Department of Energy Laboratory Plan -TJNAF

Updated Draft 5/2009

I. Mission and Overview

The Thomas Jefferson National Accelerator Facility (TJNAF), located in Newport News, Virginia is a program-dedicated laboratory for Nuclear Physics under the Department of Energy's Office of Science. Currently operated by the Jefferson Science Associates, LLC for the Office of Science, TJNAF began operations in 1995 with the completion of the Continuous Electron Beam Accelerator Facility (CEBAF), a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark structure. Its research and engineering staff are also world experts in superconducting radio-frequency technologies. The Lab has an international user community of over 1,300 researchers whose work has resulted in scientific data from 148 experiments, more than 271 *Physics Letters* and *Physical Review Letters* published, and 788 publications in other refereed journals. Collectively, there have been over 20,000 citations for work done at CEBAF.

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 (308 to date). 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. The Lab continues to receive recognition for these programs including the April 2008 award from the Virginia Math and Science Coalition Program for the Lab's DOE-ACTS teacher academy held each summer.

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:

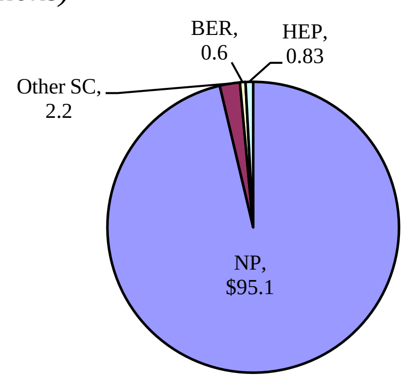
- 169 Acres
- 63 Buildings
- 684K GSF in DOE Buildings
- Replacement Plant Value: $331M
- Deferred Maintenance: $11M
- Asset Condition Index:
  - Mission Critical 0.97 (Good)
  - Mission Dependent 0.85 (Adequate)
  - Asset Utilization Index: 0.99 (Excellent)

Human Capital:

- 656 FTEs
- 1,300 active Users and Visiting Scientists

FY 2008 Total DOE Funding: $98.73M

FY 2008 DOE Funding by Source: *(BA in Millions)*



FY 2008 WFO (Non-DOE/Non-DHS) Funding: $11M

FY 2008 DHS Funding: $ 0

III. Core Capabilities

The following core capabilities distinguish TJNAF and provide a basis for effective teaming and partnering with other DOE laboratories, universities, and private sector partners in pursuit of the laboratory mission. These distinguishing core capabilities outlined below provide an additional 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 encompasses 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 (100% funded by DOE/NP)

<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 state-of-the-art 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 for its experiments. TJNAF is home to the largest nuclear physics user community of any nuclear physics laboratory in the world and produces about one-third of all U.S. Ph.D.s in nuclear physics annually. 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 of the individual quark contributions, the internal structure of the nucleon in the valence region notably the distribution of momentum and spin on the valence quarks; the exploration of the degrees-of-freedom governing baryon excitation, and the experimental and theoretical tools necessary to carry out a program of nucleon tomography;
b) the structure of nuclei, notably the short-range component of the nucleon-nucleon interaction in nuclei; the neutron radius of ^{208}Pb and the underlying quark-gluon structure of the nucleus; and
c) symmetry tests in nuclear physics, including the determination of the weak charge of the proton, to test predictions of the Standard Model.

<u>Theoretical Nuclear Physics</u>
Comprehensive theoretical support for the nuclear physics experimental program ranges from phenomenological analysis including the Excited Baryon Analysis Center (EBAC) to lattice QCD. EBAC is working in close collaboration with the experimental community to develop state-of-the-art theoretical tools for extracting the properties of nucleon excited states from the meson production data and facilitating their interpretation within QCD. The lattice QCD research is focused on the calculation of observables of direct relevance to the TJNAF experimental program, from the spectroscopy of mesons and baryons (including exotics) to form factors and generalized parton distributions.

Computational Nuclear Physics

The High Performance Computing effort in lattice QCD is focused on hadronic and nuclear physics, including the development and provision of novel software tools (Chroma) and science-optimized hardware (within the national lattice QCD program) that complement the experimental program by allowing us to calculate the consequences of QCD in the confinement regime.

The Nuclear Physics Core Capability serves DOE Scientific Discovery and Innovation mission numbers 4, 22, 26, 27, 28, 33, 34, and 35 from "Appendix A: List of DOE/DHS Missions."

2. Accelerator Science (Funded by DOE/NP, HEP, NASA, ONR)

The focus of TJNAF's Accelerator Science is on state-of-the-art high current, continuous wave superconducting, multi-pass linacs, including energy recovering linacs. Our past achievements and future plans are based on the lab's expertise in three fields, namely, Superconducting Radio Frequency (SRF) accelerating structures, liquid helium refrigeration and high current electron injectors. This expertise, complemented by a talented group of accelerator scientists, supports the four TJNAF Accelerator Science priorities: the 12 GeV CEBAF Upgrade, continued 6 GeV operation, positioning TJNAF for a future beyond 12 GeV and graduate and undergraduate education. With CEBAF, TJNAF has more integrated operating experience of superconducting linacs than anywhere else in the world. Our SRF facilities have processed 634 multi-cell cavities of 25 different types, 9 different frequencies and 6 different beta values and our injectors have produced 185 microAmps of polarized and 9 milliAmps of unpolarized continuous wave electron beams. The 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. Our technical infrastructure and our staff position us uniquely to design and apply new advances in SRF, FEL and injectors, at TJNAF, at other DOE laboratories and at laboratories around the world. Overall, 58% of TJNAF's Accelerator R&D funding comes from DOE-NP, 28% from DOE-HEP for International Linear Collider (ILC), and 7% from NASA, and 7% from other sources.

TJNAF is actively engaged in the design of an ELectron Ion Collider (ELIC) to be built at TJNAF, and collaborating with BNL and Massachusetts Institute of Technology on generic electron-ion collider R&D, funded from DOE-NP operations. Our design proposal is optimized for extremely high luminosity with high polarization, and integrates well with the 12 GeV accelerator. Generic R&D for electron-ion colliders includes scientists and engineers across the whole spectrum of expertise within the laboratory. These activities are expected to increase with explicit R&D funding from DOE-NP.

Applications of TJNAF accelerator science include participation in the Michigan State University-Facility for Rare Isotope Beam project (SRF cavities, cryogenics and accelerator physics), participation in Project X at Fermilab (SRF cavities and cryogenics), R&D for ILC (SRF gradient studies and a high-voltage electron gun), and R&D for a Basic Energy Sciences proposed 4th generation synchrotron light source (currently discussing a collaboration with Lawrence Berkeley National Laboratory). Our R&D portfolio is well suited to all these projects and the benefit to the DOE is clear.

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 uniquely positioned to lead in this area.

The Accelerator Science Core Capability serves DOE Scientific Discovery and Innovation mission numbers 25 and 26 from "Appendix A: List of DOE/DHS Missions."

3. Applied Nuclear Science and Technology

Free Electron Laser (Funded by DoD >$6M p.a. from ONR; total investment >$100M)
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 search for dark matter, development of a treatment for adult acne, energy loss in semiconductors due to interstitial hydrogen, and terahertz imaging for homeland security purposes. The primary funding source for the 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 technology transitions from the laboratory to the field.

This program has operated synergistically with the Nuclear Physics activities at TJNAF, benefitting from core capabilities such as SRF accelerators and providing back to the lab valuable experience in high average current DC injector guns, rf control systems, and beam diagnostics. It also developed a new technology deemed critical for one of the two major branches of next generation light sources for DOE: the Energy Recovering Linac (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 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.

The future of this system is based on the extension of this capability into the UV, VUV and soft X-ray region. Under AF funding of $12M, a separate wiggler system for lasing in the UV and beyond has been installed and will soon be commissioned. With pulses of 100 fs and photon energies that exceed the binding energies of most atoms, it will be able to probe complex materials interactions and energy pathways of chemical processes not presently accessible with conventional lasers. Future energy upgrades of the machine are expected to permit lasing at wavelengths shorter than 50 nm with MHz repetition rates. This exceeds by many orders of magnitude any existing soft Xray source in average brightness paving the way for meeting DOE mission needs in materials research for our energy future.

Experimental Nuclear Physics (funded by DOE/NP)
TJNAF is home to state-of-the-art detection, data-acquisition data storage and data analysis capability. These are crucial to the state-of-the-art experimental program and underpin the bio-medical applications described below.

Radiation Detection and 2D and 3D Imaging in Nuclear, Biomedical and other applications (funded by DOE/OBER)
Design and development of novel high performance (high resolution and high sensitivity) 2D and 3D single photon, emission computed tomography (SPECT), and positron emission tomography (PET), optical and x-ray computed tomography (CT) imaging systems for preclinical, clinical applications with potential for non-destructive (NDE) evaluation and homeland security applications.

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

4. Large Scale User Facilities/Advanced Instrumentation

Experimental Nuclear Physics (funded by DOE/NP)
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 expertise developed in building 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 world leadership in this field for several decades. This upgrade received CD-3 in September 2008. In partnership with BNL and scientists and engineers world-wide, TJNAF scientists and engineers are also 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.

Accelerator Science
The extensive experience of TJNAF in the design and construction of high current ERLs, in combination with the world leading capabilities in accelerator science, mean that we are uniquely placed to make a major contribution to the design and construction of future large scale user facilities in BES, especially the so-called 4th generation light sources.

The Large-Scale User Facilities/Advanced Instrumentation Core Capability serves DOE Scientific Discovery and Innovation mission numbers 4, 24, 26 and 30 from Appendix A: List of DOE/DHS Missions.

IV. Science Strategy for the Future/Major Initiatives

TJNAF's work will strengthen and extend US scientific leadership. Specifically it will continue to enhance US leadership in: the understanding of how quarks and gluons assemble into the various forms of matter; the creation and study of new forms of hadronic matter; the search for yet undiscovered forms of matter; the study of the quark structure of the atomic nucleus; and the understanding of the fundamental symmetries that govern the interactions of elementary particles.

Underlying the support of these aims is TJNAF's world leadership position in the technology of radio frequency (rf) superconductivity and its use in large accelerator systems together with expertise in related beam physics and technology areas. These capabilities will enable the creation of extraordinary tools and world leading facilities for the Department of Energy's (DOE) Office of Science, and are already benefitting nuclear medicine and national security.

TJNAF's highest priority is the completion of the 12 GeV Upgrade of CEBAF, the highest scientific priority facility in the most recent (2007) Nuclear Science Advisory Committee (NSAC) Long Range Plan for Nuclear Science. The upgrade of the accelerator and its experimental facility equipment has a Total Project Cost of $310 M; the project has achieved all major DOE milestones to date on schedule and we are expecting completion in Fiscal Year 2015.

In the period before the shutdown to complete the Upgrade installation, there is an outstanding program of 6 GeV experiments, including the first model-independent determination of the neutron radius of ^{208}Pb and a precision measurement of the weak charge of the proton. In parallel, TJNAF will advance its computing capabilities within the National Lattice QCD Computational effort to in excess of 100 Teraflops, enabling experimentally testable Lattice Quantum Chromodynamics predictions. TJNAF will advance its core competency in rf superconductivity and explore and advance baseline performance and reproducible manufacturing processes.

As noted in the NSAC Long Range Plan in 2007, there is an emerging consensus that an Electron Ion Collider (EIC) with polarized beams embodies the community's vision for reaching the next QCD frontier. TJNAF has begun working on this facility's scientific and technical development.

Finally, TJNAF will use its accelerator facilities – the Office of Nuclear Physics funded CEBAF and the Department of Defense-funded Free Electron Laser – for unique, pioneering experiments in light and x-ray production. These efforts will be incorporated in interlab collaborations to build future facilities for the Office of Science in accordance with the priorities in its Strategic Plan.

Details on each of TJNAF's four, major scientific initiatives follow.

1. 12 GeV Upgrade

- ***The activity:*** 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.
- ***Why here, why now:*** 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. The project was identified as a high priority initiative in the Office of Science's plan, "Facilities for the Future of Science: A Twenty Year Plan". It directly supports the Nuclear Physics mission and addresses the objective to measure properties of the proton, neutron, and atomic nuclei for comparison with theoretical calculations to provide an improved quantitative understanding of their quark substructure. The 12 GeV CEBAF Upgrade also supports the following goals within the Department of Energy's Strategic Plan:
  - Strategic Theme 3, Scientific Discovery & Innovation
    - Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.
    - Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

  Resources required: 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 was baselined and 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) is $22.5 million. Funding began in FY2004, $40.8M has been received as of December 31, 2008 and $37.6M has been costed or committed. The funding profile extends through FY2015. This funding is complemented by annual support from the Commonwealth of Virginia.
- ***Risk Perspectives:***
  - 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 may 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 in case of Continuing Resolution. Stimulus ARRA funding of $65M has been approved for the 12 GeV Upgrade project in FY09 which represents accelerated funds from FY10 and FY11 in the baseline profile. This funding will create additional

schedule float for several major procurements. Also, 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 is 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.

2. 6 GeV Experimental Nuclear Physics Program

- ***The Activity*:** The research program being carried out with CEBAF using beams of electrons and photons with energies of up to 6 GeV is an essential part of the national strategy for understanding the structure of matter. This program of high-priority experiments, which addresses 10 of the 13 scientific milestones identified as essential for progress in hadronic physics, has three major thrusts: the structure of the nuclear building blocks; the structure of nuclei; and tests of fundamental symmetries. Many of these experiments are foundational to the science of the 12 GeV Upgrade, and others are much more effectively carried out with the capabilities of the present accelerator configuration than with those of the Upgrade.
- ***Why Here and Why Now*:** The on-going 6 GeV research program will enable the Facility to complete the 8 of 13 SC milestones for progress in hadronic physics, providing essential information to advance our understanding of strongly interacting matter. At least two of 10 of the SC milestones that are TJNAF's responsibility are part of the initial research program of the 12 GeV Upgrade discussed below. 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.
- ***Required Resources*:** 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, and running it has utilized most of the laboratory's DOE funding for many years. Operation at the 80% level requires an inflation-corrected operations budget consistent with the FY09 budget and constant effort scenario that is the basis for this document. This budget includes the base portion of funding for both the Excited Baryon Analysis Center, the non-SciDAC portion of the Lattice QCD effort, and core Accelerator Physics R&D in support of our ongoing program.
- ***Benefit Perspective*:** Substantial/Sustaining and Potentially Transformational – The benefits of the successful completion of the 6 GeV program include: continued essential progress in the field of hadronic physics (including data needed for 8 of the SC milestones for progress in hadronic physics); the training and development of the next generation of nuclear scientists; and the enhancement of the facility's long-term success through the development of experimental and theoretical techniques essential to the success of the scientific research program. It will also ensure the continuing support and confidence of the international community which is playing such a critical role in the 12 GeV Upgrade.

- ***Risk Perspectives*:**
  - Technical Risks: *Low* – The basic capabilities of the accelerator and experimental apparatus for carrying out experiments of the type planned is now well demonstrated; capability extensions needed for some of the planned experiments are challenging but within our grasp.
  - 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 Risks: *High* – A sustained effort will be necessary to balance the demands of mounting this research program with the resource needs (both human and financial) 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.
  - *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.

Essential experiments in each of the three major scientific thrusts of the current CEBAF research program are part of a carefully crafted plan to maximize the scientific progress possible with CEBAF's present capabilities. Examples of the experiments planned in each of these three areas are: a determination of the degrees-of-freedom governing the nucleon's excitation spectrum through a measurement of the excitation spectrum using polarized targets and polarized beams; the determination of the structure of these excitations through a measurement of their transition form factors; the precise and for the first time model independent determination of the neutron radius of ^{208}Pb to provide vitally needed information for physics ranging from the modeling of neutron stars to the interpretation of atomic parity violation experiments and tests of theories of the structure of heavy nuclei; and the determination of the weak charge of the proton as a crucial component of the search for physics beyond the Standard Model.

3. ELectron Ion Collider (ELIC)

- **The activity:** This covers the development of the concept and the physics case and initial design of a future ELectron Ion Collider. According to the 2007 NSAC Long Range Plan, "The ELIC would explore the new QCD frontier of strong color fields in nuclei and precisely image the gluons in the proton." The scientific goals of ELIC are to 1) develop a quantitative understanding of the contribution of gluons and sea quarks to the binding, spin and spatial structure of the nucleon; 2) understand how the basic law that matter can be created from pure energy is intertwined within QCD to explain the formation of final hadrons due to color confinement; and 3) determine how the nuclear medium affects quarks and gluons to elucidate the quark-gluon origin of atomic nuclei.

  TJNAF will engage in R&D to develop accelerator and detector technology enabling a very high luminosity polarized ELectron Ion Collider.
- ***Why here why now:*** The facility is the natural next step beyond the 12 GeV Upgrade and such facilities take several years to germinate and start to grow. TJNAF is collaborating with

BNL and an international group of scientists in sharpening the scientific motivation and delineating the desired collider performance characteristics of an electron-ion collider. TJNAF and BNL have chartered a joint advisory committee. 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. ELIC is the innovative, CEBAF-based version of the electron-ion collider, which offers a potential increase in luminosity by two orders of magnitude.

- ***Required resources:*** Sharing rank 23 in the 20-year facilities outlook, pre-R&D for fundamental technical issues at the level of ~$3M per year starting in FY10 for four years as required. TJNAF expects to compete for this funding through peer reviewed proposals to DOE NP. Labor and infrastructure are available or can be built up readily for the pre-R&D and R&D phases. PED start in FY15 and construction start in FY19 are possible and well-matched to the 12 GeV Upgrade operations schedule. TJNAF would seek partnership with FRIB, FNAL and RHIC, as well as overseas institutes such as FZ-Jülich to support the development of our ion injector complex.
- ***Benefit Perspective:*** Potentially *Transformational* Benefits
- ***Risk Perspectives:***
  - Technical: *High risk* – A very high luminosity polarized ELIC is a technically challenging project, as it requires a very sophisticated interaction region design and Energy Recovering Linac (ERL)-based high energy electron cooling, a process whose physics and technology has yet to be experimentally demonstrated. TJNAF's expertise on ERLs and high current polarized electron sources ameliorates the risk. The recent conceptual design optimizations have reduced the R&D requirements for ELIC, in that a state-of-the-art polarized source is used and the ion energy has been lowered to around 60 GeV to drastically reduce the increase beyond state-of-the-art required in electron cooling and crab cavities. 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 polarized electron sources. Furthermore, in an international context, a potential site abroad could emerge. Risk is mitigated through recent conceptual design changes to minimize R&D needs and in development of the most compelling scientific case, which will determine choice of machine parameters in parallel with technical R&D program.
  - Management/Financial: *High risk* – Associated with budget uncertainties and the anticipated high project costs for ELIC. Risk is mitigated through R&D program to develop machine and interaction region options which are most cost effective. Significant international participation would introduce additional challenges to be mitigated through early attention to past lessons learned.

ELIC is a high-luminosity, polarized electron-ion collider which uses CEBAF as a full energy injector into an electron storage ring. ELIC has a center-of-mass energy of 10-50 GeV and extremely high luminosity of up to about 1×10^{35} cm^{-2}s^{-1}. The high luminosity is crucial to probe unknown essential features of the proton landscape, such as the impact of spin-orbit correlations. The booster rings, electron collider ring, and ion collider ring are designed as a "figure 8", a design directly aimed at spin physics opportunities. This ring-ring design could be substituted by a linac-ring design using CEBAF as a one-pass energy recovering linac, should future R&D point to the need for even higher luminosity. 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).

4. 4th Generation Light Source

- ***The activity*:** TJNAF intends to put its unique expertise and existing facilities in the service for R&D towards the design of a cost effective 4th Generation Light Source. Our present capabilities can already address in the terahertz, IR and soon to be UV ranges, the grand scientific challenges identified by BESAC. "The tools include ultrafast synchronized and tunable photons for studies of linear and non-linear out of equilibrium dynamical processes in materials whose fundamental quantum behavior is not understood. Examples include high T_c superconductors, nanomaterials, metallic hydrogen, and bio-mimetic devices for energy conversion". BESAC is in the process of producing 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 to support this DOE mission. Moreover, both approaches require superconducting rf technology for their linear accelerators, the core technology of our laboratory. TJNAF's experience in SRF, and ERLs, and the availability of its FEL and CEBAF as test beds create a unique and highly effective approach to advance beam physics and technology for ultra short pulse generation at x-ray wavelengths.
- ***Why here, why now*:** TJNAF has existing platforms with which it intends to demonstrate approaches and technologies that address the need of science as outlined in BESAC's report "Directing Matter and Energy: Five Challenges for Science and the Imagination" (U. S. DOE, December 20, 2007). The Lab expects to participate in BES funded R&D, focusing on cavity and cryomodule development ultimately to permit the demonstration of well controlled, pulse-to pulse repeatable, high duty factor x-ray bursts of femtoseconds duration and unprecedented brightness. Initial efforts will focus on extending the range of capability of our existing FEL to the VUV and soft X-ray range while studying limits to the physics and technology of the next generation sources. We intend to apply to BES for funding to support the development this upgrade and its utilization by the materials research community.

  The installed infrastructure with modest upgrade will permit the production of photons in the **VUV/Soft X-ray regime at average brightnesses exceeding that of the over-subscribed FLASH facility in Germany**. We can do this on a time scale of less than 3 years at a modest cost. We intend to apply the light produced 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. Several national laboratories have expressed interest in constructing a 4th Generation Light Source. It is believed that DOE/BES will eventually authorize the construction of a next generation light source and TJNAF intends to support any major SRF linac construction project which would occur through on-going research collaborations with LBNL, ANL, and BNL, for example. We also intend to develop our own design for such a future light source and to actively address any competition to host a next generation light source.
- ***Resources required*:** ~\$180M over the next ten years. Further resources include access to an operating ERL, and high quality multi-GeV electron beams which are both available at TJNAF. The \$180M provides initial support for the R&D required to support development of accelerator components (procurements and labor) for the light source including near term

upgrades to the TJNAF FEL for short wavelength capability at $35M capital and $39M operating budget for 5 years.

- ***Benefit Perspective*****:** *Substantial/Sustaining* benefits for affordability and capability of light source-based BES R&D and *Potentially Transformational* benefits in the investigation of time dependent and non-equilibrium processes as described in “Grand Challenges”.
- ***Risk Perspectives:***
  - 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 are already pursuing R&D in support of it. TJNAF is presently in a leadership position in SRF technology and in construction and operational experience of a 4th generation light source.
  - Management/Financial: *High risk* – Proven management approaches for interlab partnerships will mitigate and manage risks. 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.

5. **Superconducting RF Technology** (Funded by DOE/NP, HEP)

- ***The activity:*** TJNAF intends to put its experience in world-leading SRF technology to the service of the whole Office of Science as a recognized center of expertise. TJNAF’s Institute for Superconducting Radio Frequency Science and Technology supports four Accelerator Division priorities: the 12 GeV CEBAF upgrade, 6 GeV CEBAF operation, the positioning of TJNAF for a future beyond 12 GeV, and graduate and undergraduate education. TJNAF R&D strengths target improvements in SRF accelerator performance and reductions in SRF accelerator capital and operating costs, including cryogenic refrigeration costs. These strengths include cavity design, forming, assembly, processing, and testing and cryomodule design, assembly, and testing. The institute has fabricated and/or processed a wider variety of multi-cell SRF cavities than anyone else, some 634 of them, comprising 25 distinct cavity types, both CW and pulsed, as well as countless single-cell test cavities. The lab’s Free-Electron Laser (FEL) Division is tightly coupled to the institute. The goal is world leadership in each core competency. The focus is high-current, CW, superconducting, multi-pass linacs, explicitly including Energy Recovery Linacs (ERLs). Preparing for a high level of participation in creating such linacs beyond 12 GeV is the institute’s long-term vision, looking more than a decade ahead. It should be noted that cryogenics will be a major challenge. SRF Institute technical goals are to eradicate field emission up to 35 MV/m, increase the maximum field gradient to above 50 MV/m, reduce the spread in quench gradient to +/- 5% of mean, develop cavities for high currents (~1 A), increase Q at 25 MV/m, reduce cost per MV, and develop a solution for operation at 4.5 K.
- ***Why here, why now:*** TJNAF’s world-leading SRF expertise underlies about a third of the projects in the Office of Science’s 20-Year Outlook, and the institute can be a cost-effective R&D partner because of its experience and facilities. Past partnerships have resulted in

digital RF controls with FRIB's predecessor RIA , high-efficiency cryogenics funded by NASA, high-current cavities funded by ONR, high-voltage electron guns funded by ILC, and crab cavities funded by APS. Office of Nuclear Physics projects for which partnerships are envisioned are FRIB and all versions of an EIC. Support for other Office of Science projects would include the SNS Power Upgrade Project (PUP), Project X at Fermilab, and ILC. Work for others could include the LBNL FEL project. Additional R&D opportunities include options besides ELIC for an on-site facility, a positron option for CEBAF, an SRF-based fourth-generation synchrotron light source, and a possible future upgrade of CEBAF to 25 GeV. Generic schedules have been prepared for the envisioned work, and are available.

- ***Resource requirements:*** 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, CD-1 has been approved for the Technology and Engineering Development Facility (TEDF). 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 7000 to 8000 SF. 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.
- ***Risk Perspectives:***
    - Technical: *Low risk* –The long term R&D activities planned in the SRF Institute are founded on the solid expertise and widespread support we provide to laboratories throughout the world. SRF research is typically planned and executed to benefit multiple applications of the developed product.
    - Market/Competition: *Low risk* - 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.

SRF is one of the present and future core competencies vital to the Office of Science and its future accelerator-based user facilities. It is important that the Office of Science ensure that its laboratories have strong expertise and competence in all of the enabling technologies for accelerators. Accelerators enable much of the science in BES, ONP and OHEP. SRF is only one of these competencies but a critical one. A R&D program with sufficient breadth and depth to support these is vital.

V. Infrastructure/Mission Readiness

Overview of Site Facilities and Infrastructure

TJNAF is operated by Jefferson Science Associates, LLC (JSA), a joint venture between Southeastern Universities Research Association (SURA) and Computer Sciences Corporation (CSC). 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 63 DOE owned buildings (683,978 SF), two state leased buildings (37,643 SF), and 19 real property trailers (21,310 SF) totaling 732,430 (SF) plus roads and utilities. Additionally the Lab leases 43,332 SF of office and lab space from the City of Newport News located in the Applied Research Center (ARC), constructed by the City of Newport News and located on the TJNAF campus. In addition to these facilities, TJNAF has 73 shipping containers (22,040 SF) used for storage and 9,755 SF of off-site leased storage space. There are no planned real estate actions in FY 2009 or FY 2010 involving leases of more than 10,000 SF. At the end of FY 2008, a total of ~656 FTEs were employed and occupying site facilities. TJNAF serves a user and visiting scientist population of about 2,200 from the United States and around the world. In FY 2007 the Lab served 1,313 unique users and visiting scientists.

A current copy of the Land Use Plan can be can be found on the Jefferson Lab Facilities Management website. Table 1 reflects an Asset Condition Index at the beginning of FY 2009 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 2014. The Asset Utilization Index is at 100% and has been since construction of the Lab. In most areas space is not adequate to accommodate an efficient work environment. Overall Lab infrastructure data summary is presented in Table 1.

SC Infrastructure Data Summary

Replacement Plant Value ($M)		331.3
Total Deferred Maintenance ($M)		11.1
Asset Condition Index	MC	0.97
	MD	0.85
	NMD	N/A
Asset Utilization Index	Office	1.0
	Warehouse	0.91
	Laboratory	1.0
	Housing	N/A
Prior Year Maintenance ($M)		3.1

MC = Mission Critical, MD = Mission Dependent,
NMD = Non-Mission Dependent

Table 1

Facilities and Infrastructure to Support Laboratory Missions

The completion of the 12 GeV Upgrade, scheduled for FY 2015 with the addition of the fourth experimental hall along with upgrades to experimental halls A, B and C 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, 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 Utilities Infrastructure Modernization SLI project will correct this. The CEBAF Center Addition and Renovation projects that will add two wings to CEBAF Center will be the last element to ensure full modernization of the Lab facilities

The Mission Readiness assessment of technical and support facilities and infrastructure is summarized in Tables 2 and 3. TJNAF is seeking DOE support for one SLI line item project, CEBAF Center Addition and Renovation.

Core Capabilities		Mission Ready Assumes TYSP Implemented				Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capacity Gap	Action Plan	
		N	M	P	C				Laboratory	DOE
Nuclear Physics	Now			X		Bldg. 8 Central Helium Liquefier Bldg. 38 S. Access Bldg. 67 N. Access Bldg. 58 Test Lab Bldg. 97 Counting House Bldg. 90 Experimental Equipment Lab (EEL) Bldg. 102 End Station Refrigerator Bldg. 999 Accelerator Tunnel	World class 6 GeV and 12 GeV physics	Inadequate Technical & Experimental Assembly Space Deferred Maintenance Building Code Deficiencies	Bldg 90 & 97 Rehab (FY 12-15)	12 GeV Conventional Facilities (LI) FY 08-12 TEDF (SLI) FY 09-12 HD-Ice (GPP) FY 08-09 Experimental Staging (S) FY 09 Expand GPB (S) FY 09 4kw ESR Bldg & Util (S) FY 09
	In 5 Years				X					
	In 10 Years				X					
Accelerator Science	Now			X		Bldg 58 Test Lab Bldg 57 Cryogenics Test Facility	Develop technology for future superconducting RF facilities	Inadequate Work Space Aging Facilities Inadequate Utility Capacity	Injector & Cryomodule Test Facility (FY 13)	TEDF (SLI) FY 09-12 UIM -Expand CTF (S) FY 11-13
	In 5 Years				X					
	In 10 Years				X					
Applied Nuclear Science & Technology	Now			X		Bldg 18 Free Electron Laser Bldg. 90 Experimental Equipment Lab (EEL) NN Applied Research Center	Development of key technologies in accelerator, photon, and detector science	Inadequate Technical Space	Bldg 90 Rehab (FY 14-15)	
	In 5 Years				X					
	In 10 Years				X					
Large Scale User Facilities - Advanced Instrumentation	Now			X		Experimental Halls TEDF CEBAF Center Addition & Renovation	Complete 12 GeV Construction ELIC R&D and Design 4th Generation Light Source R&D and Design Complete Modernization of key facilities	Future Facilities		12 GeV Conventional Facilities (LI) FY 08-12 TEDF (SLI) FY09-12 CEBAF Center Addition & Renovation (SLI) FY13-15
	In 5 Years			X						
	In 10 Years				X					

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

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

Table 2

Support Facilities and Infrastructure

Assumes TYSP Implemented

Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan Laboratory	DOE
Work Environment	N	M	P	C			
Post Office					N/A - Utilize USPS		
Offices			X				TEDF (SLI) FY 09-12 CCA&R (SLI) FY 13-15
Cafeteria			X			Plumbing Renovation (FY 10) Kitchen Equipment (Multiple)	CCA&R (SLI) FY 13-15
Recreational/Fitness		X					TEDF (SLI) FY 09-12 CCA&R (SLI) FY 13-15
Child Care					N/A - Parents utilize local area facilities		
User Accommodations							
Visitor Housing					SURA facility available; not DOE supported		
Visitor Center			X			Rehab VARC (FY 16-17)	
Site Services							
Library				X			CCA&R (SLI) FY 13-15
Medical				X			
Examination & Testing				X			
Maintenance & Fabrication				X			
Fire Station					N/A - Services by City of Newport News		
Storage			X			Central Storage Yard (FY09)	Experimental Staging (S) FY 09
Conference and Collaboration Space							
Auditorium/Theater			X				CCA&R (SLI) FY 13-15
Conference Rooms			X				CCA&R (SLI) FY 13-15
Collaboration Space			X				CCA&R (SLI) FY 13-15
Utilities							
Communications			X				UIM (SLI) FY 11-13
Electrical			X				UIM (SLI) FY 11-13 TL Service Upgrade (S) FY 09
Water				X		Fire Protection Loop (FY 10-11) Reclaimed Water Line (FY 14)	
Petroleum/Oil					N/A		
Gases				X			
Waste/Sewer Treatment				X	N/A - Utilize local utility		
Storm Water			X			South Retent. Pond (FY16) Maintenance (Multiple)	
Chilled Water			X			TL Cooling Towers (FY09-10)	UIM (SLI) 11-13
Steam					N/A		
Flood Control				X			
Roads & Grounds							
Parking (surfaces & structures)			X			South Connector Rd (FY 09) Site Road & Parking (FY16-18)	Road & Parking Improve(S) 09
Roads & Sidewalks			X			South Connector Rd (FY 09) Site Road & Parking (FY16-18)	Road & Parking Improve(S) 09
Grounds				X			

TEDF = Technology & Engineering Development Facility

CCA&R = CEBAF Center Addition and Renovation

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

S= Stimulus, LI=Line Item, UIM=Utilities Infrastructure Modernization

Table 3

Strategic Site Investments

Modernization Program

TJNAF's investment strategy to achieve modernization goals includes:

- DOE major line item funding for new or expanded missions,
- General Plant Project (GPP) funding for improvements and modernization to support current and future missions,
- Science Lab Infrastructure (SLI) line item funding for major modernization of facilities beyond the funding capability of the Lab,
- Third party energy savings funding where a repayment funding stream is practical, and
- Adequate investment for preventive and corrective maintenance, reduction of deferred maintenance as well as needed operational leases.

Laboratory Investments

- **General Plant Projects (GPP)** Since FY 2000, TJNAF has supported modernization by investing over $11.9M in general plant projects. An additional $46M will be invested through FY 2019 to complete 29 projects identified in the TYSP that will address facility and infrastructure needs and contribute to a fully modernized and mission capable facility.

- **Maintenance Investment** TJNAF has and will **c**ontinue to adequately fund facility and infrastructure maintenance. In FY 2008 TJNAF invested ($3.1M) in maintenance spending and is committed to achieve the annual DM reduction goals. This expenditure along with other planned investments will result in the Lab's facilities meeting the DOE ACI goal by 2013.

- **Energy Savings** TJNAF using $4.2M financed through Bonneville Power Administration (BPA) executed seven projects replacing equipment that resulted in saving 3,080 Mwh of electricity and 20,400 ccf natural gas through mechanical system replacement and lighting upgrade for an annual savings of $220,000.

  Implementation of the Ganni Cycle at the Lab's Central Helium Liquefier (CHL) has dropped the electricity demand for TJNAF cryogenics from 6 Megawatts (MW) to 4.2 MW, resulting in a direct savings of $396,000 per year in electricity costs.

  Installation of geothermal heat pumps for CEBAF Center Addition saving 333.4 Mwh or $13,300 per year.

SC Strategic Investments

- **12 GeV Conventional Facilities (Line Item)** All of the conventional facilities required for construction and operation 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)** The project renovates Building 58, the current Test Lab (about 95,000 Square Feet(SF)), 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 are inefficient, poor quality work environments, and not meeting current commercial standards. The project includes construction of a new building(s) which will add over 100,000 SF of needed workspace for critical technical support functions including mechanical and electrical engineering, cryogenics engineering and fabrication, and environment, safety, and health.

- **Utilities Infrastructure Modernization Project (SLI)** This project replaces or upgrades the following utility systems:
  - Electrical Distribution: Install secondary/redundant electric feeders, increase size of site alternate power feed.
  - Process Cooling: Replace/upgrade 20 to 40 year old site cooling towers and chiller plant and provide additional computer center power and cooling.
  - Cryogenics: Upgrade cryogenics complex 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.
- **CEBAF Center Addition & Upgrade (SLI)** This project funds the modernization of the CEBAF Center, which is the hub of the Lab. It includes construction of 95,000 SF in two additional wings (Wings D and E) for the CEBAF Center as well as the rehabilitation of 67,300 SF of current space in the facility. The project accommodates: overcrowding; relocation of staff and users currently in leased space; planned staff growth; eliminates leased space.

Excess Facility/Material/Environmental

TJNAF does not have any excess facilities or environmental issues. A material disposition plan was submitted to the DOE Site Office in 2006 for the FY 2008 budget for 130 legacy concrete blocks from the Test Lab Building previously operated as the NASA Space Radiation Effects Laboratory from 1964 to 1984 and ~ 47 tons of activated material from JLab or that was transferred from other Labs early in the Lab's history. Materials are in the process of being characterized. Funds have not been identified for this disposition. While the upper range for the disposition of this material was estimated at $10M various lower cost alternatives are being evaluated.

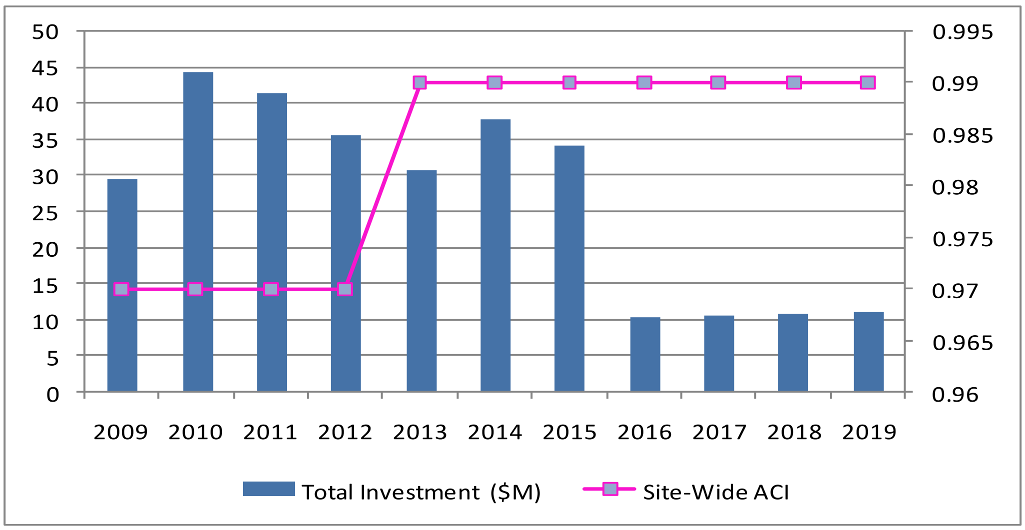
Trends and Metrics

TJNAF has seven PEMP metrics measuring performance covering Excellence in Operating, Maintaining, Renewing Facility and Infrastructure Portfolio receiving an overall score of A- for FY08. Table 4 shows the planned infrastructure investment and its impact on the Asset Condition Index (ACI) and level of deferred maintenance (DM). Graph A depicts site wide ACI and infrastructure investment. ACI for the Lab has increased from last year due to increase of facility Plant Replacement Value (RPV) and elimination of deferred maintenance. Planned projects will allow the Lab to reach the DOE goal of excellent by FY 2013 and will continue to increase as projects are delivered. The Lab is in the process of implementing the Mission Readiness Assessment process and has participated in two peer reviews this year at other SC Labs. TJNAF facilities are expected to be mission ready with implementation of the Ten Year Site Plan projects.

Facilities and Infrastructure Investments ($M) - Impact to Asset Condition Index											
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Maintenance	3.6	3.8	3.9	4.1	4.7	5.9	6.2	6.4	6.6	6.9	7.1
Deferred Maintenance Reduction	0.4	0.2	0.2	0.2	7.3	2.8	0.2	0.2	0.2	0.2	0.2
Excess Facility Disposition (overhead)	-	-	-	-	-	-	-	-	-	-	-
IGPP	-	-	-	-	-	-	-	-	-	-	-
GPP	12.5	2	2.3	2.3	2.4	4	4	4	4	4	4
Line Items	13.5	38.7	35.4	29.3	23.8	28	24	0	0	0	0
Total Investment	29.6	44.5	41.6	35.7	30.9	37.9	34.2	10.4	10.6	10.9	11.1
Estimated RPV	331	351	388	402	470	497	519	541	559	579	599
Estimated DM	11.1	11.5	11.9	12.3	5.4	2.8	2.9	3.0	3.1	3.2	3.3
Site-Wide ACI	0.97	0.97	0.97	0.97	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Table 4

[1] 12 GeV Conventional Facilities, TEDF, Utilities Modernization, and CEBAF Center Complex Addition/Upgrade.



Graph A

Sustainability

Jefferson Lab delivered an Executable Plan in December 2008 to meet the sustainability requirements of DOE O 430.2B, Departmental Energy, Renewable Energy and Transportation Management and Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management. Jefferson Lab goals include:

- Energy intensity reduction of 30% by 2015.
- Increased use of renewable energy by 7.5%.
- Potable water consumption intensity reduction of 16% by 2015.
- Incorporate sustainable practices in the design and construction of new and rehabilitation of existing facilities.
- Reduce the vehicle fleet’s total consumption of petroleum products and increase non-petroleum fuel use.
- Increase acquisition of electronic equipment meeting EPEAT product standards.

Jefferson Lab is on schedule to meet the goals established by DOE O 430.2B. The use of financing through Bonneville Power Administration for the replacement of aging HVAC equipment and lighting upgrades allowed the Lab to already reduce energy consumption by more than 20%. The Memorandum of Understanding (MOU) with Hampton Roads Sanitation District offers the possibility of a major reduction in the Lab's potable water use through the use of "reuse" water for cooling towers and landscape irrigation and will result in a 70% reduction in potable water use. A list of goals developed to date as well as progress is shown in Table 5.

Progress Against TEAM Goals

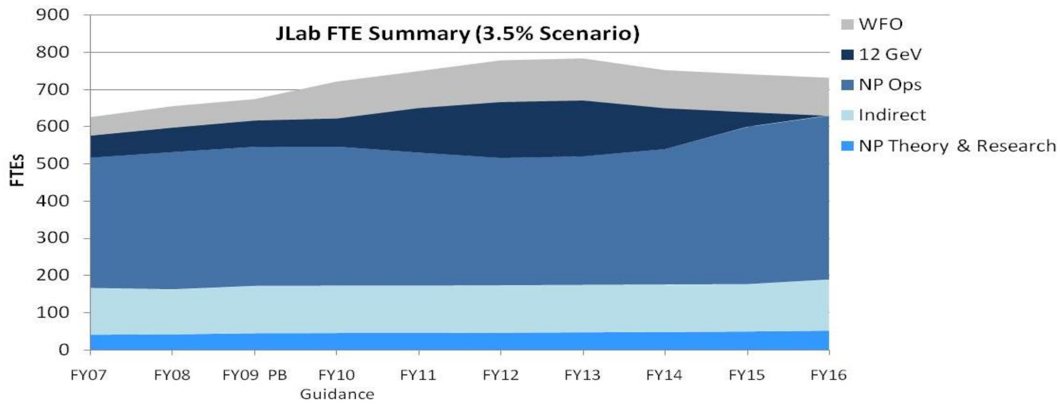
Requirement	DOE Corporate Goal	Status
Energy Reduction	30% from FY 2003 to 2015.	As of FY08, 27% reduction to date
Renewable Energy	At least 7.5% of annual electricity and thermal produced on-site by FY 2010	Have achieved 3% using RECs plus installation of geothermal wells at CEBAF Center Addition
Fleet	Maximize use of Alternative Fuel Vehicles	29% of TJNAF vehicular fleet has been replaced with Alternate Fuel Vehicles (AFV) – all fleet vehicles will be replaced by the end of 2010.
Water Reduction	16% by FY 2015 relative to FY 2007 use	Lab currently working with sanitation district to provide "reuse" water to replace potable water used for irrigation and cooling towers. Project could save TJNAF 70% of potable water use. (State stimulus funded)
Buildings	15% of existing space meets LEED guiding principles by FY 2015	Sustainability reviews are scheduled to be completed this year. TEDF and CEBAF Center Addition will enable JLab to meet the goal
	All new construction LEED Gold certified	Sustainable practices have been used for new building construction since 2002

Table 5

VI. Financial Expectations and Workforce Trends

Assumptions:

- Base Funding Increases at Least 3.5% Annually
- Major Construction and Lab Modernization efforts are Maintained (12 GeV Upgrade, SLI, GPP)
- Power Rate and Consumption Increases
- FEL Funding Increases to support Navy and EFRDC/BES programs
- Doe Not Yet Include Future Work on FRIB, Project X or SNS PUP



SUMMARY OF LAB FUNDING (M$)	FY07	FY08	FY09 PB	FY10 Guidance	FY11 @3.5%	FY12 @3.5%	FY13 @3.5%	FY14 @3.5%	FY15 @3.5%	FY16 w/transition
NP	80.4	80.7	88.5	94.3	98.9	101.2	102.9	118.3	122.3	152.6
NP (stimulus-GPP/AIP/LQCD/Cyber)			18.1							
12 GeV	9.5	14.4	28.6	22.0	34.0	66.0	43.0	18.0	2.0	
12 GeV (stimulus)			65.0							
FEL	7.8	8.4	9.6	16.8	17.8	21.0	19.0	18.0	18.0	18.0
SNS	0.1	0.2	0.2							
HEP	1.9	0.8	1.8	3.4	2.4	2.4	2.7	2.5	2.6	2.7
Safeguards & Security	1.4	1.6	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6
Science Lab Infrastructure			3.7	27.7	28.6	27.7	23.7	28.0	24.0	
Commonwealth of Virginia	1.5	1.5	7.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Other (BER, Education, WFO)	1.5	1.7	2.4	2.6	2.0	3.5	3.7	3.7	3.7	3.8
Total Funding Estimated	104.1	109.3	226.5	169.4	186.3	224.5	197.7	191.2	175.4	180.0

APPENDIX A: LIST OF DOE/DHS MISSIONS

Scientific Discovery and Innovation

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