiting the development of appropriate state-of –the-art theoretical tools and technology.

   The synthesis of the latest technology with innovative theoretical tools is particularly notable in the area of High Performance Computing in lattice QCD, which focuses on hadronic and nuclear physics. The development and provision of novel software tools (Chroma) and science-optimized hardware (within the national lattice QCD program) have 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 infrastructure, results of unprecedented precision for the hadron spectrum have been produced, as well as the first computations of hadronic scattering amplitudes, with more results to come. TJNAF's Jozef Dudek (joint appointment with Old Dominion University) received the DOE SC Early Career prize for his research on subatomic particle structure using lattice QCD in May of 2011. Half the Theory Center members are also engaged in phenomenological studies of the physics to be accessed at a future Electron Ion Collider and are contributing to the "white paper" on the physics case. In all aspects, the Theory Center works closely with the experimental community, whether in extracting the properties of nucleon excited states from hadro and photoproduction data, or in studies to constrain generalized parton distribution functions from the full kinematic range of results that TJNAF will produce.

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

2. **Accelerator Science** (funded by DOE Office of Science – Nuclear Physics, High Energy Physics, Work for Others (NASA, Department of Defense (DOD) – Office of Naval Research (ONR))

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 are based on the lab's expertise in three fields, namely, SRF niobium-based accelerating technology, liquid helium refrigeration, and high current, low emittance electron injectors. This expertise, complemented by a talented group of accelerator scientists, supports the five TJNAF Accelerator Science priorities: the 12 GeV CEBAF Upgrade, continued 6 GeV operation, positioning TJNAF for a future beyond 12 GeV, a world-class light source based on a Free Electron Laser (FEL) and Energy Recovering Linac (ERL), and graduate and undergraduate education. Pavel Evtushenko was awarded a DOE SC Early Career prize for his research at TJNAF's FEL to develop high dynamic range diagnostics for linear particle accelerators in May, 2011. The prestigious APS Robert R. Wilson prize for Achievement in the Physics of Particle Accelerators was awarded to TJNAF's accelerator physicist, Yaroslav Derbenev for 2011.

With CEBAF, TJNAF has more integrated operating experience of superconducting linacs (>35%) than any other institution in the world. TJNAF SRF facilities have processed more multi-cell superconducting cavities of multiple types and designs, to consistently higher performance levels than any other facility in the world. TJNAF electron sources and injectors have produced continuous wave electron beams with currents of 170 µA and 89% polarization and unpolarized beams of 9 mA. TJNAF cryogenics staff has received numerous awards for improving the efficiency of cryogenic plants at NASA and at other DOE facilities, notably at Relativistic Heavy Ion Collider of Brookhaven National Laboratory (BNL). Our patented cryogenic operating cycles have been licensed to a commercial vendor for all of their existing and future plants. TJNAF technical infrastructure and staff position us uniquely to design and apply advances in SRF, FEL and injectors, at TJNAF, at other DOE laboratories and at laboratories around the world.

All Office of Science projects requiring SRF expertise are currently under discussion to determine how TJNAF can support these efforts. The SRF Institute at TJNAF can be a cost-effective R&D partner because of its experience and facilities. Past partnerships include jointly funded R&D and digital RF conductivity with the Facility for Rare Isotope Beams' (FRIB) predecessor, Rare Isotope Accelerator (RIA), high efficiency cryogenics jointly funded by NASA, high-current cavities funded by ONR, high-voltage electron guns funded by International Linear Collider (ILC), and crab cavities funded by the Advanced Photon Source (APS). Office of Nuclear Physics projects for which partnerships are envisioned are FRIB and all versions of an electron ion collider (EIC). Support for other Office of Science projects would include the Spallation Neutron Source (SNS) Power Upgrade Project (PUP), Project X at Fermilab, APS Upgrade at Argonne National Lab (ANL), and International Linear Collider (ILC).

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. Applied Nuclear Science and Technology

<u>Free Electron Laser (funded by DOD >$4M p.a. from ONR; total investment >$110M)</u>
The development of key technologies in accelerator, photon, and detector science at TJNAF established a key skill base enabling the development of other advanced instruments and research tools, namely the Free Electron Laser Facility. Originally commissioned in 1995, it is currently the most powerful Free Electron Laser in the world. Producing up to 14 kW of CW average power in the near infrared regime, the coherent pulses of light have been used for research on such varied topics as the development of a treatment for adult acne, energy loss in semiconductors due to interstitial hydrogen, terahertz imaging for homeland security purposes, and a search for dark matter. The primary funding source for the Infrared (IR) FEL has been the ONR in support of its program to develop a high average power laser for shipboard defense against cruise missiles. That program has now entered a new phase with technology transfer to industry happening as the applications move from the laboratory to the field. TJNAF continues to be involved through Work for Others.

During the last year under separate $12M United States Air Force (AF) funding a new ultraviolet (UV) FEL system has provided 20 microjoule pulses of 300 nm light at 4.7 MHz repetition rates again in 120 fs pulse trains. The harmonics of that UV FEL at 10 to 13 eV provide fully coherent beams with higher average brightness by a factor of 100 than any 3rd generation storage ring and have the added capability to provide ultra-short pulses to address systems dynamically. The use of narrow-line laser photons in many cases eliminates the requirement for a monochromator giving further advantage over relatively broadband synchrotron sources. The TJNAF UV FEL leads the world in its capability. TJNAF has transported the VUV beam and measured its power in the laboratory in preparation for some demonstration experiments planned for summer 2011. Such experiments are intended to demonstrate the usefulness of such a machine and its potential for science relevant to Basic Energy Sciences (BES) programs. Specific activities are directed at temporally resolved studies of combustion dynamics in diesel engines performed by researchers from Sandia National Laboratory, studies of long-lived trace isotopes using atomic trap trace analysis (ATTA) for dating ancient groundwater by PI from ANL and work on angular resolved photoemission studies (ARPES) by a group from Brookhaven National Laboratory.

This program has operated synergistically with the Nuclear Physics activities at TJNAF, benefitting from core capabilities such as SRF accelerators (developing high gradient modules partially under BES funding and providing valuable experience in high average current DC injector guns (extending voltage standoff from 320 kV to 500 kV), rf control systems (developing a new digital control system), and beam diagnostics (studying effects which degrade beam brightness such as CSR). It also developed a new technology deemed critical for one of the two major branches of next generation light sources for DOE: the ERL. In the ERL, the electron beam is re-cycled back through the accelerator out of phase with the accelerating field so the beam's energy is extracted back into RF power. This power, which would otherwise be lost, can represent 90% of the input to a high power linear accelerator. This development is an enabling technology for next generation machines which will produce ultra-short pulses of X-rays for studies into materials as outlined in "Directing Matter and Energy: Five Challenges for Science and the Imagination, a report from the DOE Basic Energy Sciences Advisory Committee". TJNAF was the pioneer in developing this technology and its FEL remains the highest power system extant. A number of other laboratories are adopting this technology and NSF is considering the development at Cornell of a very high power system based on such experience. ERL technology is likely to become an important contribution to sustainability initiatives at DOE labs.

Experimental Nuclear Physics (funded by DOE SC – Nuclear Physics)
TJNAF is home to and developer of state-of-the-art radiation detection, data analysis and imaging techniques, fast electronics and data-acquisition, and data storage capabilities. These capabilities are crucial to the state-of-the-art and anticipated experimental nuclear physics program, and underpin the bio-medical applications described below. Scientists and engineers have also developed advanced radiation shielding solutions as part of the lab's 12 GeV program, including recently-invented and cost-effective hydrogen and boron-enhanced products, particularly well suited for absorbing neutrons.

Radiation Detection and 2D and 3D Imaging in Nuclear, Biomedical and other applications (funded by DOE SC – Biological and Environmental Research)
The Jefferson Lab Radiation Detector and Imaging Group develops, constructs and tests a variety of novel high performance (high resolution and high sensitivity) 2D and 3D single photon, emission computed tomography (SPECT), positron emission tomography (PET), and optical and x-ray computed tomography (CT) imaging systems. These imaging systems are used for a broad variety of applications including: studies of biological function in plants and small animals; motion tracking and imaging, medical preclinical and clinical applications; and the potential for non-destructive evaluation and homeland security applications. Silicon photomultipliers were explored at Jefferson Lab for nuclear physics detector systems because of their immunity to magnetic fields and have potential for highly compact photosensors for biomedical applications.

The Applied Nuclear Science and Technology Core Capability serves DOE Scientific Discovery and Innovation mission numbers 9, 14, 26, and 30 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

4. 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. The Continuous Electron Beam Accelerator is housed in a 7/8 mile racetrack and can deliver precise electron beams with energies up to 6 GeV 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 is the home of the CEBAF large-acceptance spectrometer with multiple detector systems and some 40,000 readout channels. Hall C boasts an 80 feet long high-momentum magnetic spectrometer and houses 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 Jefferson Lab staff, to facilitate user experiments.

The expertise developed in building and operating CEBAF has led to the design of an upgrade that will double the energy (to 12 GeV) and provide a unique facility for nuclear physics research that will ensure continued world leadership in this field for several decades. This upgrade will add one new experimental facility, Hall D, dedicated to the operation of a hermetic large-acceptance detector for photon-beam experiments. The upgrade 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 opportunities exist in Hall A with a proposed large-acceptance magnetic spectrometer and possible dedicated apparatus for one-of-a-kind experiments.

Jefferson Lab staff has gained the unique ability to conceive and design large accelerator facilities, building upon 6-GeV CEBAF operations and augmented with the ongoing 12-GeV Upgrade. In partnership with BNL and scientists and engineers world-wide, TJNAF scientists and engineers are thus leading the conceptual design of a powerful electron-ion collider that many believe will be needed to advance the field beyond the 12 GeV Upgrade.

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.

Accelerator Science (funded by DOE SC – BES, DOD – ONR)

TJNAF has developed state-of-the-art instrumentation for R&D, design, fabrication, chemical processing, and testing of superconducting RF cavities. This complete concept-to-delivery capability is unique in the world. In addition, TJNAF has extensive expertise in high current photoemission sources, especially polarized sources. This broad suite of hardware capabilities is complemented by world-class expertise in accelerator design and modeling. (It should be noted that Jefferson Lab accelerator physicist Yaroslav Derbenev received the 2011 APS Robert R. Wilson prize Achievement in the Physics of Particle Accelerators.) All of these capabilities are essential to the development, deployment, commissioning and operation of the CEBAF 12 GeV upgrade project. The addition of TJNAF’s Technology and Engineering Development Facility (TEDF), currently under construction, will provide 100,000 additional square feet that will enhance and collocate all SRF operations elements and will provide additional experimental assembly space. It will also provide configurable space that can be adapted to work on different kinds of srf cavities as TJNAF’s portfolio of projects expands.

In addition, this expertise can be available to other projects within the Office of Science, and also around the world. For example, the extensive experience of TJNAF in the design and construction of high current ERLs, in combination with the world leading capabilities in accelerator science and superconducting radiofrequency techniques, mean that TJNAF is making a major contribution to the design and construction of future large scale user facilities in BES, especially 4th generation light sources.

IV. Science Strategy for the Future/Major Initiatives

Science in the 21st Century is making enormous advances on several fronts in physics, chemistry, biology and other subjects through the research capabilities provided by advanced accelerator facilities and their operation as international user facilities. TJNAF possesses key capabilities and competencies in accelerator science and in the application of the modern accelerator technologies. This core competence is dominated by the employment of superconducting radio frequency techniques in multiple pass linear accelerators, energy recovery linear accelerators and free electron lasers. Continued development of these capabilities is one of the major initiatives integral to this strategic plan. Based on the studies made under the auspices of both the Nuclear Science Advisory Committee (NSAC) and the Basic Energy Sciences Advisory Committee (BESAC), TJNAF has identified areas in nuclear physics and in photon science where it can directly provide world leading user facilities meeting the identified needs of the research community. In addition it has identified collaborative roles that it can play in the provision of facilities elsewhere associated with the Office of Science (Basic Energy Sciences, High Energy Physics and Nuclear Physics) and other agencies.

The nuclear physics program being pursued by more than 1,300 staff and users is currently dominated by a series of key experiments using the Continuous Electron Beam Accelerator Facility operating at energies up to 6 GeV. Among the incisive measurements underway is a measurement of the weak charge of the proton. The motivation and interpretation of these experimental studies is underpinned by theoretical studies using state-of-the-art calculational techniques in QCD both on the lattice and in the continuum, as well as precision photon-Z boson radiative corrections to experiments like Qweak. A major goal of the laboratory is to execute the 12 GeV Upgrade Project. This project, which was identified as the highest priority for the field of Nuclear Physics by the 2007 NSAC Long Range Plan, is currently under construction and will be commissioned in 2013-2015. This will allow a unique 3D map 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 be opened. Measurements of the weak couplings of elementary particles are accessible through measurements of parity violating asymmetries. Lepton scattering has proven and continues to be a powerful tool in the elucidation of the structure of the world, and a future electron-ion collider with high luminosity could provide the opportunity to explore hadronic structure in a region dominated by the quark-antiquark sea and by gluons.

The existing free electron laser facilities at TJNAF employ a single pass electron linear accelerator followed by combinations of undulator and optical cavities. Energy recovery occurs on a second (out of phase) passage down the linac. The existing facility is set up to operate in the infrared or the ultra-violet regime. A design has been developed to install the capability to accelerate to 300 MeV in one pass and using two passes of acceleration and two passes of deceleration, to generate a continuous wave, coherent, short pulse photon beam with energies up to 100 eV and beyond in the soft X-ray region. There is no comparable facility currently available in the world. This would provide an exciting platform for photon science and would enable the studies of accelerator science needed to underpin the design of a large scale next (4th-generation light source).

Details on each of the components of TJNAF's, scientific strategy and major initiatives follow. Currently structured as a program-dedicated laboratory, a Laboratory Directed Research and Development (LDRD) program does not presently exist but is in preparation.

1. Nuclear Physics

a) 12 GeV CEBAF Upgrade Project (Funded by DOE SC – Nuclear Physics)

- ***The vision:*** The 12 GeV CEBAF Upgrade is an upgrade to the CEBAF accelerator and to the associated experimental facilities, which will enable CEBAF's world-wide user community to expand its research horizons, and will allow breakthrough programs to be launched in three key areas:
  - The experimental investigation of the powerful force fields ("flux tubes") believed to be responsible for quark confinement; understanding confinement is essential for understanding the structure of nuclear matter and is one of the major gaps in our understanding of nature; the only planned or existing facility that can test this prediction is the 12 GeV CEBAF;
  - The exploration of the quark and gluon structure of the proton, the neutron, and atomic nuclei at the most basic quantum level; and
  - The search for new physics beyond the Standard Model of nuclear and particle physics.

  The CEBAF at TJNAF is the world-leading facility in the experimental study of the subatomic structure of matter using the electroweak interaction. The 12 GeV CEBAF Upgrade directly addresses a major scientific opportunity identified in both the 2002 and the 2007 Long Range Plans in which the Nuclear Science Advisory Committee (NSAC) recommends the 12 GeV CEBAF Upgrade as its highest priority for the Nuclear Physics program. It directly supports the Nuclear Physics mission and addresses the objective to measure properties of the proton, neutron, and atomic nuclei, which, in concert with theoretical calculations, will provide an improved quantitative understanding of their quark and gluon substructure. This project serves DOE Scientific Discovery and Innovation (SC) mission numbers 22, 24, 27, 28, 29, and 30 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

  The 12 GeV Upgrade Project will be completed on schedule and within budget meeting all technical milestones to support the scientific mission described above. CD-4A (Approve Accelerator Project Completion) is expected by December 2014 and CD-4B (Approve Experimental Equipment Project Completion) will be complete by June 2015.

- ***Required Resources:*** The full scope of the 12 GeV CEBAF Upgrade project includes upgrading the electron energy of the main accelerator from 6 GeV (Giga- or billion electron volts) to 12 GeV, constructing a new experimental area (Hall D), and enhancing the capabilities in the existing experimental halls to support the most compelling nuclear physics research. The project received CD-2 Approval on November 9, 2007, and received CD-3 Approval for the start of construction on September 15, 2008. The Total Project Cost is $310 million; the Total Estimated Cost (TEC) is $287.5 million, and Other Project Costs (OPC) are $22.5 million. Funding began in FY 2004, $162M has been received as of February 28, 2011 and $125.0M has been costed or committed. The funding profile extends through FY 2015. This funding is complemented by support from the Commonwealth of Virginia, the National Science Foundation and International Funding Agencies.

- ***Risks:***
  - Technical: *Low risk* – superconducting radio frequency (SRF) work on other projects and local R&D efforts have significantly reduced the technical risks of the accelerator upgrade, and all other elements are based on known, existing technology.
  - Market/Competition: *Low risk* – CEBAF is a unique facility.
  - Financial, Management, and Other Operational Risks: *Moderate risk* – due to federal budget uncertainties. Any annual funding variations relative to the project funding profile, including lengthy Continuing Resolutions, will result in missed milestones due to schedule delay and cost increases. The mitigation plan includes delaying the start of planned procurements during the construction years by one fiscal quarter. Stimulus American Recovery and Reinvestment Act (ARRA) funding of $65M was received for the 12 GeV Upgrade project in FY 2009 which represented accelerated funds from FY 2010 and FY 2011 in the baseline profile. This funding created additional schedule float for several major procurements, but also created increased schedule risk should FY 2012 Continuing Resolutions last longer than three months. JSA/TJNAF continues to communicate on the local, state and Federal level for the critical need to maintain/increase the DOE Office of Science funding. User scientist and Commonwealth of Virginia support are very strong. The necessary staff is in place. There are no new environmental or safety risks which are not covered by existing policies and procedures.

b) Experimental Nuclear Physics Program (Funded by DOE SC – Nuclear Physics)

- ***The Vision*:** The ongoing research with CEBAF is an essential part of the national and global strategy for understanding the structure and interactions of nucleons and nuclei in terms of the quarks and gluons of Quantum Chromo Dynamics (QCD). Jefferson Lab's ongoing 6-GeV program utilizing the unique Continuous Electron Beam Accelerator Facility has given the United States leadership in addressing this challenge. The Nuclear Physics community in the US has acknowledged this leadership and its potential, and indeed the 2007 NSAC Long Range Plan recommends completion of a doubling of the energy reach of CEBAF, the 12-GeV Upgrade, as its highest priority. The 6-GeV research program presently being carried out provides a three-pronged approach including electron and photon beams with energies of up to 6 GeV, phenomenological model building and nuclear theory development, and state-of-the-art calculations of QCD using supercomputers. The research program addresses three key areas of Nuclear Science: i) Hadronic Physics; ii) Nuclear Structure and Nuclear Astrophysics; and iii) Neutrinos, Neutrino Astrophysics and Fundamental Interactions. The main emphasis of the program is in Hadronic Physics, where Jefferson Lab's ongoing research addresses 10 of the 13 scientific milestones identified as essential for progress in Hadronic Physics. Beyond Hadronic Physics, the ongoing program adds important measurements in the other two key areas, such as experiments to uniquely determine the neutron skin of nuclei, and the ongoing experiments to precisely determine the proton's weak charge. These examples directly map to the three major thrusts of the ongoing program: the structure of the nuclear building blocks; the structure of nuclei; and tests of fundamental symmetries.

  The 6 GeV research program will, in addition to completing the unique precision measurement of the proton's weak charge, enable the Facility to complete the 8 of 13 SC milestones for progress in Hadronic Physics. It is essential that the data-taking needed for the 8 milestones associated with the 6 GeV research program be completed now, as the capability for mounting many of the relevant experiments will disappear when present experimental equipment is upgraded for 12 GeV capability. As two examples, the missing ingredient to finalize a milestone related to the combined analysis of photo-production data is data on a pure polarized neutron target, hand-in-hand with a baryon analysis theoretical effort, and to finalize the electromagnetic form factor program in a region of current interest due to an emergent proton radius puzzle requires an additional low-momentum transfer run with a polarized proton target. In addition, the determination both by experiment and by lattice calculations of the lowest structure function moments needs to be finalized. This is even more urgent at present as recent more precise lattice calculations have raised doubts about previous comparisons.

The commissioning of the 12 GeV accelerator and experimental facilities will herald a new era of experimental nuclear physics at TJNAF. The increased complexity of the accelerator and the introduction of a fourth experimental hall, Hall D, with its discovery-class program to search for exotic hadronic states of QCD, represent a substantial expansion of the scale of the operations. A program aimed at three-dimensional imaging of the nucleon is expected to reveal hidden aspects of the quark-gluon dynamics. New program directions include higher-resolution maps of the nucleon's charge and magnetization distributions and a measurement of the electron's weak charge. The 12 GeV Program represents the realization of the scientific opportunities associated with the highest priority recommendation in the most recent Nuclear Science Advisory Committee (NSAC) long range plan. Two of ten SC milestones that are TJNAF's responsibility are part of the initial research program of the 12 GeV Upgrade, which was introduced in the previous section.

This initiative for the 6 GeV and 12 GeV research programs serves DOE Scientific Discovery and Innovation (SC) mission numbers 2,4, 22, 24, 26, 27, 28, 30, 33, 34, and 35 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

- ***Resources Required*:** The overall plan, presented to the TJNAF user community and to the larger US Nuclear Physics community during the NSAC Long Range Plan process, was to run the facility at about 80% of full utilization during the construction period as a balance between completing the essential science needing 6 GeV beams and speeding the construction of the 12 GeV Upgrade through redirection of resources from our base program. This research program has been the raison d'être for TJNAF since its inception. During 12 GeV operations, scientific through-put will increase by 30%; supporting this level of effort will require a significant increase in funding.

  With the advent of the 12 GeV operations, the intent is to operate the facility for about 35 weeks per year with, on average, experiments in three of the four halls taking data at any given time. This requires an increase in staff scientists to support 4-Hall operations and the Hall D experimental program, engineers and technicians needed to support the increased complexity of four-hall operations, resources, and additional staffing for accelerator operations. There are in addition a number of exciting initiatives being proposed by the user community which would significantly enhance the 12 GeV research capabilities and which will require that the laboratory secure additional equipment funds, including potential international resources. These initiatives include the Super BigBite Spectrometer (SBS), the MOLLER apparatus, and the SoLID system.

- ***Risks*:**
  - Technical Risks: *Low/moderate* – The basic capabilities of the accelerator and apparatus for carrying out experiments of the type planned with up to 6 GeV beams, is now well demonstrated; capability extensions needed for some of the planned experiments are

challenging but within our grasp. While substantial resources and time are required to commission the 12 GeV operation of the accelerator and experimental facilities, there is confidence that this does not represent a substantial technical advance from what is currently understood.

- Market Risk/Competition: *Low* – While other groups are also working in this general area, the CEBAF accelerator provides unique capabilities for experiments using electro-weak probes.
- Financial, Management, and Other Operational Risks: *High/moderate*
  a) Much effort has been necessary to balance the demands of mounting the 6 GeV research program with the resource needs of the 12 GeV Upgrade project. There is a risk of the loss of both essential science and the cohesion and support of our User community. The mitigation strategy is to work with the User community to make the case for increased overall funding for the Office of Science and for the Lab and to ensure that the highest impact experiments are carried out in whatever budget scenario TJNAF faces. Further, JSA and SURA continue to garner support for basic research in the Office of Science through participation on the Task Force for American Innovation and the Energy Sciences Coalition.
  b) The transition to full scale and capability operations in the 12 GeV era involves an increase in resources from the current level of operations. The ability to deliver on this will depend on the out-year budgets.
- *Operational Risk: Low* – the operation of the CEBAF facility and its associated experimental equipment over the last decade has demonstrated our ability to deliver the 6 GeV research program assuming adequate funding is available to support this operation.

c) Theoretical and Computational Nuclear Physics Program (Funded by DOE SC – Nuclear Physics)

- ***The Vision*****:** The world class program in nuclear theory focused on hadronic physics addresses two of the thirteen Office of Science milestones for hadronic physics. The creation of a *Physics Analysis Center* will draw on world theoretical expertise in developing appropriate theoretical tools and computational framework required for detailed analyses of quark and gluon distribution in mesons and nucleons. The research program being carried out at Jefferson Lab is an essential part of the national strategy for understanding the structure of matter contributing to a worldwide effort to explore the spectrum and the internal dynamics of hadrons. The data to be taken at Jefferson Lab during the next decade will be of unprecedented scope and precision. Definitive answers to the basic questions of "do there exist hadrons with structure beyond those of the simple quark model" and "what is the detailed internal flavor, momentum, angular momentum and spatial distribution of nucleons" will require continuing engagement and collaboration between experimentalists and theorists both at Jefferson Lab, at US universities and the wider hadron physics community. The *Physics Analysis Center* will help achieve this. The EBAC project, which will complete its mission in March 2012, is a good example of such an analysis project. However, it is limited in manpower, in its model-dependence and in its scope. Nevertheless, its successes provide a "proof of concept". The need is to take this to another level. Jefferson Lab with its position in the experimental community, its experience with EBAC and the expertise of its staff in both theoretical and phenomenological analyses is best placed within the US to take a lead with such a global endeavor. Equally important is to work with other accelerator laboratories, particularly BES and Gesellschaft fur Schwerionenforschung (GSI), and university collaborators, to develop and share analysis methodologies.

Key steps are:

- the formation of a *Physics Analysis Center* with world-class leadership,
- the facilitation of pooling of world expertise in scattering and reaction theory, with well documented underpinning formalisms,
- the training of a generation of theoretical and experimental graduate students and postdocs to carry out such analyses,
- the promotion of a culture change within both experimental and theoretical communities of working together with common methodologies and the sharing of data,
- a forum for communicating this expertise with regular workshops/graduate schools and meetings in the US, Europe and Asia, focused in the short term on Jefferson Lab, on Julich and GSI, and on Beijing,
- leadership of such an umbrella effort for both baryon and meson spectroscopy, and with extensions to eventually understanding the internal dynamics of hadrons.

This input from the theoretical community is essential to the success of the discovery-class program at 12 GeV.

This initiative for the 6 GeV and 12 GeV research programs serves DOE Scientific Discovery and Innovation (SC) mission numbers 2,4, 22, 24, 26, 27, 28, 30, 33, 34, and 35 from "Enclosure 1: List of DOE/NNSA/DHS Missions.". This program is of the highest priority addressing scientific milestones HP 7, 8, 11, 14 and 15 identified as essential for progress in hadronic physics.

- ***Resources Required*:** This effort will be led from Jefferson Lab, with the appointment of a senior staff scientist, whose sole responsibility will be to work with the world network of theorists and experimentalists, together with a dedicated team of at least 4 postdoctoral researchers based at Jefferson Lab. Together with networking costs this requires roughly $825K per year. This investment will lead to a total analysis effort from university groups and their graduate students and postdocs a factor of 20-30 larger. This multiplier will only be achieved and yield the definitive results precision physics demands if there is coordination within a single framework. This would be provided by the Jefferson Lab *Physics Analysis Center* working with theorists at Forschungszentrum (FZ)-Julich and experimenters at GSI.

While 12 GeV data will not be available for some years, it is crucial that the methodology and training all take place well in advance. Robust methods need to be developed, and then tested using the high statistics data already taken by heavy flavor factories such as BaBar, and on-going experiments at BES and COMPASS at CERN. Consequently, this effort must start in FY 2012.

To make such a broad program feasible requires the engagement of a large number of researchers within the US and worldwide, for which networking support is essential. Of equal importance is the utilization of the appropriate technology. GPUs currently provide an ideal way to perform the numerous repetitive computations needed for Amplitude Analyses. Whilst dedicated clusters exist at collaborating US universities, such as CMU, a cluster at Jefferson Lab will be essential. This will require an initial investment of $125K. Jefferson Lab expertise in heterogeneous computing will be essential in ensuring that over the next decade the technology used remains fit-for-purpose.

- ***Risks*:**
    - Technical Risks: *Moderate* – Limited world expertise in the analysis methods required for such a project to deliver comprehensive analyses with globally accepted results. Networking has already begun, and a consortium known as NABIS already formed.
    - Market Risk/Competition: *Low* – A key aspect of the *Physics Analysis Center* is its worldwide engagement. The collaborations GlueX and CLAS12 have signed up to this endeavor, as have groups in FZ-Julich, GSI, BaBar and LHCb. This uses competition as a stimulus to drive the project forward.
    - Financial, Management, and Other Operational Risks: *High* – The transition to full analyses operations in the 12 GeV era involves an increase in resources and will depend critically on the out-year budgets.
    - Operational Risk: *Moderate* – Advances in theory, computation and the expected precision of future experimental data should ensure that, with coordinated effort, substantial progress will be achieved towards understanding the fundamental structure of hadronic matter.

2. **Electron Ion Collider (EIC)** (Funded by DOE SC – Nuclear Physics)

- *The Vision*: The Nuclear Physics community in the US has identified an electron ion collider as a major new opportunity for the field. Indeed, the 2007 NSAC Long Range Plan stated "An Electron-Ion Collider (EIC) with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia." Such a facility would continue the Jefferson Lab program of studying the fundamental structure of nuclear matter into a regime where the dynamics is governed by a plethora of soft quarks, antiquarks and gluons.

  Over the last two years, there has been considerable progress in developing the physics case for such a facility. In spring 2010 there were five workshops organized by the Jefferson Lab user community. This was followed up in the fall by a 10 week program at the Institute for Nuclear Theory in Seattle entitled "Gluons and the quark sea at high energies: distributions, polarization tomography". The experience of the Jefferson Lab community in developing the physics program of the 12 GeV upgrade facility has been a great asset in establishing the value of high luminosity over a wide kinematic range to facilitate the capability of 3D imaging of the partons. Extending this capability to low Bjorken x where the sea of gluons and quark-antiquark pairs are dominant requires an electron ion collider with high luminosity $\sim 10^{34}/cm^2/s$ at a center-of-mass energy of 20-65 GeV. These parameters are now agreed upon as the goals for an EIC facility and provide the basis for developing the machine design. Two major physics goals of this facility can be broadly stated as:

    - Discover the collective effects of gluons in nuclei
    - Map the spin and spatial structure of quarks and gluons in nucleons

  In addition, one can study the emergence of hadronic matter from quarks and gluons and test the Standard Model and its possible extensions. The physics motivation for the EIC is still a subject of substantial effort in the community and it is expected that a white paper will be generated in the next year in preparation for another NSAC Long Range Plan.

TJNAF has been developing a concept for this facility with a first stage called the medium-energy electron-ion-collider MEIC. This facility could be later upgraded to a higher-energy EIC operating at center-of-mass energies exceeding 100 GeV. MEIC would be a high-luminosity, polarized electron-ion collider which would use CEBAF as a full energy injector into an electron storage ring. MEIC has a center-of-mass energy of 20-65 GeV and high luminosity of about $1x10^{34}$ $cm^{-2}s^{-1}$. The booster rings, electron collider ring, and ion collider ring are designed as a "figure 8", a design directly aimed at spin physics opportunities. The range of nuclei considered includes polarized light ions (^{1}H, ^{2}H, and ^{3}He) and medium to heavy nuclei (such as ^{12}C, ^{40}Ca, and ^{197}Au). TJNAF is actively engaged in the design of an Electron-Ion Collider (EIC) and is collaborating with BNL and the Massachusetts Institute of Technology on generic electron-ion collider R&D, funded from DOE-NP operations. TJNAF's design proposal is optimized for extremely high luminosity with high polarization, and would integrate well with the 12 GeV accelerator. These activities have increased with explicit R&D funding from DOE-NP. The near term goal is to complete an end-to-end design to enable reliable costing.

The facility is a natural next step for TJNAF beyond the 12 GeV Upgrade and such facilities take several years to germinate. TJNAF is collaborating with BNL and an international group of scientists in further developing the scientific motivation as well as in accelerator R&D. TJNAF and BNL have chartered a joint advisory committee (EICAC). Eventually, the magnitude of the project may make broad international participation a prerequisite, and a competitive situation with regard to site choice of an electron-ion collider may emerge. TJNAF expects to play a role independent of location, because its experience and expertise in SRF technology, high current polarized electron sources and energy recovery will benefit any future electron-ion collider design. MEIC is the innovative, CEBAF-based version of the electron-ion collider, which offers excellent polarization capabilities, high luminosity, and an unprecedented full-acceptance detector integrated in the collider interaction region based upon mostly state-of-the-art parameters beyond electron cooling.

This initiative serves DOE Scientific Discovery and Innovation mission numbers 25, 26, and 30 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

- ***Resources Required:*** R&D for fundamental technical issues at the level of \$1-\$3M per year have been requested. TJNAF has submitted proposals to DOE NP, and was awarded \$0.9M for FY 2011. TJNAF has established partnerships with ANL, National Superconducting Cyclotron Laboratory (NSCL), Fermi National Laboratory (FNAL), and Brookhaven National Lab (BNL), as well as overseas institutes such as FZ- Jülich to support development of the ion injector complex. TJNAF collaboration with GSI and other institutes is facilitating detector R&D.

- ***Risks:***
    - Technical: *High risk* – A very high luminosity, polarized EIC is a technically challenging project, as it requires a very sophisticated interaction region design and an ERL-based high energy electron cooling, a process whose physics and technology has yet to be experimentally demonstrated at MEIC energies. TJNAF's expertise on ERLs mitigates the risk. The recent conceptual design optimizations have reduced the R&D requirements for EIC, in that a state-of-the-art polarized source is used and the ion energy has been lowered

to 100 GeV to drastically reduce the increase beyond state-of-the-art required in electron cooling and crab cavities. The R&D program will further reduce technical risk significantly.

- Market/Competition: *High risk* – Brookhaven National Laboratory has a competing proposal for an electron-ion collider, based on RHIC, and other institutions and laboratories, e.g., MIT, are interested in developing enabling technologies, specifically higher-current polarized electron sources. Furthermore, especially since a proposal is being developed to augment the Large Hadron Collider with an electron beam, a potential project abroad could emerge. Risk is mitigated through recent efforts to minimize R&D needs, to complete a first-order MEIC design mostly based upon state-of-the-art parameters, and to assume an ERL-based electron cooling concept.
- Financial, Management, and Other Operational Risks: *High risk* – Associated with budget uncertainties and the anticipated high project costs for EIC. Risk is mitigated through the R&D program to develop machine and interaction region options which are most cost effective and a staged scenario where we would initially construct MEIC. Significant international participation could alleviate financial risk but would introduce additional management challenges. This could be mitigated through early attention to past lessons learned.

3. **Photon Science and Next Generation Light Sources** (Funded by DOE/BES, DOD ONR)

- ***The Vision*:** As discussed in Section III: Core Capabilities TJNAF has a strong program in Free Electron Lasers based on ERLs. That effort is now poised to expand into utilization of vacuum ultraviolet (VUV) photons in the 10 eV range and above for the benefit of condensed matter physics studies as supported by BES. The development of photon science efforts at Jefferson Lab is envisioned to proceed in several stages:

  1) Establishment of an on-going world-class research effort utilizing the VUV photons available from our presently operational system.. Following proof of capability demonstrations this summer TJNAF intends to petition BES for support of operations to permit unique science studies using this light source which provides two or more orders of magnitude higher brightness than any third generation light source while additionally providing the capability for fast temporal studies utilizing the 4.68 MHz repetition rate 150 fs pulses. Operation as an established user facility will permit the growth of a significant photon user base at Jefferson Laboratory to guide the future development of this facility. TJNAF is also using these facilities to pursue machine studies related to the extension of linac technology applicable to next generation light sources. Specific studies include the development of the crucial high brightness injectors and preservation of the electron beam brightness during subsequent acceleration.

  2) The possible second phase of this development would be the construction of an upgraded system in the present facility expanding the photon energy reach of the machine into the soft x ray region. Specific capabilities are to be determined in consultation with the user community but are expected to fall in the 100 to 550 eV photon energy range with average brightnesses exceeding existing sources by 4 to 6 orders of magnitude. TJNAF has already developed a conceptual design and has proposed to build such a continuous wave, high average brightness, short pulse free electron laser operating in the soft X-ray regime over a rapid time scale for around $100M. This device is named JLAMP (Jefferson Lab AMPlifier). JLAMP could produce photons in the VUV/Soft X-ray regime at an average brightness substantially exceeding that of the FLASH facility in Germany. Modifications to this proposal could extend its photon reach and/or provide additional capabilities as desired by the User community and

satisfy a significant scientific need at a cost substantially less than required for a full scale CW hard x ray machine. BESAC has produced a position paper called Next Generation Photon Sources for Grand Challenges in Science. Two approaches to producing the required photons are identified: Free Electron Lasers and Energy Recovering Linacs. TJNAF has world class expertise in both of these technologies and both would be used in JLAMP. JLAMP would provide a platform for:

- Research into the nature of materials as identified in the Grand Challenges report and develop a strong user base of support for such activity through BES.
- Research in advanced accelerator concepts which have the potential for substantial reduction of costs and better performance for future large-scale light sources and other applications.

3) A third component of this vision is the construction of a major next generation light source producing CW beams up to the hard x ray regime by multiple FEL user ports. A CD-0 statement of mission need is imminent for such a facility. TJNAF is presently developing a conceptual design and a project plan to position Jefferson Lab to proceed with a CD-1 level proposal. The lab anticipates substantial contributions from regional authorities in the development of this machine design proposal. It should also be noted that building up the photon user community in the southeast would have major benefits to science growth in the nation and wider visibility and utilization of DOE supported photon research. TJNAF believes that this phased program of parallel development of a performance optimized FEL facility and substantial dedicated user community at Jefferson Lab offers the best value for the nation and the most cost effective way to realize the scientific vision outlined in BESAC's report "Directing Matter and Energy: Five Challenges for Science and the Imagination" (U. S. DOE, December 20, 2007).

This initiative serves DOE Scientific Discovery and Innovation mission numbers 9, 14, and 26 from "Enclosure 1: List of DOE/NNSA/DHS Missions."

- ***Required resources*:** Operations costs of the existing VUV User facility are less than $10M per year to support a substantial set of user experiments. The cost of JLAMP construction is estimated at ~$100M. Extensions to 550 eV photon energy would cost a total of around $250M and could be done in a phased manner after the first investment, if desired. Operations cost would be approximately $18M per year and this would include the staff needed to operate the facility and to support the facility and science operations. The next generation light source (item 3.) may be expected to cost $1B to $1.5B for a green field site. It is anticipated that substantial savings would accrue from existing Jefferson Lab infrastructure and the low costs in Virginia. Ongoing R&D for BES is anticipated to be at the level of $3.5M and the work for others for the DoD – ONR is expected to continue at the current level of ~$4M per annum.
- ***Risks:***
  - Technical: *Moderate risk* – The pioneering ERL-based FEL at TJNAF has given us world-leadership and tremendous experience in the design and operation of high beam power energy recovery systems and could be used as a unique test-bed facility for technology demonstration. However, future light source designs push the limits of accelerator science and technology, and thus there is risk involved and consequently the need for early experimentation to establish the technological limits of such machines.
  - Market/Competition: *High risk* – Many U.S. and international laboratories are interested in

a 4th generation light source and several appear to be submitting proposals which are remarkably similar to the JLAMP proposal. Several institutions are interested in the full next generation light source, most notably LBNL and the University of Wisconsin.

- Financial, Management, and Other Operational Risks: *High risk* – Proven management approaches for inter-laboratory partnerships will mitigate and manage risks. This is also mitigated by a sizeable staff with experience in the construction and operation of srf accelerators Availability of federal funds is seen as a severe financial risk. The high cost of presently envisioned next generation facilities, challenges its financial viability hence significant efforts toward cost reductions are essential.

4. Superconducting RF Technology

- ***The Vision*****:** TJNAF plans to continue development of SRF technology to improve performance and reliability. In addition, further development directed towards specific future applications will enable the Laboratory to position itself to make major contributions to new projects in the US and around the world. In the coming years, TJNAF expects to transfer its current technology to US industry (e.g. AES, Niowave), and concentrate on developing new applications of SRF.

  Applications of TJNAF accelerator science include the linac of the Spallation Neutron Source at Oak Ridge National Laboratory, participation in the Michigan State University-Facility for Rare Isotope Beam project (SRF cavities, cryogenics and accelerator physics), Argonne National Lab's APS, participation in Project X at Fermilab (SRF cavities and cryogenics), R&D for ILC (SRF gradient studies and a high-voltage electron gun), R&D for Basic Energy Sciences on 4th generation light sources, Eurpoean Spallation Source and MYRRHA. TJNAF's R&D portfolio is well suited to all these projects.

  TJNAF is pursuing funding and design options to expand the current Injector Test Facility into an Injector and Cryomodule Beam Test Facility. Expansion of the TJNAF Injector Test Facility would provide capability for testing and development of integrated injector components including DC, RF and SRF photocathode guns, capture and booster SRF cavities and beam diagnostics. Many of the DOE projects listed above will require new high brightness, high current injectors, and TJNAF is well positioned this area.

- ***Required resources*****:** The planned R&D activities will be conducted in part by using the SRF Institute's evolving set of R&D facilities, including the present Cavity Forming Facility, Cavity Processing Facility, Vertical Cavity Testing Facility, Cavity Assembly Facilities, Cryomodule Assembly Facilities, and Horizontal Test Facilities. In addition, for the Technology and Engineering Development Facility (TEDF) is presently under construction (Science Laboratory Infrastructure (SLI) project). TEDF includes a 70,000-square-foot, stand-alone building situated between the Test Lab and Jefferson Avenue, a 30,000-square-foot addition to the Test Lab, and rehabilitation of the Test Lab. The net increase in facility area would be 48%, and the associated office area would increase from 7,000 to 8,000 SF. TJNAF is pursuing funding for a refurbished EB welder and processing equipment to enhance the capabilities of the facility. At present, the SRF Institute has about 60 people. Depending on the degree of automation incorporated in the new facilities, staffing would increase at least to 80 but maybe to as many as 100. The Old Dominion University Center for Accelerator Science, initiated in 2008 in collaboration with TJNAF, will be useful as a resource for staffing.

- ***Risks***
  - Technical: *Low risk* – The long term R&D activities planned in the SRF Institute are founded on the solid expertise and widespread support TJNAF provides to laboratories throughout the world. SRF research is typically planned and executed to benefit multiple applications of the developed product.
  - Market/Competition: *Low risk* – TJNAF's SRF leads the research competition in number of cavities processed, and improvements to the surface cleaning and polishing processes. SRF outreach to vendors provides new business opportunities by improving the vendor's construction and chemical processing via SBIR and STTR agreements.
  - Financial, Management and Other Operational Risks: *Moderate risk* – As funding fluctuates, so does the ability to manage an ongoing research and development program. There is some difficulty attracting and retaining scientific, engineering and technical staff when a program budget fluctuates. SRF has supplemented its research budget with a variety of collaborative efforts. What is needed is a cross-cutting commitment within Office of Science to ensure the on-going support for this unique national resource.

V. Work for Others

Baseline WFO Program

At TJNAF, one of the core competencies is in the area of accelerator science and in particular superconducting radiofrequency acceleration. The Lab's preeminent expertise in this area has enabled a line of research that builds upon the requirements of the Office of Science nuclear physics program but has impact in a much broader array of applications. While this program has great potential for expanding the capabilities of the Office of Science, a significant effort in accelerator research has been supported by the US Department of Defense, particularly the Office of Naval Research and, at a lesser scale by the US Air Force. This WFO program has been a spectacular success on several fronts. The device funded is a Free Electron Laser (FEL) incorporating an Energy Recovering Linac (ERL), which has operated at 14 kW in the infra-red wavelength range, several orders of magnitude higher power than any other comparable device in the world. The ERL aspect decelerates the electron beam, recovering the energy of the beam into the radiofrequency cavities and the electrons are dumped at 10 MeV, simplifying operations dramatically. This success has spawned major ERL machine construction efforts in Japan at KEK, Cornell in the US, and in Berlin, Germany at Helmholtz-Zentrum Berlin fur Materialien und Energie.

The work permitted a Broad Agency Announcement for a program of work to be executed in industry to take the power of this device up by one, then a second, order of magnitude for use as the basis of a shipboard defensive weapon system. TJNAF participates in this phase of the program only through work for others for the designated industrial contractors. No classified work is performed on the TJNAF site.

The FEL work has enabled TJNAF to develop a VUV FEL with substantial new capability in chemistry, condensed matter physics, biology and materials science. This facility can be cost-effectively upgraded to the soft X-ray (100 eV) photon range (a proposal was submitted to BES last year (JLAMP)). It should also be noted that the DOD funded FEL facility has been used to search for axion (light pseudoscalar particles) and has been proposed as a site for the DarkLight experiment to search for new massive neutral vector particles.

Table 1. Work for Others Funding (BA in $M)

Sponsors	FY 2010 Actual Funding Received	FY 2011 Estimated Funding Level	FY 2012 Request
DOD	2.5	3.8	2.8
NRC	-	-	-
DHHS/NIH	-	-	-
All Other Federal Work	0.4	0.4	-
Non-Federal Work	1.3	0.5	0.2
Commonwealth of Virginia	-	**9.0**[1]	-
Total WFO	**4.2**	**4.8**	**3.0**
Lab Operating	105.2	108.4	111.9
WFO as % of Lab Operating	**4.0%**	**4.4%**	**2.7%**
DHS	-	-	-
WFO + DHS as % of Lab Operating	**4.0%**	**4.4%**	**2.7%**

1. $9.0M funding received in FY 2011 from Commonwealth of Virginia is not included in totals since it provided funding for the 12 GeV upgrade, a DOE project, and is not funding work being performed for an outside agency.

It is clear from this history that the WFO program is synergistic with TJNAF's mission to pursue scientific frontiers aligned with the priorities of the Office of Science. While there is a potential risk of competition between the WFO program and the DOE program for top class accelerator physicist and SRF engineering skills, the TJNAF experience has been very positive. The combination of R&D projects supported by DOE and by WFO provides a dynamic and stimulating environment that enables the Lab to attract and retain top-quality people in the accelerator field.

In the recent past, TJNAF has been successful in engaging the Commonwealth of Virginia to support of the 12 GeV Upgrade project ($9M received in FY 2011). This non-recurring support is captured contractually as a WFO transaction. The lab has also engaged Virginia to explore the possibility of seed funding to support development of our FEL-based photon science program.

WFO Strategy for the Future

The segue of the DOD ONR work to the Innovative Naval Prototype effort led by Boeing has not prompted the curtailment of the FEL R&D supported by ONR. Informal discussions with ONR indicate a mutual vision of continuing non-classified work on accelerator R&D, which could enable advances or inform the INP program on specific issues. The success of the past program for mutually beneficial development encourages a vision for the future.

As the current FEL WFO program becomes commercialized, it becomes more important to develop new initiatives to maintain TJNAF's exceptional capability in accelerator science. In nourishing high technology programs such as the superconducting radiofrequency acceleration, high intensity electron sources, and high performance cryogenics, it is important that the laboratory maintain a rich mix of research, development and production. In this regard, it is of great importance to pursue opportunities to develop cutting-edge SRF projects that utilize our unique expertise in association with accelerator construction elsewhere. While there are several options within DOE, TJNAF is involved in discussions with other partners, particularly on the international scene. For example, there is interest in Jefferson Lab participation in SRF development for the European Spallation Source (ESS) in LUND, Sweden and the MYRRHA project at MOL, Belgium. In addition, TJNAF has had discussions with China and India. In order to ensure that TJNAF does not over commit our resources and to avoid large gaps between projects, it has developed a business plan for Jefferson Lab SRF activities. Moreover, the Lab is seeking to rationalize our portfolio around two main technology axes – continued evolution of elliptical cavities (such as developed for CEBAF and SNS), and development of spoke cavities for low-beta particles (protons and ions). At this time, the latter seems to hold the most growth potential.

There are other potential WFO developments associated, for example, with the detector technology used in the nuclear physics experiments. In the past, such technology at the laboratory has led to a successfully marketed mammography device. Should such opportunities arise in the future under the WFO rubric, TJNAF would entertain them, again provided the scale was appropriate and the perspective retained.

What is important for the strategy is that TJNAF maintains an appropriate perspective with regards to our core mission, currently nuclear physics, but in any case, the provision of user facilities for Office of Science programs. If the balance is right, all the programs stand to win.

TJNAF envisages a total WFO program not exceeding 7-10% on average.

VI. Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

TJNAF 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 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.

TJNAF consists of 60 DOE owned buildings (684,832 SF), two state leased buildings (37,643 SF), and 15 real property trailers (18,750 SF) totaling 741,225 (SF), plus roads and utilities. Additionally, the Lab leases office and lab space (44,280 SF) from the City of Newport News located in the Applied Research Center (ARC), which was constructed by the City of Newport News and adjacent to the TJNAF campus. In addition to these facilities, TJNAF has 72 shipping containers (22,080 SF) used for storage and 19,030 SF of off-site leased storage space. There were no real estate actions in FY 2010 or planned for FY 2011 involving leases of more than 10,000 SF. At the close of FY 2010, ~820 employees were employed and occupying site facilities. Each day, TJNAF hosts on average, ~100 users from the United States and around the world.

The Lab currently has a shortage of technical and office space. The Test Lab has the largest amount of deferred maintenance of any Lab building. Accelerator Site electrical distribution and cooling towers have reached the end of their service life. Communications, computing air conditioning and power, and the Cryogenics Test Facility serving the Test Lab have reached their capacity and need to be expanded to meet the Lab's mission.

A current copy of the Land Use Plan can be can be found on the TJNAF Facilities Management website. Table 1 reflects an Asset Condition Index as of 1 October 2010 that meets the current goal established by DOE SC for Mission Critical Facilities. Mission Dependent Facilities are below the established goal due to aging real property trailers. Through GPP and SLI investments, TJNAF will achieve the SC goal for Mission Dependent Facilities by FY 2015. The site wide Asset Utilization Index is ~ 100% and has been since construction of the Lab. In most areas space is not adequate to accommodate an efficient work environment.

Table 1. SC Infrastructure Data Summary

Total Replacement Plant Value ($)		$316,910,947		
Total Deferred Maintenance ($)		$15,556,758		
Site-Wide ACI (B, S, T)		0.951		
			# Assets (B, S, T)	GSF (B, T)
Asset Condition Index (B, S, T)	Mission Critical	0.961	54	633,977
	Mission Dependent	0.844	41	69,605
	Not Mission Dependent	0.000	0	0
			# Assets (B, T)	GSF (B, T)
Asset Utilization Index (B, T)	Office	100	19	171,122
	Warehouse	92.06	10	45,315
	Laboratory	100	35	452,079
	Hospital	0	0	0
	Housing	0	0	0

B = Buildings; S = Structures; T = Trailers

Facilities and Infrastructure to Support Laboratory Missions

The completion of the 12 GeV Upgrade, scheduled for FY 2015, adds a fourth experimental hall along with upgrades to existing halls and will provide TJNAF users with state-of-the-art facilities necessary to advance science in support of DOE SC goals. Additionally, completion of the Technology and Engineering Development Facility (TEDF), scheduled for FY 2013, will provide a first rate facility for the advancement of research and development in superconducting radio frequency (SRF) technology. While the support facilities and infrastructure are not mission-ready today, the completion of the TEDF, the Utilities Infrastructure Modernization SLI project and the Research and User Support Facility would enable TJNAF to meet its current modernization goals by 2017.

TJNAF assesses the condition of its facilities on a four year cycle using a software package called "VFA Facility" that is offered by Vanderweil Facility Advisors (VFA). Overall, the condition of the facility infrastructure is good. There are, however, shortages in office technical and experimental assembly work space. Currently over 18,750 square feet of temporary trailers are used to provide both office and technical space. GPP and SLI funded projects have been identified in the Lab's Ten Year Facilities Plan to correct these shortages and eliminate temporary trailers. The Experimental Staging Facility, General Purpose Building Expansion, 4 KW End Station Refrigerator Building, installation of a new 22 MVA substation, and replacement of the Test Lab Cooling Towers completed in 2010 provided some of the needed critical infrastructure. Completion of the 12 GeV and TEDF projects will provide an additional 154,000 SF of technical and experimental space. In addition to space provided by these two projects, the Ten Year Facilities Plan identifies 102,000 SF of additional needed technical, office, or support space.

A Mission Readiness Peer Review of TJNAF was held in September 2010 with a very favorable outcome. The review did not report any findings and identified three opportunities for improvement.

The Mission Readiness assessment of technical and support facilities and infrastructure is summarized in Enclosure 2. TJNAF is seeking DOE support for two SLI line item projects; the Utilities Infrastructure Modernization Project and the Research and User Support Facility currently in the SLI funding profile for 2013. Completion of these projects will upgrade critical site support utilities and allow consolidation of staff currently in leased space, provide additional conference space and bring the buildings up to desired sustainability and aesthetic standards.

Strategic Site Investments.

- **12 GeV Conventional Facilities (Line Item)** Conventional facilities required for construction, pre-operation, and some operations of CEBAF at 12 GeV are included as part of the 12 GeV CEBAF Upgrade project. The conventional construction includes 36,400 SF of new space including an extension to the tunnel, a fourth experimental hall, and upgrades to Halls A, B and C.
- **Technology & Engineering Development Facility (SLI) (CD-3B)** The project renovates the current Test Lab (about 95,000 square feet), removes over 10,000 SF of inadequate and obsolete work space in and adjacent to the Test Lab, and removes 12,000 SF of dilapidated trailers that do not meet current commercial standards. The project includes construction of a new building and a building addition which will add over 117,000 SF of needed workspace for critical technical support functions, including mechanical and electrical engineering, cryogenics engineering and fabrication, and environment, safety, and health. The project has been submitted as two Leadership in Energy and Environmental Design (LEED) projects (Technology and Engineering Development Building and Test Lab Addition/Rehab) with the design goal of achieving, LEED Gold (second highest designation). Energy savings from the Test Lab Renovation are estimated at 762,570 kWh/yr of electricity and 7,437 therms of natural gas for a total of utility cost savings of $52,000/year.
- **Utilities Infrastructure Modernization Project (SLI) (CD-1)** This project replaces or upgrades the following utility systems:

  - Electrical Distribution: Replace accelerator site primary and secondary electric feeders and provide an alternate power feed capable of restarting the Central Helium Liquifier (CHL).
  - Process Cooling: Replace/upgrade 20 to 40 year old site cooling towers serving the Accelerator Site Low Conductivity Water (LCW) systems and provide additional computer center cooling and uninterruptable power.
  - Cryogenics: Upgrade Cryogenics Test Facility adjacent to the Test Lab (TEDF) to fully support SRF and FEL R&D and experimental hall operations.
  - Communications: Replace 20 to 40 year old underground communications and data cabling and equipment.

  This project initially programmed for FY 2011-13 funding has been delayed. The Lab has requested FY 2013 funding for this critical project.

- **Research and User Support Facility (SLI)** This project funds the modernization of, and additions to, the CEBAF Center, which is the hub of the Lab. Construction includes two additional wings (95,000 SF) and the rehabilitation of 67,300 SF of space in the building. The project alleviates overcrowding of personnel, relocates staff and users currently occupying leased space, accommodates planned staff growth needed for the additional 12 GeV experimental hall and reduces leased space in the Applied Research Center and in commercial storage warehouses. The project will be designed and constructed to meet LEED Gold standards and reduce energy consumption of the existing building by 30%.

Maintenance Strategy

TJNAF utilizes small business subcontractors to perform the majority of facility maintenance tasks. Maintenance investment will continue at a level to maintain the facilities mission ready. The Lab has developed SLI or GPP projects to significantly reduce deferred maintenance. It is estimated the TEDF and UIM projects will eliminate over 70% of the Lab's deferred maintenance associated primarily with the rehabilitation of the Test Lab and elimination of temporary trailers. The Lab has a trailer disposal plan to replace trailers with permanent building space.

Excess Facility/Material/Environmental

TJNAF does not have any excess facilities or environmental issues. The Lab is in the process of recycling 130 concrete blocks from the Test Lab Building from when it was operated as the NASA Space Radiation Effects Laboratory (1964 to 1984). DOE recently determined that these blocks are not subject to the moratorium on the release of radioactive material. The plan is to recycle these blocks during FY 2011. The Lab has an active metal recycling program with more than 80,000 pounds recycled during the first half of FY 2011.

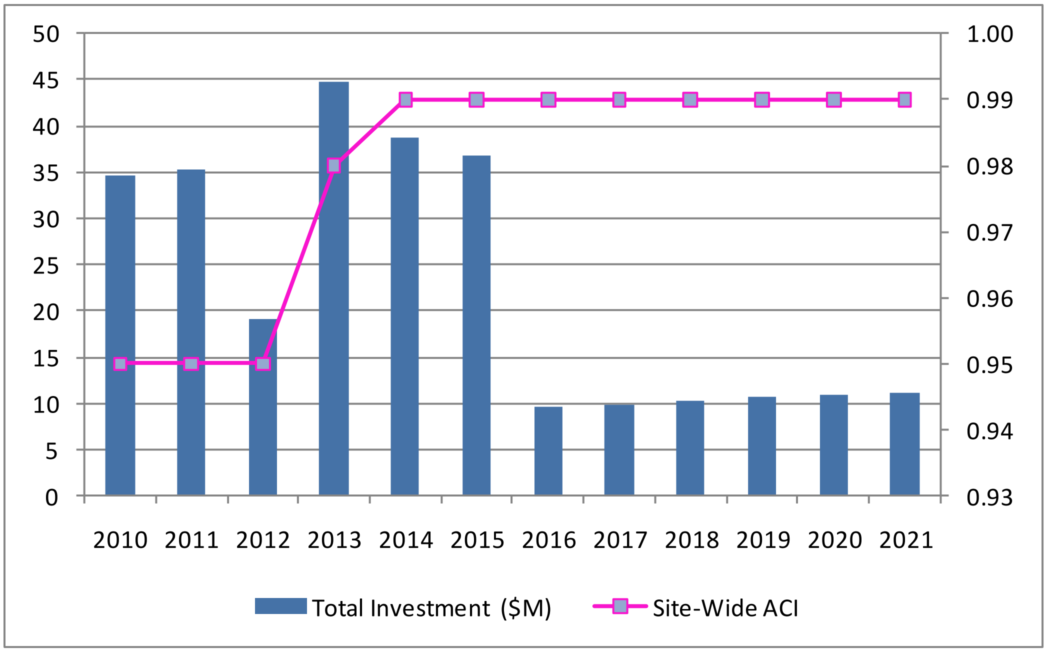
Trends and Metrics

Table 2 shows the Lab's planned infrastructure investment and the positive impact on the Asset Condition Index (ACI) and level of deferred maintenance (DM). Figure 1 depicts site wide ACI and infrastructure investments. Planned projects would allow the Lab to reach and sustain a DOE performance rating of "Excellent" by FY 2013. TJNAF facilities are expected to be mission ready upon completion of the projects identified in the Ten Year Site Plan.

Table 2. Facilities and Infrastructure Investments (BA in $M)

	2010 Actual	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	4.9	4.2	4.7	5.2	5.7	6.0	6.6	6.8	7.0	7.3	7.5	7.7
Deferred Maintenance (DM) Reduction												
Excess Facility Disposition (overhead)	-	-	-	-	-	-	-	-	-	-	-	-
IGPP	-	-	-	-	-	-	-	-	-	-	-	-
GPP	2	2.5	2.2	4.6	3.1	3.1	3.1	3.1	3.2	3.3	3.4	3.5
Line Items	27.7	28.5	12.3	35.0	30.0	27.6	0	0	0	0	0	0
Total Investment	34.6	35.2	19.2	44.8	38.8	36.7	9.7	9.9	10.2	10.6	10.9	11.2
Estimated Replacement Plant Value (RPV)	316.6	327.8	339.6	378.6	411.3	433.2	479.1	493.5	512.3	527.7	543.5	559.8
Estimated DM	15.6	16	16.5	8.1	5	5.1	4.5	4.6	4.7	4.9	5	5.2
Site-Wide Asset Condition Index (ACI)	0.95	0.95	0.95	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Figure 1. Facilities and Infrastructure Investments



Site Sustainability Plan.

TJNAF submitted its Site Sustainability Plan to the Office of Science in December 2010. The Lab's strategy addresses sustainability requirements in three areas; facility energy efficiencies, renewable energy and potable water reduction, and changing behaviors. The greatest challenge to the Lab is to reduce energy and water consumption while doubling the accelerator energy to 12 GeV. Figure 2 depicts the historical and projected purchased electricity for the Lab through FY 2020. FY 2014 will be the first full year of operating both Central Helium Liquifier (CHL) plants which is projected to increase the total purchased energy 91% above the FY 2008 baseline.

Figure 2. Historical and Projected Purchased Electricity

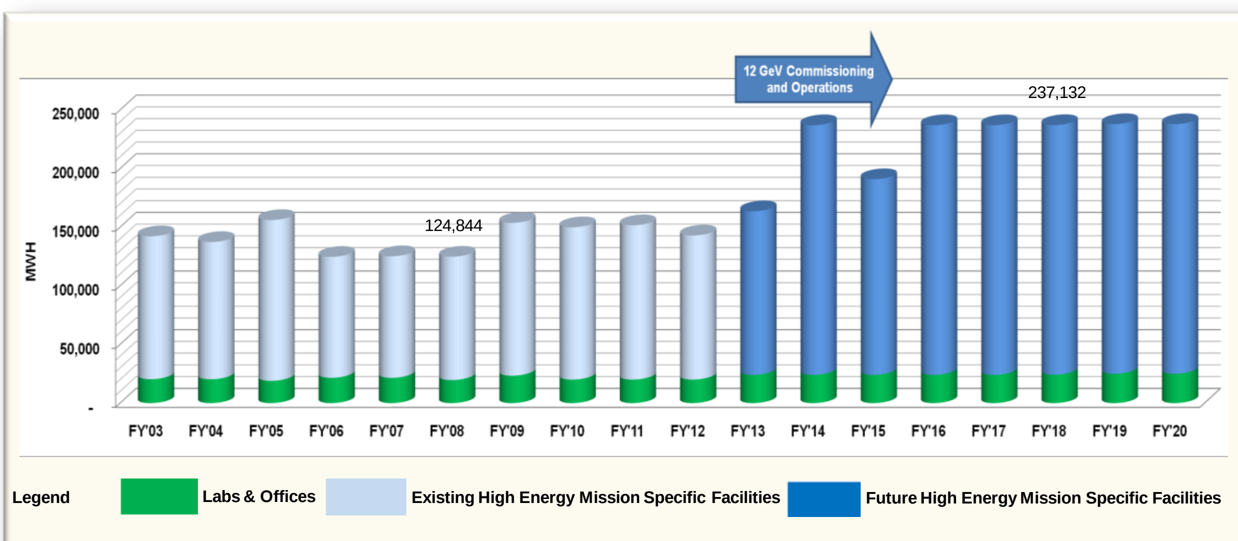


Figure 3 depicts the Lab's strategy to reduce Scope 1 and 2 GHG by 28%. The strategy is dependent on appropriate levels of funding and the ultimate success of the portfolio approach to sustainability. The strategy includes:

CEBAF Improvement Projects	**Annual Energy Savings (Mwhs)**
Rebuild CHL 1 / Ganni Cycle	16,000
Refrigeration Recovery / 2 K Helium	1,200
Retrofit Existing DC Power Supplies	960
Replace ESR Refrigerator	2,000
Upgrade 10K Liter Dewar	2,000
Optimize Warm Compressor Design	1,600
High Efficiency Klystrons	23,980
Efficient RF Sources	7,990
Beam Schedule Optimization	4,240
Total	**59,970**

CEBAF Improvement projects implementation cost approximately $56,360,000

Solar PV Project	**Annual Energy Generation**
1.7 Mw Roof and Parking Lot Mounted Solar PV System	2,172 Mwhs

Solar PV project implementation annual cost / $304,000 (Power Purchase Agreement)

ECMs (Offices and Labs)	**Annual Energy Savings (Mwhs)**
LED Lighting Upgrades	832
Building Re-commissioning	351
HVAC Controls Upgrades	175
Building Envelope / Window Upgrades	250
Total	**1,600**

ECM (offices & Labs) implementation cost approximately $1,000,000

Renewable Energy Credits (RECs)	**Annual Cost Range ($1.00 - $5.00 / REC)**
45,595 Mwhs = 45,595 RECs	$125,000 - $500,000

Figure 3. Scope 1 and 2 Greenhouse Gas Reduction Plan

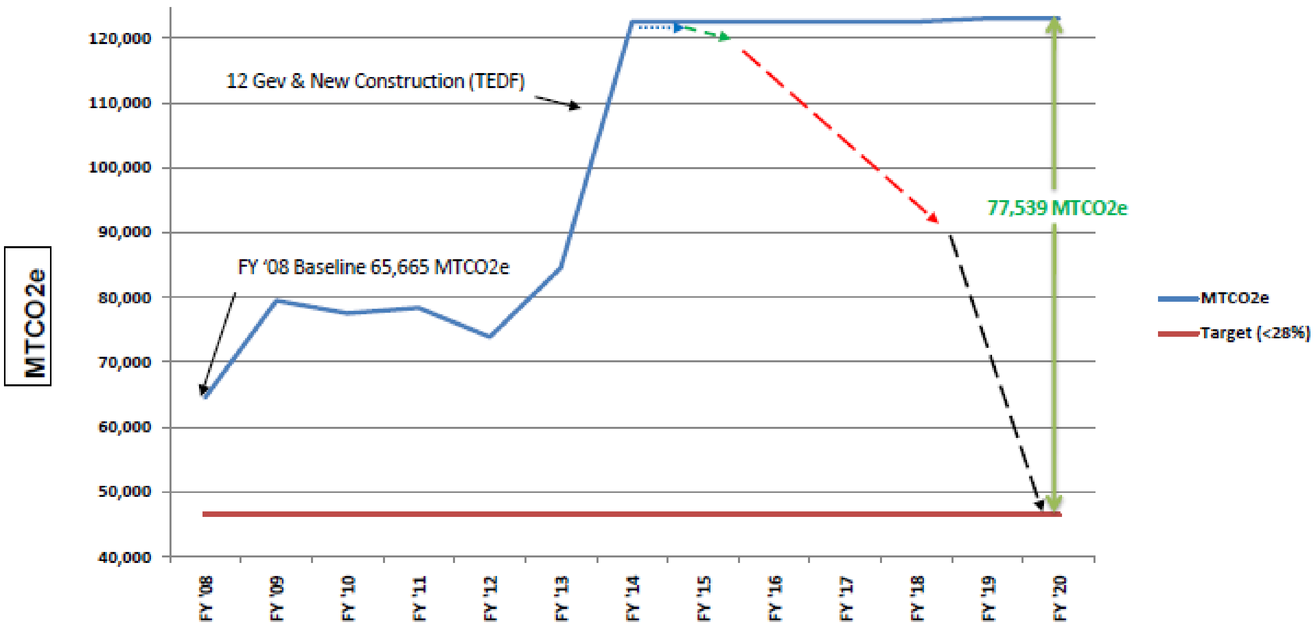


Chart Reference	Reduction Strategies	GHG Reduction (MTCO2e)	Procurement Cost (Capital and R&D) / $K	Implementation Schedule (FYs)	% Total GHG Reduction Amount
	ECMs (Offices / Labs)	845	$1,030	FY 2012 - 2014	1%
	1.7 MW Solar PV	1,123	$304 / Year (10 year PPA)	FY 2013	1.5%
	CEBAF Improvement Projects	29,976	$56,360	FY 2011 - 2019	38.5%
	Renewable Energy Credits	45,595	$125 - $500 / Year	FY 2018 - Ongoing	59%

Facility Energy Efficiencies: The Lab is addressing both conventional facilities as well as the CEBAF Improvement projects' equipment. The Lab has identified maintenance and General Plant Projects (GPP) to improve building system efficiency to reduce energy and water consumption. Included is the funding of efficiency tools such as advanced metering and meeting guiding principles in more than 15% of the buildings. The LEED Gold Technology and Engineering Development Facility SLI funded project will greatly contribute to energy conservation once completed in FY 2013. These efforts are projected to reduce energy utilization intensity by more than 30% by FY 2015 compared to the FY 2003 baseline. Several CEBAF Improvement projects have been developed (see above lists). Improvements to these systems offer the best promise and could lead to a decrease in energy use of 59,970 Mwhs/year (38.5 % of the required GHG reduction).

Renewable energy and potable water reduction are being sought through multiple projects. Geothermal heat pumps reduce energy consumption for both heating and cooling by taking advantage of the thermal energy generated stored in the Earth. Jefferson Lab has to-date installed 190 wells which provide a total of 186 tons of cooling and heating capacity. The TEDF project, currently under construction, will install an additional 198 wells and provide 170 tons of cooling and heating capacity. Another energy initiative underway is a 2 MW Solar Power Purchase Agreement for the site. The Lab is working to obtain "Reuse Water" for use in Lab cooling towers and for irrigation from Hampton Roads Sanitation District (HRSD) allowing Jefferson Lab to meet and exceed the water conservation Executive Order and DOE sustainability goals. Two options are being evaluated to provide Virginia Level 1 reuse water to the Lab; 1) installation of a Membrane Bioreactor (MBR) package system or 2) installation of an underground pipeline to the Lab from the HRSD James River Treatment Plant. Under either option, the reuse water would be directly used for irrigation, but would receive additional treatment before use in the cooling towers to prevent scaling and minimize cooling tower water treatment costs. TJNAF would use up to 200,000 GPD of reuse water. This initiative could reduce the Lab's potable water use by 70%.

Behavioral change. Included under this category are sustainable purchasing, resource conservation, electrical and water equipment maintenance, travel reduction through video conferencing, and alternate work schedules. The Lab routinely exceeds a 95% goal of procuring silver rated electronics EPEAT (Electronic Product Environmental Assessment Tool) products. Lab conservation programs include irrigation water management through rain sensors, night setback of building systems, and an energy conservation policy to maintain consistent heating and cooling temperatures and prohibit personal appliance use. The night setback program has reduced energy use in the Applied Research Center by 10%. Equipment preventative and corrective maintenance including retro commissioning is regularly performed to maintain systems at peak efficiency. Video conferencing software has been obtained to improve this capability and assist in the reduction of travel. The Lab currently uses alternate work schedules on a limited basis and tele-work programs are being evaluated to assist in the reduction of Scope 3 Green House Gas emission reductions.

TJNAF has made progress in meeting the Office of Science Sustainability/DOE Goals as depicted in Table 3. The highest risk is for the Scope 3 GHG and water reduction goals. It is estimated that an investment of ~$7M is required to meet the water reduction goal. The identified water reuse project would result in savings greater than the prescribed goal. The excess water savings could be used to meet the water reduction goal at other Office of Science Labs. The Lab has to date completed 4 of the 14 goals.

Table 3. Progress Against Office of Science Sustainability Goals

Requirement	DOE Corporate Goal	Status	Risk of Non-attainment (H,M,L)
Scope 1 and 2 Greenhouse Gas (GHG) Emissions	28% reduction from 2008 to 2020	Reduce Scope 2: CEBAF Improvement projects have been developed Analyzing solar purchase power agreement REC purchase to supplement **Lab will require significant investment to meet goal**	H
Energy Reduction	30% from FY 2003 to 2015.	Have achieved 19.6% Energy Utilization Intensity reduction to date. **Lab will exceed goal** through identified Energy Conservation Measure projects for existing facilities and completion of a new LEED Gold designed facility.	L
Renewable Energy	At least 7.5% of annual electricity and thermal obtained through RECs or 3.75% produced on-site by FY 2010	Purchasing REC equal to 7.5% of annual Mwh electrical use,. **Complete**	L
Fleet –Alternative Fuel Consumption	10% annual increase in Alternative Fuel consumption from 2005 to 2015.	Alternative fuel consumption has increased 57% relative to the FY 2005 baseline. **Lab will meet goal.**	L
Fleet - Petroleum Consumption	2% annual reduction from 2005 to 2015.	Fleet petroleum consumption reduced about 50% relative to the 2005 baseline. **Complete**	L
Fleet – Light Duty Vehicles	75% of light duty vehicles purchased must be alternative fuel vehicles by 2015.	72% of TJNAF's vehicles classified as "Light Duty" are AFV. **Lab will meet goal.**	L
Advanced Metering	Use to the maximum extent practical, for electricity by October 2012, steam and natural gas by October 2016. Standard meters for water.	Exceeding deadline for electricity, natural gas and water metering. Scheduled to have site wide metering system for all utilities completed by FY 2011 end. **Lab will meet goal.**	L
Cool Roofs	Use for new roofs per Secretarial memo of June 1, 2010.	New construction and major renovation projects currently under construction are designed to meet cool roof requirements. Future roof replacements / upgrades will comply with cool roof requirements as economically feasible. **Lab will meet goal.**	L
Training and Outreach	DOE facility energy managers to be Certified Energy Managers (CEM) by September 2012.	**Complete**	L
Sulfur Hexafluoride (SF_6) Capture	Implement capture program by September 2012	**Complete**	L
Scope 3 GHG	13% reduction from 2008 to 2020.	Developing programs to reduce staff commuting, business travel emissions, and large scale on-site solar PV electricity generation to reduce T&D loss emissions.	H
Buildings	15% of existing space meets guiding principles by FY 2015 (baseline excludes buildings of 5,000 SF or less)	0% facilities >5,000 GSF comply with 100% of HPSB Guiding Principles. Targeted (2) existing facilities and (2) LEED Gold facilities to comply by FY 2014. **Lab will meet goal.**	L
	All new construction and major renovations LEED Gold certified	Technology and Engineering Development Facility designed to achieve LEED Gold certification. Construction scheduled to complete FY 2013. **Lab will meet goal**	L
Water Intensity Reduction	16% by FY 2015 relative to FY 2007 use	Working with local utility on water reuse project. Project Est. $7M. Funding not yet identified.	H
Water Consumption Reduction	20% reduction of industrial, landscaping and agricultural use by 2020 relative to 2010.	N/A – do not use non-potable water for ILA	L

VII. Human Resources

Current and Future Workforce

The workforce at TJNAF has grown from 640 in 2005 to its current level of 830 employees. It is expected to reach ~785 by 2016. The changes in staffing levels can be attributed primarily to the 12 GeV upgrade project, the addition of a fourth experimental hall, the addition of more than 100,000K square feet of engineering, design and research support facilities, and an expanding research program. Staffing levels will fluctuate to support project and mission needs over the next five to six years. In 2016, the optimal workforce will be right-sized with the appropriate set of skills, the right balance of permanent and temporary positions, structured to efficiently and effectively meet mission requirements, appropriately compensated, and with an improved representation of women and minorities. Figure 1 reflects the staffing level and skill mix that will be required to achieve mission success by 2016.

Figure 1

Skills Mix	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016
Scientist	154.9	172.5	171.3	170.0	166.0	169.9	165.5
Engineer	161.3	192.3	181.1	184.8	165.5	160.6	152.4
Technical	273.2	301.6	308.3	296.7	299.9	287.8	276.6
Administrative	133.4	138.4	138.5	142.1	144.7	144.4	142.3
Total TJNAF FTEs	**722.8**	**804.8**	**799.2**	**793.6**	**776.1**	**762.7**	**736.8**

The optimal staffing profile will be comprised primarily of scientists, engineers and technicians in order to meet mission outcomes. The technical and scientific staff required will possess a unique set of skills including SRF, superconducting magnet, and accelerator R&D expertise. To achieve this mix of skills, the workforce will include some regular as well as temporary employees to supplement peak work activities during construction, installation and full operations. The plan ensures the staffing expertise and skill mix needed to deliver the 12GeV science program are fulfilled and that there is controlled growth in overhead.

Historically, TJNAF has been challenged to increase the representation of females and minorities in scientific and engineering jobs due in part to the relative dearth of female and minority engineering graduates and Physics PhDs entering the work force. The Lab has done relatively well with minority representation, but continues to be challenged with increasing female scientist and engineer representation.

To accomplish this, enhanced diversity outreach efforts are in place through continued participation in targeted job fairs at both universities and professional organizations, an increase in the number of students in the Cooperative Education Engineering program, as well as a strong college/university network with a focus on our SURA universities. The Lab has specifically targeted females by participating in such events as the “Introduce a Girl to Engineering” Week, and attendance at professional associations such as the Society of Women Engineers job fair. Other outreach activities include the creation of the JSA Minority Undergraduate Research Assistantship program targeting minority undergraduate physics majors at SURA universities. An ongoing evaluation of diversity efforts will continue to determine where resources might be best applied to increase the Lab’s representation.

Obstacles and Strategies

The obstacles that can affect TJNAF's ability to achieve its optimum workforce are discussed in detail, along with impacts and possible strategies.

1. **Funding Uncertainty**
   Operating under annual continuing resolutions for the past several years creates uncertainty in managing both day-to-day operations, as well as long term strategic planning. This uncertainty has, and will continue to impact the Lab's ability to recruit. Examples include positions being open for more than 200 days for highly skilled engineers and technicians and a 15% increase in job offer rejections in the past six months. Anecdotal feedback from recent interviewees indicates that they do not feel that TJNAF is a stable employer of choice.

   In FY 2011, 30% of all hiring actions needed to meet critical milestones and provide operational support were put on hold during the first six months of the fiscal year due to the budget uncertainty.

   Strategies to mitigate the possible impacts include the use of a matrixed workforce to strengthen the existing skill mix, cross training activities for employees with more unique knowledge of systems, and the use of term and contract employees.

2. **Recruiting**
   The recruitment of critical and unique skills to assist TJNAF in achieving core capabilities is an ongoing area of focus. Skill sets that are critical to success include SRF scientists and engineers, superconducting magnet engineers, electrical and mechanical R&D engineers. The identified hard-to-fill skills are often associated with extended recruitment searches. This has impacted project schedules. To minimize the duration of the recruitment search, the Lab has taken steps to aggressively recruit externally as well as develop internal talent. An example is the SRF engineers. The Lab has utilized its network to attract such candidates with some success. Other strategies pursued to address recruiting needs include the use of online social media and technical resources to promote opportunities and market the Lab as an employer of choice; outreach to the broader technical community and the hiring of junior talent for development into higher level positions. The hiring of a junior Superconducting Magnet engineer has provided the Lab with the opportunity to groom young talent while supporting the Lab's core capabilities.

3. **Competitive Salaries**
   TJNAF currently has an overall salary market lag of 6.4% according to DOE approved national market surveys. The recent implementation of a pay freeze and the inability to "catch up" exacerbates this. The overall market lag for the Lab in FY 2013 is expected to nearly double to 12%. The lag is more pronounced for critical skill sets, most notably for scientists and engineers:

Position	FY 2011 Lag	FY 2013 Lag
Scientist	9 %	14%
ES&H Engineer	11%	17%
Electrical Engineer	14%	19%
Chemical Engineer	17%	24%

   To manage the issue of competitive salaries and maintain core capabilities, the Lab will make targeted market adjustments for critical skills based on the recent decision by DOE to allow for a

1.5% adjustment pool. Additionally, retention/sign-on bonuses will be used as appropriate for selective, hard to fill positions.

4. Aging Workforce

The retirement eligible population at Jefferson Lab at the end of FY 2011 will be approximately 28% of the total workforce. Of these, two thirds will be scientists/computer scientists (27%), engineers (14%), and senior technical specialists (26%). Nearly 42% of these potential retirees are either supervisors or managers.

Strategies to mitigate the loss of key leadership and technical skills include:

- succession planning activities targeted at filling both near and long term vacancies
- technical and leadership education programs within the Lab as well as external training to complement developmental needs such as the Senior Laboratory Leadership Program at the University of Chicago
- cross training in scientific and technical areas
- corporate reach back to assist in recruiting and retention

VIII. Cost of Doing Business

TJNAF's approved metrics and performance indicators provide an excellent understanding and means of tracking the cost of doing business. This information is presented to Thomas Jefferson Site Office twice annually. There is a clear vision of the scientific future, staffing and infrastructure needs. Over the next six years, TJNAF will experience steady yet manageable cost growth. Although power demand will double by 2016 with the completion of the 12 GeV upgrade, TJNAF has negotiated and received a special status from the Commonwealth of Virginia which results in extremely low electricity rates from Dominion Power. TJNAF will continue modernization of Lab facilities which will control increases in indirect costs through reductions in deferred maintenance and increased energy efficiency. Staffing needs are understood into 2016 with detailed plans by skill type. Bottoms up activity based planning and budgeting allows the Lab to understand and control overheads. Indirect and fringe rates will continue to remain fairly stable. Overhead rates have been relatively constant at ~20% of the total budget for the past 10 years. Fringe rates have remained consistently low at 29%. Overall, benefits are in line with national comparators and are expected to remain so.

Budget Process

TJNAF continues to utilize a Work Breakdown Structure (WBS) for all work activities including indirect activities. Planning and budgeting efforts are aligned with the DOE mission, goals and requirements as depicted in Figure 1. Specific work direction resulting from strategic planning is then articulated at the activity level through detailed Annual Work Plans.

Figure 1

The AWP and the Lab's final operating budget are developed through a series of management reviews each chaired by the Laboratory Director. The managers and owners of the activities are engaged in not only presenting their own budget requests but in reviewing the requirements and requests from all other activities. The result is an activity based budget and AWP that is well understood and supported by all management levels.

Once finalized and approved, the AWP is maintained by the Chief Operating Officer. Often dynamic as the year progresses, changes to the baseline are controlled. The WBS and AWP also serve as a central tool and process for the TJNAF's Contractor Assurance System.

Metrics

Table 1 provides detailed information regarding TJNAF's overhead trends since 2008. The modest increase in the indirect workforce is a result of term positions for the 12 GeV construction project and facility modernization efforts and a shift of ~20 FTEs to indirect funding in support of the SRF institute. The SRF institute provides support to multiple programs in SC and DOD. The shift to indirect enables a more equitable cost recovery for work performed.

Table 1. Laboratory Overhead Trends - TJNAF (Cost Data in $M)

	FY 2008	FY 2009	FY 2010	FY 2011 Est.	FY 2012 Est.
1. Direct FTE Ratio					
Numerator: Direct FTE's[1], which represent time charged to client funded work[2], including capital but excluding LDRD	**535**	**529**	**558**	**627**	**621**
Supplemental Data: Indirect FTE's (all non direct FTE's, to include LDRD and organizational burden[3])	**121**	**131**	**165**	**178**	**178**
Numerator: Total FTE's (subtotal of direct and indirect FTE's)	**656**	**660**	**723**	**805**	**799**
Direct FTE Ratio (%): Direct FTE's/Total FTE's	**82%**	**80%**	**77%**	**78%**	**78%**
2a. Total Overhead/Total Lab Cost					
Numerator: Total overhead cost, which includes institutional overhead, LDRD and organizational burden[3] to the extent this overhead is allocated to client funded work[2].	**$24.4**	**$26.0**	**$31.2**	**$35.4**	**$35.8**
Denominator: Total lab cost includes all cost charged to client funded work[2] (operating and capital). Includes subcontracts and procurements[4] and line item construction costs.	**$107.7**	**$118.2**	**$184.9**	**$216.5**	**$235.6**
Total Overhead/Total Lab Cost (%):	**22.7%**	**22.0%**	**16.9%**	**16.4%**	**15.2%**
2b. Total Overhead/Total Lab Operating Cost					
Numerator: Same as preceding metric.	**$24.4**	**$26.0**	**$31.2**	**$35.4**	**$35.8**
Denominator: Same as preceding metric, but exclude line item construction costs.	**$98.6**	**$103.3**	**$123.1**	**$117.7**	**$119.4**
Total Overhead/Total Lab Operating Cost (%):	**24.7%**	**25.2%**	**25.3%**	**30.1%**	**30.0%**
2c. Total Overhead/Total Internal Lab Operating Cost					
Numerator: Same as preceding metric.	**$24.4**	**$26.0**	**$31.2**	**$35.4**	**$35.8**
Denominator: Same as preceding metric, but exclude subcontracts and procurements[4] charged to client funded work[2].	**$94.9**	**$101.5**	**$97.5**	**$93.2**	**$94.6**
Total Overhead/Total Internal Lab Operating Cost (%)	**25.7%**	**25.6%**	**32.0%**	**38.0%**	**37.8%**
3. Fringe Rate					
Numerator: Total cost of employee benefits (including statutory benefits), not including paid absences.	**$14.58**	**$15.36**	**$17.09**	**$18.78**	**$19.81**
Denominator: Total base salary cost.	**$51.33**	**$52.93**	**$58.36**	**$65.66**	**$69.21**
Fringe Rate (%):	**28%**	**29%**	**29%**	**29%**	**29%**

1. *A Full Time Equivalent (FTE) is calculated as actual hours charged divided by the expected hours to be charged by a normal employee during a year.*
2. *"Client funded work" refers to "direct charges"/"direct funded work."*
3. *"Organizational burden" refers to an overhead pool that accumulates the cost of managing and operating an organization or group of organizations and is usually allocated on a rate established specifically for recovering the cost of the organization and/or grouping. It includes space charges.*
4. *"Subcontracts and procurements" includes services performed for and purchases made by the laboratory that are charged directly to programmatic work, e.g., subcontracts for consulting, postdoctoral R&D fellowships at national laboratories, construction, architect and engineering services, material and equipment purchases, inter-entity work orders to other DOE laboratories, R&D at universities, and etcetera.*

** FY 2008, FY 2009, and FY 2010 data reflect actual costs. FY 2011 and FY 2012 are estimates (adjusted for escalation using a factor that is appropriate to the individual laboratory).*

Major Cost Drivers, Decisions and Trade-Offs

- **Salaries and Fringe Benefits**

  A detailed staffing plan by skill mix exists through 2017. TJNAF expects temporary growth in direct and indirect staffing to support 12 GeV construction and Lab modernization efforts. Salaries comprise ~50 percent of the Lab's total operating budget. Salary increases and pay adjustments have been consistent with modest cost of living increases. The pay freeze in effect until FY 2013 will result in a significant market lag in salaries. This will be compounded by the current DOE guidance that prohibits adjustments, post pay freeze, necessary to reach parity with market salaries.

As outlined in section VII, scientists will lag the market by 15% and certain categories of engineers by 16%.

TJNAF has a defined contribution plan provided by TIAA-CREF. TIAA-CREF provides consultation services to employees at no charge, and the Lab does not pay administrative fees associated with the management of the plan.

Benefits Cost Control - The Lab's medical insurance premium rate increases, averaging ~7% for the past few years, have been below the market average of 11%. This is due in part to a healthy workforce and extremely low workers compensation costs.

As part of the annual renewal process, the Lab reviews each of its medical plans and examines various options on the services covered, premium rates and cost to employees and retirees. Increases in coinsurance and co-payment charges are considered, taking into account the effect on premium rates versus the out-of-pocket costs for employees. In recent years, such increases have been implemented to control costs to DOE. Since medical expenses are expected to continue to rise in the future at rates above inflation, the Lab will closely monitor increasing costs and associated impacts on both the Lab and employee. Analysis of the data will be carefully weighed to position TJNAF to be able to remain competitive, which is critical to retaining and attracting world class talent. The cost of medical plans is shared with current employees at a 25%/75% split and retirees at 50%/50% split.

- **Site Power and Utilities**

  Power demand will double in the 12 GeV era from ~19 to ~38 MW. Operational reconfiguration and efficiencies, adjusting running weeks and schedule when necessary, and modifying run schedules to take advantage of power bill structure will help mitigate the cost increases. As already mentioned, TJNAF has negotiated lower rates with Dominion Power through a beneficial State Rate which at ~6 cents per kwh, is far lower than the standard General User and Federal Rate. TJNAF utilized 3rd party financing in 2002 to replace aging HVAC equipment and lighting upgrades to reduce energy consumption saving in excess of $225,000 per year. TJNAF implemented innovative helium process technology (Ganni Cycle) that reduced electric demand and costs by trimming the equipment operation based on actual cryogenic requirements. A current expansion of the Central Helium Liquefier will use this technology and other operational efficiencies to operate at reduced levels during periods when the accelerator beam is not scheduled to be delivered. Construction and operation of cooling towers has been modified to reduce the number of cooling towers as well as the use of variable frequency drives to operate the system. This will save both energy and operating cost by reducing duplication of equipment as well as maintenance.

  TJNAF has implemented on-site power load management practices using power draw monitoring to manage electrical demand charges for all system operations. TJNAF is also participating in an electrical load curtailment program at the electrical grid level for electrical load management through EnergyConnect (a company providing load management solutions), which resulted in payments to TJNAF of $189,000 in FY 2010 and $379,000 in FY 2011.

  Sustainability elements have been incorporated into all facility designs. The CEBAF Center Addition was constructed in 2006 utilizing geothermal heat pumps for office heating and air conditioning as well as a heat wheel to pre-treat makeup air. Recently constructed experimental staging and general purpose storage buildings, also utilize geothermal heat pumps. The

Technology and Engineering Development (SLI) project which expands the current test lab by 100,000 square feet will result in two LEED Gold buildings scheduled to be completed in FY 2013.

- **Infrastructure Modernization and Maintenance**
  - TJNAF is in its 27th year of operation using the 1965 vintage Test Lab as its major technical work facility. More than 18,750 SF of temporary trailers currently provide both technical and office space. Science Lab Infrastructure funding (SLI) for a CEBAF Center Addition in 2004 added more than 60,000 SF of office, conference, and computing space, and allowed for the razing of more than 30,000 SF of temporary trailers. The currently funded Technology and Engineering Development Facility (SLI) will renovate the Test Lab plus add more than 100,000 SF of technical space and offices to LEED Gold standards. When completed in FY 2013, this project will greatly extend the life of the facility, remove more than 22,000 SF of trailers and space, and reduce energy use and operating cost. Utilities infrastructure modernization activities are planned to renew key electrical, process cooling, cryogenic, and communications infrastructure directly supporting the science program. These utility improvements form the Utilities Infrastructure Modernization project planned for FY 2013. The Research and User Support Facility project planned for FY 2016 will upgrade the existing 24 year-old building to LEED Gold standards and consolidate staff in leased space into quality offices and conference space.

    Since 2000, the Office of Nuclear Physics has funded more than $11M in GPP projects plus $10M in ARRA funds to enhance the infrastructure and meet Lab needs. The more than $100M of SLI funding programmed and $25M in GPP already funded since 2000 have greatly improved lab facilities. Continued support from both SLI and GPP to complete the modernization process will provide the proper facilities to support TJNAF's mission. Overall, the modernization will reduce increases in operating costs by:

    - Eliminating 70% of the current deferred maintenance.
    - Reducing energy consumption and cost by designing new facilities to LEED standards. Energy reduction will be at least 30% of American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Std. 90.1. The TEDF project renovation of the Test Lab will reduce electric and natural gas consumption 70% less than the current building systems.
    - Constructing long term need facilities on site and reducing off site leases.
    - Replacing temporary facilities with permanent ones with longer service life.

Appendix 1. Annual Work for Others Report

TJNAF provides a summary description of the laboratory's WFO activities as listed in Table I (Work for Others Funding).

With respect to TJNAF 's activities categorized in Table 1 as "All Other Federal Work," the description below 1) identifies the Federal entities that comprise this group, and 2) provides a brief explanation of the work effort for each Federal entity in Sections A and B below. Similarly, with respect to the laboratory's activities categorized in Table 1 as "Non-Federal Work," TJNAF uses descriptions in this Appendix in Section C below to identify 1) the types of non-Federal organizations that comprise this group, and 2) individual significant efforts.

A. DOD

Agency: Department of Defense
Office of Naval Research:
Total Funds Expected FY11: $3,004,000 FY12: $2,400,000
Total Funds Received through Q2 FY11: $1,517,000
Scope: Utilize both the UV and IR Free Electron Lasers at Jefferson Lab for studies related to electron beam production, transportation, and light generation that underpin performance requirements for high performance FELs in areas related to high power scaling. Efforts will also include tasks related to optical and electron beam diagnostics and critical material testing.
Utilize the FEL electron beam to study the effects of RF impulses on electronics.
High Power FEL Studies (Boeing Support). Participate in system analysis planning activities and attend meetings to tie Start to End modeling to specs for critical tolerances and identification of measurements to resolve beam properties to verify compliance with tolerances. Collect, compile, organize and provide to Boeing existing procurement specifications for hardware designs pertinent to the FEL.

Joint Technology Office (JTO):
Total Funds Expected FY11: $48,000 FY12: $200,000
Total Funds Received through Q2 FY11: $48,000
Scope: JTO Optical Coating Testing. Characterize mirror coatings produced by CSU and commercial vendors to the unique FEL pulse structure and out-of-band radiation.

Air Force:
Total Funds Expected FY11: $726,000 FY12: $200,000
Scope: UV Laser Microengineering Project - Extension of effort to perform lasing of the UV FEL and use the light in the Aerospace Microengineering Station.

B. ALL OTHER FEDERAL WORK

NASA:
Total Funds Expected FY11: $383,000 FY12: $0
Total Funds Received through Q2 FY11: $383,000
Scope: Cryo Engineering Support for NASA3- Supports the Johnson Space Center's current planned modification of the Space Environment Simulation Laboratory Chamber A, for the testing of the James Webb Space Telescope (JWST), the successor to the Hubble Space Telescope.

C. NON-FEDERAL WORK

1. UNIVERSITIES

University of Wisconsin
Total Funds Expected FY11: $110,000 FY12: $0
Total Funds Received through Q2 FY11: $55,000
Scope: University of Wisconsin Synchrotron Radiation Center (SRC) SRF Injector Gun - Work on specifications and procurements leading to construction and test of SRF electron gun. Work is to be done under direction of PI or designee from SRC. LLRF Specification for UW Superconducting RF Electron Gun - The Jefferson Lab RF project group will design, assemble, program and provide one Low Level RF (LLRF) control system to the University of Wisconsin Synchrotron Radiation Center (SRC) for their new Superconducting RF Electron Gun project.

Michigan State University:
Total Funds Expected FY11: $276,000 FY12: $224,000
Total Funds Received through Q2 FY11: $0
Scope: Contribute to Conceptual Design related to the cryogenic facilities of FRIB.

2. COMMERCIAL BUSINESSES

STI Optronics, Inc.:
Total Funds Expected FY11: $41,000 FY12: $0
Total Funds Received through Q2 FY11: $0
Scope: Radiation and Halo Effects in FELs - Design MW class FEL beam lines, perform & evaluate simulations, and determine which collimators are good choices for both the 15 kW FEL and MW class FEL.

Alameda Applied Sciences:
Total Funds Expected FY11: $25,000 FY12: N/A
Total Funds Received through Q2 FY11: $0
Scope: Perform low temperature and crystallographic material characterization measurements on samples of SRF thin film coatings developed by AASC under their DOE SBIR.

Southeastern Universities Research Association, Inc.:
Total Funds Expected FY11: $9,000,000 FY12: N/A
Total Funds Received through Q2 FY11: $9,000,000
Scope: Jefferson Science Associates, LLC, was requested by Southeastern Universities Research Association, Inc., ("SURA") to use these funds for an upgrade of the Jefferson Lab's research facilities, which will maintain the Lab's leadership in the field of nuclear physics and secure the benefits of such a facility for the Commonwealth of Virginia. SURA advanced the funds provided in this Agreement which were appropriated by the Commonwealth of Virginia in FY10 and FY11 for use at the Thomas Jefferson National Accelerator Facility.

Enclosure 1: List of DOE/NNSA/DHS Missions

Scientific Discovery and Innovation (SC)

1. Develop mathematical descriptions, models, methods, and algorithms to enable scientists to accurately describe and understand the behavior of the earth's climate, living cells, and other complex systems involving processes that span vastly different time and/or length scales to advance DOE missions in energy and environment
2. Develop the underlying understanding and software to enable scientists to make effective use of computers at extreme scales—many thousands of multi-core processors with complicated interconnections; and to transform extreme scale data from experiments and simulations into scientific insight
3. Advance key areas of computational science and discovery that advance the missions of the Office of Science through partnerships within the Office of Science, R&D integration efforts with the Department's applied programs, and interagency collaborations. For example, ASCR's new applied mathematics research efforts in optimization and risk assessment in complex systems has been identified as important to the research efforts in the Office of Electricity Delivery and Reliability (OE), Office of Nuclear Energy (NE) and other applied energy programs, and critical to cyber security research in other federal agencies
4. Deliver the forefront computational and networking capabilities that enable researchers to extend the frontiers of science
5. Develop networking and collaboration tools and facilities that enable scientists worldwide to work together and share extreme scale scientific resources
6. 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
7. 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
8. 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
9. 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
10. 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 during the studies of the past six years, e.g., in areas such as solar energy conversion, electrical energy storage and transmission, solid state lighting and other aspects of energy efficiency, geological sequestration, catalysis, and materials in extreme energy environments
11. 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
12. 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
13. 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
14. 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
15. Foster integration of research by leveraging DOE computational capabilities across BER programs and promoting coordination of bioenergy, climate and environmental research across DOE's applied technology programs and other agencies such as the Department of Agriculture, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration
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
17. Advance fundamental low temperature plasma science and high-energy-density plasma science and to coordinate these programs with those of other agencies and the National Nuclear Security Administration

18. Understand the highly non-linear behavior of high-temperature, magnetically confined plasmas and ultimately to learn how to create, confine, and control a burning plasma
19. Develop the fundamental understanding to fabricate materials that can withstand the material-plasma interface and to develop other enabling technologies needed for a sustainable fusion energy source
20. Operate scientific user facilities that maintain world-leading research programs in high-temperature, magnetically confined plasmas, and to participate in the design and construction of ITER, the world's first facility for studying a burning plasma
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
27. Understand how quarks and gluons assemble into the various forms of matter and to search for yet undiscovered forms of matter
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 develop a better understanding of the neutrino, the nearly undetectable fundamental particle produced by the weak interaction that was first indirectly observed in nuclear beta decay
30. Conceive, plan, design, construct, and operate national scientific user facilities to make important discoveries in order to advance the understanding of nuclear matter. 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
33. Increase opportunities for under-represented students and faculty to participate in STEM energy and environment education and careers leveraging the unique opportunities at DOE national laboratories
34. Contribute to the development of STEM K-12 educators through experiential-based programs.
35. Provide mentored research experiences to undergraduate students and faculty through participation in the DOE research enterprise

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: Facilities Mission Readiness by Core Capability

Core Capabilities		Mission Ready Assumes TYSP Implemented				Key Buildings	Facility and Infrastructure Capability Gap	Action Plan	
								Laboratory	DOE
		N	M	P	C			GPP	
Nuclear Physics	Now			X		• Central Helium Liquefier • South Access Bldg • North Access Bldg • Test Lab • Counting House • Experimental Equipment Laboratory (EEL) • End Station Refrigerator • Accelerator Tunnel	• Inadequate: Technical & Experimental Assembly Space • Inadequate Service Bdgs • Deferred Maintenance • Building Code Deficiencies	• Counting House Sustain. Improvements (FY12) • Service Bldg 68 Addition (FY12) • Hall B Fire Sprinkler (FY12) • Cooling North & South LINAC (FY12) • Relocate Shipping & Receiving from EEL (FY15-17) • Experimental Equipment Laboratory Rehab (FY 16-19)	• 12 GeV Conventional Facilities (LI) FY 08-12 • Technology & Eng. Development Facility (SLI) FY 09-12
	In 5 Years				X				
	In 10 Years				X				
Accelerator Science	Now			X		• Test Lab • Cryogenics Test Facility	• Inadequate Work Space • Aging Facilities • Inadequate Utility Capacity	• Injector & Cryomodule Test Facility (FY 13)	• Technology & Eng. Development Facility (SLI) FY 09-12 • Utilities Infrastructure Modernization -Expand CTF (SLI) FY 13-14
	In 5 Years				X				
	In 10 Years				X				
Applied Nuclear Science & Technology	Now			X		• Free Electron Laser • Experimental Equipment Laboratory (EEL) • NN Applied Research Center	• Inadequate Technical Space • Assembly • Staging • Inadequate South Site LCW	• Experimental Equipment Laboratory Rehab (FY 16-19) • South Site LCW Plant (FY11) • FEL Offices (FY18-21)	
	In 5 Years				X				
	In 10 Years				X				
Large Scale User Facilities - Advanced Instrumentation	Now			X		• Experimental Halls • Experimental Equipment Laboratory (EEL) • CEBAF Center	• Inadequate experimental halls for planned program • Inadequate experimental support and work space • Inadequate work space for scientists & users		• 12 GeV Conventional Facilities (LI) FY 08-12 • Technology & Eng. Development Facility (SLI) FY09-12 • Researcher and User Support Facility (SLI) FY16-18
	In 5 Years			X					
	In 10 Years				X				

N = Not, M = Marginal, P = Partial, C = Capable

S= Stimulus GPP, LI=Line Item, SLI= Science Lab Infrastructure, UIM=Utilities Infrastructure Modernization

Real Property Capability		Mission Ready Assumes TYSP Implemented				Facility and Infrastructure Capability Gap	Action Plan: Laboratory	Action Plan: DOE
		N	M	P	C		GPP	
Work Environment	Now			X		• Insufficient Offices • CEBAF Center Bldg systems at end of service life • No recreational/fitness facilities • Cafeteria undersized	• FEL Offices (FY18-21) • Sustainability Improvements Technical Support Bldgs (FY13-14)	• TEDF (SLI) FY09-12 • Researcher and User Support Facility (SLI) FY16-18
	In 5 Years			X				
	In 10 Years				X			
User Accommodations	Now			X		• Minimum User and visitor areas		• Researcher and User Support Facility (SLI) FY16-18
	In 5 Years				X			
	In 10 Years				X			
Site Services	Now			X		• Poor location of RADCON Calibration Facility • Limited Computer Center Cooling • Unconsolidated of Facility Storage • Inadequate Site Laydown Area	• RADCON Calibration Facility (FY13) • Cooling for LQCD Data Center FY12) • Relocate Shipping & Receiving (FY15-17)	• UIM(SLI) FY 13-14
	In 5 Years			X				
	In 10 Years				X			
Conference and Collaboration Space	Now			X		• Insufficient conference/collaboration space • Auditorium too small		• Researcher and User Support Facility (SLI) FY16-18
	In 5 Years				X			
	In 10 Years				X			
Utilities	Now			X		• Aging electrical distribution • Aging Cooling water systems • Complete fire protection loop • Aging/inadequate comms/data • Insufficient cryogenics • Aging Access Control System • Sustainability	• MCC Sustainability Improvements (FY13) • VARC Sustainability Improvements (FY13) • Upgrade Access Control System (Security - FY11) Fire Prot Loop (FY-14)	• UIM(SLI) FY 13-14 • Water Reuse (TBD) FY14
	In 5 Years				X			
	In 10 Years				X			
Roads & Grounds	Now			X		• Inefficient Site Lighting and coverage • Stormwater Mgmt Shortfalls • Roadway surface improvements • Parking Shortage	• Misc Lighting Projects (FY11-15) • Storm water (FY15) • Misc Paving (FY14-15) Parking Improvements (FY15)	
	In 5 Years				X			
	In 10 Years				X			
N = Not, M = Marginal, P = Partial, C = Capable						S= Stimulus GPP, LI=Line Item, SLI= Science Lab Infrastructure, UIM=Utilities Infrastructure Modernization		

Enclosure 3: Site Plan

Lab Site Map – Planned Infrastructure Projects