*Thomas Jefferson National Accelerator Facility*

# *INSTITUTIONAL PLAN*

# *FY 2004 - FY 2008*

**October 10, 2003**

**Jefferson Lab**
**12000 Jefferson Avenue**
**Newport News, Virginia 23606**

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# I. LABORATORY DIRECTOR'S STATEMENT

This Draft Institutional Plan presents a focused vision of world leadership in hadronic physics and selected supporting core competencies, outlines the specific programmatic intent and institutional objectives Jefferson Lab will pursue in FY04 through FY08, and provides program priorities over the next 20 years.

This is a pivotal time for JLab and the future offers both rich opportunities and some challenges. The CEBAF accelerator has far exceeded the initial design goals allowing development, in close collaboration with the User community, of a research program that is even richer and more exciting than originally anticipated. Recent results such as the highly accurate determination of the nucleon form factors and the identification of what may be the first penta-quark state, have demonstrated the potential of our scientific program for unexpected insights and discovery. JLab expertise in superconducting radio-frequency (SRF) technology has resulted in the successful support of the Spallation Neutron Source as well as the record-breaking Free Electron Laser (the first application of the energy-recovering linac or ERL), thus providing a solid return on investment in the form of advanced accelerator capabilities made available to the Office of Science, DOE, and the nation.

Outstanding among our challenges is the fact that the long term future of hadronic physics hinges on the timely realization of the 12 GeV Upgrade at JLab. Second, JLab operates at less than optimal utilization due to funding constraints, rejecting many outstanding research proposals and presenting many of its Users with the obstacle of a four year backlog of approved experiments. Finally, adequate funding is required for JLab to maintain its core competency in SRF technology. All of these problems result from the competition for resources in a time of budget pressures both inside and outside of DOE.

The Lab is guided by a sharp programmatic vision that is outlined in this Institutional Plan, by a strategic plan informed by this vision, and by a constant striving for managerial excellence and effectiveness in implementing the plan. A systematic program to refine work processes is underway with the aim of achieving the greatest programmatic output for a given funding level. Management has renewed their efforts to continuously strengthen a culture of high performance that extends to all areas of work, and underscores the importance of safe operation as a core institutional value.

To meet these challenges and seize the opportunities will require that Lab management engage all available resources - most importantly, our human capital. We must be vigilant and continue to revise processes, streamline operations, and think “outside the box” to take advantage of our unique capabilities, facilities and opportunities. This Institutional Plan demonstrates a continuing commitment to excellence in all areas of performance.

Christoph W. Leemann, Director

## II. LABORATORY CAPABILITIES IN SUPPORT OF DOE'S OBJECTIVES

### DOE's OFFICE OF SCIENCE OBJECTIVES

Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons; to the elements in the universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability, possessing radically different properties from known matter.

Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

Create and sustain the discovery class tools, 21st Century scientific and technical workforce, research partnerships, and management systems that provide the foundations for a highly productive, world-class national science enterprise.

### JEFFERSON LAB GOALS

World leadership in exploring the complex dynamics by which quarks, interacting via gluons, form the stable matter of everyday experience.

Exemplary operation of unique facility, leadership in formulating research plan, leadership and support in theoretical analysis, and creation of multi-Tflop/s computing capability.

Completion of 12 GeV Upgrade construction project and scientific research program.

Develop a research program beyond 12 GeV including higher energy (~25 GeV) fixed target capability and/or an electron-light ion collider (ELIC) with highest achievable luminosities.

World leadership in SRF and ERL technology, applied to new SC accelerator projects.

A multifaceted photon science program based on the use of the THz, IR, and DUV from the JLab FEL.

Institutional management based on best practices, aligned with the President's Management Agenda, emphasizing performance, outreach, education, corporate citizenship, security, safety and environmental protection.

## JEFFERSON LAB CAPABILITIES

Nuclear and particle physics: experimental, theoretical, and computational (simulation, high performance computing for LQCD)

Advanced detectors and data acquisition and analysis technology

Superconducting radio-frequency science & technology

Polarized electron sources

Accelerator and beam physics

Accelerator-driven light sources (FELs and synchrotron radiation sources)

2 K cryogenics

Very large real time systems for accelerator control and data acquisition

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## JEFFERSON LAB MAJOR FACILITIES

**CEBAF (Superconducting Radio-Frequency Accelerator):**
From 0.05 to (currently) 6 GeV, 100 picoamps to 200 microamps, continuous-wave electron accelerator, upgradeable to ~25 GeV. Simultaneous beams to 3 experimental Halls with polarization exceeding 80%.

**Hall A:** Two high resolution magnetic spectrometers

**Hall B:** Large acceptance superconducting toroidal magnet system for detecting multiparticle final states (capable of handling 1 Tbyte/day)

**Hall C:** Two general purpose spectrometers (one high momentum and one for short-lived final states) and experiment-specific equipment

**Superconducting Radio-Frequency Technology Facility:**
Superconducting accelerator cavity fabrication, surface treatment, cryomodule assembly and test, and research facilities

**FEL User Facility:** IR/UV upgrade free-electron laser designed to provide 10 kW of laser light with picosecond pulse length, transform-limited bandwidth, and diffraction-limited emittance

**LQCD Aggregate Computer:** A 0.4 Tflop/s commodity-PC-based system to be upgraded to mutli-Tflop/s system in 2005

**Applied Research Center:** In collaboration with local colleges/universities and the City of Newport News, share cooperative R&D laboratories in lasers, plasmas and materials

## III. LABORATORY SCIENTIFIC AND TECHNICAL VISION AND STRATEGIC PLAN

This Institutional Plan documents our overarching twenty-year vision and a more detailed five-year plan for the Thomas Jefferson National Accelerator Facility (Jefferson Lab or JLab) in its quest to advance fundamental research on the quark structure of matter. We seek to consolidate our world leadership in exploring the complex dynamics by which quarks, interacting via gluons, form the matter of everyday experience. To this end, Jefferson Lab will continue to support its international User community of over 2000 scientists as they conduct research using the unique CEBAF accelerator and its associated experimental equipment. We will further provide theoretical analysis to guide and evaluate experiments, and develop state of the art computer simulation to compute experimentally verifiable physics parameters. Finally, we will strive to keep our research capabilities at the forefront by continually upgrading and improving them with the goal of optimizing the scientific output of the Laboratory.

Jefferson Lab will also lead the world in the technology of RF superconductivity (SRF) and energy-recovering linacs (ERL) by continuing our research and development programs in these areas. We will also assist as needed in providing these technologies and the supporting knowledge base for the construction of new accelerators for Office of Science research projects at other laboratories in nuclear physics, basic energy sciences, and possibly high energy physics.

Jefferson Lab's Free Electron Laser (FEL) – providing THz to DUV light - will support both a thriving photon basic science program examining dynamics in complex physical, chemical, and biological systems, and the development of applications ranging from nanostructures to thin films of unprecedented properties. The supporting technology development is expected to enable MW level laser beams for defense applications.

<u>Over the next five years,</u> Jefferson Lab will build on the significant results of its first seven years of research operation. These beautiful data show the power of the original vision for the facility, and the confluence and synergy of theory, state-of-the-art experimental equipment, forefront accelerator technology, and emerging capabilities in high performance computing. These same elements, enhanced by recent developments and advances, are at the core of our plans to maintain and strengthen JLab's role as one of the leading international centers for the study of how nucleons are built from quarks and gluons, and how this structure leads to the standard nucleon-based picture of the nucleus.

Specifically, Jefferson Lab will:

- develop a highly refined picture of the shape neutrons and protons assume as a consequence of the quark-gluon interplay, including transient excited states of these particles,
- make progress toward explaining how the force between nucleons is produced by their quark-gluon structure,
- extend these studies to nuclei and explore how the nucleon properties are modified inside a nucleus, and
- establish the energy and (equivalent) distance scales where the quark-gluon aspects manifest themselves in nuclei.

To solve these tantalizing riddles, JLab will continue to pursue its three-pronged, coordinated approach:

- carry out advanced experiments using JLab's unique facility that provides Users with an intense, highly-polarized, high quality electron beam of up to 6 GeV energy, while

continually improving the effectiveness and efficiency of the operation of this worldwide unique facility;
- theoretical analysis – carried out by a strong team, closely associated with the experimental program - as a means to guide both the conceptualization of experiments and their interpretation; and
- advanced computer simulation in the context of a national collaboration to compute experimentally verifiable numbers (sustained computing speeds for the relevant calculations in Lattice Quantum Chromodynamics (LQCD) of >10 Tflop/s will be achieved).

In support of its primary mission of fundamental research in nuclear physics, JLab has developed world-leading advanced accelerator capabilities that are unparalleled in the nation. These capabilities have been put to use in the construction of the Spallation Neutron Source, the largest current project of the Office of Science. They have also found application in the development of JLab's record breaking and seminal FEL. This machine first demonstrated the concept of reliable, high-power energy recovery in superconducting linacs, and has become the paradigm for a large number of proposed advanced accelerators. The Navy and the Air Force fund most of the Jefferson Lab FEL work, and Jefferson Lab is proud to be able to contribute in these critical times work of relevance to national security.

In the next five years, Jefferson Lab will also complete successfully, on cost and on schedule, its commitments to the Spallation Neutron Source: a 2 K cryogenic plant and about 800 MeV of superconducting linac. The JLab FEL program will develop the enabling technology for MW class FELs for shipboard self-defense, and will support a scientific program that will develop in a national context under the aegis of the funding agency.

<u>The essential step forward for this decade</u> is the realization of the 12 GeV Upgrade; it is motivated by outstanding science and has been endorsed by the community through the Nuclear Science Advisory Committee (NSAC) Long Range Planning process. The higher beam energies and enhanced experimental equipment provided by the 12 GeV Upgrade project are essential to refine and complete our picture of nucleon structure, and to address such fundamental issues as quark confinement and quark correlations in the nucleon. Complementary advances in our capabilities in nuclear theory will be provided by the LQCD project. JLab aims to achieve CD3, construction start for the 12 GeV Upgrade by FY07.

A prerequisite to the achievement of these goals is exceptional institutional management. Jefferson Lab will continue to evaluate its management of human capital, will evaluate and redesign key processes as needed, and will maximize the cost savings potential of its recent reorganization. The Lab's commitment to "the goal is zero" with regard to safety, health, and environmental matters will remain an integral part of our culture. The completion of CEBAF Center (CC) Addition I, and the start of CC Addition II amplified through 3rd party financing of additional infrastructure improvements, will be a visible testimony to the Lab's exceptional management style and culture. JLab will continue to serve the local community and build on its outstanding education and outreach programs.

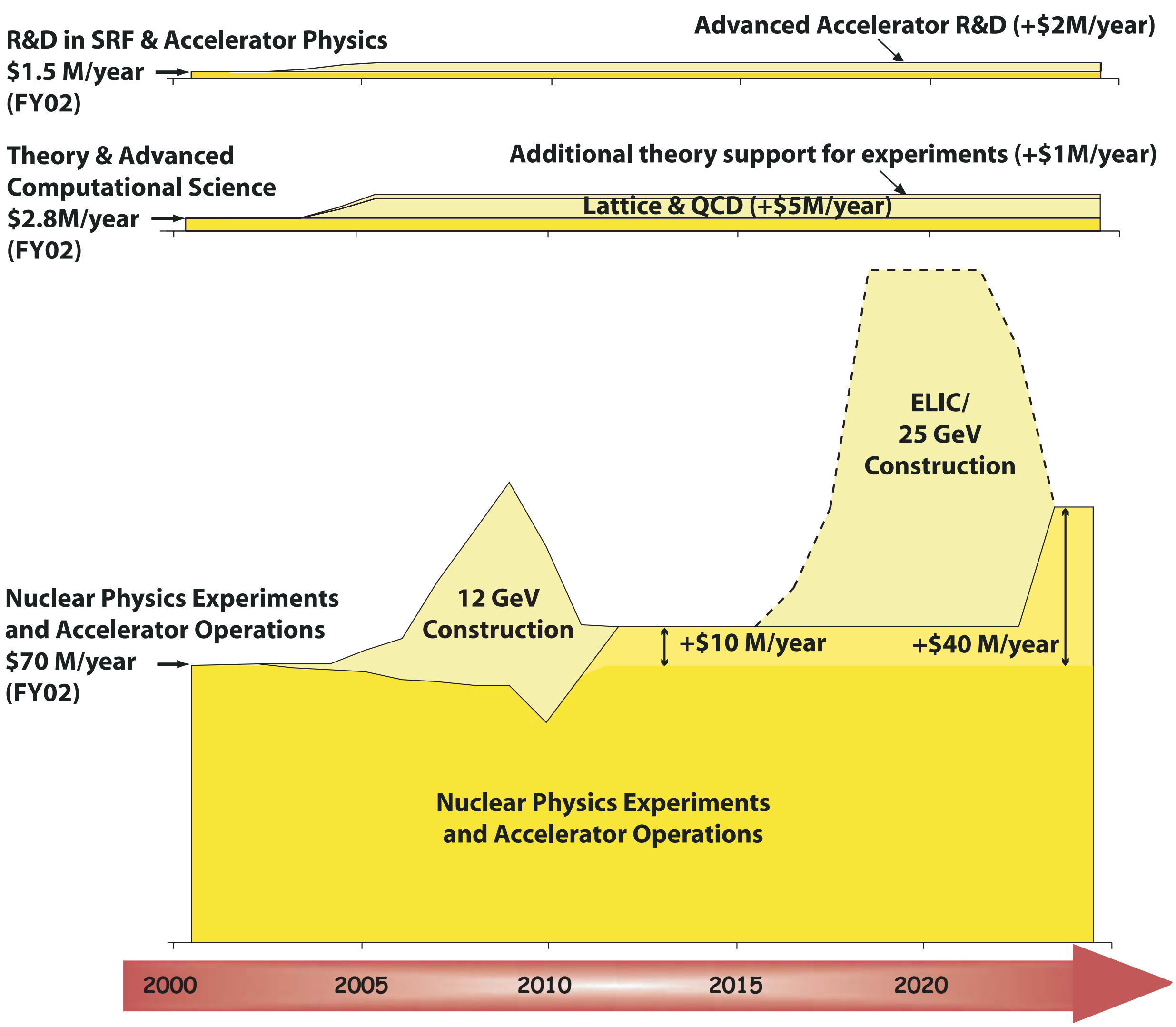
<u>On the twenty-year horizon</u>, even higher energies will be needed to carry out our nuclear physics mission. Both higher energy (~25 GeV) fixed target capability and colliding beam capability providing even higher center-of-mass energies ($\sqrt{s}$~65 GeV) with the highest luminosities achievable may be required. JLab has a concept that incorporates both capabilities, at performance levels not projected elsewhere, that retains the broadest possible experimental flexibility. The research program driving this design has obtained NSAC endorsement for its central scientific role in nuclear physics, and JLab will work to make it part of the next NSAC long-range plan.

# Envisioned Evolution of Jefferson Lab Nuclear Physics Program

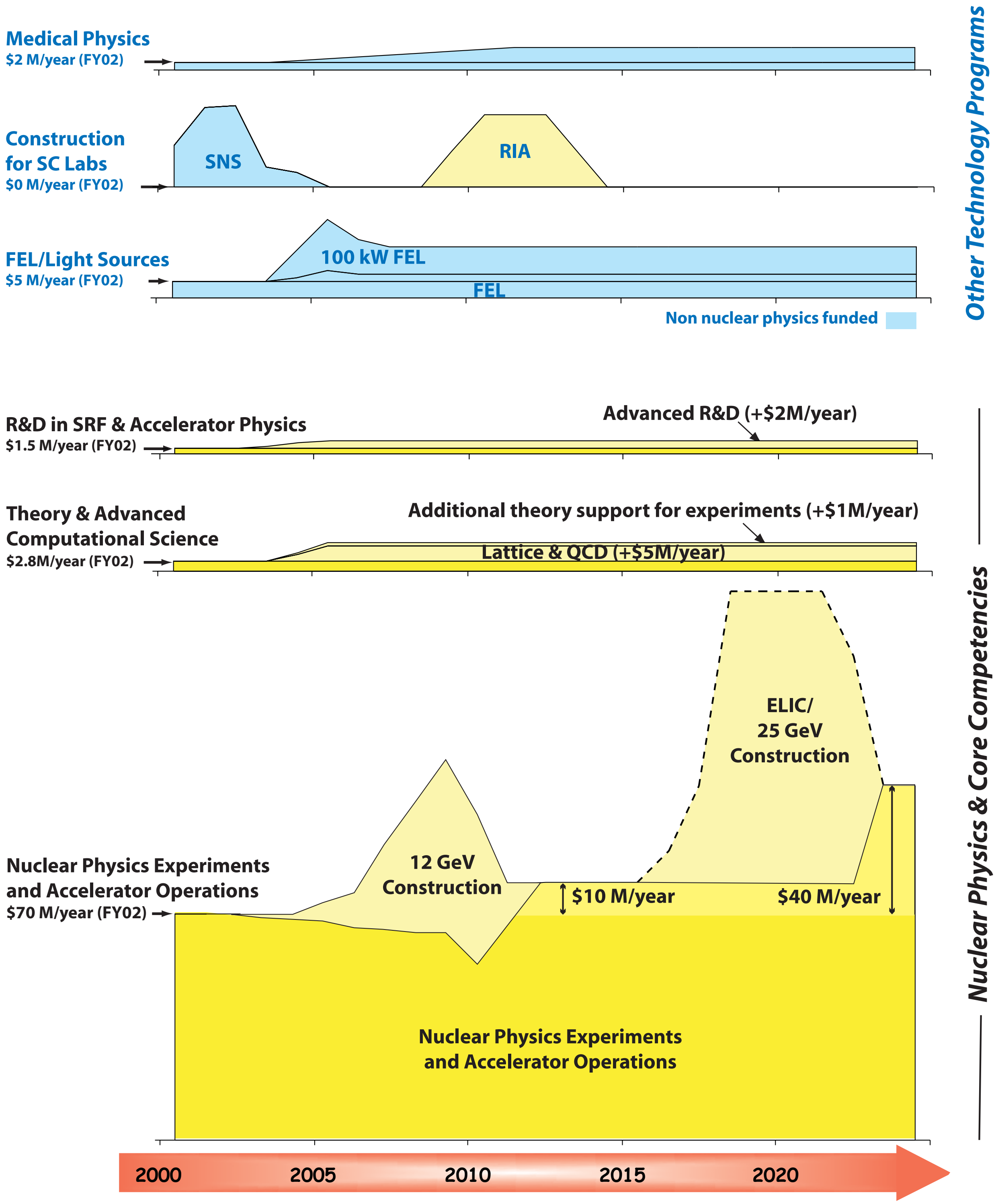
***Today (6 GeV)***
*Nucleon Form Factors, Polarizabilities*
*Missing Baryon Resonances*
*Nucleon Spin Structure*
*Few-body Properties*
*Many-body Nuclei*

***2010 (12 GeV)***
*Quark Confinement*
*Valence Quark Distributions*
*Quark Correlations (GPDs)*
*Nuclear Medium Effects*
*Charm Production*

***2025 (25 GeV/ELIC)***
*Nucleon Spin (GPDs)*
*Flavor Correlations (GPDs)*
*Sea Quarks*
*Hadronization*



# Envisioned Evolution of Jefferson Lab Science and Technology Programs



## IV. RESOURCE PROJECTIONS

Table IV-1 reflects Jefferson Lab's key performance goals, FY02 and FY03 actual funding, FY04 President's Budget and FY05 through FY08 requirements funding. We show Nuclear Physics funding separately for operating, capital equipment, and GPP/AIP (General Plant Project/Accelerator Improvement Program), LQCD, RIA, and 12 GeV. Priorities emerging in each fiscal year are likely to dictate some variation in the allocation from that projected in the table to optimize mission productivity.

Other major resources include funding provided for the FEL and the Spallation Neutron Source (SNS). For the SNS project, Jefferson Lab is the lead partner for the refrigeration system and the cryomodules. With $19.9M of funding provided by the Office of Naval Research (ONR) in FY00-03, Jefferson Lab designed and commissioned an upgrade to the IR Demo FEL that will increase the optical power output in the infrared to over 10 kW when the upgrade is fully commissioned in 2004. The Air Force Research Laboratories provided $6.0M of funding in FY01-03 to add 1 kW of UV capabilities to the FEL Facility by late 2004.

Tables IV-1 and IV-2 raise important issues with regard to the funding of the Laboratory and its Users. Most importantly, the Nuclear Physics (NP) operations funding we receive is significantly below the level necessary for optimum scientific productivity and responsible stewardship of the Laboratory facilities and infrastructure. In FY04, the Nuclear Physics funding projected is $3.2M above FY03 NP funding. The FY05 NP requirements budget reflects a total increment of $17.7M (in AY$) above the FY04 NP President's Budget. This increase, combined with a $300K decrease in RIA funding, would be used as follows:

- $2.6M for capital equipment
- $3.1M in GPP for infrastructure improvements
- $0.6M for Lattice QCD
- $3.3M for the 12 GeV Upgrade
- $1.6M for inflation at 2%
- $1.3M for Accelerator R&D
- $1.2M for facilities maintenance
- $1.0M for the Excited Baryon Analysis Center (EBAC)
- $1.0M for an additional 2 weeks of running
- $0.8M for additional research staff
- $0.7M for advanced SRF R&D
- $0.4M for SNS overhead loss
- $0.3M for improved beam availability
- $0.1M for Accelerator Improvement Projects (AIP)

Funding at this budget level would address the issues presented throughout this Institutional Plan and summarized in Section VII. The $1M to support increased running weeks would permit us to increase accelerator operations from the 30 weeks of FY04 to 32 weeks in FY05. This, in combination with the improved operations efficiencies, is estimated to increase scientific productivity by about 10%.

The second important issue is related to the current level of staffing (Table IV-2) at the Laboratory, which was established by DOE based on NSAC guidance that assumed strong funding of Jefferson Lab User groups so that they could provide on-site effort for installation and operation of their experiments and for maintenance of the equipment they built. Most of our User groups do not receive sufficient funding to provide this assumed and very necessary support function. This situation must be rectified or long-term operational reliability and our ability to continue to mount important new physics experiments will suffer.

Table IV-3 summarizes the results of our contract performance measures for FY01 and FY02.

**Table IV-1**
**Jefferson Lab Funding and Key Performance Goals**

| (Actual Year $ in Millions - BA) | FY2002 (Actual) | FY2003 (Actual) | FY2004 (PresBud) | FY2005 (Req) | FY2006 (Req) | FY2007 (Req) | FY2008 (Req) |
|---|---|---|---|---|---|---|---|
| SCHEDULED ACCEL OPS FOR NP (wks) | 25.6 | 30.4 | 30.0 | 32.0 | 32.0 | 32.0 | 32.0 |
| MAXIMUM ENERGY | 5.7 | 5.5 | 5.7 | 6.0 | 6.0 | 6.0 | 6.0 |
| BEAM AVAILABILITY (%) [1] | 72.8 | 65.4 | 72.0 | 74.0 | 74.0 | 74.0 | 74.0 |
| HALL AVAILABILITY (%) | 86.9 | 89.6 | 82.0 | 82.0 | 82.0 | 82.0 | 82.0 |
| EXPERIMENT MULTIPLICITY [2] | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| HALL WEEKS | 58.4 | 72.6 | 72.0 | 76.8 | 76.8 | 76.8 | 76.8 |
| **FUNDING** | | | | | | | |
| Office of Science | | | | | | | |
| Nuclear Physics | | | | | | | |
| Operating | 65.6 | 70.1 | 73.7 | 82.0 | 83.6 | 85.3 | 87.0 |
| Capital Equipment | 6.0 | 6.4 | 6.1 | 8.7 | 8.9 | 9.1 | 9.3 |
| GPP [3] | .6 | .8 | .5 | 3.6 | 3.7 | 3.8 | 3.9 |
| AIP | 1.3 | .8 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 |
| LQCD | .4 | .4 | .4 | 1.0 | 1.4 | 1.8 | 2.0 |
| RIA | .2 | .4 | .3 | | | | |
| 12 GeV TPC (above redirect)[4] | | .5 | .5 | 3.8 | 7.5 | 25.0 | 41.2 |
| **Subtotal Nuclear Physics** | **74.1** | **79.4** | **82.6** | **100.3** | **106.3** | **126.2** | **144.6** |
| SciDAC-LQCD/PPDG | .7 | .7 | .8 | 2.6 | 3.0 | 3.0 | 3.0 |
| Computational & Tech Research | .1 | | | | | | |
| Biological & Environ. Research | .8 | 1.1 | .8 | .6 | .7 | .7 | .7 |
| Prog Direction-Undergrad Fellowship | .1 | | | .4 | .4 | .4 | .4 |
| Facil Support-CEBAF Ctr Additions | | 1.5 | 3.9 | 5.1 | 1.1 | 8.0 | 6.3 |
| Facil Support-Test Lab Rehab | | | | | | .8 | 6.0 |
| **Total Office of Science** | **75.8** | **82.7** | **88.1** | **109.0** | **111.5** | **139.1** | **161.0** |
| Office of Management, Budget & Eval | | | | | | | |
| SNS | 22.6 | 6.7 | 3.0 | .4 | .4 | | |
| FEL (NAVY, AF, JTO) | 4.3 | 8.1 | 8.0 | 8.0 | 11.0 | 11.0 | 11.0 |
| BPA | 4.6 | | | | | | |
| CRADA – AES | | .2 | | | | | |
| Office of Security & Emergency Ops | 1.0 | 1.1 | 1.0 | 1.5 | 1.6 | 1.6 | 1.6 |
| Light Source Funding | | | | | 3.0 | 5.0 | 10.0 |
| Commonwealth of Virginia [5] | 1.4 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **TOTAL FUNDING** | **109.7** | **100.0** | **101.3** | **120.1** | **128.7** | **157.9** | **184.8** |

1 Availability is averaged over all running experiments
2 Multiplicity indicates expected # of experiments running at the average
3 GPP Funding includes Strategic Facilities Plan
4 Includes R&D, Pre-Ops, and Ops above redirected NP
5 Includes Commonwealth of Virginia/Federal request for FEL building addition in FY05 requirements

**Table IV-2**
**Jefferson Lab Personnel Summary (Average)**

| Full-Time Equivalent (FTE) | FY2002 (Actual) | FY2003 (Actual) | FY2004 (Pres Bud) | FY2005 (Req) | FY2006 (Req) | FY2007 (Req) | FY2008 (Req) |
|---|---|---|---|---|---|---|---|
| Office of Science (excluding SNS) | 472 | 468 | 479 | 538 | 568 | 576 | 599 |
| SNS | 67 | 51 | 35 | 3 | 3 | | |
| Safeguards and Security | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| FEL (NAVY, AF, JTO) | 50 | 55 | 55 | 40 | 50 | 50 | 50 |
| Light Source | | | | | 6 | 10 | 10 |
| Commonwealth of Virginia | 16 | 12 | 11 | 11 | 11 | 11 | 11 |
| Indirect | 114 | 118 | 122 | 124 | 125 | 125 | 125 |
| **TOTAL LAB PERSONNEL** | **724** | **709** | **707** | **721** | **768** | **777** | **800** |

*Includes all full-time staff, part-time staff, contract labor and joint/bridged positions*

**Table IV-3**
**FY2001 and FY2002 Contract Performance Measure Results**

| Performance Measure | Points Earned 2001 | Points Earned 2002 | Points Available |
|---|---|---|---|
| **Outstanding Science and Technology**<br>*Produce outstanding science and technology*. | **285.1** | **285.9** | **300** |
| **Reliable Operations**<br>*Achieve reliable performance of the accelerator and detectors at required specifications to ensure the scientific success of the Laboratory.* | **245.7** | **246.1** | **250** |
| **Scientific and Technical Manpower**<br>*Contribute to the education and training of the future scientific/technical work force for the nation, emphasizing meaningful, unique research experiences at the forefront in its areas of physics.* | **74.0** | **74.4** | **75** |
| **Corporate Citizenship**<br>*Serve the public and the national interest in important areas where Jefferson Lab has special competencies that are mission related.* | **74.1** | **74.1** | **75** |
| **Quality Performance in EH&S**<br>*Protect workers, the public and the environment, adhere to the ALARA concept, and comply with laws, regulations, statutory requirements, and appropriate national initiatives (recycling, waste reduction, etc.) at lowest reasonable cost.* | **96.9** | **90.2** | **100** |
| **Business and Administrative Practices**<br>*Maintain effective and efficient business and administrative practices at Jefferson Lab.* | **93.5** | **96.1** | **100** |
| **Responsible Institutional Management**<br>*Manage and operate Jefferson Lab in accordance with generally accepted quality management principles so as to achieve its mission goals in a cost effective manner while satisfying its customers and providing a culture which builds trust and facilitates continuous improvement in all areas of the institution.* | **93.0** | **93.0** | **100** |
| **Spallation Neutron Source (SNS)**<br>*Contribute effectively to the successful design and construction of the SNS at ORNL by meeting project obligations on schedule.* | **27.9** | **35.0** | **35*** |
| Total | **990.2** | **994.8** | **1035** |

* SNS performance measure points increased from 30 to 35 in FY2002; total points available in FY2001 was 1030

# V. SUMMARY OF MAJOR PROGRAM INITIATIVES

The following major program initiatives are provided for consideration by DOE. Inclusion in this plan does not imply DOE approval of or intent to implement an initiative.

## 1. FIVE-YEAR PLANNING

### A. Increasing the Energy of CEBAF to 12 GeV

The physics opportunities associated with a systematic energy upgrade of CEBAF have been endorsed in the most recent (2002) NSAC Long Range Plan, which states as one of the principal recommendations: "*We strongly recommend the upgrade of CEBAF at Jefferson Lab to 12 GeV as soon as possible. The 12 GeV Upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This upgrade will provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon description of matter, and the nature of quark confinement.*" NSAC further underscored the importance of the upgrade by noting that "*we should emphasize that smaller initiatives – even medium size initiatives such as the Jefferson Lab Upgrade – should be accommodated within a constant effort budget*."

In March 2003 the Upgrade and its timeliness were reviewed again by NSAC in response to a request from the Office of Science that all proposed projects in the field be categorized in three tiers in both the importance of the science and the readiness of the facility for construction. The committee confirmed the Long Range Plan recommendation, declaring the Upgrade's science program as "*absolutely central*" to progress in the field, and went on to note that "*The Upgrade has the support of a large and active user community (~1100 scientists from 29 countries); it has been enthusiastically reviewed by numerous outside peer groups and will be unique worldwide. The realization of the Upgrade will create synergies with other fields of research, most notably with large-scale computing, high-energy physics, and astrophysics.*" NSAC also identified the project as "*fully ready to initiate construction*," noting that "*all remaining R&D is focused on cost reduction and/or improved technical contingency; no R&D is needed to demonstrate feasibility.*"

The 12 GeV Upgrade will make profound contributions to the study of nuclear matter. In particular, it will allow breakthrough programs to be launched in four main areas:

- *The experimental study of gluonic excitations in order to understand the confinement of quarks.* Theoretical conjectures, now strengthened by Lattice QCD (LQCD) simulations, indicate that the most spectacular new prediction of QCD – quark confinement – occurs through the formation of a string-like "flux tube" between quarks. Determining the spectrum of gluonic excitations of mesons will directly test our understanding of confinement and provide key information for unraveling its mysteries if current theory is incorrect.

- *The determination of the quark and gluon wavefunctions of the nuclear building blocks.* A vast improvement in our knowledge of the fundamental structure of the proton and neutron can be achieved. "Deep inelastic scattering" cross sections and polarization observables will be extended for the first time to the critical region where the basic three-quark structure of the nucleon dominates. In addition, similar measurements of new "deep exclusive scattering" cross sections will open the door to a comprehensive characterization of these wavefunctions through the framework of the Generalized Parton Distributions, which will provide direct access to information on the correlations among the quarks.

- *Exploring the limits of our understanding of nuclei.* A diverse program of measurements that (taken together with the hadron studies outlined above) will provide a firm intellectual underpinning for all of nuclear physics by answering the question “How does the phenomenological description of nuclei as nucleons interacting via an effective interaction parameterized using meson exchange arise from the underlying dynamics of quarks and gluons?"

- *Tests of the Standard Model of electro-weak interactions and the determination of fundamental parameters of this model.* Precision, parity-violating electron scattering experiments made feasible by the 12 GeV Upgrade have the sensitivity to search for deviations from the Standard Model that could signal the presence of new physics. Planned studies of the three neutral pseudoscalar mesons will provide key parameters of low energy QCD.

The Upgrade project has an estimated total project cost of $250M (AY$). In addition to funding from DOE/NP, we are seeking resources from other agencies and foreign collaborators. The project will double the beam energy by adding ten new cryomodules to the accelerator placed in the existing free spaces in the linacs. In addition, the helium refrigerator capacity must roughly double, some of the beam recirculation and transport magnets must be upgraded and a few of them must be replaced. The experimental equipment in each of the three Halls would be enhanced, and a fourth Hall would be added to house the major new detector needed for investigation of quark confinement.

The main development and prototyping thrust is in the area of cryomodules. The dual objective is to increase the accelerating gradient and Q value to provide increased energy gain within the envelope of doubled cryogenic capacity. The newest cryomodules show a significant performance improvement over those initially installed in CEBAF. Further improvements are anticipated in the next generation, now being prototyped, that use longer accelerating structures (while retaining the same overall cryomodule length), improved surface treatments, and better assembly procedures. The first of these new cryomodules has been installed in the CEBAF accelerator and is meeting our expectations. In addition, control alternatives will be explored that have the potential for significant reductions in the required RF power for the accelerating structures.

## B. Strengthening Nuclear Theory at JLab

The full realization of the scientific benefits of the Laboratory’s mission to explore the quark and gluon structure of the nucleon requires extensive theoretical work. Jefferson Lab maintains a strong nuclear theory group in partnership with Hampton University, Old Dominion University, and The College of William and Mary. We plan to strengthen this group in two important ways: the establishment of an N* excited baryon analysis center (EBAC); and continued growth of our program in and facilities for LQCD calculations.

### *Excited Baryon Analysis Center and Related Theory in Support of Experiments*

We are proposing to DOE the establishment at JLab of an Excited Baryon Analysis Center to develop and refine the theoretical and computational tools necessary to carry out the analysis of the large body of data associated with the nucleon structure program. Its scientific mission will be to identify the resonances and map out their electromagnetic couplings, thus providing comparison with results from LQCD calculations, and constraints on and insights into the modeling of baryons. It would include two permanent staff and several term/visiting positions, and its research activity would be guided by a Scientific Advisory Board. It is also essential to add theoretical strength in phenomenology and radiative corrections.

### *Advanced Computational Science: Lattice Quantum Chromodynamics (LQCD)*

The development of LQCD (advanced computational techniques to solve Quantum Chromodynamics numerically in the "strong" regime that is appropriate for understanding nucleon structure) was identified in the NSAC 2002 Long Range Plan as "*crucial for answering fundamental questions in strong-interaction physics."* The report went on to note that *"successful nuclear physics programs at Jefferson Lab and RHIC urgently need to make connection to QCD. An aggressive and dedicated effort is needed…."* Jefferson Lab is a key participant in the National Computational Infrastructure for Lattice Gauge Theory, the DOE SciDAC project that brings together theorists, computer scientists, and engineers to tackle demanding quantum chromodynamics calculations.

This collaboration is making significant progress in improving the software used in these calculations and is poised to begin tera-scale simulations of QCD. In FY02-03, a 128-node cluster was commissioned and began tackling key problems including the pion form factor and moments of nucleon structure functions and generalized parton distributions. An additional 256-node cluster is expected to be operational by the end of 2003, yielding an aggregate performance approaching 0.5 teraflop/s. We plan to increase this capacity to 8 teraflops by FY06, and to grow thereafter to keep pace with demands. To realize this capability, funding will have to grow from $1.1M/year in 2003 (including both SciDAC and base funding) to roughly $4M in 2005 and 2006, and then average roughly $5M/year, including all upgrade and operating costs.

## C. Maintaining and Enhancing Accelerator R&D

There is a need within High Energy and Nuclear Physics (HENP), but also Basic Energy Sciences (BES) and other science agencies such as the NSF, for SRF driven accelerators, with associated energy recovery systems and high brightness electron sources. In basic accelerator, beam, and photon physics, JLab is engaged in leading studies crucial for developing future ERL-based light sources worldwide. For example, our ERL development is critical for 3–6 GeV hard x-ray facilities and would yield a hundredfold increase in brightness over storage rings as well as offering sub-picosecond pulses for entirely new experiments in the time domain. Most of this research can only be done at Jefferson Lab—a world leader in superconducting electron accelerators and FELs, and the world leader in ERLs—which built the 6 GeV CEBAF electron accelerator and the JLab FEL on cost and schedule, and now is a leading collaborator on ERLs with Cornell, BNL, LBNL, ANL, Daresbury, Erlangen, and JAERI. Our approach is two-fold: to demonstrate energy recovery at high current on the one hand, and at high energy on the other. Our present ERL is based on superconducting radiofrequency (SRF) technology developed at JLab, and has recirculated 5 mA at 40 MeV. We are currently bringing into operation a 10 mA, 150 MeV machine for the 10kW FEL Upgrade, and we are designing for an eventual capability of 100 mA. At the same time, we have demonstrated 1 GeV energy recovery on the 6 GeV CEBAF recirculating accelerator, from which the ERL derives. Eventually a combination of these technologies will form the basis for a final ERL light source design, and are under consideration for use in the design of a number of high power, energy-recovered machines proposed by the HENP community (ELIC, eRHIC). Key to achieving a high-average-current ERL will be the development of a high-brightness CW injector capable of supplying 100 mA or more. For the SRF modules for these machines, modifications are required to provide for additional damping of higher order excited modes to minimize beam breakup instabilities. As part of the ongoing ONR-funded program at JLab, initial studies have been performed and possible approaches for increased damping have been identified.

### D. Advancing Photon Science

The Jefferson Lab FEL operates in an area that is unattainable with sub-picosecond tabletop lasers, even at a specific wavelength, due to its combination of high repetition rate and power per pulse. In addition we have an aggressive program to reduce the pulse lengths down to the attosecond regime so that we can meet frontiers of the time domain as well as ultra-high fields in a fully tunable device. During 1999–2001, JLab's original kilowatt-scale IR FEL was run for scientific users for a total of 1800 hours (limited by funding). The JLab home page (http://www.jlab.org/fel/) contains a link to a comprehensive bibliography of the resulting publications. In fields including not only physics but chemistry, biology, and materials science, the experimentation has changed thinking about linear and nonlinear dynamical processes, while in basic accelerator, beam, and photon physics, the FEL and ERL are opening regions of study with implications for future research tools for basic science. In the near term, with the THz/IR/UV FEL operating at up to 10 kW, we will expand our canvas to include atomic, molecular and optical physics in the mid-IR, in dynamical experiments in the far-IR, and in fundamental material and biological interactions in the UV region. In all areas we will have many orders of magnitude more peak and average brightness than any other source in the world. Scheduling of FEL time is via a Program Advisory Committee, and even though we have operated only one user at a time, we still fall well within the normal DOE-BES light source metrics for cost per published result.

## 2. LONG-RANGE PLANNING

### A. CEBAF Beyond 12 GeV

A future upgrade of CEBAF beyond 12 GeV would build on the physics insights obtained from the 12 GeV Upgrade, and expand on our understanding of the structure of the nucleon and nuclear binding. Strong physics cases have been established for two possibilities: an extremely high luminosity (~$10^{38}$ cm$^{-2}$ sec$^{-1}$), CEBAF-like accelerator providing beam energies in the 20-30 GeV range; and an electron-light ion collider (ELIC) operating at much higher center of mass energies (in the 20-65 GeV range) with very high luminosity (design studies indicate luminosities as high as $10^{35}$ cm$^{-2}$ sec$^{-1}$ may be achievable). The facility at Jefferson Lab can be upgraded to provide either (or both) of these options in a straightforward manner.

An energy upgrade of CEBAF to 25 GeV would support extensions of the CEBAF 12 GeV program to smaller Bjorken $x$ and higher $Q^2$ and, in particular, support a program of deeply virtual meson production that would permit the flavor separation of the Generalized Parton Distributions (GPDs) that characterize the nucleon's properties. A high-luminosity ELIC would permit us to:

- complete our quantitative understanding of how quarks and gluons provide the binding and the spin of the nucleon;
- learn how quarks and gluons evolve into hadrons via the dynamics of confinement through measurements of the spin dependence of this complex process known as hadronization – a key aspect of the transition from the deconfined state of free quarks and gluons in the Big Bang to stable hadronic matter; and
- determine how the nuclear medium affects quarks and gluons.

While questions remain on the details of the science program and on technical aspects of the facility design, the March 2003 NSAC review of new facility proposals identified this program as likely to be "absolutely central" to the field of nuclear physics.

An upgrade of CEBAF to 25 GeV would use the existing CEBAF footprint. All of the present cryomodules would be replaced by the new 12 GeV design, and arc magnets, the beam switchyard, and the Hall equipment would be changed and/or upgraded. The task is relatively straightforward. Construction of the ELIC facility would require the upgrade of Jefferson Lab's CEBAF accelerator to a 5 GeV energy-recovering linac and the realization of a storage ring complex, accelerating and storing light ions of up to 100 GeV. The ELIC project could also include the 25 GeV fixed-target facility.

The R&D on energy recovered linacs (ERLs), beam cooling, and high-brightness polarized electron sources needed for the ELIC facility is also of interest for beam cooling at RHIC, for our FEL, and for X-ray sources under consideration at Cornell and elsewhere. The first experiment aimed at demonstrating the feasibility of energy recovery at both high current and high energy took place on the GeV scale using CEBAF in March 2003. Work is also needed on the design of an interaction region and detector that, taken together, support the combination of the very high luminosity and very high detector acceptance and resolution essential to carry out this physics program.

We expect that over the next five years the scientific motivations for these different possibilities and the technical details of their realization will be developed more fully, permitting the community to optimize its choice for the next generation facility.

### B. Next Generation Light Source

Jefferson Lab's success with the IR Demo FEL demonstrated an efficient means of producing high average power and high brightness light for the R&D community using energy recovery. Further experiments at high energy on CEBAF define an R&D path towards a next generation X-ray source based on SRF driven energy recovered linacs. A proposal presented to DOE's Basic Energy Sciences Advisory Committee (BESAC) was strongly endorsed and Jefferson Lab will play a major role in developments in this area. In addition, active discussions have taken place among SURA universities concerning a world class X-ray source that could be developed by Jefferson Lab either on-site, or at a partner-location in the 2006-2009 timeframe, taking full advantage of the FEL user community and the Laboratory's core competencies in SRF, electron source and accelerator technology.

# VI. OPERATIONS AND INFRASTRUCTURE STRATEGIC PLAN

## 1. SCIENTIFIC AND TECHNICAL PROGRAMS

### A. Nuclear Physics: 6 GeV Experimental Program

Our understanding of the structure of matter has undergone a profound transformation in recent years. It is now known that quarks and gluons – not protons and neutrons – are the basic components of nuclei, and that they, together with electrons and photons, are the fundamental constituents of matter. Along with the discovery of quarks and gluons has come an understanding of their interactions – the “strong interactions” – so that now nuclear and sub-nuclear physics have, for the first time, a basis as solid as the theory on which atomic and molecular physics are built. There is a striking analogy between the latter well-established sciences and the physics of quarks and gluons: the proton and neutron are now believed to be “quark atoms” (bound states of quarks held together by gluons) just as ordinary atoms consist of electrons bound by photons to the atomic nucleus. Moreover, nuclei themselves may be considered analogous to molecules, both being relatively weakly bound compounds of their respective “atoms”.

The fundamental theory of strong interactions, called QCD, guides experimentation at Jefferson Lab’s CEBAF. Although it is assumed that QCD is exact, it has only been tested in the very high energy regime, where the interaction becomes weak and perturbative calculations are feasible. The scientific goal of CEBAF is to investigate the transition region between this “asymptotically free” high-energy regime and the strongly interacting regime, where our understanding of the underlying physics is very rudimentary, and where the matter we see around us is formed.

The broad thrust of the nuclear physics experimental program underway using the 6 GeV beam from CEBAF can be organized into six major research themes addressing key scientific questions of paramount importance for our understanding of nuclear physics. These themes coincide with the broad directions of the field of nuclear physics as identified in two key documents: the 2002 Long Range Plan of NSAC (the Nuclear Science Advisory Committee of the U.S. Department of Energy and the National Science Foundation) and the recent decadal survey of the field by the National Research Council of the National Academy of Sciences. We identify these questions here to place our research program in this broader context. Each corresponds to an outstanding question in nuclear physics that the laboratory's users address with a coordinated program of experimental and theoretical work. **The six themes are:**

***On the Structure of the Nuclear Building Blocks:***

**1) How are the nucleons made from quarks and gluons?** -- a program of measurements addressing this first question that must be answered in the quest to understand nuclear physics in terms of the fundamental theory of strongly interacting matter: quantum chromodynamics (QCD).

**2) How does QCD work in the ‘strong’ (confinement) regime?** -- experiments and theory aimed at examining the fundamentally new dynamics that underpin all of nuclear physics: the confinement of quarks.

**3) How does the NN force arise from the underlying quark and gluon structure of hadronic matter?** -- a broad program of experimental and theoretical work focused on moving beyond current phenomenological descriptions of the nucleon-nucleon force (for example, to determine its basic nature as a mixture of meson exchange, quark exchange, and color polarization effects).

***On the Structure of Nuclei:***

**4) What is the structure of nuclear matter?** -- a broad program of experiments taking advantage of the precision, spatial resolution, and interpretability of electromagnetic interactions to address long-standing issues in nuclear physics and identify the limits of our understanding.

**5) At what distance and energy scale does the underlying quark and gluon structure of nuclear matter become evident?** -- a combination of experimental and theoretical work now being carried out at Jefferson Lab and in the community at large focusing on few-body systems where directly interpretable experiments can be compared with exact calculations that are now feasible in the context of ab initio calculations of nuclear properties.

***Symmetry Tests in Nuclear Physics:***

**6) Is the "Standard Model" complete? What are the values of its free parameters?** -- The Standard Model has been highly successful in describing phenomena in nuclear and particle physics. Traditional tests have been performed at the Z pole and through high-energy searches for new particles. JLab has launched a program aimed at testing the theory and determining its constants in both the electro-weak and strong sectors using an alternate approach – precision measurements at low energies.

To address each of these major questions in the field, a series of "campaigns" have been developed in which a comprehensive program of experimental measurements and theoretical calculations aims to answer the question. So, for example, to answer the question "How are the nucleons made from quarks and gluons?" the Jefferson Laboratory research community has identified four major campaigns:

- What are the spatial distributions of u, d, and s quarks in the hadrons?
- What is the excited state spectrum of the hadrons, and what does it reveal about the underlying degrees-of-freedom?
- What is the QCD basis for the spin structure of the hadrons?
- What can other hadron properties tell us about 'strong' QCD?

A campaign typically consists of a sequence of experiments that, taken together, provide the needed experimental data, and the associated theoretical work that is essential to understand and interpret the results. When data is particularly important we often carry out independent experiments to determine the necessary quantities to avoid being misled by an unidentified systematic error in an individual experimental result. It is also often the case that the analysis and interpretation of the first few experiments in a campaign identify key new information that is required to complete our understanding and/or follow up on a surprising result.

The campaign to determine the spatial distributions of the u, d, and s quarks in the nucleon is an excellent example of this process. In principle, six sets of measurements are required: four that determine the electric and magnetic elastic electron scattering form factors of the proton and the neutron, and two that determine the electric and magnetic weak neutral current form factors of the proton (to provide access to the s-quark distributions). Each must cover a broad range of momentum transfer, requiring in some cases multiple experiment setups to cover the changing experimental conditions. We are about 2/3 of the way through the completion of the first round of measurements in this program, with data taken and published on the electric form factor of the proton, data from two experiments on the neutron electric form factor ready for publication, and data from one experiment on the magnetic form factor of the neutron published, and from another (covering much higher momentum transfers) under analysis. Precise data on the magnetic form factor of the proton is available from earlier experiments at other facilities. New apparatus is under construction to facilitate experiments extending the range of momentum transfer measured for the electric form factors of both the proton and neutron. The first data has been taken on the weak neutral current form factor at a single momentum transfer (measuring a sum of electric and magnetic components). An experiment to complete the electric and magnetic separation of this form factor at a single momentum transfer is ready to run, and a major experiment to determine it over a broad range of momentum transfer (the G0 experiment) will begin taking data early in FY04. A major new apparatus and new accelerator capabilities had to be developed to prepare for this measurement.

The first of the experiments in this campaign, which determined the ratio of the electric and magnetic form factors of the proton to high $Q^2$, has provided one of the most interesting results from the CEBAF program. The data have demonstrated that the radial distribution of charge and magnetization in the proton differ significantly. These data, taken together with the neutron data, are providing a stringent test for quark-based models that should describe the nucleon's internal structure and have sparked a resurgence of theoretical interest in the problem. Understanding the difference between the proton electric to magnetic form factor ratio result and earlier experiments that measured the same quantity using a different technique are also advancing our knowledge of how to interpret these difficult experiments, and motivated a new measurement using a third technique. Finally, theoretical insights that have come from these new data are a strong motivation for a new class of (deep exclusive scattering) experiments that will become possible with the 12 GeV Upgrade, providing a window on the correlations between the quarks in the hadrons.

Each of the research themes outlined above has a similar set of campaigns. In each (except for the last, in which our first experiment is in the final stages of preparation) we have made important progress and substantively enhanced our understanding of nuclear physics. In each, we have a clear plan for the near-term future and are keeping a keen eye toward breakthrough surprises that will lead the science in new directions toward even deeper levels of understanding.

### a) Accomplishments

The single most important factor in judging the effectiveness of the operation of the CEBAF facility is the quality and quantity of science it produces. In each of the first seven years of operation, that science has been judged outstanding. In this section, we review some of the highlights of the CEBAF program to date, and then identify a few of the accomplishments since the last Institutional Plan.

*Highlights of the 6 GeV Research Program*

Construction of CEBAF was completed in 1995, and full research operations using it have been underway since late 1997. In this short period of time the facility has delivered handsomely on its promised research mission: 81 full experiments and parts of 23 more are complete; over 85 Phys. Rev. Letters or Physics Letters, 185 papers in other refereed journals, 22 technical publications, and nearly 300 invited talks and 600 contributed talks have been presented at conferences, symposia, and workshops. There have also been 148 PhDs granted based on that research and 126 more are in progress. JLab research now produces about 1/3 of all US PhDs in nuclear science. In this brief summary, we can only cover a few of the highlights of that research program. The summary is organized according to the research themes outlined above.

*The effort to understand how the nucleons are made from quarks and gluons is fundamental to hadronic physics*, and is being explored at JLab first by measurements of the nucleon form factors, and by experiments determining the moments of the momentum distribution functions describing the quarks in the nucleon. These moments can now be computed using Lattice QCD in a modern, relativistic description of nucleon structure.

Remarkable new data from Jefferson Lab are elucidating the electromagnetic structure of the proton and neutron. A JLab experiment has found that the charge and current distributions in the proton differ significantly. A second has mapped out the distribution of electric charge in the neutron precisely. Although the total charge of the neutron is zero, since the net contributions from its positively (mostly u) and negatively (mostly d) charged quarks are in perfect balance, its distribution of charge is not, and provides a sensitive test of quark-based theories of the nucleon. There are indications from high-energy hard-scattering data that strange quarks and antiquarks ($s\bar{s}$) play a role inside the nucleon. Determining the contribution of $s\bar{s}$ pairs to the nucleon's form factors requires separating the response of nucleons to the electromagnetic and weak interactions through the measurement of parity-violating asymmetries in electron scattering. The first such experiments showed that the contribution of the strange quarks to the charge distribution of the proton is much smaller than many theories predicted.

As was the case with atomic structure, we must study the excitation spectrum of the proton to understand its wave function. CEBAF's high energy photon and electron beams are an ideal tool for this study as we know the electromagnetic coupling to the quarks in the nucleon. Through electron scattering and photon absorption experiments, we can determine how the nucleon absorbs energy and momentum. The continuous nature of the CEBAF beam also provides a unique and essential new capability: now we can "follow" the excited nucleon after it has absorbed a precisely measured energy and momentum, and see how it de-excites. Since most excited states are short-lived and broad, these measurements require detailed analyses of complex final states. For high-lying states direct transitions to the ground state occur infrequently, and more often the de-excitation is a cascade process including multiple particle emission.

Precise studies of the excitation of the first excited state of the proton, the $\Delta(1232)$, at Jefferson Lab have revealed its quadrupole component, which implies a shape change of the proton between its ground and its first excited state. These deformations result from asymmetric internal distributions of electric charge and current due to the motion of quarks and gluons in the nucleon constrained by the QCD confinement mechanism. Comparison of these data with Lattice QCD calculations suggest that the deformation is mostly due to the meson cloud surrounding the proton.

Many other excited states have been predicted within the constituent quark model as a result of its specific symmetry properties. Only a small number of them have been observed in elastic pion-nucleon scattering, the main source of information so far. Resonance structures observed in more complex final states using the large acceptance spectrometer CLAS at JLab may be due to some of the "missing" resonances, but need further analyses to be conclusive. The main limitation in extracting the physics from the vast experimental data already in hand, and more expected in future running, is from the absence of focused scientific manpower with expertise in hadron phenomenology and complex baryon spectroscopy. In order to address this problem we propose to establish an Excited-Baryon Analysis Center (EBAC) at Jefferson Lab.

JLab data exploring the spin structure of the nucleons have provided fascinating information on the valence quark structure under the extreme condition where a single quark carries most of the nucleon's momentum. Other experiments have determined the evolution of the spin response of the nucleon from a distance scale large compared to the nucleon, where meson and nucleon degrees-of-freedom dominate, to small distance scales (< 1/5 the nucleon's diameter) where partonic degrees-of-freedom govern the nucleon's spin structure.

The CEBAF energy of 6 GeV has also allowed us to probe some aspects of the newly-discovered Generalized Parton Distributions (GPDs). GPDs represent the two-parton correlation functions that can, for the first time, be accessed through the Deeply Virtual Compton scattering (DVCS) process. Pioneering DVCS measurements at JLab can be interpreted through GPDs and perturbative QCD, and, when extended through the capabilities that the Upgrade will bring, these experiments will provide the basis for the construction of detailed tomographic images of the quark distributions in the proton for the first time.

*To explore how QCD works in the 'strong' (confinement) regime*, one of our most important efforts has been aimed at the determination of where the dynamics of the q-q interaction makes a transition from the strong (confinement) to the perturbative (QED-like) QCD regime. The measurement of the momentum transfer (or, correspondingly, distance scale) behavior of the pion form factor provides key information on this subject, as the transition is expected to occur earliest in the simplest QCD systems, and so the pion form factor provides our best chance to determine the relevant distance scale experimentally. The pion form factor has been determined by scattering electrons from the virtual pion present in the proton. JLab data has provided the first information about the pion charge distribution beyond its rms radius, providing the first serious test for QCD models of pion structure. An extension of the experiment that will probe even smaller distance scales is now underway, and with the 12 GeV Upgrade we expect to be able to identify the distance scale at which QCD becomes "weak" – or well described by the perturbative calculations that work so well at extremely high energies.

*To investigate the origin of the NN force from the underlying quark and gluon structure of hadronic matter* we have several main programs. The first studies the form factors of simple nuclei ($A \leq 4$) in an effort to understand how well a meson exchange-based NN force can describe nuclei (this program is also a key aspect of understanding the transition from the quark-gluon description to the meson-nucleon description of nuclei, and is described below). Other experiments are inferring the nucleon-meson form factors, and investigating whether there is evidence for "color transparency" in nucleon propagation and whether the nucleon's properties are modified in the nuclear medium.

The question of whether a nucleon bound in the nuclear medium has different properties than a free nucleon has been a long-standing issue in nuclear physics with important implications for our understanding of the NN force. It was first considered seriously with the discovery of the nuclear EMC effect some twenty years ago, in which scattering from quarks inside a nucleus was discovered to differ in non-trivial ways from the scattering of quarks in a free nucleon. JLab data comparing the ratio of the electric and magnetic form factors for the proton in nuclei with the "free" value of that same ratio provides evidence that it may be more economical to describe nuclei using the assumption of a medium-modified nucleon.

*Our exploration of the structure of nuclear matter has included many important programs*. Among them are: how well does nuclear theory describe the energy and spatial structure of the single particle wavefunctions; what can the introduction of an "impurity" in the form of a particle containing strangeness such as the $\Lambda$ tell us about the nuclear environment and the NN force; and can the parameterized NN force adequately describe the short-range correlations among the nucleons? The reason for asking this last question can be understood by comparing the average nucleon size with the average nucleon density inside a nucleus; this comparison tells us that nucleons have considerable overlap. Coincidence (e,e′p) experiments in which the proton is "knocked-out" of the nucleus provide precision information on the nuclear single-particle wave functions. Systematic studies indicate that a significant amount of single-particle strength is shifted to highly excited states and to states where the nucleons have large momenta (assumed to originate from correlated pairs of nucleons with a large, but opposite momenta). The large kinematic range provided by the CEBAF facility has made it feasible to directly access these states for the first time, and a large program of (e,e′p) experiments is being carried out for nuclei from $^{2}H$ to $^{197}Au$. Preliminary results have already provided direct confirmation of an excess of nucleons moving at high speed inside a nucleus. Direct observation of correlated nucleon pairs has been an elusive goal of the field for nearly three decades; JLab data on double-proton knock-out from $^{3}He$ provide a clear observation of such correlated nucleon pairs. Planned experiments will measure the ratio of knocked-out proton-proton and proton-neutron pairs in order to investigate this phenomenon in further detail.

*The identification of the distance and energy scale at which the underlying quark and gluon structure of nuclear matter becomes evident* has been one of the major accomplishments of the JLab program. One of the principal goals of nuclear physics is to understand quantitatively, over a wide energy range, the structure and reactions of nuclei. The "standard" description of nuclei considers them as assemblies of nucleons – protons and neutrons – interacting via effective interactions. The dominant nucleon-nucleon interaction at large distances (> 2 fm) is due to pion exchange, which is theoretically well-understood; it has a peculiar tensor character that leads to a strong coupling between the spatial and spin degrees of freedom of the nucleons. At short inter-nucleon distances the interaction is predominantly characterized by a strong repulsion, but it is poorly understood. It is influenced by heavy-meson exchange, quark-exchange mechanisms, and the excitation of nucleon resonances.

The interplay between these two main aspects of the nucleon-nucleon interaction – its short-range repulsion and long-range tensor character – has profound consequences for the spatial and spin structure of nuclei. For example, it causes the deuteron, the simplest nucleus consisting of a proton and neutron bound together, to have a toroidal shape when the proton and neutron spins are opposite and a dumbbell shape when their spins are aligned. This picture of the deuteron, derived within the context of the nucleon-meson framework, has been confirmed down to distance scales of ~0.5 fm by the recent precise measurements at Jefferson Lab of all three electromagnetic form factors of the deuteron. These results indicated that the nucleon-meson description is valid down to much smaller distance scales than previously thought, and provide a firm intellectual foundation for further work in the field.

A second set of JLab experiments (notably those dealing with the deuteron photo-disintegration) has exposed the limits of this approach to nuclear structure. Nucleon-meson models fail to describe the high-energy two-nucleon breakup of deuterium while these data are consistent with the quark-gluon picture. These experiments indicate that when the distance scale is reduced to <0.1 fm the internal quark-gluon structures overlap, and a description in terms of the underlying quark and gluon degrees of freedom is necessary.

Calculations of the electromagnetic properties of light nuclei, which are essential to this program, are carried out by convoluting the nuclear wave functions (obtained from the effective interactions mentioned above) with the form factors of the constituent nucleons. JLab's precision measurements of nucleon form factors (also motivated by our studies of the internal structure of the proton and the neutron) have provided crucial data for the interpretation of these experiments.

*Our first experiment in an effort to test the completeness of the "Standard Model" and identify quantitatively the values of its free parameters* will begin this year with an experiment measuring the decay width of the $\pi^0$, which is highly sensitive to low energy QCD dynamics as calculated using chiral perturbation theory. The Standard Model (SM) has been broadly successful in describing phenomena in nuclear and particle physics. Traditional tests have been at the Z pole and through high-energy searches for new particles. JLab has launched a program aimed at both testing the theory and determining its constants in both the electro-weak and strong sectors using an alternate approach – precision measurements at low energies. This program will begin with a measurement of the weak charge of the proton.

## *Recent Accomplishments*

*Understanding how the nucleons are made from quarks and gluons*

A real surprise with the potential to profoundly change our understanding of hadronic matter was the recent discovery of the penta-quark baryon $\Theta^+(1540)$. Various models predict a total of ten low-lying (ground-state) penta-quark states. Three of these states have exotic quantum numbers (the $\Theta^+(1540)$ being one of the three) that – in the constituent quark model - require a minimum of five quarks, or more precisely four quarks and an anti-quark. Clarifying the nature of the observed $\Theta^+(1540)$ and searching for its exotic companions will likely have dramatic consequences for our understanding of the nature of strongly interacting matter.

A large block of experiments with CLAS using polarized electrons on a hydrogen target was completed. The $N\rightarrow\Delta(1232)$ transition was studied with high statistics to investigate the effect of the pion cloud on the $\Delta$ deformation. A study of N* excitations in the 2-pion channel was completed to investigate high-mass resonance excitations at high momentum transfer, search for new resonances, and provide higher statistics for K-$\Lambda$ and K-$\Sigma$ production. Also, a measurement of the N-$\pi$-$\pi$ channel and K-$\Lambda$ production was completed at lower energy (3.2 GeV), with the goal to perform a longitudinal and transverse (L/T) separation in hyperon production and to study of the N* mass region near 1.7 GeV at lower momentum transfer in the search for missing resonances. A Hall C measurement extended our knowledge of the $N\rightarrow\Delta$ transition form factor to a $Q^2$ of 7.5 $(GeV/c)^2$. At such a large $Q^2$-value the results can be connected to GPDs.

Two experiments expanding our understanding of the structure functions that characterize the nucleons were carried out or analyzed. The neutron spin asymmetry $A_1^n$ was determined at three x-values from measurements with a polarized $^3$He target in Hall A. These results established for the first time that $A_1^n$ becomes positive at larger x-values and also have significant implications for the spin structure of the valence u and d quarks. The $F_2$ structure function was studied by an L/T separation in the previously unmeasured low-$Q^2$ region.

Additional measurements with CLAS of Deeply Virtual Compton Scattering on the proton studied its t and $Q^2$ dependence. These measurements will provide further insight in the application of factorization and thus in the extraction of information on the GPDs. We also obtained our first results for the cross section and longitudinal polarization transfer in Real Compton Scattering on the proton have convincingly established that the handbag mechanism is dominant in the kinematical region accessible with 6 GeV at JLab. Thus these experiments will provide sensitive input on the GPDs.

Progress was also made toward the goal of determining the contribution of $s\bar{s}$ pairs to the nucleon's form factors. The G0 experiment, which will be carried out over the next few years, aims to determine this contribution through a series of measurements of parity-violating asymmetries in electron scattering. The initial commissioning phase for the new G0 spectrometer was successfully completed with the first engineering run. This engineering run included close to 100 hours of "dress rehearsal" data.

Quark-hadron duality studies were completed at the highest $Q^2$-value achievable at a 6-GeV JLab. In addition a study of spin duality on the neutron using a polarized $^3$He target in Hall A was completed. One septum magnet was successfully operated in Hall A in order to study the GDH sum rule on the neutron with nearly real photons which will extend the earlier measurement down to a $Q^2$-value of 0.02 $(\mathrm{GeV/c})^2$.

*Exploring how QCD works in the 'strong' (confinement) regime*

The ratio of the electro-production of positive and negative pions in a variety of nuclei was shown to be an alternate to the identification of the QCD transition, and data on the pion form factor, $F_\pi$, were extended from 1.6 to 2.5 $(\mathrm{GeV/c})^2$ where theoretical calculations begin to diverge.

*Investigating how the NN force arises from the underlying quark and gluon structure of hadronic matter*

A measurement of the photoproduction of vector meson production from various nuclear targets with the goal of studying its medium modification was completed. A total of about $10^3$ $e^+/e^-$ pairs have been identified, which should be sufficient to yield a sensitive test of various models.

*Exploring the structure of nuclear matter*

Proton knock-out was studied from $^{3,4}$He and $^{16}$O. First results have already provided further insight into single-particle wavefunctions to high $Q^2$ and short-range nucleon-nucleon correlations. Data on inclusive scattering from a variety of nuclei, and detailed measurements of the $^3$He(e,e'pp)n using CLAS have provided the important new information on the nature of the ground state correlations in nuclei.

There has been major progress in preparation for second-generation hypernuclear spectroscopy experiments (the electro-production of bound states in hyperonic nuclei) at Jefferson Lab. The second septum magnet in Hall A is now ready for installation. The construction of the High-resolution Kaon Spectrometer with mainly Japanese funding is nearing completion for Hall C. These setups will provide dramatic enhancements of production rates for hypernuclei and unprecedented energy resolution.

*Identifying the distance and energy scale at which the underlying quark and gluon structure of nuclear matter becomes evident*

Further accurate measurements were performed in Halls A and B of the energy and angular distribution of the cross section and of the proton polarization for deuteron photodisintegration, which will provide additional insight in the transition from nucleonic to partonic degrees of freedom. In addition, exclusive electro-disintegration of the deuteron was studied in a large $Q^2$-range up to high values of the missing momentum and energy. This extensive investigation of the simplest bound nucleon system will provide detailed insight in various aspects of the nucleon-nucleon force.

*Testing the completeness of the "Standard Model" and identifying quantitatively the values of its free parameters*

Our first experiment in this area will begin this year measuring the decay width of the $\pi^0$, which is highly sensitive to the quark masses: the PrimeX experiment. We have also carried out a conceptual design review and started research and development for a new experiment, $Q_{Weak}$, which will measure the weak charge of the proton. This experiment has received major funding from the NSF and Canada.

## b) The CEBAF Accelerator and Its Experimental Facilities

The high energy, continuous-wave electron beam provided by the CEBAF accelerator together with the instruments in its experimental facilities provide an ideal tool for carrying out this research. Since the electromagnetic interaction is well understood, the electron has no internal structure, and CEBAF can provide electrons with energies up to 6 GeV, experimenters can probe distance scales ranging from the size of a large nucleus down to about 1/10$^{th}$ the size of the proton. In this section we provide a brief overview of the accelerator and its associated experimental facilities. Together they provide a unique set of tools for addressing the fundamental questions in nuclear physics outlined above.

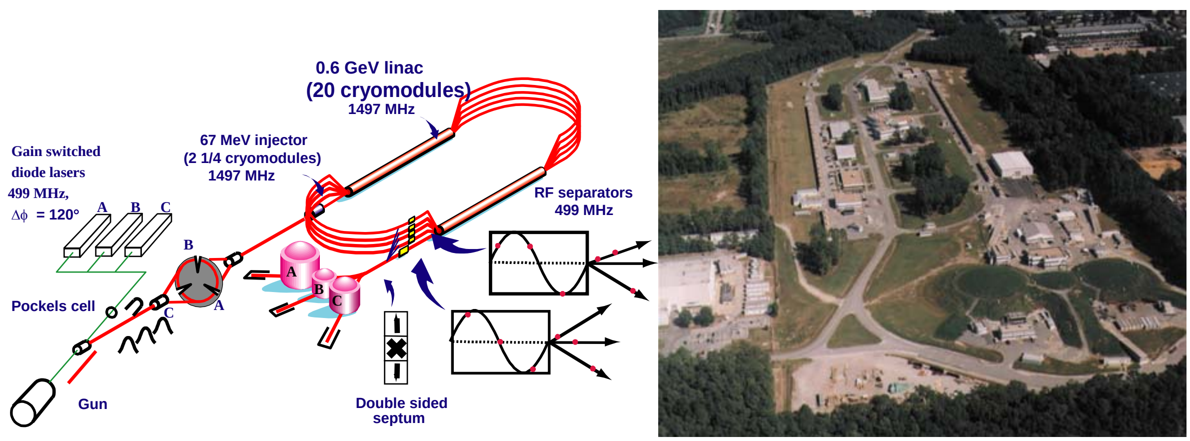



Figure VI-1: The CEBAF accelerator (left) and an aerial photo of the accelerator site (right).

### Accelerator Overview

CEBAF at Jefferson Lab embodies the first and presently the biggest large-scale implementation of microwave superconductivity in nuclear and particle physics. The unique ability to produce high energy (up to 6 GeV), spin-polarized (in excess of 80%), precise, ultra short (sub-picosecond) bursts of electrons in a continuous train repeating at tens to hundreds of MHz stems from the sustained, reliable and stable operation of a superconducting radiofrequency recirculating linac at 2 K. This allows us to have a high resolution microscope probing deeper and cleaner into nuclear matter.

The overall layout of the accelerator is shown in Figure VI-1. At the heart of the facility are two 400 meter-long tunnels housing two superconducting radiofrequency standing-wave linear accelerators operating at 1.5 GHz in a continuous mode. The superconducting microwave cavities are housed in specially designed 2 K cryostats, fed by a Central Helium Liquifier (CHL) plant, which also provides the liquid helium for the cryogenic experimental targets and the much smaller sub-100 MeV superconducting linac for the Free Electron Laser. Each linac in the CEBAF tunnel can boost the energy of the relativistic electrons comfortably up to a good fraction of a GeV, so in multiple recirculation of anywhere between 1 to 5 passes, beams of varying energy (between tens of MeV to 6 GeV), varying intensity (between few nanoamperes to hundreds of microamperes) and polarizations (between 0% to 80%) can be delivered to three experimental Halls (A, B and C) simultaneously for a multitude of experiments. The separation of the beam into the three Halls after multiple passes is achieved by a 500MHz RadioFrequency Separator in combination with a Lambertson Septum magnet. The separate beam lines from the end of the accelerator to the targets in the independent Halls provide the experimenters with relatively independent knobs to manipulate the beam direction and size onto the target. Transporting the beam between the two linacs and between different recirculation paths are five magnetic transport arcs on each side of the two linacs, north and south, that have been precisely designed and are operated in a programmed manner to transport the beams of different energies into designed semicircular orbits for matching optically into the next pass through the linac or delivery to the experiments.

The injector complex to the accelerator is equally crucial, providing high quality spin-polarized electron beams for injection into the linac. At the heart of this complex is a photocathode DC electron gun, driven by three independent gain-switched and properly phased lasers, with the optics and Pockels cells etc. necessary for producing circularly polarized light of both handedness (necessary for producing spin polarized electrons of either “helicity” states). A chopper system, bunching radiofrequency cavities, transport and an initial energy boost up to 45 MeV all precede injection into the linacs proper.

Diagnostics including beam position monitors, beam current monitors, optical transition radiation monitors, HARPs, RF phase and amplitude monitors, Mott Polarimeters, etc. are scattered throughout the complex. Relevant and useful signals are fed into a central control system run by the EPICs software system. An operating crew consisting of expert operators, accelerator physicists and engineers, experimental physicists, and a technical crew run the facilities three shifts a day for an entire 24 hour period continuously for weeks and months except for a few short and long shutdowns for maintenance and repair and/or experimental configuration changes and holidays. The supporting infrastructure consists of a dedicated SRF Test Lab in support of the linacs, an Injector Test Cave in support of the electron source and injector, an Experimental Equipment Lab (EEL) building to stage experimental systems, an engineering Technical Services building, multiple tech shops and the CHL plant. The hundreds of CW 1.5 GHz klystrons, and associated DC and RF electrical systems, are housed in galleries on the surface above the tunnels. The electrical path length and phase variations and mechanical changes to the linac lengths due to seasonal and diurnal variations in climate are constantly manifest in the beam behavior and hence monitored and controlled for optimized experimental conditions.

*The Development of the Accelerator’s Capabilities*

CEBAF was designed and built, on schedule and on budget, as a 4 GeV recirculating superconducting CW electron accelerator, simultaneously serving three experiments with widely differing needs. Following an initial commissioning period, all of the original design goals were achieved by 1997, and CEBAF has been operating for a broad range of experiments in all three Halls ever since. However, the capabilities of the machine have been aggressively upgraded over the years to meet the demands of the experimental program. CEBAF now routinely provides beam specifications that are unmatched anywhere in the world.

Energy – the machine operates routinely at up to 5.8 GeV, 45% above the original specification and has run for brief periods at 6 GeV. In FY05, the accelerator will be operated routinely at 6 GeV with currents up to 15 μA to meet the requirements of the DVCS experiments in Halls A and B, and the transversity experiment in Hall A. In FY06, the accelerator will operate at 6 GeV with the highest currents allowed by the operating envelope (≤130 μA) for the structure function dependence, inclusive eN scattering, pion transparency, and $G_E^p$ experiments in Hall C.

Polarization – a polarized gun was not included in the original CEBAF project and this capability has been added over the last five years with AIP support from DOE. Starting with bulk gallium arsenide cathodes providing 35% polarization, the current was slowly increased from 30 μA to 100 μA per Hall. The use of strained gallium arsenide cathodes allowed the polarization to be increased to 70%, initially at low currents and then increasing to 100 μA. Recently, we have shown that the polarization can be increased to 80% by modifying the cathode cleaning technique. In FY05, we intend to use a new cathode material, a gallium arsenide super-layer structure and new Ti-Sapphire lasers whose wavelength can be precisely matched to the band-gap. This combination is expected to provide up to 90% polarization at up to 130 μA. This multi-year program to improve the polarization and current enhances the physics capability for polarization experiments (figure of merit proportional to $E^2P^2I$) as shown in Figure VI-2.

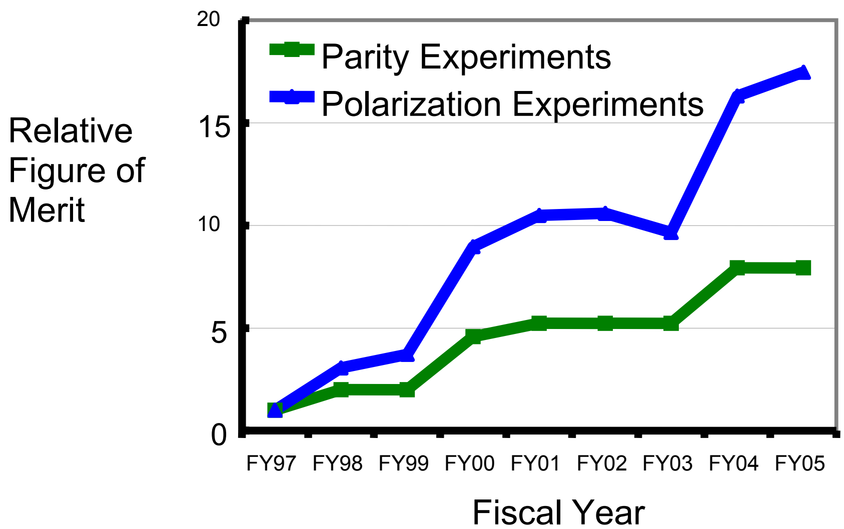



Figure VI-2: The development over time of the experimental figure of merit for parity and polarization experiments at Jefferson Lab

Parity Quality Beams – the parity experiments (e.g. HAPPEX, HAPPEX-2, G0 and the future lead parity experiment) require high current and high polarization simultaneously, but are less demanding of the maximum energy. The figure of merit for parity experiments (proportional to $P^2I$) has improved even more dramatically than for the polarization experiments as shown in the Figure. The helicity-correlations (changes in current, position and angle correlated with helicity flipping) are extremely small (current changes are less than 1 part in $10^6$) so that the results published by HAPPEX required no corrections because the measured errors were so small. We are presently working to meet the requirements of a lead (Pb) parity experiment in FY06 that are a factor 20 smaller.

Availability – enhancing the accelerator capabilities (modifying and upgrading the hardware and associated software controls) is detrimental to improving the availability, where steady running with a constant configuration would be preferable. Nevertheless, the accelerator Uptime is usually about 85% of the scheduled time. However, the percentage of time when the accelerator is simultaneously able to meet the needs of the three experimental Halls is lower than 85% (usually around 72%). This will be the major area of focus during the coming years.

*Recent Accomplishments of the Accelerator*

There have also been substantial enhancements of the accelerator's capabilities recently. The most significant was in support of the G0 experiment that began commissioning in FY02; it required a bunch structure of 31.2 MHz rather than the nominal 499 MHz. A new Ti-Sapphire laser was purchased which, with a strained Gallium Arsenide cathode, is capable of producing electrons with >75% polarization at the correct bunch frequency. Although the total bunch current was well within our standard parameters, the bunch charge was more than six times the original specification. A careful set-up of the Injector was needed based on modeling of the injector with high space charge, but simultaneous running of G0 with other experiments caused additional complexity. The bunch charge was high enough to saturate one style of Beam Position Monitor (BPM) electronics necessitating software and hardware changes. Helicity-correlated changes, which occur when the polarization direction is reversed, are monitored and corrected to within 20 nm for beam position, and 1 ppm for beam current. The beam halo was eliminated at the $10^{-6}$ level. The initial engineering run was sufficiently successful that further running has been approved in FY04.

*The Experimental Facilites*

The three experimental Halls at Jefferson Lab have been equipped with instrumentation that was carefully selected to emphasize complementary aspects of the scientific program, further enhancing the versatility of the facility. Hall A has a pair of high-resolution magnetic spectrometers optimized for precision electron-scattering coincidence experiments. Hall B has a large acceptance (nearly $4\pi$) detector and ancillary equipment (including a photon tagger) that supports broad-ranging studies of both electron- and monochromatic photon-induced reactions with loosely correlated particles in the final state and experiments involving low luminosity. Hall C has a pair of moderate resolution spectrometers, with one capable of high-momentum particle detection and the second optimized for the detection of short-lived reaction products. Hall C also has additional space and infrastructure to support major new setups for specific measurements not well suited to the basic instrumentation in any of the three Halls.

*Hall A*

Hall A began its experimental program in May 1997. The Hall is equipped with two optically identical, high-resolution ($\delta p/p=10^{-4}$) magnetic spectrometers (HRS Figure VI-3); each has a relatively large solid angle and a maximum momentum of 4 GeV/c. The detector packages have been optimized differently: one for detecting electrons and one for detecting hadrons. The detector package in the hadron spectrometer includes a focal plane polarimeter. As of June 2003, twenty-eight experiments have been completed in Hall A, and roughly half the desired data have been obtained (intentionally) on one more.

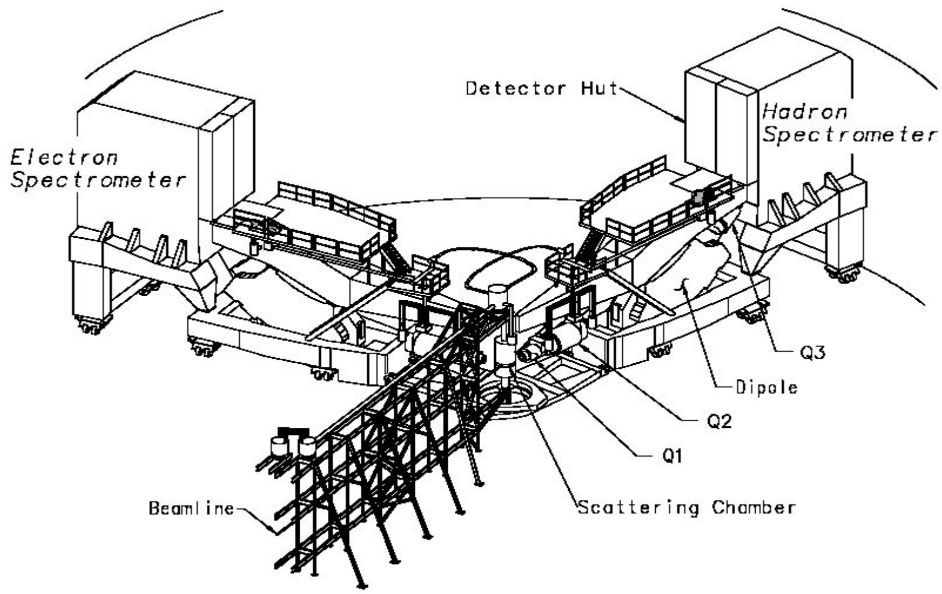



Figure VI-3: The Hall A High Resolution Spectrometers (HRS)

The Hall A spectrometers are being utilized for detailed investigations of the structure of nuclei, mainly using the $(e,e'p)$ and $(\vec{e},e'\vec{p})$ reactions. The measurements are extending the range of momentum transfers and internal nucleon momenta investigated well beyond the previously known region, revealing the limitations of the traditional picture of nuclear structure that is based on nucleons interacting via meson exchange. In heavy nuclei, these experiments are also providing information on how the nucleon's properties change when it is embedded in the nuclear medium. In few-body systems, where exact calculations can be performed in the nucleon and meson-based description of nuclei, experiments have shown that this description works to distance scales of order 0.5 fm (half the n-p spacing in the deuteron), but it becomes increasingly difficult to use this picture to explain photodisintegration data at higher energies that are probing shorter distance scales. At higher energies simpler models based on quarks or constituent counting rules provide a more economical qualitative description of the experimental data.

There are many other components of the Hall A program, including, for example: precision measurements of nucleon structure through the determination of the charge, magnetic, and weak neutral current form factors and measurements of transition form factors to excited states; investigations of the low-energy structure of the proton and its excited states through Compton scattering and the measurement of transition form factors; and studies of nuclear structure through experiments in which hypernuclei are created by replacing one of the nucleons by its strange counterpart, the $\Lambda$ hyperon.

*Hall B*

The final Hall to begin physics operations, is equipped with a large acceptance (nearly $4\pi$) detector, the CEBAF Large Acceptance Spectrometer (CLAS), which is shown in Figure VI-4. It was designed to carry out experiments that require the simultaneous detection of several loosely correlated particles in the hadronic final state, and to be able to perform measurements at limited luminosity.

The magnetic field in the CLAS has a toroidal configuration generated by six iron-free superconducting coils. Its particle detectors consist of drift chambers to determine the trajectories of charged particles, Cherenkov counters for the identification of electrons, scintillation counters for the trigger and for time-of-flight measurements, and electromagnetic calorimeters to identify electrons and to detect photons and neutrons. The continuous nature of the CEBAF beam is critical to the functioning of such a multi-particle coincidence detector. Hall B also includes a bremsstrahlung photon tagging facility so that the CLAS can investigate real as well as virtual photon processes.

A major research program for the CLAS is the investigation of the quark-gluon structure of the nucleon, especially the detailed study of its spectrum of excited states. As in atomic physics, the spectrum of this system contains vital information on the nature of its constituents and the forces between them. It is not understood why the naïve constituent quark model is so successful in explaining the particle spectrum discovered so far. CLAS will either support this model by discovering the complete pattern of states it predicts or, more likely, it will reveal its shortcomings.

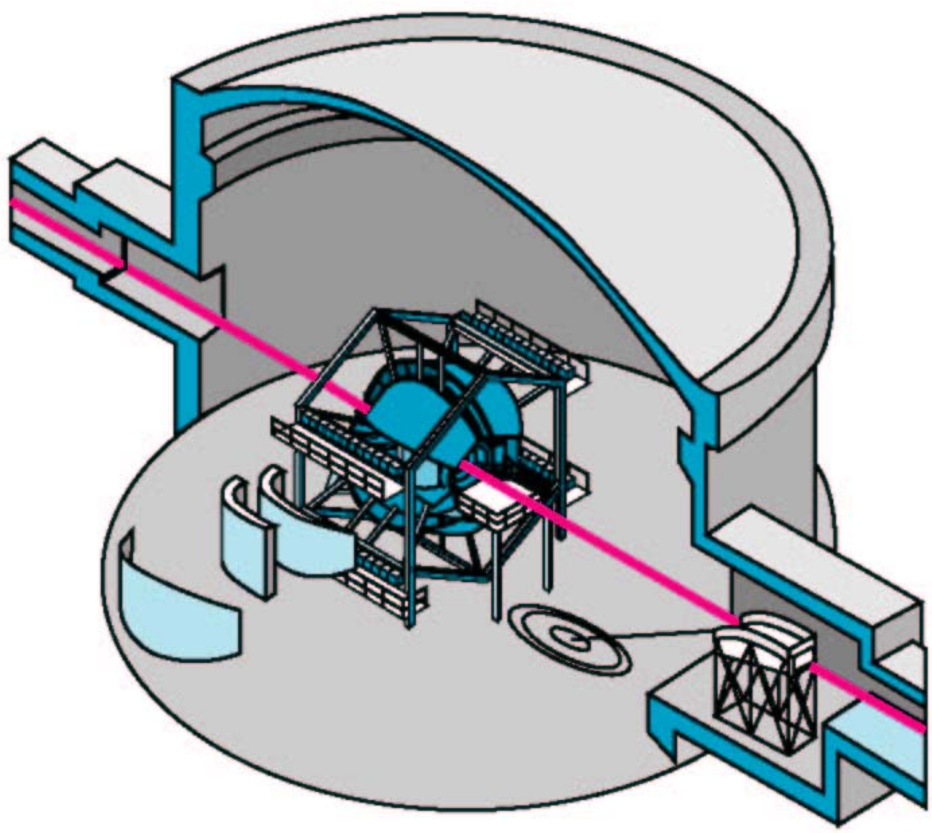


Figure VI-4: Hall B Instrumentation

One reason it is doubtful that the simple quark model will continue to be successful is that it ignores the gluons that QCD guarantees are plentiful in the proton. While there is no evidence yet for states involving gluon excitation, models indicate that most of the predicted “gluonic” states will decay in complicated many-particle modes that would not have been observed with the previous generation of detectors. CLAS is being used for an initial search for such states, but a definitive search will require the 12 GeV electron beams of the energy Upgrade project and a new, optimized detector (planned for the new Hall D to be constructed as part of the Upgrade).

The CLAS spectrometer is also being used in a variety of other investigations requiring data on multi-particle final states, including short-range correlations between nucleons in nuclei, the importance of three-body forces in nuclei, and the modification of the nucleon's properties in the nuclear medium.

Physics research using CLAS began in December 1997. Since then, the detector has taken the complete data for thirty-five experiments and partial data on a total of nineteen more experiments. Most running of CLAS involves simultaneous data taking by a number of experiments, all using the same operating conditions for the beam, the target, and the spectrometer. For example, the e1 group includes fourteen experiments involving electron scattering from the proton. A measure of the power of this new device is that in one week of running, CLAS provided a data set on single pion electro-production roughly equal to the worldwide sum of all previous data in this energy and momentum transfer regime, and a data set on double pion electro-production that is an order of magnitude larger than previously available data.

Hall B operation generally has involved interleaved running of different "groups" that have been created for experiments with common running conditions. These include unpolarized and polarized proton and deuteron targets, $A \geq 3$ nuclear targets, and incident beams of photons and polarized or unpolarized electrons. In addition, three unique experiments involving special conditions (or even different apparatus) have been run. As of June 2003 we have obtained complete data for nine of the run groups, more than half the ultimate data set for four more run groups, and complete data for two unique experiments. The completed data sets correspond to the equivalent of 49 finished experiments (or 35 complete plus 19 partially complete).

*Hall C*

Hall C's present complement of equipment, shown in Figure VI-5, includes two general-purpose magnetic spectrometers. The High Momentum Spectrometer (HMS) has a large solid angle, a moderate resolution ($10^{-3}$), and a maximum momentum of 7 GeV/c. The Short Orbit Spectrometer (SOS) has a large momentum acceptance and a very short (7.4 meter) optical path to facilitate the detection of particles having short lifetimes, such as $\pi$'s and K's.

Since the start of the physics program in November 1997 through June 2003, a total of eighteen experiments have been completed in Hall C covering a broad spectrum of topics in nuclear physics, and about half the desired data has (intentionally) been obtained on three additional experiments. Experiments using the standard equipment in the Hall have investigated a broad variety of phenomena including the pion form factor, deuteron photodisintegration at high energies, color transparency, kaon production, excitation of the delta resonance in the proton, duality, and deep inelastic scattering in nuclei for $x > 1$.

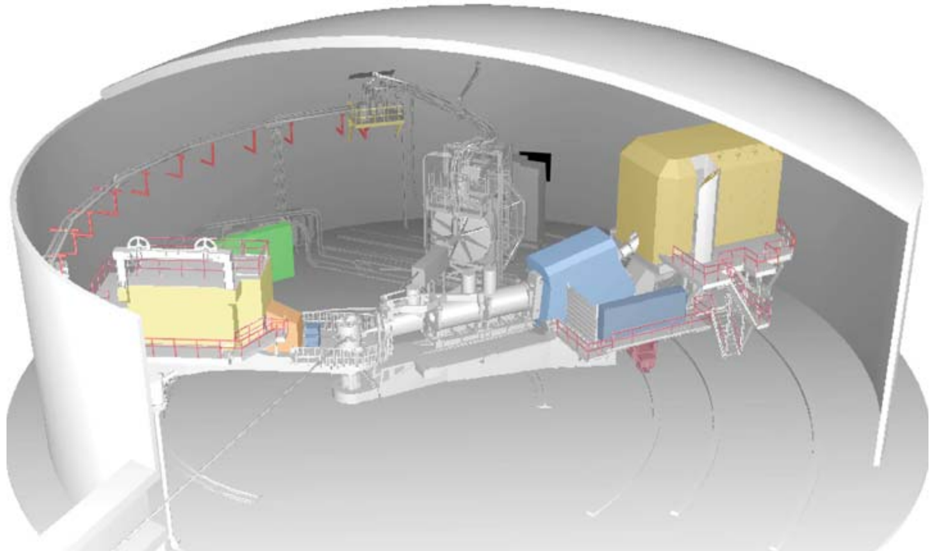


Figure VI-5: Hall C and its present complement of equipment, including (from left to right) the SOS, G0, and HMS Spectrometers

Hall C was planned to support the installation of additional specialized detectors designed to investigate specific problems. Experiments of this type to date include: the $t_{20}$ experiment (E94-018), which separated the elastic form factors of the deuteron to high momentum transfer; the Hyper Nuclear Spectrometer System (HNSS) experiment (E89-009), which demonstrated the feasibility of performing hypernuclear physics experiments at Jefferson Lab; two independent precision determinations of $G_E^n$, the electric form factor of the neutron, to high $Q^2$ (E93-038, which used a high current polarized electron beam and a neutron polarimeter, and E93-026, which used a polarized target and low-current polarized beam). Additional "major installation" experiments planned in Hall C include: precision measurements of parity violation in the scattering of polarized electrons from protons to measure the contribution of the $s$ and $\bar{s}$ quarks to the magnetization and charge distributions of the proton and neutron down to a few percent of their "natural" values of unity (this experiment will be carried out using a major new specialized apparatus that was commissioned late last year – the G0 spectrometer); a second-generation, high-resolution hypernuclear spectrometer system that will support a systematic program of measurements in these systems; and a precision test of the theory of electro-weak interactions that will measure , the weak charge of the proton, at low $Q^2$, where it hasn't yet been tested.

*Data Acquisition*

The data acquisition systems in all three Halls are operating reliably at data rates and event rates that meet the requirements of experiments approved for the next few years. The installed systems will continue to be improved in terms of stability and throughput to increase the yield of physics data from the Halls, to meet the requests of experimenters for new features, and to keep pace with the ever-increasing demands of the experiments.

There are two main challenges for data acquisition at Jefferson Lab. Both stem from a common source: the rapid evolution of computing software and hardware. The first challenge is that the hardware currently in use in all three Halls is rapidly becoming, or is already, obsolete. During the next five years we must actively pursue new hardware technologies to maintain and upgrade our data acquisition systems. The second challenge is that computer hardware and software are evolving so rapidly that a considerable effort is expended ensuring that software systems are portable from old systems to new. This includes the problem of ensuring that newer and older systems can communicate with each other. We intend to meet this challenge on several levels. Adopting commercial communications protocols guarantees continuity across platforms, as does increasing the use of platform independent technologies such as JAVA. Our support of embedded operating systems is being diversified from VxWorks to include Linux. We are also increasing our use of model-centered, rather than code-centered, programming techniques to increase the portability and maintainability of our software.

*Data Reconstruction and Analysis*

The computing facilities for data reconstruction and analysis have been built up since 1995 in concert with the ramp up of the experimental program. Recent data rates to tape regularly exceed 20 MB/s, with accumulations of up to 1 TB of data per day. Tape storage was augmented at the end of FY01 with the addition of a second robotic silo giving a capacity of 12,000 tapes. This will provide sufficient storage capacity for the steady-state experimental program over the next few years.

The storage system is currently equipped with eight RedWood (50 GB tape capacity), ten 9840 (20 GB tape capacity), and fifteen 9940 (60 GB tape capacity) drives. The 9840 drives were introduced to improve overall tape accessibility since, although the tapes have a lower capacity, they have a much faster load and access time than the RedWoods and are very suitable for storing frequently accessed data sets. Due to the mechanical unreliability, short tape-head lifetimes, and high maintenance costs of the RedWood drives, we are proceeding with a program of replacing them with newer technology 9940 drives that are capable of equivalent data rates with 60 GB tape capacity. Fifteen of these drives are in place, and the migration of data from RedWood to 9940 media was completed in December 2002. The combination of the 9940 and 9840 tapes and drives provide complementary abilities for a wide range of usage, and with the expected evolutions of these drive technologies we have an upgrade path for at least the next five years that will retain backwards compatibility for the media.

The mass storage silos are managed by a locally written software package – Jasmine – that was put into production in May 2001. This new system provides control of the silos and tape drives and in addition integrates the disk pool management to provide a complete mass storage management system. This software was designed as a distributed system that provides high performance and that will scale with the expansion of the tape and disk subsystems to provide adequate performance for all needs for the foreseeable future, including anticipated data acquisition rates of up to 100 MB/s. The system has no single point of failure, and is able to provide storage access even while individual components are upgraded or replaced.

The mass storage architecture now includes over 45 TB of disk pools, which is expected to expand by some 10-20 TB per year over the coming years. These disk pools are constructed from aggregated storage servers based on Linux systems and utilize either IDE or SCSI disk depending on expected usage modes. These storage systems are presented to the user in an integrated namespace. Uses vary from staging space for data moving between tape storage and the processing farm, to storage for frequently accessed data, to working space for analysis projects.

The mass storage system currently stores nearly a petabyte of data, which is increasing at a rate of about 200 TB per year. The tape subsystem handles a total well in excess of 4 TB/day (and up to 10 TB/day during data migration).

The reconstruction and analysis system consists of a farm of 350 compute nodes, providing some 24000 SPECint95 of processing power. This farm is built from dual Intel CPUs running the Linux operating system. In addition to the batch systems, interactive analysis capability is provided centrally with two 4-processor Solaris systems and three 4-processor Linux systems. A moderate expansion of the batch and interactive computing systems is foreseen over the coming years, including a program of replacing older systems.

The network supporting data reduction and analysis is entirely high-throughput Gigabit Ethernet, except to individual farm nodes that have 100 Mbit/s links to a switch where 24 nodes share a Gigabit uplink to the mass storage systems. The general-purpose backbone network infrastructure is built around Gigabit Ethernet, with 100 Mbit/s connections to physicists' desktop systems to permit fully distributed and efficient analysis and data access. As data analysis needs grow, more and more analysis will be done at collaborating institutions. In addition, more and more simulated data created at off-site locations must be moved to Jefferson Lab and subsequently analyzed and shared with collaborators.

To facilitate these activities, we are participants in the Particle Physics Data Grid (PPDG) collaboration, with a goal of providing computing and data "grid" services to enable transparent, efficient, and secure access to data and compute resources. As part of this effort we are currently deploying pilot systems to Florida State University (FSU) to enable remote access to the Jefferson Lab storage system and the ability to run jobs at either site providing cross-site load balancing. This three-year project will provide the tool kit ("middleware") on which to build fully grid-enabled applications that should allow physicists to access and manipulate data in an intuitive way no matter where the data or compute resources are physically located. Although the PPDG involves US DOE Laboratories and Universities, it is part of a huge international focus across many scientific disciplines and industrial partners to provide a ubiquitous computing grid of infrastructure and services.

### c) Facility Operations

The mission of CEBAF accelerator and experimental facilities operations is the delivery of world-class science advancing our understanding of atomic nuclei. The quality of the research program is reviewed each year by a joint DOE/SURA Science and Technology peer review panel. The key activity in direct support of that mission is the delivery of electron beams with unique characteristics to powerful apparatus in Jefferson Lab's three experimental Halls that meet our Users' needs and expectations. The effectiveness of this operation is tracked and reviewed through a series of metrics that compare delivered research with expectations for the year. We strive to continually improve our capability to routinely and reliably deliver simultaneous beams to three Halls with individually chosen energy and current (and with beam polarization available in at least two Halls, and generally three) and to enhance the reliability of the experimental apparatus. In addition, we continuously enhance the capabilities of the accelerator and the experimental apparatus to keep the experimental program on the cutting edge of science.

*Operations Metrics*

The productivity of facility operations is dependent, in large measure, on the efficiency with which beam is delivered (within specifications) to each experimental Hall, and on the efficiency with which the experimental apparatus in the Hall takes the required data when the beam is available. As we move from newly-commissioned equipment (be it the accelerator or the experimental Halls) to well-understood, well-characterized apparatus, the availability of the equipment should improve. To track this process, and to measure our overall operational efficiency, Jefferson Lab sets as one of our key performance metrics, the availability of the accelerator and the experimental apparatus.

The goals for the accelerator availability, outlined in Appendix B of our contract, increased from 50% (in FY96) to 80% (in FY99 and beyond). Since FY99 the performance goals have been adjusted each year to properly reflect what is possible for the level of funding provided, and also for unusual activities such as the initial operation at significantly higher beam energy or installation of a major device such as the polarized source. Similar goals have been set for each experimental Hall, with the starting year being the first year of physics operation, Hall-by-Hall. If we can execute this plan well, the overall operational efficiency (the product of accelerator and Hall availabilities) should reach about 65%. In addition, the average experiment multiplicity should exceed two in full operation, limited by the manpower available for tearing down and re-installing specialized equipment between experiments.

*Maintenance Plans*

Jefferson Lab is committed to ensuring that the most reliable, cost effective accelerator facility is available to our Users to conduct experiments. The Long Range Development Plan (LRDP) is the starting point for ensuring that the availability of CEBAF is maintained, and that the capabilities of the accelerator complex are developed to match the requirements of the Physics Users. The elements of the plan are summarized, evaluated, and prioritized for each individual system.

In the years ahead, there are two major operations issues that need to be addressed: (i) the increasingly stringent demands being placed on CEBAF's electron beam properties by the experimental nuclear physics program are stretching the machine capabilities significantly, and (ii) the aging of the CEBAF accelerator systems and support complex is a root cause of growing accelerator availability problems. While the basic availability of the accelerator continues to be about 85%, the availability of beam meeting the detailed needs of simultaneously running experiments has dropped to close to 70%. Addressing the first issue requires continuing, significant capability upgrades to the accelerator; these are discussed in section VI.1.A.e. To address the availability issues, we have developed an accelerator Long Range Development Plan (LRDP).

To create this plan, we began by reviewing our extensive database on sources of accelerator downtime. This allowed us to identify problem subsystems, evaluate long-term trends in their reliability, and prioritize work to upgrade them. Goals were established for each subsystem by identifying the level of performance and reliability that would guarantee that it will support its share of our overall availability goal. Our stretch goal is to raise the accelerator availability for simultaneously running experiments to better than 85%.

The biggest gains will come from a recalibrated and reliable Machine Protection System (MPS), a reduced rate of Fast Shutdown Device (FSD) trips, and improved magnetic transport and beam optical systems. The availability improvement plan calls for reducing the contribution to accelerator down time for each of these subsystems by a factor between five and ten. The plan also calls for more modest improvements (factors of two to three) in the contributions of the RF (radio-frequency), SRF (superconducting radio-frequency), software, vacuum, injector, diagnostics and cryogenic systems to the accelerator downtime. The cumulative effect of these improvements will get the accelerator availability to our target goal. It is an aggressive plan, based upon knowledge of the systems and subsystems of the CEBAF accelerator complex and is contingent upon funds available to direct to the specific availability upgrade projects. A healthy Accelerator Improvement Plan (AIP) budget, coupled with funding to sustain our accelerator LRDP, will be critical to meeting this goal.

The Long Range Development Plan provides a prioritized list of Upgrade Tasks, both for improved availability and additional capability. It serves as a road map for maintaining and improving the accelerator systems in the long haul.

Since the number of Tasks that can be addressed each year will be strongly dependent on the budget, the more pressing Tasks will be developed more completely than those that can reasonably be delayed. This prioritization will be done each year by development of an Annual Work Plan (AWP) based on the actual budget allocation for the current year and updated estimates for the out years.

The long-range vision for each system has been evaluated and prioritized. In some cases, it was obvious that the existing technology would not be capable of supporting the requirements in the long term so an upgrade path had to be developed. In others, the requirements put on the system by the demands of the 6 GeV experimental program required tighter tolerances than could be met with the existing hardware. All of these requirements were evaluated and prioritized for each system separately and then integrated together to create an overall prioritization.

Since the JLab Institutional Plan projects forward five years, this is the appropriate timescale for creating detailed cost and schedule estimates. The Tasks that will be addressed in the five to ten year period will be listed with little detail, but there is considerable value in establishing a rough list of expected Tasks out to ten years. At this time, the following accelerator systems have been evaluated:

- Beam Position Monitors (BPMs)
- Instrumentation and Controls
- Cryogenics
- Diagnostics
- Injector
- Power Supplies
- RF Systems
- Safety Systems

It is expected that each year, elements of the LRDP would be funded as Accelerator Improvement Projects (AIP), usually those that increase the capabilities of the accelerator rather than improving the reliability. This document will therefore also serve as the basis for requests for AIP funding.

This plan includes a cost effective and efficient scheduled maintenance program for JLab that is consistent with our mission, safety, health, reliability, quality, and environmental protection. Effective maintenance maximizes the useful life of the equipment and facilities, minimizes unplanned downtime, provides an improved work environment, and produces information to make management decisions, all within a given resource level. Additionally, it provides a guide to ensure resources are applied effectively and in support of Lab requirements.

Plans for the long-term maintenance of the experimental facilities are handled in a manner similar to the accelerator, with identified problems affecting the near-term availability handled on an impact-based priority system, and upgrades for the longer term managed in concert with evolving plans for increased physics capabilities as discussed below. Because the experimental equipment is relatively new, most upgrades have been based on capability needs, with the exception of a considerable amount of “radiation hardening” that has been necessary as the luminosity of the executed experiments has risen. However, as the equipment approaches the end of its first decade of use, we are seeing signs of the need for reconstruction of some of the base equipment items. This reconstruction is being undertaken with an eye toward future needs.

*Accelerator Capability Development (near-term)*

The CEBAF accelerator's primary objective is to provide reliable User service with all the required beam properties: variable RF microstructure, energy, energy spread, current, emittance, polarization, and reproducibility. It is designed for continuous operation and is most productive when run for the longest period compatible with the accelerator's annual maintenance requirements (since the helium refrigerator must be operated continuously, with or without beam).

The primary short-term plans for enhancing the accelerator capabilities include:

a) We expect to evaluate a new photocathode that potentially can deliver better than 75% polarization, while reducing helicity-dependent current fluctuations. Halls A and C will receive beam from newly acquired, commercial Ti-Sapphire lasers. These lasers have enough power to generate beam currents in excess of 100 µA to both Halls A and C. Their fast turn-off time will eliminate polarization dilution due to beam bleed through between adjacent halls.

b) The total charge that can be obtained from a single spot on the cathode depends on the beam current. Presently, at high current, the cathode can deliver 300 Coulombs allowing beam delivery for up to three weeks without intervention. When the quantum efficiency at an operating spot drops, it becomes necessary to pick a new spot on the cathode. Exhaustion of the available spots necessitates reactivation of cathode, which takes approximately 4 hrs. One of the causes of this drop in quantum efficiency is that the ions from the residual gas in the gun back bombard the cathode. Improvements in the vacuum will reduce the need for spot moves to less than once a week. We have also reduced the time to move the spot to much less than an hour.

c) We are working towards reducing the RF trips to improve operation at energies up to 6 GeV. These include reducing the operator intervention with a software package for automatic reset of RF trips, and optimizing the klystron to cavity match such that high performance cavities have the needed RF power.

## d) Results from the Campaigns

### *The Research Plan and Schedule*

CEBAF's research program was planned with the active participation of our User group, which now has over 2000 members. Collaborations were formed within this group to build the spectrometers, detectors, and data acquisition systems and to propose experiments. These Users contributed well over 400 man-years of effort to the construction of the initial complement of experimental equipment and are playing a major role in the various upgrade and new equipment projects underway.

A total of 1,132 scientists from 187 institutions in 29 countries are collaborators on one or more of the approved experiments; their home institutions are listed in the tables attached to the end of this section (Tables VI-3 and VI-4), and summarized in Table VI-1 (on the next page). Table VI-2 summarizes the status of the 143 currently approved experiments, while a more detailed listing of the experiments and their status (as of June 2003) is provided in Appendix B. A total of 81 experiments have been completed, as well as major fractions of 23 more (corresponding to an equivalent of about 16 additional completed experiments). Thus we have completed about two thirds of the presently approved program. Completing the remainder of the presently approved program would require about five years of running the accelerator for 30 weeks/year with an overall operational efficiency (product of Hall and accelerator availability) of ~60%.

**Table VI-1**
**Users On Experiments, June 2003**

| User Home Institution | Number of Experimenters | Number of Organizations |
|---|---|---|
| Universities (U.S.) | 580 | 91 |
| International | 410 | 85 |
| Other Federal Laboratories | 49 | 10 |
| Jefferson Lab | 93 | 1 |
| TOTAL | 1132 | 187 |

**Table VI-2**
**Experimental Program Status, June 2003**

| Hall | Approved Experiments | | | | Conditionally Approved Expts |
|---|---|---|---|---|---|
| | # Expts Completed (full/partial) | Total Days Run | # Expts in Queue | Days to Be Run | |
| A | 28 / 1 | 502.6 | 21 | 356.3 | 3 |
| B | 35 / 19 | 418.5 | 28 | 270.9 | 2 |
| C | 18 / 3 | 435.9 | 18 | 265.7 | 3 |
| Total | 81 / 23 | 1357.0 | 67 | 892.9 | 8 |

The process of deciding which experiments should be run and the order for running them is critical to the productivity of the research program of CEBAF at Jefferson Lab. A key element in this process is the traditional mechanism of an external Program Advisory Committee (PAC), consisting of distinguished physicists who are experts in the field of nuclear physics and chosen to provide broad perspective. Prior to presentation to the committee, the Physics Division's Technical Advisory Committee or TAC (which includes representatives from the Accelerator Division) reviews each proposed experiment for feasibility and impact on the Laboratory's resources. The PAC reviews proposed experiments on the basis of their scientific merit, technical feasibility, and manpower requirements, and makes scientific ratings and recommendations to the Laboratory's Director, who makes the final decision.

To develop the running schedule, the PAC ratings are considered together with the demonstrated technical capabilities of the accelerator and experimental equipment and a detailed understanding of the long-term goals of the research program. This schedule is released at the end of the second and fourth quarter of each fiscal year, three months before the beginning of a six-month running cycle. The schedule for major new experiments requiring long lead times and large-scale equipment installation is determined a year in advance. The schedule is the key document that defines our commitments to the User community for research operations for the coming year. The most recent schedule that was developed following this process is available on the JLab website at the url:
http://www.jlab.org/exp_prog/experiment_schedule/2003/pub_Jul3/schedule.pdf

To prepare for experiments and capability improvements that require even longer lead times, the Physics Division develops and reviews semi-annually a list of approved (but not yet run or scheduled) experiments that are likely to run in the two year period beyond the released schedule (i.e. with a three-year time horizon) and provides a very tentative ordering for their execution. This list is used by the JLab Research Operations Committee (JROC) to develop long-range plans for the capability enhancements to the end stations and accelerator that are necessary to carry out the highest priority physics. It is also used by the Director's Council for long-term planning and to prioritize resource allocation.

An element of the experiment approval process that is important to the long-term evolution of the program is "jeopardy": any experiment that has not run within three years of approval, for whatever reason, must return to the PAC for a new review (which will include a new rating for its scientific priority) or lose its approved status. This system provides a means of continually improving the overall quality of the science as the field moves forward, and avoids the situation where an old, modest-priority experiment waits in the queue for an unconscionably long time.

Jefferson Lab incorporates the expertise and vision of PAC members in its planning process through workshops and reviews. A broad review of the overall science program began with a workshop/review of our few-body physics program held immediately following PAC14. Similar workshops examining our other major research thrusts have taken place since, and the process will continue rotating through the program indefinitely, adding new areas as they evolve into major elements of the overall program.

PAC15 initiated PAC involvement in the planning for the scientific program and equipment complement for the 12 GeV Upgrade. This process is broadly based on the PAC involvement that was so successful in defining the initial equipment complement for CEBAF. 12 GeV planning has included a major session at PAC19 that considered all of the science proposals used to motivate the Upgrade in the "White Paper" presented to the NSAC Long Range Plan. A similar session at PAC23 (early in 2003) reviewed the pre-Conceptual Design Reports (pCDRs) written for each proposed Hall upgrade, and the community's plans for the overall pCDR for the experimental facilities. This pCDR, which is now under final review by the entire JLab User community, includes both the science motivation for the Upgrade and the equipment plans. The advice we receive from the PAC is augmented by high-level input from our Science and Technology Peer Review Committee and the JLab Science Policy Advisory Group (SPAG).

The experimental program that has resulted from this deliberate and thoughtful process is broad in scope and covers many of the most interesting topics in nuclear science today. The approved experiments are listed by title in the table in Appendix B. Running this program successfully is the Laboratory's highest priority and the central focus of our near-term planning.

## e) Accelerator and Experimental Facilities Development: Capability Upgrades

JROC develops long-range plans for the capability enhancements that are necessary to carry out the highest priority physics. This plan is also used by the Director's Council for long term planning and to prioritize resource allocation. In this section we describe near-term and long-term plans for both the accelerator and the experimental halls.

### *Accelerator Capability Development*

*Polarized Beam Production*

One of the unique features of CEBAF is that it provides spin-polarized electron beams in precise high quality sub-picosecond bursts in a continuous train at tens to hundreds of megahertz. The figure of merit for experiments requiring polarization (P) is enhanced quadratically with polarization, but also improves with higher beam energy (E) and beam current (I), being given by: $E^2P^2I$. In addition there are significant physics experiments involving parity violation and also requiring polarization, whose figure of merit goes as: $P^2I$. The quadratic increase of the intrinsic value of polarization makes it desirable to attain as high a degree of polarization as possible.

The degree of polarization routinely achieved at CEBAF is always higher than 70%, with the maximum achieved to date being slightly in excess of 80%. The near to long term goals for the CEBAF performance calls for enhancing the polarization to 85% to 90% level and eventually beyond it, while preserving the intensity of the beams to currents up to hundreds of microamperes. The production of high current polarized electron beams depends on two key ingredients: photocathodes and the driving laser for illuminating cathode surface.

Strained GaAs superlattice photocathodes are described as the "holy grail" of photocathodes. They provide high polarization AND high quantum efficiency simultaneously. They also improve beam quality for parity violation experiments. The promise of significantly improved quantum efficiency compared to the photocathodes currently used at CEBAF would greatly improve CEBAF's ability to meet high current/high polarization demands of some approved experiments. Historically, good superlattice photocathodes have been difficult to obtain. Recently however, SVT Associates of Eden Prairie, MN, USA has demonstrated the ability to reliably produce very good GaAs superlattice samples.

High profile parity violation experiments require extremely stable beam conditions. The photocathodes presently used at CEBAF introduce problematic beam position and beam current fluctuations that make it difficult to successfully conduct these experiments. The manufacturing process for strained GaAs superlattice photocathodes eliminates the mechanism that produce these beam parameter fluctuations. As a result, we expect these photocathodes will provide more stable beam conditions that will significantly improve our ability to conduct physics experiments that have demanding beam parameter specifications.

The current plan is to purchase five high quality specially prepared photocathode samples. Each sample will provide about six pieces of material suitable for installation in our test stands and photoguns. Samples must be prequalified on the Test Cave Gun Test Stand. Promising photocathode samples could then be installed in the tunnel guns during four-day shutdowns.

To provide higher beam polarization, improved operating lifetime of the photoguns and improved beam quality, plans are in place for replacing low power diode lasers with high power modelocked Ti-sapphire lasers at CEBAF photoinjector. The wavelength of Ti-sapphire lasers can be tuned to precisely match the bandgap of the photocathodes. This will provide the highest possible beam polarization to experiments. The wavelength of diode lasers cannot be easily tuned. Ti-sapphire lasers are also more powerful than diode lasers. More laser power will provide longer uninterrupted periods of beam delivery. Finally, diode lasers do not turn OFF completely between pulses. As a result, the low current beam at Hall B is contaminated by beam generated by the Halls A and C diode lasers. Modelocked Ti-sapphire lasers do a much better job of turning OFF between pulses. Using modelocked Ti-sapphire lasers for high current experiments at Halls A and C will greatly improve Hall B beam quality.

Plans are in place for installing two modelocked Ti-sapphire lasers, one for each high current Hall, during extended shutdowns, tentatively scheduled for June 2004.

*Enhancing Accelerator Systems – Long Standing Issues*

Over time, with the operation of CEBAF through the last six years for various nuclear physics experiments, various critical areas have been identified that could benefit from re-examination and rework in order to improve the machine performance. These areas can be categorized as follows: (i) injector complex; (ii) a robust beam-based magnetic optics model for the entire CEBAF accelerator; (iii) beam lines to the Halls; (iv) dependable diagnostics; (v) integration of RF and its controls for the entire complex, including integrating new higher performance cryomodules into the linacs; (vi) the isolation of the central helium liquifier from power glitches and associated robustness of the control cards.

The CEBAF injector serves three Halls for nuclear physics experiments demanding a diverse set of beam parameters for three simultaneous experiments at any particular time. Practically it serves as three separate and different accelerators wrapped up in one. The dynamic range of the required beam parameters is sufficiently large to warrant consideration of three, or possibly at least two, independent injector guns providing beams that can be merged into the linear accelerator for injection to achieve the most optimal and maximal performance. Merging beams of different intensities, polarizations and energies transversely without diluting the quality of the beam phase space is a challenging task. However, a detailed study to incorporate two independent guns to serve three different beams is underway at present and is expected to lead to an understanding of the cost-benefit trade offs within a year. Yet another important ongoing activity is a look at shortening the straight drift section from the gun into the first cryomodule to minimize growth in beam phase space caused by space charge at low energies. A possible working solution is already at hand. Finally, reproducibility of the injector's mechanical and electrical hardware as well as RF power and phase stabilities will lead to a better operational model of the gun-injector complex that can be comfortably relied upon for demanding nuclear physics experiments requiring extreme precision and control of beam properties (e.g. G0 experiment, parity quality experiments of the HAPPEX type, Hypernuclear experiments, $Q_{Weak}$ etc.).

The actual magnetic optics of CEBAF as seen by the electron beam needs to be modeled after beam based observations. This is because the cycling of the accelerator magnets over time and their operation at higher fields than were used in the original field measurements (which were done at fields corresponding to 4 GeV rather than 6 GeV) has resulted in systematic changes in the residual integrated magnetic fields for each magnet arising from ambient fields, hysteresis etc. These changes all contribute to uncertainties in the electron trajectories. In order for the machine control system to routinely restore the optics and RF configuration to within a few percent of the desired configuration automatically and to scale it linearly and nonlinearly with beam energy changes we require a robust beam-based model of the machine residing in the controls interface. An aggressive activity in this area is presently underway, including existing successful computer optics models such as TRACY-II etc., imported to the machine software controls files.

Beamlines to the experimental Halls should provide the experimenter with independent knobs to fine tune the beam properties suitable for the particular experiment underway at any particular time without affecting the rest of the accelerator complex. This capability requires a thorough design review of each beam lines optics and diagnostics and eventual investment in new hardware and controls. JROC, in concert with the CEBAF Performance Integration Team, has initiated a critical look into this topic with a view towards increased physics productivity for the future.

The diagnostics complex for the entire CEBAF complex – beam position monitors, beam current monitors, energy measurement, polarimeters, etc. needs to be precise enough for the experiments and at the same time not too fine grained to cripple the safety locks prematurely. With increasingly challenging and precise experiments scheduled on the accelerator over time, the demands on appropriate beam diagnostics have increased markedly. The engineering and physics design of new diagnostics is now integrated under a new diagnostics performance integrator, charting out a plan of action for the next five years.

The newly designed, tested and installed cryomodule in the South Linac zone 21 and the new cryomodule under construction for installation in the North Linac zone 11, are modules with much higher performance than the original CEBAF modules (exceeding the energy gain per module by a factor of two or more over the older modules) and with compact mechanical designs requiring special integration with the CEBAF cryogenics system, RF control and overall EPICS control systems. Ideally, it would be best to integrate an entirely new vertically integrated RF zone, with cavity, cryomodule, RF power, RF control and beam control in a new unoccupied zone in the north linac (say zone 26) so that it could serve as a real prototype as well as functioning unit for the eventual 12 GeV upgrade of CEBAF. The cost of such a project is under study at present and is part of the machine long-term investment program.

Finally, the CHL is the primary plant at the center of our cryogenic operation and is vulnerable to external factors out of local control, such as power glitches, storms, etc. Strategies for isolation of the CHL from catastrophic surges as well as hardening of its mechanical, electrical and electronic control card systems is under active scrutiny at present.

The results of the studies of all the above areas will feed into a long-term investment portfolio for the CEBAF accelerator complex.

*Reaching Higher Energies*

The newly installed cryomodule in the South Linac 21 zone has the intrinsic energy gain capacity of up to 70 MeV per pass, when properly powered by RF and appropriate controls. Constrained to be powered and controlled by the existing units in the tunnel and associated controls, the module can reach up to 55 MeV per pass. This will allow us to reach almost up to 6 GeV in multiple passes, without however any contingency or overhead for gradient loss elsewhere. A newly conceived and designed cavity and cryomodule system, the planned prototype for the 12 GeV energy Upgrade of CEBAF, will reach energy gains exceeding 100 MeV per single pass and is planned for completion and installation in the tunnel for the North Linac 11 zone by the end of FY04 or beginning FY05. With no new RF power hardware or control software, this prototype will perform sub-optimally. However it will be sufficient to give the required margin for operation at 6 GeV with some contingency. Eventually a new zone, NL 26, is planned to be fitted with a vertically integrated fully powered RF station (cavity, cryomodule, RF power klystrons, controls and beam controls software) that will be the ultimate test of the 12 GeV prototype.

*100 MV Cryomodule*

Jefferson Lab's key competency in SRF technology is being applied to the development of high-performance cryomodules for the 12 GeV Upgrade program. Design studies conducted in 1998 led to a baseline concept for the 12 GeV Energy Upgrade based on a 5.5-pass machine, the addition of new, higher-performance cryomodules and possibly the replacement of a few existing ones. This concept calls for cryomodules that, in the same length as the existing units, will provide energy gains 4–5 times higher than the original CEBAF design. This required redesigning the cryomodule to increase its active length by 40%, and the development of superconducting cavities operating at gradients of 19 MV/m and $Q_0$ of 8 x $10^9$ (compared to 5 MV/m and 2.4 x $10^9$ respectively, for the CEBAF design).

Key elements of the upgraded design are:

- Elimination of the cold ceramic RF windows (source of frequent arc trips in CEBAF).
- Reduced size of helium vessel from a whole cavity pair to just around the active cells of each cavity and an integrating header.
- Elimination of all helium-to-beamline vacuum joints, and all indium gasket seals.
- Redesign of the fundamental RF power coupler to eliminate emittance-diluting transverse kick and to improve match to 460 $\mu$a beam current.
- Change from waveguide to coaxial couplers for extraction of higher order mode power.
- Improved automation and quality assurance (QA) of cavity treatment and assembly processes to control contaminants that produce field emission and to assure optimum cavity $Q_0$ (minimum heat generation).
- Increased shunt impedance and geometry factor for the accelerating cavities. Two cell shape options are being investigated. One (LL) is optimized for minimum 2 K heat load; the other (HG) is optimized for minimum peak surface electric fields. See Figure VI-6. Both designs have been prototyped, and to investigate and clarify system integration issues, a prototype cryomodule will include four of each design.
- New cavity tuner with fine, no-backlash mechanical and piezoelectric actuators.
- Redesigned input waveguide to handle up to 13 kW.
- Careful cryogenic engineering to assure good heat transfer for stable operation at the higher operating gradients and heat generation levels.

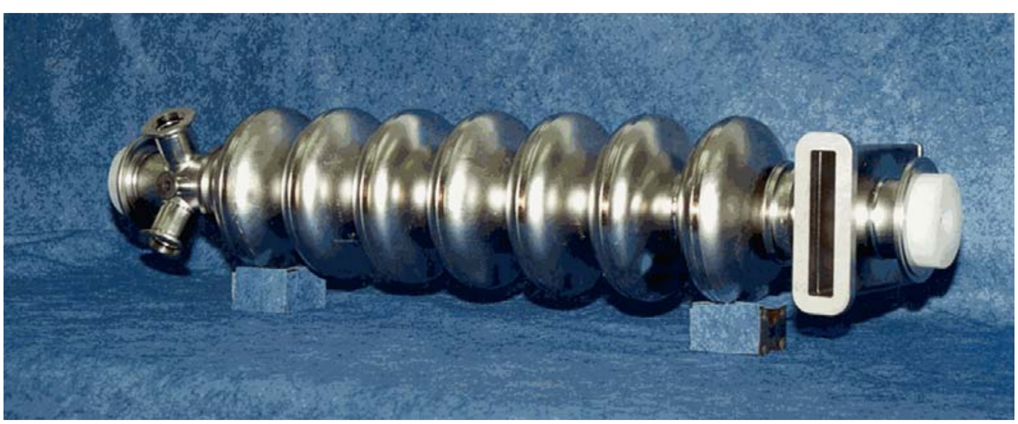


Figure VI-6: A typical prototype niobium upgrade cavity

We are presently building a final prototype of the Upgrade cryomodules that will incorporate all lessons learned in the construction of a pair of preliminary prototypes. These have successfully met their design goals, which are midway between the performance achieved in CEBAF and that required for success in the Upgrade. This final prototype, "*Renascence,*" will be built using drawings, procedures and travelers destined for use in the construction project. A typical prototype niobium upgrade cavity is shown in Figure VI-6.

One of the key challenges to constructing a high-performance cryomodule is to consistently attain and retain good performance of individual cavities from initial qualification through the process of assembling the cavities into a sealed string. An intense focus on clean assembly is essential, avoiding the introduction of particulates that could serve as sites for emission of electrons when exposed to the high electric fields characteristic of superconducting cavities. We are confident that we will be successful in this clean assembly, because of the excellent performance achieved by the preliminary prototypes. Investments in automated tooling and improved procedural techniques are yielding improved performance. Gradients of 15-17 MV/m were achieved in these two most recent cryomodule sets. When improvements associated with the new cell geometries and further treatment and assembly procedure improvements are folded in, the prospects for realizing the requirements for the 12 GeV Upgrade are high.

*Site Cryo Capacity*

With an increased number of experiments being planned in the three existing Halls of the CEBAF accelerator complex, the increasing demand on the operation of the accelerator at higher energies reaching up to 6 GeV, increasingly powerful cryogenic targets designed for the nuclear physics experiments, demands on higher current electron beams and finally demands on the JLab Free Electron Laser (FEL) accelerator to support higher power electron beams for production of higher average power infrared and ultraviolet light, all add up to significantly higher demand on the site cryogenic capacity than currently available. With the FEL not yet operating at the higher powers, the site cryogenic capacity is just at the limit of delivering needed cooling for the existing program. This capacity clearly would not be sufficient with the future slate of experiments, including the $Q_{Weak}$ experiment, even for the 6 GeV program. Plans to bring into active operation the existing stand-by refrigerator at a moderate cost are being actively pursued at the cost of losing total stand-by capacity. Alternatively, a totally independent augmented facility in its new housing is also being considered, albeit at a higher cost. These options will be eventually integrated into the facility investment long-range development plan.

*Experimental Hall Facilities Plan*

There was a large investment in the initial equipment for the three experimental Halls for CEBAF at Jefferson Lab, as outlined above. This base equipment is CEBAF's "workhorse" equipment, but it will always be necessary to construct both new and ancillary devices to carry out "standard" high-priority experiments that have already been approved and new instrumentation to respond to exciting new scientific initiatives. Over time, it is necessary to modify the existing equipment to improve its reliability and to keep its performance at state-of-the-art (just as was described above for the accelerator). Eventually, we will have to replace major end station apparatus to keep the facility's capabilities at the cutting edge of nuclear physics research.

We request equipment funds each year to respond to these needs. The funds are divided between Jefferson Lab and collaborating user groups in a manner similar to that used for the construction of the base equipment in the Halls. Funding for such initiatives has already served many useful purposes. In Hall C, it has supported the development of the $t_{20}$ deuteron channel, the HNSS, and the neutron polarimeter for one of the two $G_E^n$ measurements. A variety of specialized targets, including unpolarized, high-power cryotargets for hydrogen, deuterium and helium, and polarized targets for hydrogen, deuterium and $^3$He have been developed for all three Halls. Basic beamline instrumentation has been enhanced with the addition of a number of devices such as the beam polarimeters in Halls A and B.

Plans for the near-term future in Hall A include: septum magnets that will allow us to use the spectrometer pair at scattering angles as far forward as 6$^o$; and upgrades of the HRS detectors and particle hodoscopes. Hall B projects are: a pair spectrometer that will be used both for photon beam monitoring and for the Primakoff experiment PRIMEX (which will perform an accurate measurement of the $\pi^\circ \rightarrow \gamma\gamma$ coupling constant); and an electronics system that will permit parasitic checking of the CLAS drift chamber performance during data-taking. Two multi-year projects are underway in Hall C: the $G^0$ spectrometer and the second-generation hypernuclear system (both discussed briefly above). A third project, the construction of the apparatus for the $Q_{Weak}$ experiment, is a major new initiative now under development.

Equipment funding will continue to be used to improve beam-line instrumentation, to build upgraded polarized and cryotargets for all three Halls, and to develop general-purpose infrastructure for polarized and cryogenic target development and support at the Laboratory. We will also begin a key effort to carry out the R&D necessary to refine design choices and optimize performance for the new detectors needed for the 12 GeV Upgrade equipment. Continued equipment funding is critical to the long-term success of the research program.

**Table VI-3**
**U.S. Institutions with Researchers on Experiments at Jefferson Lab**

Abilene Christian University, Abilene, TX
American University, Washington, DC
Argonne National Laboratory, Argonne, IL
Arizona State University, Tempe, AZ
Boston University, Boston, MA
Brookhaven National Laboratory, Upton, NY
California Institute of Technology, Pasadena, CA
California State University, Los Angeles, CA
Carnegie Mellon University, Pittsburgh, PA
Catholic University of America, Washington, DC
Christopher Newport University, Newport News, VA
City College of New York, New York, NY
College of William and Mary, Williamsburg, VA
Duke University, Durham, NC
Eastern Kentucky University, Richmond, KY
Florida International University, Miami, FL
Florida State University, Tallahassee, FL
George Mason University, Fairfax, VA
George Washington University, Washington, DC
Georgetown University, Washington, DC
Gettysburg College, Gettysburg, PA
Hampton University, Hampton, VA
Harvard University, Cambridge, MA
Indiana University, Bloomington, IN
Indiana Univ. Cyclotron Facility, Bloomington, IN
James Madison University, Harrisonburg, VA
Jefferson Lab, Newport News, VA
Kansas State University, Manhattan, KS
Kent State University, Kent, OH
Lawrence Berkeley Laboratory, Berkeley, CA
Los Alamos National Laboratory, Los Alamos, NM
Louisiana Tech University, Ruston, LA
Mass. Institute of Technology, Cambridge, MA
Mississippi State University, Mississippi State, MS
MIT Bates Linear Accelerator, Middleton, MA
MITI, Median ParkWay, Durham, NC
National Science Foundation, Washington, DC
New Mexico State University, Las Cruces, NM
NIST, Gaithersburg, MD
Norfolk State University, Norfolk, VA
North Carolina A & T St. Univ., Greensboro, NC
North Carolina Central University, Durham, NC
North Carolina State University, Raleigh, NC
Northeastern University, Boston, MA
Northwestern University, Evanston, IL
Ohio State University, Mansfield, OH
Ohio University, Athens, OH
Old Dominion University, Norfolk, VA
Oregon State University, Corvallis, OR
Pacific Northwest Laboratory, Richland, WA
Pennsylvania State University, State College, PA
Phillips Geophysical Laboratory, Lexington, MA
Princeton University, Princeton, NJ
Quantum Design/Quantum Magnetics, San Diego, CA
Renaissance Technology, Stony Brook, NY
Rensselaer Polytechnic Institute, Troy, NY
Rice University, Houston, TX
Rutgers University, New Brunswick, NJ
Southern Univ. at New Orleans, New Orleans, LA
Stanford Linear Accelerator Center, Stanford, CA
Stanford University, Stanford, CA
Syracuse University, Syracuse, NY
Temple University, Philadelphia, PA
Texas A&M University, College Station, TX
Triangle Univ. Nuclear Laboratory, Durham, NC
University of California, Los Angeles, CA
University of Colorado, Boulder, CO
University of Connecticut, Storrs, CT
University of Georgia, Athens, GA
University of Houston, Houston, TX
University of Idaho, Moscow, ID
University of Illinois, Urbana-Champaign, IL
University of Kansas, Lawrence, KS
University of Kentucky, Lexington, KY
University of Maryland, College Park, MD
University of Massachusetts, Amherst, MA
University of Michigan, Ann Arbor, MI
University of Minnesota, Minneapolis, MN
University of Mississippi, University, MS
University of New Hampshire, Durham, NH
University of North Carolina, Chapel Hill, NC
University of Notre Dame, Notre Dame, IN
University of Pennsylvania, Philadelphia, PA
University of Pittsburgh, Pittsburgh, PA
University of Richmond, Richmond, VA
University of Rochester, Rochester, NY
University of South Carolina, Columbia, SC
University of Southern California, Los Angeles, CA
University of Texas, El Paso, TX
University of Texas, Houston, TX
University of Virginia, Charlottesville, VA
University of Washington, Seattle, WA
University of Wisconsin, Madison, WI
Virginia Poly. Inst. & State Univ., Blacksburg, VA
Virginia State University, Petersburg, VA
Western Kentucky University, Bowling Green, KY

**Table VI-4**
**Foreign Institutions with Researchers on Experiments at Jefferson Lab**

| Country | Institution Name |
|---|---|
| ARMENIA | Yerevan Physics Institute, Yerevan, Armenia |
| AUSTRALIA | University of Adelaide, Adelaide, Australia |
| BELGIUM | Ghent State University, Ghent, Belgium |
| BRAZIL | University of Sao Paulo, Sao Paulo, Brazil |
| CANADA | Queen's University, Kingston, ON, Canada |
| | St. Mary's University, Halifax, Nova Scotia, Canada |
| | TRIUMF, Vancouver, BC, Canada |
| | University of British Columbia, Vancouver, BC, Canada |
| | University of Manitoba, Winnipeg, Canada |
| | University of Northern British Columbia, Prince George, BC, Canada |
| | University of Regina, Regina, SK, Canada |
| | University of Saskatchewan, Saskatoon, SK, Canada |
| CHINA | China Institute of Atomic Energy, Beijing, China |
| | Peking University, Beijing, China |
| COLUMBIA | Universidad de los Andes, Columbia |
| CROATIA | Rudjer Boskovic Institute, Zagreb, Croatia |
| CZECHOSLOVAKIA | Nuclear Physics Institute, Prague, Czechoslovakia |
| FRANCE | DAPNIA, C. E. A. SACLAY, Gif-Sur-Yvette, France |
| | Institut de Physique Nucleaire, Orsay, France |
| | Institut des Sciences Nucleaires, Grenoble, France |
| | Universite Blaise Pascal, Aubiere, France |
| | Universite de Clermont-Ferrand, Clermont-Ferrand, France |
| GERMANY | Deutsches Elektronen Synchrotron, Hamburg, Germany |
| | Forschungszentrum Juelich Institut Fuer Kernphysik, Juelich, Germany |
| | Univ. of Tubingen, Tubingen, Germany |
| | Universitaet Giessen, Giessen, Germany |
| | Universitaet Mainz, Mainz, Germany |
| | Universitat Bonn, Bonn, Germany |
| GREECE | University of Athens, Athens, Greece |
| INDIA | Indian Institute of Technology, Kanpur, India |
| INDONESIA | University of Indonesia, Jakarta, Indonesia |
| ISRAEL | Birzeit University, Birzeit West Bank, Israel |
| | Racah Inst. of Physics, The Hebrew Univ., Jerusalem, Israel |
| | University of Tel Aviv, Israel |
| ITALY | INFN, Ferrara, Italy |
| | INFN/Bari, Bari. Italy |
| | INFN/Sanita, Roma, Italy |
| | INFN, Sezione Lecce, Lecce, Italy |
| | Istituto Nazionale di Fisica Nucleare, Genova, Italy |
| | Int. School Advanced Studies Sissa, Trieste-Miramare, Italy |
| | Lab. Naz. Frascati, Frascati, Italy |
| | Univ. Pisa, Pisa, Italy |
| | Univ. Roma II, Roma, Italy |

| Country | Institution Name |
|---|---|
| JAPAN | Osaka Eectro-Commun. University, Osaka, Japan |
| | Osaka University, Osaka, Japan |
| | Shizuoka University, Shizuoka, Japan |
| | Tohoku University, Sendai, Japan |
| | Univ. of Tsukuba, Ibaraki, Japan |
| | Yamagata University, Yamagata, Japan |
| NETHERLANDS | NIKHEF, Amsterdam, The Netherlands |
| | Rijks Universiteit Utrecht, Utrecht, The Netherlands |
| | University of Utrecht, Utrecht, The Netherlands |
| | Vrije Universiteit, Amsterdam, The Netherlands |
| NORWAY | Norwegian Defense Research Establishment, Kjeller, Norway |
| POLAND | Jagellonian University, Krakow, Poland |
| ROMANIA | University of Bucharest, Bucharest, Romania |
| RUSSIA | Budker Institute for Nuclear Physics, Novosibirsk |
| | Institute for High Energy Physics |
| | Inst. for Theor. & Experimental Physics, Moscow, Russia |
| | Joint Institute For Nuclear Research, Moscow, Russia |
| | Nuclear Physics Institute, St. Petersburg, Russia |
| | Tomsk Polytechnical University, Tomsk, Russia |
| SOUTH AFRICA | University of South Africa, Pretoria, South Africa |
| | University of Stellenbosch, Stellenbosch, South Africa |
| SOUTH KOREA | Chungnam National University, Daejeon, Korea |
| | Kyungpook National University, Taegu, Korea |
| | Seoul National University, Seoul, Korea |
| | Yonsei University, Seoul, Korea |
| SPAIN | Universidad de Barcelona, Barcelona, Spain |
| | Universidad de Valencia, Valencia, Spain |
| SWEDEN | University of Lund, Lund Sweden |
| SWITZERLAND | University of Basel, Basel, Switzerland |
| UKRAINE | Institute for Physics and Technology, Kharkov, Ukraine |
| | Kharkov State University, Kharkov, Ukraine |
| UNITED KINGDOM | Glasgow University, Glasgow, Scotland |

## B. Nuclear Theory and Advanced Computing

### a) Theory in Support of our Nuclear Physics Mission

The full realization of the scientific benefits of the Laboratory's mission to explore the quark and gluon structure of the nucleon requires extensive theoretical work. Jefferson Lab maintains a strong nuclear theory group in partnership with Hampton University, Old Dominion University, and the College of William and Mary. The group includes expertise spanning a broad range from the nuclear many-body problem to strong QCD, as appropriate for a laboratory working at the interface between nuclear and particle physics. In addition to supporting the CEBAF experimental program directly, Jefferson Lab theorists collaborate closely with other theorists around the world on CEBAF-related problems.

Last year was a typically productive one for the Theory Group. The group published 32 new papers in refereed journals, gave 33 talks at international conferences and workshops that will be published in conference proceedings, and gave another 25 invited talks at major conferences which publish no proceedings. The Theory Group's papers continue to be so frequently cited that several have appeared on "top ten" citations lists. The group continues its sponsorship of workshops on specialized topics related to the CEBAF program, and a seminar program aiming to bring important new developments in theory to the attention of the Laboratory and User community. To supplement this program, the Theory Group continues to run its highly successful Mini-Lecture Series of short courses for experimentalists and graduate students on key new developments in nuclear theory.

We plan to strengthen the Theory Group in two important ways: the establishment of an Excited Baryon Analysis Center (EBAC); and continued growth of our program in and facilities for Lattice QCD calculations.

### b) Excited Baryon Analysis Center and Related Theory in Support of Experiments

A significant portion of JLab's research effort has been committed to understanding the structure of the nucleon. Our N* or excited baryon program, which aims to identify the many missing states in the excitation spectrum of the nucleon, is a key element in that effort. State-of-the-art detectors and experimental techniques have been brought to bear on the experimental questions that must be addressed. A second essential element is provided by the Lattice Hadron Physics Collaboration (LHPC) centered at Jefferson Lab and MIT, and discussed further below. However, a third essential piece of the program needs strengthening: a concerted effort dedicated to the analysis and interpretation of data, particularly from CLAS, that would bridge the gap between theory, formulated in terms of quark-gluon degrees of freedom (provided by the lattice and quark models), and a theory formulated in terms of meson-baryon degrees of freedom, which can be compared to experiment.

Advances in theoretical methods used to interpret these new data are essential. For example, the treatment of multi-particle final states in a manner consistent with the constraints of unitarity and analyticity, is in its infancy at best, and yet such techniques are essential for a reliable interpretation of a significant portion of the recently-obtained data.

To resolve this problem, we propose the establishment of a center at JLab for the analysis of data related to the $N^*$ program. Its primary mission will be to develop, maintain, and update the theoretical and computational tools necessary to carry out higher-level analysis of the large body of data associated with the JLab $N^*$ program. This center will work in close collaboration with the Data Analysis Center at George Washington University. The magnitude of this task will require the creation of several new positions: both a senior and a mid-level theorist with broad expertise in the field of reaction theory, phenomenological analysis, and with a background in hadronic physics with electromagnetic probes; and 2 to 3 new term/visiting positions. The visiting positions would be filled with scientists (experimentalists and/or theorists) with background depending on the specific needs of the experimental program and analysis effort. The research activity of the N* Center would be guided by a Scientific Advisory Board. It is also essential to add theoretical strength in phenomenology and radiative corrections.

### c) Advanced Computational Science: Lattice Quantum Chromodynamics (LQCD)

A full realization of the scientific benefits of the Laboratory's mission to explore the quark and gluon structure of the nucleon requires extensive theoretical work. A major new theory initiative in support of the nuclear physics program is the development of advanced computational techniques to solve Quantum Chromodynamics numerically in the "strong" regime that is appropriate for understanding nucleon structure. Jefferson Lab is a key participant in the National Computational Infrastructure for Lattice Gauge Theory, the DOE SciDAC project that brings together theorists, computer scientists, and computational scientists to tackle demanding quantum chromodynamics calculations. This collaboration is making significant progress in improving the software used in these calculations and is poised to begin tera-scale simulations of QCD.

The importance of this work is reflected in the NSAC April 2002 Long Range Plan, Opportunities for Science:

*"Advances in computational physics and computer technology represent great opportunities…To exploit these opportunities, dedicated facilities must be developed with world-leading computational capabilities for nuclear physics research.*

*Lattice QCD is crucial for answering fundamental questions in strong-interaction physics, and it is widely recognized that definitive Lattice QCD calculations require multi-teraflops resources—resources now available at reasonable cost. In addition, successful nuclear physics programs at Jefferson Lab and RHIC urgently need to make connection to QCD. An aggressive and dedicated effort is needed for the U.S. to regain a competitive edge—an edge that has been lost to Japan and Europe—in using Lattice QCD to understand hadronic physics. The nuclear science component of an internationally competitive lattice effort requires dedicated facilities providing sustained performance of 0.5 teraflops by 2002, growing to 15 teraflops by 2005."*

Consistent with this recommendation, the National Lattice QCD Executive Committee, which oversees the LQCD SciDAC activity, has endorsed a plan for deploying, by FY06, a distributed multi-terascale computing capability which includes 8 teraflop/s ($10^{12}$ floating point operations per second) of computing at Jefferson Lab, and a comparable capacity at Fermi National Accelerator Laboratory (FNAL) and BNL.

Both Jefferson Lab and the High Energy Physics Lattice effort at FNAL have adopted a cost optimized commodity computing model based upon large clusters of inexpensive nodes connected by high speed cluster interconnects. As part of this optimization, Jefferson Lab has led the effort to specify and implement an application specific messaging interface and library to facilitate highly overlapped computation and communication. Additional optimizations of low-level linear algebra routines are now underway.

In FY02-03 a 128-node cluster was commissioned and began tackling key problems including the pion form and moments of structure functions and generalized parton distributions. An additional 256-node cluster is expected to be operational by the end of FY03. The capability of these clusters will yield an aggregate performance approaching 0.5 teraflop/s. During FY04-06, the Laboratory's aggregate capacity is planned to grow to 8 teraflops, and to continue to grow thereafter to keep pace with demands. During this timeframe, planned funding for state-of-the-art lattice calculations at Jefferson Lab will grow from $1.1M/year in 2003 (including both SciDAC and base funding) to roughly $4M in 2005 and 2006 (as the first terascale clusters are deployed) and then average roughly $5M/year, including all upgrade and operating costs.

## C. 12 GeV and Beyond

### a) Physics Motivation for the 12 GeV Upgrade

There has been a remarkably fruitful evolution of our understanding of strongly interacting matter during the almost two decades that have passed since the parameters of CEBAF were defined. These advances have revealed important experimental questions best addressed by a CEBAF-class machine at higher energy. Fortunately, favorable technical developments coupled with foresight in the design of the facility make it feasible to triple CEBAF's beam energy from the original design value of 4 GeV to 12 GeV (corresponding to doubling the achieved energy of 6 GeV to 12 GeV) in a cost-effective manner. The Upgrade can be realized for a modest fraction of the cost of the initial facility. This Upgrade would enable the worldwide community using CEBAF to greatly expand its physics horizons.

Raising the energy of the accelerator to 12 GeV provides three general advantages:

- It allows crossing the threshold above which the origins of quark confinement can be investigated. Specifically, 12 GeV will enable the production of certain “exotic” mesons, whose existence will establish the origin of quark confinement as due to the formation of QCD flux tubes and whose spectrum encodes information on the mechanism within QCD responsible for their formation. If these exotic mesons are not found, their absence will present a serious challenge to our present understanding of “strong” QCD, and the normal meson spectra accumulated will provide essential information for revising that theory. With 12 GeV one also crosses the threshold for charmed meson production.

- It allows direct exploration of the quark-gluon structure of hadrons and nuclei. It is known that inclusive electron scattering at the high momentum and energy transfers available at 12 GeV are governed by elementary interactions with quarks and gluons. The original CEBAF energy is not fully adequate for study of this critical regime. With continuous 12 GeV beams one can cleanly access hadron structure throughout the entire “valence quark region” and exploit the recently developed Generalized Parton Distributions to access experimentally both the correlations in the quark wavefunctions of the hadrons and their transverse momentum distributions. 12 GeV beams will also allow us to identify precisely the limits of the long-standing nucleon and meson based description of nuclei, and to fully access and characterize the transition from this description to the underlying quark-gluon description.

- In addition to these qualitative changes in the physics reach of CEBAF, the 12 GeV Upgrade also allows important new thrusts in CEBAF's present research program, generally involving the extension of measurements to substantially higher momentum transfers (probing correspondingly smaller distance scales). We also note that most experiments that want to run at a presently accessible momentum transfer can do so more efficiently (e.g., consuming less total beam time) at a higher electron beam energy.

In each of the programs described here these benefits of the energy upgrade will always be significant.

The research program of the new facility is focused on four major research themes that coincide with broad directions of the field of nuclear physics as identified in two key documents: the 2002 Long Range Plan of the Nuclear Science Advisory Committee of the U.S. Department of Energy and the National Science Foundation and the recent decadal survey of the field by the National Research Council of the National Academy of Sciences. We identify these themes here to place our research program in this broader context. Each addresses outstanding questions in nuclear physics that the Laboratory's Users address with a concerted program of experimental and theoretical work.

The Programs Driving the 12 GeV Upgrade of CEBAF include:

***Gluonic Excitations and the Origin of Quark Confinement***
Experiments and theory aimed at examining the fundamentally new dynamics that underpin all of nuclear physics: the confinement of quarks.

***How are the Nuclear Building Blocks Made from Quarks and Gluons?***
A program of measurements addressing the first question that must be answered in the quest to understand nuclear physics in terms of the fundamental theory of strongly interacting matter: quantum chromodynamics (QCD).

***On the Structure of Nuclei***
Two broad programs that take advantage of the precision, spatial resolution, and interpretability of electromagnetic interactions to address long-standing issues in nuclear physics. They aim to understand the QCD basis of nuclear physics through investigations of the origins of the NN force and its short range behavior, and by identifying and exploring the transition from the meson/nucleon description of nuclei to the underlying quark and gluon description.

***In Search of the New Standard Model***
Experiments aimed at identifying physics beyond the Standard Model of electro-weak interactions through precision tests of its predictions, and by measuring low energy parameters of the theory to deepen our understanding of chiral symmetry breaking.

Each of these programs is a major motivation for the energy upgrade. The first, a program of gluonic spectroscopy, will provide data needed: i) to test experimentally our current understanding that quark confinement arises from the formation of QCD flux tubes; and ii) to explore the mechanism behind the formation of these flux tubes. If our present understanding is incorrect, the experiment has the sensitivity necessary to decisively test first-principles Lattice QCD calculations of the mesons -- the simplest of the strongly-interacting systems. The second program will explore the complete quark and gluon wavefunctions of the nucleons through measurements: i) of quark momentum distributions in the critical, but previously unreachable, valence quark region; and ii) of exclusive reactions that build on the framework of the recently developed Generalized Parton Distributions. The third will address outstanding issues in nuclear physics, completing a very fruitful area presently under investigation with CEBAF at 6 GeV, and extending this program in important new directions. Finally, the last program will use precision measurements at modest energies to explore the validity of the Standard Model of electro-weak interactions and measure key parameters of that theory. In the second half of this report we outline the plans for the Upgrade, summarizing the accelerator and experimental equipment upgrades required to accomplish these physics goals, and review the readiness of the project.

The research program supported by the 12 GeV Upgrade is expected to have a profound influence on the field of nuclear physics and it has important implications beyond it. Its goal is nothing less than providing a firm intellectual foundation for the field by explaining how nucleons and the NN force arise from the underlying quark and gluon structure of strongly-interacting matter. In doing so, it will dramatically improve our understanding of quantum chromodynamics in the "strong" (confinement) regime, where it is still only poorly understood. It will be testing the accuracy of that theory, both by examining its applicability in the "strong" regime and by performing high accuracy tests of its predictions for the electro-weak force. By determining the energy and distance scales at which the underlying quark-gluon structure emerges in the description of nuclei, it will define the range of applicability of the approximation that describes nuclei in terms of nucleons interacting via an effective interaction parameterized by meson exchange. Information on how quarks propagate through nuclear matter and how hadrons are formed when a quark is struck will be important for interpreting experiments aimed at finding and exploring the quark-gluon plasma. The progress in superconducting RF accelerator technology that will result from the project will also be important for a variety of accelerator applications beyond nuclear and particle physics -- most notably the next-generation light sources for basic energy sciences.

The draft of the pre-Conceptual Design Report for the Upgrade, which is available on the JLab website (http://www.jlab.org/div_dept/physics_division/pCDR_public/pCDR_12-1/) has a detailed discussion of the science motivation driving the 12 GeV Upgrade that is summarized above. Even more detail is available in the pre-Conceptual Design Reports for each of the experimental halls, which are also posted on the JLab 12 GeV webpage.

The larger nuclear physics community has extensively reviewed and endorsed the physics program driving the Upgrade and the importance of higher-energy electron beams. Beginning with the "Barnes Panel" of NSAC (4/82), which set the scientific and technical goals for the CEBAF facility, the need for higher energies was anticipated in the planning for the initial facility. In setting the design energy for the new, cw electron accelerator to 4 GeV, they foresaw "*a new frontier for the investigation of nuclear phenomena in the momentum transfer range Q=5-15 fm*$^{-1}$." The "Bromley Panel" of NSAC (4/83), which reviewed and chose the accelerator design for the facility, preferred the SURA design, because it "*could readily be extended in energy to 6 GeV, or above*", and noted that: "*Experience has taught us that the option of obtaining (higher energies) should not be given up lightly.*" Based on these recommendations and related advice, the CEBAF tunnel was designed to permit upgrades to ~25 GeV.

Since operations began using CEBAF, NSAC and its subcommittees have first supported the concept of the energy Upgrade, and then (in the 2002 Long Range Plan), formally recommended it. The NSAC 1996 Long Range Plan stated (in text under recommendation #1): "*With the superconducting accelerator technology at CEBAF performing so well, the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring*." Then the NSAC Intermediate Energy Review (9/98), chaired by James Symons, noted: "*The possibility of tripling the CEBAF design energy opens up a wealth of scientific opportunities. In particular, it adds a powerful new probe into gluonic degrees-of-freedom in mesons and strange quarkonia, permits precision studies of deep inelastic scattering in the valence quark region, opens up studies of few body systems at the shortest possible range, and provides the most powerful means to study scaling effects and nuclear transparency*."

The NSAC 2002 Long Range Plan includes the Upgrade as one of its principal recommendations: "*We strongly recommend the upgrade of CEBAF at Jefferson Laboratory to 12 GeV as soon as possible. The 12 GeV upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This upgrade will* *provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon description of matter, and the nature of quark confinement."* The Long Range Plan went on to note that this is the only major construction initiative that is feasible within a constant effort budget: *"We should emphasize that smaller initiatives - even medium size initiatives such as the Jefferson Lab Upgrade - should be accommodated within a constant effort budget*."

In March 2003, the Upgrade and its timeliness were reviewed again by NSAC in response to a request from the Office of Science that all proposed projects in the field be categorized in three tiers in both the importance of the science and the readiness of the facility for construction. The committee confirmed the Long Range Plan recommendation, declaring the Upgrade's science program as "*absolutely central*" to progress in the field, and went on to note that "*The Upgrade has the support of a large and active user community (~1100 scientists from 29 countries); it has been enthusiastically reviewed by numerous outside peer groups and will be unique worldwide. The realization of the Upgrade will create synergies with other fields of research, most notably with large-scale computing, high-energy physics, and astrophysics."*

### b) Project Description for the 12 GeV Upgrade

The proposed facility will be unique worldwide. The concept of the 12 GeV Upgrade has been studied extensively: plans for the accelerator portion of the upgrade are detailed in a 1999 internal JLab report, *Interim Point Design for the CEBAF 12 GeV Upgrade*; and plans for the experimental equipment are documented in a series of pre-Conceptual Design Reports completed late in 2002 for the individual Hall projects and a draft pre-Conceptual Design Report that presents the science motivation and summarizes the Hall equipment plans for the entire project. In its March 2003 Facilities Review, NSAC identified the 12 GeV Upgrade project as "*fully ready to initiate construction*," noting that "*all remaining R&D is focused on cost reduction and/or improved technical contingency; no R&D is needed to demonstrate feasibility.*"

#### *The Accelerator*

The accelerator portion of the Upgrade is straightforward. The basic elements can be seen in Fig. VI-7. The Upgrade utilizes the existing tunnel and does not change the basic layout of the accelerator. There are four main changes: additional acceleration in the linacs, stronger magnets for the recirculation, an upgraded cryoplant, and the addition of a tenth recirculation arc. The extra arc permits an additional "half pass" through the accelerator to reach the required 12 GeV beam energy, followed by beam transport to Hall D that will be added to support the meson spectroscopy initiative. Table VI-5 presents the key parameters of the upgraded accelerator.

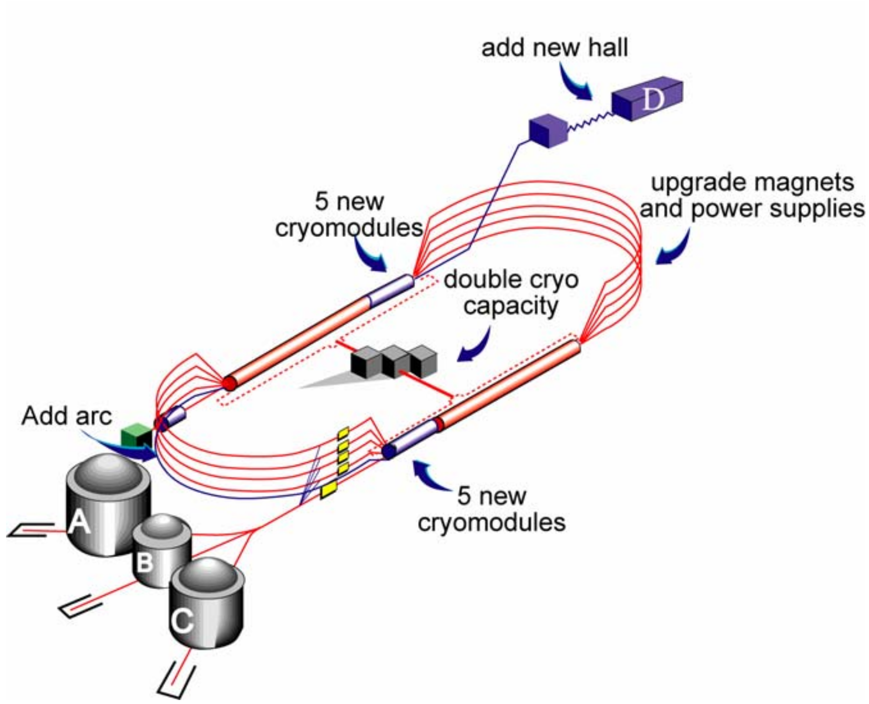



Figure VI-7: The configuration of the proposed 12 GeV CEBAF Upgrade.

**Table VI-5:**
**Selected key parameters of the CEBAF 12 GeV Upgrade**

| Parameter | Specification |
|---|---|
| Number of passes for Hall D | 5.5 (add a tenth arc) |
| Max. energy to Hall D | 12.1 GeV (for 9 GeV photons) |
| Number of passes for Halls A, B, C | 5 |
| Max. energy to Halls A, B, C | 11.0 GeV |
| Max. energy gain per pass | 2.2 GeV |
| Range of energy gain per pass | 3:1 |
| Duty factor | cw |
| Max. summed current to Halls A, C* (at full, 5-pass energy) | 85 μA |
| Max. summed current to Halls B, D | 5 μA |
| New cryomodules | 10 (5 per linac) |
| Central Helium Liquifier upgrade | 10.1 kW (from present 4.8 kW) |

*Max. *total* beam power is 1 MW.

The key R&D issues for the Upgrade were raising the performance of SRF cavities and cost-effectively increasing the bending power of the recirculation arcs; both have been addressed. A new cryomodule has been designed that packages eight 7-cell cavities in the space used for eight 5-cell cavities of the original design. This provides 40% more acceleration per cryomodule with no change in cavity gradient. The new 7-cell design exceeds the gradient necessary to provide a 100 MeV cryomodule. The upgrading of the ARC dipole magnets proved to be particularly straightforward: the addition of a return iron path that converts the original ‘C’ configuration to an ‘H’ configuration dramatically reduces saturation and meets performance specifications for field uniformity at higher energy operation. The remaining R&D effort is focused on optimizing cost and/or increasing technical contingency.

Motivated by the science, the 12 GeV Upgrade derives its name from the fact that it will deliver a 12 GeV electron beam to the new end station, Hall D, where it will be used to produce 9 GeV polarized photons for the new gluonic and $s\bar{s}$ spectroscopies. The accelerator will, in addition, be able to simultaneously send electrons with maximum energies of 2.2, 4.4, 6.6, 8.8, or 11.0 GeV to the existing Halls A, B, and C. The increased physics power of the present halls comes from the qualitative jump in energy and momentum transfer that the Upgrade brings, and from the enhanced instrumentation capabilities planned for the detector complements in each of them.

### *The Experimental Equipment*

The experimental equipment planned for the Upgrade project takes full advantage of apparatus developed for the present program. In each of the existing halls, new spectrometers are added and/or present equipment upgraded to meet the demands of the 12 GeV program. A new hall, Hall D, will be added to support the meson spectroscopy program. The plans for the new detector and detector upgrade projects necessary to carry out the program are also at an advanced state, with detailed technical solutions in hand and extensive modeling of the performance of the equipment for a broad spectrum of key experiments it will carry out.

In Hall A, the Upgrade will add a large angular-and momentum-acceptance magnetic spectrometer (to be called the Medium-Acceptance Device, or MAD), and a high-granularity electromagnetic calorimeter, both of which supplement the existing High Resolution Spectrometers. The spectrometer will provide a tool for high-luminosity, high-$x$ studies of the properties of nucleons with an 11 GeV beam, and will also be used for selected investigations of the GPDs, where high luminosity and good resolution are needed.

In Hall B, the CEBAF Large Acceptance Spectrometer (CLAS), which was designed to study multi-particle, exclusive reactions with its combination of large acceptance and moderate momentum resolution, will be upgraded to CLAS$^{++}$ and optimized for studying exclusive reactions (emphasizing the investigation of the GPDs) at high energy. It will also be used for selected valence quark structure studies involving neutron “tagging” or polarized targets capable of supporting only very low beam current. Most importantly, the maximum luminosity will be upgraded from $10^{34}$ to $10^{35}$ cm$^{-2}$ s$^{-1}$. The present toroidal magnet, time-of-flight counters, Cherenkov detectors, and shower counter will be retained, but the tracking system and other details of the central region of the detector will be changed to match the new physics goals.

In Hall C a new, high-momentum spectrometer (the SHMS, Super-High-Momentum Spectrometer) will be constructed to support high-luminosity experiments detecting reaction products with momentum up to the full 11 GeV beam energy. This feature is essential for studies such as the pion form factor, color transparency, duality, and high-$Q^2$ $N^*$ form factors. The spectrometer will be usable at very small scattering angles in conjunction with the existing HMS.

Finally, in Hall D, a tagged coherent bremsstrahlung beam and solenoidal detector will be constructed in support of a program of gluonic spectroscopy aimed at testing experimentally our current understanding that quark confinement arises from the formation of QCD flux tubes.

### c) Beyond 12 GeV

#### *Physics Motivation*

There are indications that completing our understanding of the quark-gluon structure of matter may require a future upgrade of CEBAF beyond 12 GeV. Studies by Jefferson Lab Users and by physicists associated with the Electron Laboratory for Europe (ELFE) project have established that there is a strong physics case for the construction of an extremely high luminosity (~$10^{38}$ $cm^{-2}$ $sec^{-1}$) CEBAF-like accelerator with energies in the 20-30 GeV range. A strong physics case is also developing for an electron-light ion collider (ELIC) operating in the 20-65 GeV center-of-mass energy range. As noted in the NSAC 2002 Long Range Plan, "*many of the outstanding scientific opportunities that have been identified …. require the higher beam energies that will be provided by the* CEBAF 12-GeV Upgrade*, which should take place at the earliest opportunity. In the longer term, an Electron-Ion Collider has been put forward as the next major facility for this field. This is an exciting proposal for which the scientific case will be refined in the next few years. In parallel, it is essential that the necessary accelerator R&D be pursued now, to ensure that the optimum technical design is chosen."*

The facility at Jefferson Lab can be upgraded to provide either (or both) of these options in a straightforward manner. An energy upgrade of CEBAF to 25 GeV would support extensions of the CEBAF 12 GeV program to smaller $x$ and higher $Q^2$, and, in particular, support a program of deeply virtual meson production that would permit the flavor separation of the Generalized Parton Distributions that characterize the nucleon's properties. A high-luminosity electron-light ion collider (ELIC) in the center-of-mass energy range $\sqrt{s}$ of 20-65 GeV, would build on the physics insights obtained from the CEBAF 12 GeV upgrade, and expand on our understanding of the structure of the nucleon and nuclear binding. While questions remain on the details of the science program and on technical aspects of the facility design, we expect that the facility's research program will be absolutely central to the field of nuclear physics. In particular, such a facility will provide a unique tool to:

- complete our quantitative understanding of how quarks and gluons provide the binding and the spin of the nucleon;
- learn how quarks and gluons evolve into hadrons via the dynamics of confinement through measurements of the spin dependence of this complex process known as hadronization – a key aspect of the transition from the deconfined state of free quarks and gluons in the Big Bang to stable hadronic matter; and
- determine how the nuclear medium affects quarks and gluons.

#### *Accelerator Design*

We have developed a novel approach to the facility, shown schematically in Figure VI-8. It is an integrated design that can provide both external beams of 25 GeV electrons and electron-light ion collisions at center-of-mass energies between 20 and 45 GeV with a very high luminosity (~$10^{35}$ $cm^{-2}$ $sec^{-1}$). This extraordinary luminosity is achievable through the combination of an energy-recovering linac and an electron ring with only ~100 turns (avoiding beam emittance growth and the associated luminosity losses). A 5 GeV polarized electron beam is produced using the CEBAF linacs with upgraded accelerating structures operating as an energy recovering linac (ERL). After colliding with protons/light ions circulating in a storage ring at energy of 100 GeV, the electrons are re-injected into the CEBAF accelerator for deceleration and energy recovery. The same accelerator that provides 5 GeV electrons for the collider mode can also provide up to 25 GeV for fixed target experiments for physics by adding a 5-pass recirculator as in present CEBAF but at ~5 GeV per pass.

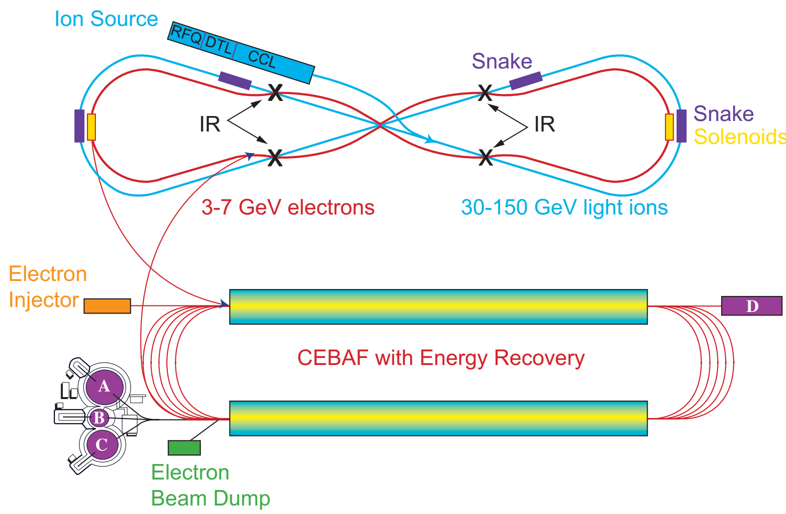



Figure VI-8: A Schematic of the Proposed Electron-Light Ion Collider Facility

“Figure-8” rings are used for the ions for spin preservation and flexible manipulation of all species of interest; this configuration has a zero spin tune, which avoids intrinsic spin resonances and spin resonance-crossings. Longitudinal polarization can be obtained for all ion species at all energies by introducing solenoids in the straight sections or horizontal dipoles in the arcs. Electron cooling of the ions is necessary for luminosities above $10^{32}$ $cm^{-2}$ $sec^{-1}$.

***R&D Required***

Significant accelerator-physics R&D is required to resolve key design issues for the proposed facility to include: the demonstration of the high average current polarized electron source, high energy electron cooling of the ions, high current and high energy demonstration of energy recovery, and integration of the IR design with a real detector geometry. This R&D is also of interest for beam cooling at RHIC, for the JLab FEL program, and for X-ray sources under consideration at Cornell and elsewhere.

A high charge-per-bunch, high average current polarized electron source is a significant technical challenge. The highest average (unpolarized) electron current that has been demonstrated from a photocathode source is ~1 mA at the JLab FEL. The circulator ring concept appears promising for easing this requirement.

Cooling of the intense ion bunches contemplated here also requires high electron beam current (*hundreds* of mA, but unpolarized). Electron cooling at such high energy can only be conceived in the context of superconducting RF ERLs (as has been demonstrated and routinely used in the Jefferson Lab IR FEL). The BNL/BINP collaboration is seriously pursuing the design and prototyping of an ERL-based electron cooling device for RHIC, and Jefferson Lab has recently formally joined in collaboration with BNL.

Energy recovery has been demonstrated reliably at the JLab IR FEL with average current up to 5 mA and for energies up to 50 MeV. Establishing the feasibility and high-efficiency operation of ERLs at an average current of order 100 mA, as required both for the electron cooling device and for the collider itself, and at an energy of several GeV, requires the experimental investigation and understanding of a number of issues. The first experiment aimed at demonstrating the feasibility of energy recovery at high current and high energy took place on the GeV scale using CEBAF in March 2003. Extensions of this experiment will further investigate the ability for phase space management and to quantify beam quality degradation in

GeV scale ERLs. The experimental investigation of high average current effects is planned at the JLab FEL Upgrade (10 mA), the Cornell/JLab ERL prototype, and the BNL electron cooling prototype (both 100 mA).

Finally, work is needed on the design of an interaction region and detector that, taken together, support the combination of the very high luminosity and very high detector acceptance and resolution essential to carry out this physics program. We expect that over the next five years the scientific motivations for these different possibilities and the technical details of their realization will be developed more fully, permitting the community to optimize its choice for the next generation facility.

## D. Core Competencies

### a) SRF and Advanced Accelerator R&D

#### *Current Laboratory Activities and Capabilities*

Jefferson Lab is the site of two pioneering applications of SRF technology to accelerators. CEBAF, The Continuous Electron Beam Accelerator Facility, has been operational since 1995 and has been delivering reliably an electron beam of exceptional quality to 3 experimental halls for medium energy nuclear physics. CEBAF is at present the largest worldwide implementation of SRF technology for particle accelerators. The free-electron laser (FEL) is a unique facility that has produced light in the infrared and at THz frequencies at average power levels exceeding, by several orders of magnitude, what has been achieved anywhere else, and is now in the process of extending its capabilities to higher power in the infrared (10 kW) and ultraviolet (1kW).

CEBAF and the FEL are also test beds for extension of the SRF technology to new directions that may enable new applications. For example, high power energy recovery was demonstrated in the FEL and is used in its routine operation as a user facility. A recent energy recovery experiment using CEBAF demonstrated that energy recovery could be applied to high input to output energy ratios with little beam degradation. As a result, energy-recovering SRF accelerators are now integral parts of many of the light sources that are being considered and even proposed worldwide.

The existence and operation of CEBAF and the FEL as reliable and powerful user facilities necessitated and demonstrated an integrated, systematic attack on all the technical issues associated with SRF accelerators (superconductivity, surface science, ultra high vacuum and clean-room technology, cryogenics and refrigeration, cryostat design, electromagnetism and RF design, microphonics and controls, beam physics and instabilities, etc.).

This broad range of expertise resides in three closely integrated departments of the Jefferson Lab Accelerator Division: the SRF Institute, the Center for Advanced Studies of Accelerators (CASA) and the Engineering Department. With this level of expertise Jefferson Lab has the capability for rapid design, development, and prototyping of new SRF systems for the scientific community. This was demonstrated when Jefferson Lab was asked to design and develop cavities, cryomodules, and the refrigeration system for the Spallation Neutron Source on a very tight schedule. Jefferson Lab is also actively involved with MSU and ANL in the development and testing of cavities and control systems for RIA, and is collaborating with Cornell in the design of their proposed light source and possible construction of a prototype.

The experimental capabilities in SRF R&D reside mostly in the Test Lab of the SRF Institute. A partial list of these capabilities includes:

- A dedicated refrigerator capable of 300 W at 2 K
- A vertical test facility containing a large number of dewars of various sizes with a dedicated control room for the testing of cavities over a broad range of sizes, geometries, and frequencies
- A large magnetically shielded (<10 mG) cryomodule test cave with a dedicated control room and RF power sources
- Cavity fabrication and electron beam welding capability
- Clean room with integrated chemistry and high-pressure rinsing system
- A large electropolishing facility
- An extensive surface science and analytical laboratory (Scanning Auger microscope, scanning field emission microscope, transmission electron microscope, secondary ion mass spectrometer…)
- Several high-vacuum, high-temperature furnaces
- Material and metallurgical testing facilities (microscopes, cryogenic tensile test facility…)
- RF laboratory for the development of SRF cavity control systems.

A staff equivalent to 60 FTEs of effort is dedicated to SRF activities at Jefferson Lab, including 10 Ph.D. level scientists, 20 professional engineers, 6 graduate students and post-doctoral scientists, and many visitors and in-house technologists.

***National, International and Industrial Collaborations***

| | |
|---|---|
| ANL | RF structures and microphonics control for RIA |
| BNL | SRF photocathode electron gun and cryomodule for RHIC-II electron cooling |
| Cornell | FEL and energy-recovering linacs |
| LANL | High RRR Nb microstructure |
| MSU | RF structures design and testing for RIA |
| NIST | Properties of Nb |
| ODU | H in metals |
| ORNL | Cavity, cryomodule design, prototyping and fabrication for SNS |
| SUNY | H in Nb |
| UVa | H in grain boundaries, SQUID microscope |
| | |
| Daresbury | DC gun and cryomodule for 4GLS ERL prototype |
| DESY | Cavity fabrication and testing, properties of Nb |
| FZK | Ultra high vacuum |
| FZR | SRF photocathode electron gun |
| KEK | Power couplers and material processing for SNS |
| TESLA | Broad collaboration of SRF R&D for linear colliders and x-ray FELs |
| | |
| AES Inc. | High-current (1 A, 750 MHz) electron injector for FEL |

***Critical Technical Issues***

Many (but not all) of the potential applications of the SRF technology fall into 4 broad areas, each of them with its critical technical issues that will need to be addressed by an R&D program in order to bring them to a successful completion.

*Low to medium current, cw accelerators*
Examples of this category include the CEBAF 12 GeV upgrade and beyond, and RIA.
Because of the cw operation, the cavities in these applications will operate at relatively modest gradient. RF losses (and by implication refrigeration capacity) will, on the other hand, be a

major cost driver. Beam currents being low, the required installed RF power will be dictated by the level of microphonics (coupling of mechanical vibrations to the RF fields), and not by the beam power.
The critical technical issues in this category are:

- Cavities with low losses, high $Q_0$ in cw operation at modest gradient (~20–25 MV/m)
- New cavity geometries
- Control and mitigation of microphonics, RF control of cavities
- Consistency in the performance of cavities

*Pulsed high-current proton or ion accelerators*
Examples in this category include spallation neutron sources.
Because of the high beam current, the gradients will be modest (10–20 MV/m) and will be dictated by the capabilities of the RF power sources and power couplers. The pulsed operation could generate large frequency excursion that will need to be mitigated.
The critical issues are:

- Dynamic behavior of SRF cavities, frequency control
- Beam halo, activation
- New cavity geometries
- HOM power generation and extraction
- RF power couplers

*Pulsed high-energy lepton linacs*
Examples are linear colliders, muon colliders, neutrino factories.
These machines are characterized by a large size and a large number of components.
The critical technical issues are:

- Cost-efficient designs
- High gradient in cavities
- Consistency in the performance of cavities
- Cheap reliable power couplers
- Reliability of accelerator complex, high availability

*Energy recovering linacs*
Examples in this category include light sources, free electron lasers, electron coolers.
These accelerators are characterized by large beam currents that are simultaneously accelerated and decelerated in the same cavities, so there is little net transfer of RF power between the sources and the cavities. These high currents still generate large amounts of HOM power that will need to be extracted in order to prevent beam instabilities. Small fluctuations in the beam properties can also cause a large random beam loading that will have to be controlled.
The critical technical issues are:

- Cavity designs for high current
- HOM mitigation and extraction
- Beam instabilities
- RF control of random beam loading, microphonics
- Halo mitigation and control

***Plans for Evolution of the Program for the Next Three to Five Years***

Jefferson Lab's activities in the next 5 years to support the development of SRF accelerators will follow several directions. Some will be in direct support of one of the broad categories described in the previous section, some will be generic, and some will targeted to specific programs.

*Activities in Support of Specific Identified Programs*

- Complete SNS
- 100 MV cryomodule for 12 GeV energy upgrade
- High-$\beta$ cryomodule for RIA
- RF controls for 12 GeV Upgrade and RIA
- High-current cryomodule (1 A) for U. S. Navy (spinoff for e-cooling)
- Jefferson Lab's ultimate goal for ELIC: cost effective, 1 A, HOM-free cryomodule with high-Q cavities operating cw at 30 MV/m

*Generic SRF R&D Activities*

Even after more than 30 years of R&D in many laboratories worldwide, the SRF technology still suffers from a lack of consistency in the performance of superconducting cavities. Exceptional performance can be achieved and has been demonstrated many times but not consistently. This has a major impact on the cost of SRF accelerators. First, in order to achieve a guaranteed performance they must be over-designed; second, the components, and in particular the cavities, need to undergo an extensive and expensive series of tests before assembly into cryomodules. We plan to address this issue with the following activities:

- Analysis and control of fabrication procedures and processes (and their reduction to a minimal set) that yield consistent high performance (in gradient and $Q_0$)
- Studies of the fundamental material properties of niobium and their correlation to its RF superconducting properties
- New materials

*Activities in Support of Medium Energy Accelerators (12 GeV Upgrade and RIA)*

These accelerators are characterized by cw operation, low beam loading, and modest gradient.

- Cavity geometries for high shunt impedance (*i.e.* low losses)
- Procedures to increase $Q_0$
- Geometries for intermediate $\beta$ (RIA specific)
- Geometries with low sensitivity to microphonics
- RF control of electromagnetic fields in cavities with large Lorentz detuning
- Piezo control of microphonics
- Cost efficient cryomodule design

*Activities in Support of Energy-Recovering Linacs (Light Sources, FELs)*

These accelerators are characterized by large circulating current, but low beam loading.

- Cavity geometries with HOM control and extraction to support 0.1 to 1 A
- Photocathode electron guns for 0.1 to 1 A
- High-current, high-energy energy-recovery demonstration (0.1 A, ~1 GeV)
- RF control of electromagnetic fields in cavities with large Lorentz detuning and random beam loading
- Piezo control of microphonics
- Interaction between high-current beams and electromagnetic fields in superconducting cavities, instabilities, beam halo
- High power RF couplers

*Activities in Support of Linear Colliders*

- Development of fabrication procedures and processes to achieve high gradients
- Development of cost-efficient designs and fabrication procedures

In addition we will continue to use CEBAF and the FEL as test beds for the development of procedures directed toward the improvement of the reliability and availability of SRF accelerators.

### b) Biomedical Instrumentation and Imaging

The Detector Group of the Jefferson Lab Physics Division is a world leader in the development of application-specific scintillator-based nuclear medicine imaging detectors. The group's collaborations with multiple institutions are testament to the contribution the Detector Group is making by leveraging resources at Jefferson Lab to advancing biomedical research*. Biomedical instrumentation and imaging research efforts in the Detector Group of the Physics Division have evolved since 1995 as an adjunct to the group's primary support mission for the nuclear physics program. These efforts are based on the group's expertise in several areas: 1)radiation detector development, including component technologies of pixellated scintillators, position-sensitive photomultiplier tubes and light guides; 2) fast analog detector readout electronics and computer-controlled data acquisition; and 3) Monte Carlo and analytic simulation and tomographic image reconstruction for nuclear medicine imaging. Instrumentation development is aided when necessary by the expertise of the Fast Electronics and Data Acquisition Groups.

The biomedical activities are focused in the area of nuclear medicine, in which images of human or animal physiology are obtained by introducing pharmaceuticals that are labeled with gamma- or positron-emitting radionuclides and then observing the emitted particles. In collaboration with academia, other DOE national laboratories and industrial partners the group has developed and evaluated compact, portable gamma and positron imaging devices as well as hand-held non-imaging intraoperative probes. The goals are to improve understanding of human physiology and disease mechanisms, and, ultimately, to improve patient care. The group's work is currently concentrated in two main areas: 1) dedicated organ imaging for cancer, including breast (scintimammography, positron emission mammography), brain and heart imaging; and 2) high resolution, high sensitivity gamma imaging of small animals. New technology is patented for licensing by industry. The DOE Office of Biological and Environmental Research, Medical Sciences Division has funded the group's detector development projects in the areas of breast imaging, brain imaging and a novel small animal imaging system. In addition, the group is a major party in a recently funded NIH grant to West Virginia University Center for Advanced Imaging.

The DOE Office of Biological and Environmental Research, Medical Sciences Division has funded or is supporting the following projects:

- Breast imaging: "Dedicated Diagnostic Positron Emission Mammography System"
- Brain imaging: "A Compact High Resolution Gamma Camera to Image the Biodistribution of Iodine-131 in Radioimmunotherapy"
- Small animal imaging: "A Novel Apparatus to Perform *In Vivo* Anatomical and Functional Imaging of Radioisotope Labeled Molecules in Non-Anesthetized, Non-Restrained Small Animals"

*Ongoing biomedical partnerships with academic institutions include:

- Department of Radiology, Johns Hopkins University, Baltimore, MD (small animal imaging)
- PET Facility and SPECT Research Group, Department of Radiology, Duke University Medical Center, Durham, NC (positron emission mammography, brain tumor imaging)
- Departments of Biomedical Engineering and Nuclear Medicine, Case Western Reserve University, Cleveland, OH (small animal imaging)
- Department of Radiology and Cardiovascular Division, University of Virginia, Charlottesville, VA (scintimammography, small animal imaging)

- Hampton University Center for Advanced Medical Instrumentation, Hampton, VA (scintimammography)
- Department of Radiology, Virginia Commonwealth University Health System, Richmond, VA (positron emission mammography)
- Departments of Biology, Physics and Applied Science, The College of William and Mary, Williamsburg, VA (small animal imaging)
- Department of Radiology, West Virginia University, Morgantown, WV (positron emission mammography)
- Department of Radiology, George Washington University Medical Center, Washington, DC (scintimammography)
- Department of PET and Nuclear Medicine, Royal Prince Alfred Hospital, Sydney, Australia (small animal imaging)

Collaborations with other DOE national laboratories and industry include:
- Oak Ridge National Laboratory, Oak Ridge, TN (small animal imaging)
- Dilon Technologies, Newport News, VA (scintimammography)

The group's success in biomedical technology development originates from directing its core competencies in detector development for basic nuclear physics research to biomedical problems. Experience gained with the biomedical imaging effort has also benefited the nuclear physics program. For example, the tagged photon beam profiler was built for Hall B using the same position sensitive photomultiplier array technology developed for gamma breast imaging.

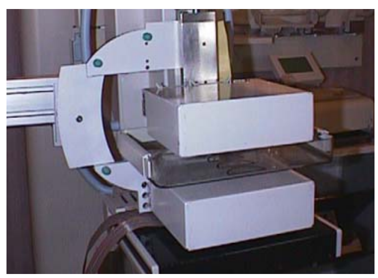


Figure VI-9: Jefferson Lab positron emission mammography (PEM) system used to image metabolically active breast tumors at Duke University Medical Center, shown integrated with an X-ray mammography system.

*Vision and Opportunities*

There are many opportunities for Jefferson Lab in the area of biomedical instrumentation and imaging, especially in nuclear medicine, with its ability to image molecular processes using radiolabeled tracers. Small animal models are vital for understanding human physiology and disease; instrumentation for 3-D small animal gamma imaging is underdeveloped. Multimodality capabilities for combined *in vivo* functional and structural imaging are of increasing interest. Our goal is to continue to design and to develop unique compact devices for radiotracer imaging in humans, small animals and biological systems for physicians and basic biomedical scientists. The near and long term scientific objectives of the group are to leverage the unique technical capabilities of the group and Jefferson Lab to continue to make significant contributions in the areas of biomedical research.†

†Near term (0-5 year) scientific objectives are:
- Develop and evaluate first and second generation high resolution, high sensitivity small animal gamma imagers with animal motion compensation.
- Develop a high resolution brain imager for I-131 radioimmunotherapy applications.

- Develop positron emission mammography and scintimammography imagers for guiding breast biopsy.
- Develop breast imaging systems with dual-modality (single gamma and positron) and double-sided (single gamma) capabilities.
- Develop compact, portable cardiac imagers (gamma and positron) for emergency rooms and intensive care suites.

Longer term (5-10 year) scientific objectives are:

- Develop high sensitivity nuclear medicine imaging systems with sub-millimeter resolution.
- Develop other organ-specific detectors (e.g. prostate) for patient imaging.
- Develop multimodality imaging systems that incorporate non-nuclear detectors and imaging capabilities (e.g. optical, X-ray, MRI, MEG).
- Develop detectors and imagers for non-nuclear biomedical imaging applications.

## E. Free Electron Laser (FEL)

### a) Work for DOD

#### *Higher Power FEL Upgrades (100 kW )*

One of the primary attractions of the configuration of the Jefferson Lab FEL is the affordability of power scaling. The 10 kW FEL upgrade will provide ten times more optical power for approximately twice the capital investment compared to the original 1 kW Demo FEL; thus the net cost of providing light is reduced by approximately a factor of five. This favorable power scaling continues as this type of FEL is scaled in power to the 100 kW range and beyond. Industrial stakeholders in the FEL program and the defense community have interests in pushing FEL technology beyond 10 kW. For industrial applications, studies by our Laser Processing Consortium (LPC) partners indicate that high value-added processing such as micro fabrication is commercially attractive at the 10 kW level, and at the 100 kW level, high volume processes such as surface modification of metals and polymers become attractive. The defense community has made large R&D investments over the last three decades in high-energy lasers for directed energy applications. Only an FEL offers the option of tunability, short-pulse time structures, and all electric drive. Until the FEL Demo device, FELs had been written off as an option for directed energy because of the lack of a development path to high average power. The Navy continues to be an important stakeholder for the FEL program because of the ability to tune IR FEL radiation to the windows in the atmospheric spectrum where there is minimal absorption. Jefferson Lab expects to continue to partner with the ONR and the Naval Sea Systems Command in the development of FEL technology beyond the 10 kW range of the current FEL upgrade. In response to the interest of the Navy and our industrial partners, we have proposed point designs for several 100 kW versions of the IR Demo FEL that could be initiated as construction projects shortly after we complete benchmarking the performance of the 10 kW IR FEL upgrade project in FY03. One option involves relatively straightforward and modest hardware upgrades to the 10 kW device: (1) increasing the injector; (2) replacement of the first two FEL cryomodules with CEBAF energy upgrade modules; and (3) increased power handling capability for the IR optical cavity mirrors and energy recovery dump. The highest power levels would be of interest for materials damage, materials processing, and gas dynamics applications. The second option for a 100 kW FEL involves a stand-alone device where all hardware is optimized for the most cost effective production and handling of 100 mA and higher accelerator currents. This would involve the use of lower frequency SRF cavities and RF systems such as those currently being developed at Jefferson Lab and Los Alamos National Laboratory for DOE's Spallation Neutron Source at Oak Ridge National Laboratory. This option offers the opportunity to customize a 100 kW or higher power facility for industrial, scientific or defense applications. Depending on expected continuing development of the brightness of the Jefferson Lab photocathode electron sources, a 30-40 kW UV FEL could be incorporated into either higher power IR FEL system to expand both the scientific and industrial utility.

## b) Science Program

### *Basic Research with Light Sources*

The Free Electron Laser (FEL) at Jefferson Lab is three orders of magnitude brighter than any table-top sub-picosecond laser and as such marks a watershed opportunity for new science at the frontiers of ultrafast and high field phenomena. A basic research program using light sources has been under development since 1999 to diversify Jefferson Lab from the exclusively nuclear physics domain to incorporate multi-disciplinary, next-generation light source research activities. These emerging research programs are scheduled on the FEL on the basis of advice from a Program Advisory Committee (PAC). With the FEL Facility upgrade in FY02, attention is being paid to the science identified in the October 2000 workshop "Scientific Frontiers with Accelerator-Based Lasers," and on a 10 page proposal submitted in January 2003 to DOE-BES. These guide the evolution of the FEL into a comprehensive user facility for basic and applied research with light. In particular the Basic Energy Sciences Advisory Committee described the science as "mission critical" and is organizing a series of workshops to define the new scientific opportunities which lie in the following areas:

1. Real-time and spectroscopic chemical dynamics (esp. in dilute systems)
2. Fabrication and characterization of new materials (high power / tunability)
3. Real-time dynamics of biological processes (tunability / short pulses)
4. Non-linear infrared surface spectroscopy (high power)
5. Fundamental limits in atoms and molecules (high-field ultra-fast attophysics)

We have further established scientific teams and leaders to prepare for and take advantage of the opportunities afforded by the upgraded FEL in the following areas:.

1. Biophysics (Bob Austin, Princeton)
2. PLD (Anne Reilly, CWM)
3. Nano (Brian Holloway, CWM)
4. Atomic, Molecular and Optical (Bob Jones, Brookes Pate, UVA)
5. Condensed Matter Dynamics (Gunter Luepke, CWM)
6. Chemistry (Ian Harrison, UVA)
7. THz (Al Sievers, Cornell, Tatiana Globus, UVA, X.-C. Zhang, RPI)

### *Extended Capability in the FEL User Facility*

By FY04, the present (FY00-02) upgrades of the FEL are scheduled to be complete and operational. These upgrades will provide powers above 10 kW in the mid infrared (2-14 microns) and approximately 2 kW in the visible and ultraviolet wavelengths extending to 300 nm. In addition, we expect to incorporate extended wavelength agility by adding broad band mirrors in the optical cavities; and options for increased flexibility in the laser time structure by adding hardware for single and multiple pulse streams with pulse energies varying from the millijoule to microjoule range.

### *Extension to the X-ray Regime*

The FEL Facility also will provide X-ray radiation using two sources that are being incorporated into the Facility during the FEL upgrade period. The IR Demo FEL produced a source of high flux (~$10^8$ photons/s), ultra short pulse (300fs) X-rays (in the 5-40 keV range) by Compton scattering of the circulating IR laser radiation with the input electron beam. The FEL upgrade will provide a 10 – 50x improvement in brightness and an increased energy range to above 400 keV. Because the Compton X-rays are synchronized with the FEL light, two color experiments are possible (also known as pump-probe experiments) where one color of light is used to initiate a chemical or physical reaction and the synchronized second color is used to follow the progress of the reaction with sub-picosecond time resolution.

***Extension to the Terahertz Regime***

The FEL Facility will be capable of providing an intense source (>1W/cm$^{-1}$ ) of partially coherent long wavelength (terahertz) radiation that is 100,000 times brighter than any other broadband source in the world. The THz light is obtained by extraction of the synchrotron radiation from the chicane bending magnet immediately prior to the wiggler. The radiation was characterized on the IR-Demo-FEL and funding was received from the ARO to transport THz beam and set up a dedicated facility. This will be accomplished in FY04. The high power offered by the JLab FEL is ideal for imaging and for driving non-linear phenomena. In particular, there is significant scientific and technical interest in terahertz radiation for solid-state physics, medicine and biology and in homeland security areas such as portal screening, de-mining, explosive and biological agent detection.

## 2. INFRASTRUCTURE

### A. Administrative Practices

Jefferson Lab's Administration Division continues to undertake initiatives that add value to the Laboratory and are responsive to the expressed needs of both internal and external customers. The 2003 Administrative Peer Review Panel confirmed this value, agreeing with its predecessors that, "The quality of the support provided by the Administration Division continues to be exceptional."[1] Focusing on best practices and continuous improvement, we have leveraged our limited resources in support of Jefferson Lab's vision and goals. While we believe that we are close to the optimal balance of administrative support to direct research dollars, we continue to monitor our performance and deliver cost effective services to the Laboratory.

*Performance-Based Contracting*

Through our performance-based contract with DOE, we establish and commit to clear objectives and measurable goals that derive from Jefferson Lab's mission. These high-level objectives in turn comprise the source from which staff objectives flow, thereby ensuring that staff remain focused on work that is aligned with the Laboratory's purpose. Optimal performance by individuals, who are held accountable through management, contributes directly to achieving the Laboratory's goals. Thus the performance-based contract facilitates the self-assessment and performance management processes that engender continuous improvement at Jefferson Lab.

The framework within which our business and administrative functions are assessed is Section 6 of Appendix B of our contract. The evaluation is based on a key performance measure (an annual peer review by a panel of Chief-Administrative-Officer-equivalents from private industry, national laboratories, DOE, and the scientific community) along with a set of secondary measures. The peer review process, supplemented by the DOE Site Office's ongoing operational awareness, has been determined by DOE to be an innovative and effective approach for reviewing and improving business and administrative performance. Our overall

[1] Administrative Peer Review of the Thomas Jefferson National Accelerator Facility, March 3-5, 2003

FY02 assessment resulted in a rating of 93.5 out of 100 points for an adjectival rating of *Outstanding* in Business and Administrative Practices.

*Administration Division Office*

The Administration Division Office is responsible for guiding and directing the Division, which includes Business Services, Human Resources and Medical Services, and Facilities Management, toward fulfillment of Jefferson Lab's mission. In addition to providing leadership and coordinating Division initiatives, the Division Office works to ensure that Department activities are in concert with the Laboratory's programmatic goals. It endeavors to secure required resources through the Laboratory's budgeting process, reports and negotiates contract performance metrics, performs quality assurance (QA), and facilitates both continuous process improvement throughout the Division and communication with other Divisions. In addition, line managers in each of the departments are responsible for integrated safety and security management, and the Division Office oversees these efforts.

*Future Improvement Goals and Initiatives*

Administrative practices at Jefferson Lab continue to focus on high-value, cost-effective performance results monitored through a strong and well-established self-assessment program. The high level goals and initiatives listed below are supplemented by the more detailed ones presented in the subsequent administrative functional area descriptions.

People — A comprehensive approach for attracting, compensating, developing, and retaining a quality workforce will be propagated Laboratory-wide. Areas of current and planned focus include the performance appraisal system, effective team, career, and management development, and succession planning.

Processes — Modern information technologies and process improvements are being applied to publication approvals, space and storage management, on-site deliveries, telephone usage and systems, travel requests and expenses, applicant tracking and human resources information systems, and business-to-business applications (two million items on-line to date) to name a few. In all cases, the metric employed is that there must be a clear benefit to the Laboratory's programmatic activities and goals as well as a cost benefit.

Facilities — The Strategic Facilities Plan prepared in FY00 and revised this year lays out a programmatically driven ten-year plan for maintenance and upgrades of existing facilities, removal of some older facilities, and construction of new facilities. The goal is to aggressively implement this plan consistent with the on-going evolution of the programmatic activities at Jefferson Lab.

## B. Human Capital

The Human Resources Department is fully integrated with Jefferson Lab's mission and committed to providing quality customer service based on expertise, innovation and integrity. HR supports Jefferson Lab's programmatic initiatives through a variety of functional units including employment, compensation and benefits, employee relations, training and performance, and medical services.

Human Resources, in partnership with the Laboratory's senior management team, has taken a comprehensive approach to meeting the needs of the employee while simultaneously meeting the programmatic needs of Jefferson Lab. To that end, HR continuously creates, enhances and evaluates programs that assist in attracting, compensating, developing, and retaining a healthy and productive quality workforce.

In support of the Laboratory's workforce and succession planning efforts, HR developed a Lab-wide Staffing Plan and includes in its review of all Lab performance appraisals notes on staff members viewed as having high potential by their management chain.

Working closely with a cross-divisional Review Committee, HR has taken the lead in updating and restructuring the Laboratory's Administrative Manual. When complete, the online Manual will contain a streamlined Policy Section linked to related operational procedures and will provide user-friendly information to both managers and staff members.

More training programs have been made available on the web in 2003 and this well received trend will continue into 2004 and beyond.

Advances in technology (a new HRIS that integrates with the Laboratory's financial systems and a new applicant tracking system) have increased our effectiveness and efficiency as well as expanded the services provided.

Medical Services works in partnership with other Human Resources staff, and safety and industrial hygiene staff to enhance the Laboratory's wellness and prevention efforts. Medical Services also supports the medical imaging activities of the Laboratory's Detector Group and the Free Electron Laser (FEL) Group during their biologic research activities. Ongoing goals include contributing to the Laboratory's healthcare cost containment program and enhancing services to the Laboratory and its staff without increasing costs.

### *Laboratory Personnel*

The success of Jefferson Lab's scientific program depends on its ability to attract and retain a diverse world-class workforce. As of September 30, 2002, the SURA/Jefferson Lab workforce was comprised of 621 employees plus 17 Commonwealth of Virginia employees. Table VI-6 shows full and part-time Laboratory staff composition. Between the end of FY01 and the end of FY02, the percentage of staff with Ph.D.s, master's degrees, or bachelor's degrees increased from 56% to 57%.

Jefferson Lab is a relatively small laboratory with many one-of-a-kind positions. This creates the staffing challenges of recruiting, selecting, and retaining individuals with highly specialized scientific, technical and managerial skills. The Laboratory maintains an international recruiting program utilizing targeted advertising, professional conferences, collaborative working arrangements, scientific and technical journals, and university contacts as a means of identifying potential candidates for key positions.

The Laboratory also has programs to train, update, and enhance the capabilities of existing staff. These programs include on-site courses (classroom and CBT), on-the-job training, attendance at professional conferences and workshops, skill-enhancement training, and specialized training. Tuition assistance is available for employees in job-related degree programs.

### *Affirmative Action and Equal Employment Opportunity*

Jefferson Lab values and encourages the individual uniqueness and differences that a diverse workforce provides. To create a diverse culture, the Laboratory continuously strives to expand recruiting efforts to include international recruiting, partnerships with Historically Black Colleges and Universities (HBCUs) and Hispanic Speaking Institutions (HSIs), direct recruiting through a variety of minority publications and web sites, participation in minority-targeted career fairs, and personal networks within influential minority organizations.

The Affirmative Action Profile (Tables VI-7 and VI-8) shows that Jefferson Lab staff increased by 3.3% from the end of FY01 to the end of FY02. During this period, the number of minority staff increased from 105 to 116 (10.5%) and the number of females increased from 166 to 177 (6.6%). HR and Jefferson Lab management are focused on continuous improvement in identifying and hiring additional minority staff.

*Future Improvement Goals and Initiatives*

Recommend workforce planning strategies based on the Laboratory's programmatic needs.

Recommend additional enhancements to the Performance Appraisal System and other avenues for providing feedback in support of a fully integrated communication, appraisal, staff development and succession planning process.

Meet hiring/promotion/retention goals in Affirmative Action job groups currently underutilized, increase the number of minorities and females in our candidate pool, and increase the number of minorities and females in the Jefferson Lab workforce.

Continue working toward full partnership with the Laboratory's staff in attaining programmatic goals with talented, productive employees in a satisfying, high-morale environment.

**Table VI-6**
**Laboratory Staff Composition**
**as of September 30, 2002**
**(Highest Degree)**

| **Occupational Codes** | **Total #** | **Ph.D # (%)** | **MS/MA # (%)** | **BS/BA # (%)** | **AS/AA # (%)** | **Other # (%)** |
|---|---|---|---|---|---|---|
| Professional Staff | | | | | | |
| Scientists | 130 | 88 (68%) | 12 (9%) | 27 (21%) | 1 ( 1%) | 2 (2%) |
| Engineers | 152 | 0 (0%) | 35 (23%) | 52 (34%) | 23 (15%) | 42 (28%) |
| Mgmt & Admin | 133 | 31 (23%) | 32 (24%) | 46 (35%) | 9 ( 7%) | 15 ( 11%) |
| Support Staff | | | | | | |
| Technicians | 135 | 0 (0%) | 4 (3%) | 18 (13%) | 40 (30%) | 73 (54%) |
| All Others | 71 | 0 (0%) | 0 (0%) | 6 (8%) | 9 (13%) | 56 (79%) |
| **Totals** | **621** | **119 (19.2%)** | **83 (13.4%)** | **149 (24.0%)** | **89 (13.2%)** | **188 (30.3%)** |

Note: Regular and term lab employees and SURA employees are included in Tables VI-6, VI-7 and VI-8. Students, casuals, state employees and contract labor are excluded from Tables VI-6, VI-7 and VI-8.

## Table VI-7
### Affirmative Action Profile
### Full and Part-time Employees (Jefferson Lab and SURA)
### as of end of FY2001 (9/30/01)

| Occupational Codes | Total | | Minority Total | | White | | Black | | Hispanic | | Native American | | Asian/Pacif. Islander | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| Professional Staff | | | | | | | | | | | | | | |
| Scientists/ Engineers | 226 (87%) | 35 (13%) | 36 (14%) | 5 (2%) | 190 (73%) | 30 (11%) | 10 (4%) | 3 (1%) | 5 (2%) | 0 (0%) | 1 (0%) | 0 (0%) | 20 (8%) | 2 (1%) |
| Mgmt & Admin | 71 (59%) | 50 (41%) | 8 (7%) | 7 (6%) | 63 (52%) | 43 (36%) | 1 (1%) | 6 (5%) | 3 (2%) | 0 (0%) | 0 (0%) | 0 (0%) | 3 (2%) | 1 (1%) |
| Support Staff | | | | | | | | | | | | | | |
| Technicians | 115 (82%) | 26 (18%) | 22 (16%) | 5 (4%) | 93 (66%) | 21 (15%) | 16 (11%) | 3 (2%) | 3 (2%) | 1 (1%) | 0 (0%) | 0 (0%) | 3 (2%) | 1 (1%) |
| All Other | 20 (26%) | 58 (74%) | 5 (6%) | 17 (22%) | 15 (19%) | 41 (53%) | 5 (6%) | 17 (22%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Totals | 432 (72%) | 169 (28%) | 71 (12%) | 34 (6%) | 361 (60%) | 135 (22%) | 32 (5%) | 29 (5%) | 11 (2%) | 1 (0%) | 1 (0%) | 0 (0%) | 26 (4%) | 4 (1%) |

## Table VI-8
### Affirmative Action Profile
### Full and Part-time Employees (Jefferson Lab and SURA)
### as of end of FY2002 (9/30/02)

| Occupational Codes | Total | | Minority Total | | White | | Black | | Hispanic | | Native American | | Asian/Pacif. Islander | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| Professional Staff | | | | | | | | | | | | | | |
| Scientists/ Engineers | 241 (85%) | 41 (15%) | 40 (14%) | 8 (3%) | 201 (71%) | 33 (12%) | 12 (4%) | 4 (1%) | 5 (2%) | 1 (0%) | 1 (0%) | 0 (0%) | 20 (7%) | 3 (1%) |
| Mgmt & Admin | 76 (57%) | 57 (43%) | 9 (7%) | 9 (7%) | 67 (58%) | 48 (36%) | 2 (2%) | 8 (6%) | 3 (2%) | 0 (0%) | 0 (0%) | 0 (0%) | 3 (2%) | 1 (1%) |
| Support Staff | | | | | | | | | | | | | | |
| Technicians | 111 (82%) | 24 (18%) | 23 (17%) | 4 (3%) | 88 (65%) | 20 (15%) | 16 (12%) | 2 (1%) | 3 (2%) | 1 (1%) | 0 (0%) | 0 (0%) | 4 (3%) | 1 (1%) |
| All Other | 16 (23%) | 55 (77%) | 4 (7%) | 19 (27%) | 12 (17%) | 36 (51%) | 4 (6%) | 19 (275%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Totals | 444 (72%) | 177 (28%) | 76 (12%) | 40 (6%) | 368 (59%) | 137 (22%) | 34 (6%) | 33 (5%) | 11 (2%) | 2 (0%) | 1 (0%) | 0 (0%) | 27 (4%) | 5 (1%) |

## C. Business Services

The Business Services Department (BSD) plays a strategic role in service of the Laboratory staff and scientific community. Inclusive in this role is our responsibility to provide effective and efficient Procurement and Staff Services support through the use of performance-based methodologies and careful internal controls that lead to innovative best-in-class business practices. Some examples of these business practices include: a proactive socioeconomic procurement program that has received numerous awards from the DOE and regional Business Agencies; expansion and enhancement of the web-based E-commerce system for site wide use; the development of a web-based vendor database to expand our Small Business outreach efforts and to reach a larger population of vendors; comprehensive logistical support services for conferences, meetings and Laboratory special events; and the planning and first-phase implementation of the SURA funded capital improvement campaign for the SURA Residence facility.

*Future Improvement Goals and Initiatives*

Business Services' near-term and long-term strategies for meeting our commitment to support the accomplishment of the Lab's mission and high-level objectives are outlined as follows:

Near-Term

- Review Technical Stockroom material acquisition and inventory process and products for streamlining opportunities.
- Complete implementation of the new Web-based Vendor File and Information System to improve customer support and access to sources.
- Initiate process review of the P-Card program to identify potential process improvements.
- Review the integrated conference management system to identify opportunities for optimizing the efforts associated with full-range comprehensive conference support.

Long-Term

- Continue efforts to fully network and streamline copier services throughout the Lab complex.
- Manage completion of the capital improvement campaign for the SURA Residence Facility.
- Explore feasibility of alternative payment methods for cafeteria users.
- Explore additional opportunities to utilize e-commerce as a mechanism for minimizing the Technical Stockroom on-hand inventory.

**Table VI-9**
**Subcontracting and Procurement**

| **($ in Millions -- Obligated)** | **FY 2002** | **FY 2003** | **FY 2004** |
|---|---|---|---|
| Subcontracting and Procurement from: | | | |
| Universities | 2.5 | 2.7 | 2.8 |
| All Others | 43.7 | 29.7 | 34.2 |
| Transfers to Other DOE Facilities | 0.0 | 0.0 | 0.0 |
| **Total External Subcontracting and Procurements** | **46.2** | **32.4** | **37.0** |

**Table VI-10**
**Small and Disadvantaged Business Procurement**

| ($ in Millions – Budget Authority) | FY 2002 Goal | FY 2002 Achieved | FY 2003 Goal |
|---|---|---|---|
| Procurement from S&DB | 2.6 | 4.2 | 1.7 |
| Percent of Annual Procurement | 6% | 9.5% | 6% |

## D. Site, Facilities and Infrastructure Management

### *Site and Facilities Description*

The Jefferson Lab site, located in Newport News, Virginia (Figure VI-10), includes 162 acres owned by the DOE and eight acres owned by the Commonwealth of Virginia. SURA owns 44 acres adjacent to the site. The facilities include the CEBAF accelerator complex serving three experimental halls, the FEL Facility, a central office building (CEBAF Center), two major laboratory buildings, and various other support structures totaling 738,258 sq ft (see Table VI-12). Included are 43,818 square feet of office trailers and 21,160 square feet of storage containers. The replacement value of conventional facilities and utilities is $197 million (see Table VI-13). Figures VI-11, VI-12, and VI-13 show age, condition, and use of space.

The accelerator enclosure is a 7/8-mile racetrack-shaped concrete tunnel located 25 feet underground. The tunnel houses a 65 MeV injector, two 600 MeV linacs—one in each straight section of the racetrack—and six kilometers of beam transport lines. The CHL, a 75,000 liquid liter, 4800-watt refrigerator plant located in the interior of the racetrack, supplies liquid helium at 2 K to the accelerator for the ultracold needed for superconducting operation. The Machine Control Center houses the computer systems that control and monitor accelerator operations. The FEL generates high power infrared light using the accelerator technology, and shares the CHL.

The experiment area consists of three large domed concrete halls, partially underground and mounded with earth for shielding. The floors are about 36 feet below existing grade, and the domes extend up to 45 feet above grade. Hall A is 174 feet in diameter, Hall B 98 feet, and Hall C 150 feet. The major support building for the experimental physics area is the Counting House, where physicists control and monitor the experimental runs. Some 35 support structures in the accelerator/experimental area complement these major structures.

Major structures on the remainder of the site provide administrative space, as well as laboratory and technical support facilities. CEBAF Center provides office space, an auditorium, and a cafeteria, and houses the computer center. The Experimental Equipment Laboratory (EEL) provides light laboratory space for detector fabrication and machine shops. The Test Lab is a high-bay building housing major component assembly, test, and maintenance functions.

The City of Newport News has constructed the Applied Research Center (ARC) building on an 11-acre site directly adjacent to the Laboratory. The 121,000 sq ft structure, completed in the spring of 1998, provides office and light laboratory space for lease to qualified tenants. Jefferson Lab has leased 42,492 sq ft. Five local collaborating universities also have leased space. The ARC is the anchor for the city's planned 200-acre Jefferson Center for Research and Technology, a technology park for high technology R&D and production activities.

The Facilities Management Department manages a facilities condition assessment program that utilizes a multidisciplinary team including an architect, engineers, EH&S personnel, and building occupants to evaluate the functional condition and maintenance needs of each facility. These evaluations are performed on a three-year cycle. Results of the assessment are prioritized and either handled as a corrective work request or programmed for future General Plant Project (GPP) funding. This condition assessment program is in its second year of use. The overall condition of the buildings, utilities, and other structures is adequate; however the size of the maintenance backlog (deferred maintenance) is growing. For example, the low conductivity water system usage has reached the limits of its current capacity and there is a need to install additional emergency generator capacity. There are currently no excess facilities.

### *Site and Facilities Trends*

The following is a summary of the facilities changes that have occurred over the last two years:

Change in total square footage:

| | |
|---|---|
| Hall C Shed | + 540 sq ft |
| Bldg SF Correction (Polylining) | + 67,396 sq ft |
| Trailer SF Correction (Polylining) | - 6,393 sq ft |
| Container SF Correction (Polylining) | + 240 sq ft |
| Storage Containers | + 800 sq ft |
| Storage Tent | +1,200 sq ft |
| Lease SF Correction (Polylining) | + 456 sq ft |
| Change in space leased off site | -1,942 sq ft |

In FY02, the annual maintenance performed was over $3 million and was less than needed to keep the Laboratory's conventional facilities sound and capable of supporting operational requirements for the long term. This amounted to about 1.6% of the Replacement Plant Value of the facilities (buildings, utilities, roadways). Actual maintenance costs include indirect and direct funded supplies, maintenance, and repair contracts, and a portion of indirect funded Facilities Management Department salaries.

FY03 maintenance funding is slightly above the level for FY02. The current value of our deferred maintenance is $12.6M.

### *Site and Facilities 10-Year Plan*

Plans and budgets are being developed for the accelerator energy upgrade to 12 GeV. This effort will involve significant machine alterations and civil construction including a new experimental hall, expansion of the CHL building, a technical support building, and other facilities to support the increased energy operations. An addition to the FEL building is currently being planned and budgeted. This addition, when complete, will house lithophotography equipment and additional research labs.

We are currently in the process of updating our Strategic Facilities Plan for FY04-FY13, which outlines facilities requirements over the next ten-year period. The plan identifies projects to maintain existing facilities, make energy savings alterations, provide office and technical space for staff per projections, eliminate substandard storage space and structures at the end of their useful life, and eliminate leases that do not lead to building ownership. Details of the GPP and Line Item Projects are located in Appendix C.

The immediate need is for a larger computing center and office space to replace inadequate office trailers and to support a growing number of program staff and users, storage to replace inadequate storage containers, technical space, and relocation of Shipping & Receiving. Among the remaining critical needs is a substantial upgrade in the capacity, redundancy, and monitoring of the HVAC for the accelerator and experimental hall areas. Roads and parking areas in the accelerator area need to be completed. Aging equipment in the older buildings on site requires replacement to ensure reliability.

Site development continues to be guided by the area themes identified by Jefferson Lab's Site Development Plan, written in 1988, revised in 1993, and currently being updated. An important principle of this plan is to co-locate compatible functions and to reserve the maximum amount of space near the accelerator site for future additional end stations or technical facilities benefiting from proximity.

### *Capital Investment Requirements*

Historically, Jefferson Lab has been provided $300K annually in General Plant Project (GPP) funds. Beginning in FY02 the GPP funding level has increased to $500K annually. The GPP requirement identified in the Budget Submission for FY05 is $3.6M for specific projects. The Laboratory is not allocated any General Plant Equipment funds. The use of alternative financing sources such as 3$^{rd}$ Party Financing is being investigated for a Technical Support Building and a Shipping and Receiving Building.

### *Assets Management*

Condition Assessment surveys are conducted for all facilities on a three year cycle by a cross functional team. In addition to looking at the specific condition of the facilities, utilization of equipment, property, and space are also included. In conjunction with our annual inventory of sensitive property, management also identifies excess equipment, which is processed for disposal.

The below-indicated square feet of trailer and container space will become excess property as a result of completion of the indicated planned line item and GPP funded projects (Table VI-11).

| | |
|---|---|
| CEBAF Center Addition Phase 1 | (22,000 sq ft) |
| Technical Support Building | ( 9,000 sq ft) |
| Storage Building Phase 1 | (14,000 sq ft) |

### *Energy Management and Sustainable Design*

Four projects have been developed for construction under a Utility Incentive Program. Three have been completed and the fourth is in the final stages of construction. In addition to the capital improvements that will result in energy savings, two of the projects will replace aging mechanical equipment more than 37 years old. The four projects are:

- Replace VARC HVAC
- Build a Central Chiller Plant to replace Test Lab and accelerator service buildings HVAC
- Upgrade CEBAF Center Controls
- Upgrade lighting in various buildings

Energy evaluations have been conducted on a number of our facilities and energy savings projects identified. The four projects listed above are the largest of the currently planned projects. Additional utility metering is being installed to allow tracking of energy consumption at the building level. Funding availability is the factor limiting the level of efforts in this area. None of our buildings has currently achieved Energy Star status.

Jefferson Lab is incorporating sustainable design principles into our current operations and construction activities at several levels. The planning for all new construction projects is reviewed in the context of the National Environmental Policy Act process as to the impact of an action on the natural, human, and social environments. Designs include provisions for energy and life cycle cost goals. Construction that disturbs physical land requires submission of erosion control and safety/spill prevention plans by the construction subcontractor as appropriate for the project. A requirement for recycling specified products has been added to all new facility construction contracts. Hazardous waste management is prescribed in our Laboratory Environmental Health & Safety Manual.

### *Summary*

Jefferson Lab has incurred modest infrastructure spending since most facilities were new when the Lab was established. However, as the facilities have aged, appropriate funding levels are required to maintain or reduce the level of deferred maintenance.

The greatest infrastructure need is for additional utility capacity for currently planned experiments and for new facilities to support existing needs. The scientific program has progressed from commissioning of the base equipment to large, complex programs stressing the capacity of installed utilities and technical development and set-up space. During initial construction the Lab was not permitted to include adequate space for anticipated User needs. As User participation has grown, those facilities have also been stressed.

**Table VI-11**
**Facilities Plan Funding Needs FY2003-FY2009 (AY M$)**

| ($ in Millions) | GPP Projects | Line Item Projects | Operating Expense Projects Including Rent | Indirect Funded Maint. |
|---|---|---|---|---|
| FY2004 Target | 0.5 | 3.9 | 1.6 | 3.1 |
| FY2005 Required | 3.6 | 5.1 | 1.5 | 3.2 |
| FY2006 Required | 3.7 | 0.0 | 1.7 | 3.6 |
| FY2007 Required | 3.8 | 0.8 | 1.3 | 3.8 |
| FY2008 Required | 3.9 | 7.1 | 1.3 | 4.2 |
| FY2009 Required | 4.0 | 8.0 | 1.3 | 4.4 |
| **Total Facilities Plan** | **19.5** | **24.9** | **8.7** | **22.3** |

Note: This chart includes facilities that are funded or are being requested to be funded by DOE. Details of the GPP and Line Item Projects are in Appendix C of this Institutional Plan.

**Figure VI-10 Site Plan**

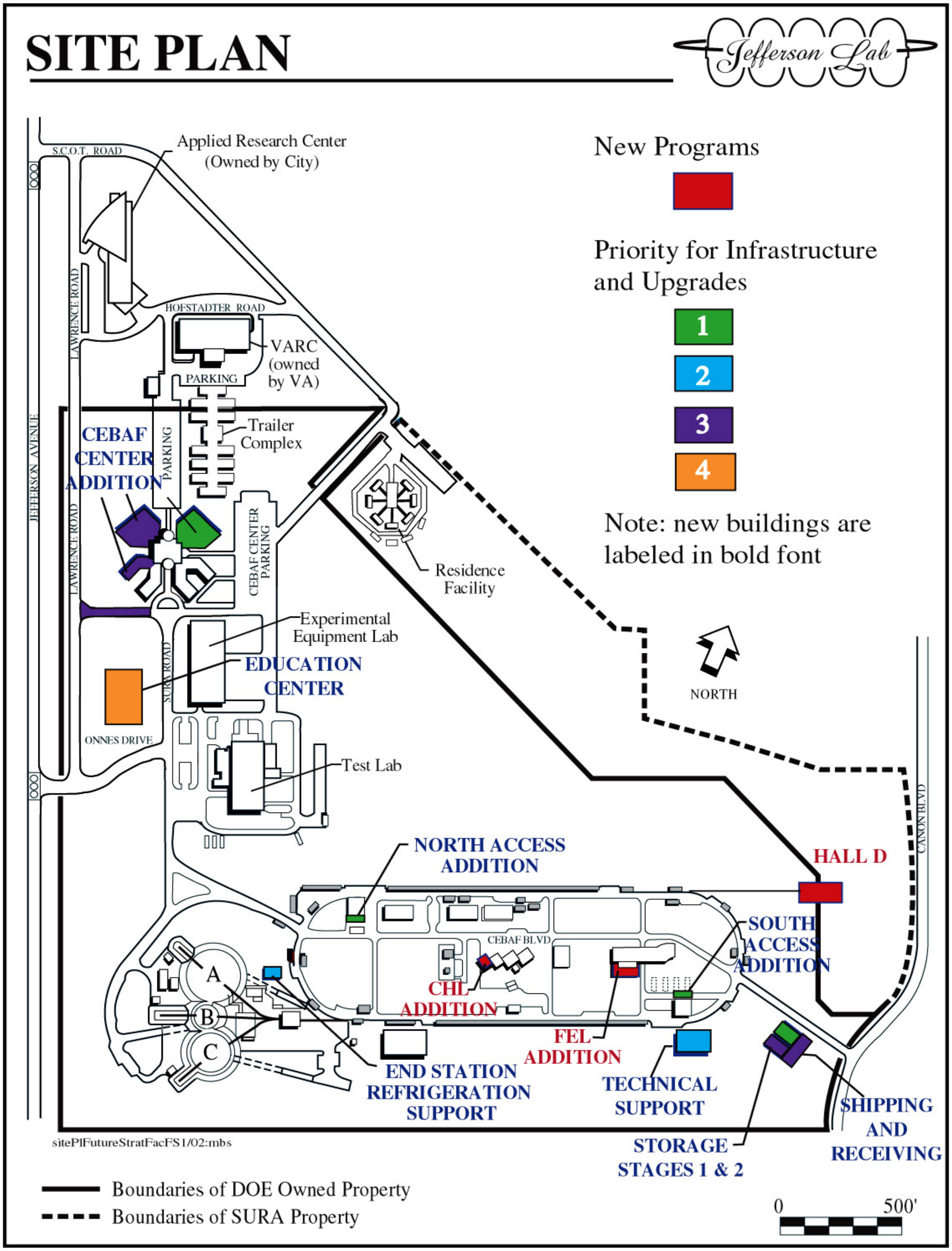


**Table VI-12**
**Laboratory Space Distribution**

| Location | Area (Sq. Ft.) |
|---|---|
| Main Site | 684,872 |
| Leased -Off Site | 53,386 |
| | 738,258 |

**Table VI-13**
**Facilities Replacement Value (FY02 M$)**

| Facility Type | Replacement Value |
|---|---|
| Buildings | 184 |
| Utilities/Roadways | 13 |
| Accelerator Technical Systems | 315 |
| Experimental Equipment | 197 |
| TOTAL | 709 |

**Figure VI-11**
**Age of Laboratory Buildings (Years)**

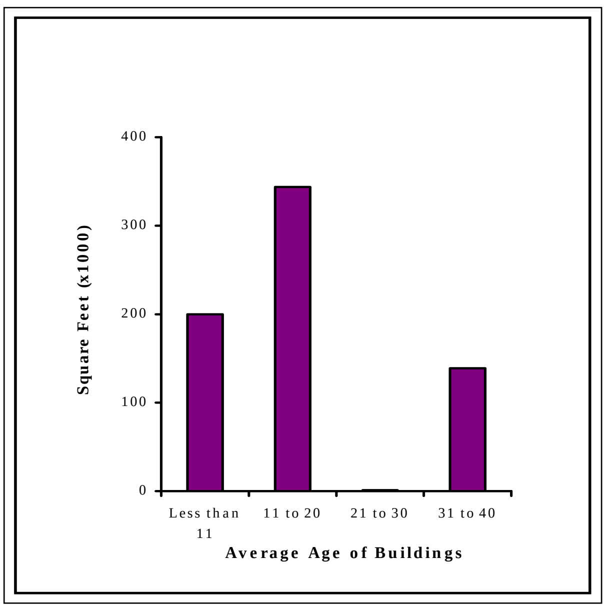



**Figure VI-12**
**Condition of Laboratory Space**

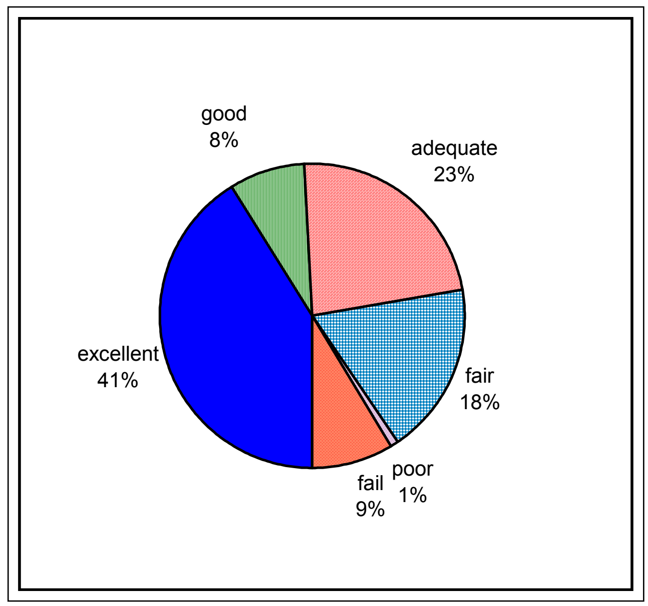
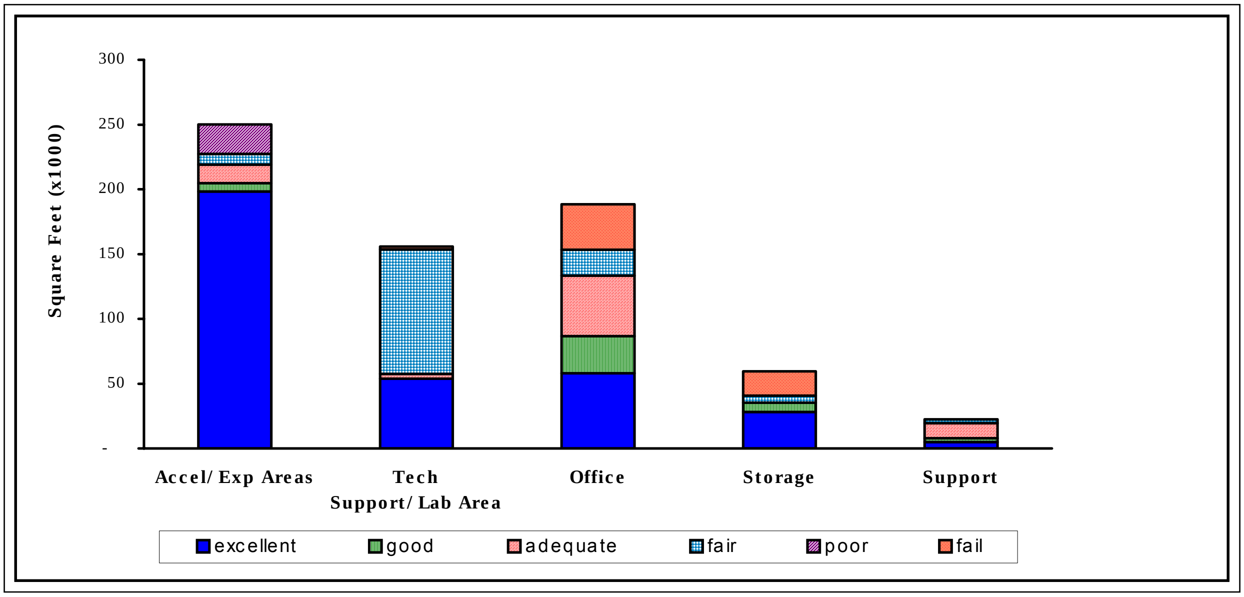


**Figure VI-13**
**Use and Condition of Laboratory Space**




## E. Physical and Cyber Security

### *Physical Security*

Jefferson Lab is a low-hazard, non-nuclear accelerator facility chartered to conduct unclassified research into the fundamental nature of matter. As such the Laboratory has no classified material, no special nuclear material, no biological select agents, and no facilities designated as critical to the national interest. The Laboratory is categorized as a "Property Protection Facility," the lowest level of security consideration authorized at any DOE facility. The core technologies used to design and operate the accelerator and the FEL or those related to use of the electron beam for research are available in open literature and are not considered "sensitive" national security technologies. The Jefferson Lab Technology Review Committee (JLTRC) monitors activity (Cooperative Research and Development Agreements, Work For Others, and User Facility Agreements, etc.) which could potentially generate proprietary or "export control" sensitive information and technologies. This committee is chaired by the Technology Transfer Manager and includes members with technical, legal and procurement expertise. The JLTRC and Jefferson Lab management recognize that naval and industrial interest in the FEL facility may lead to the development or use of sensitive technology or information at Jefferson Lab. Anticipating that possibility, the Jefferson Lab is implementing a "graded" approach to FEL security that includes a staffed security gate, building access control, and a separate experiment room access control system.

Jefferson Lab uses Integrated Security Management consisting of both a centralized element in its management structure and a decentralized element in the assignment of security as a line management responsibility. Security focuses on providing protection of personnel, property, and information (i.e. cyber, business and personnel sensitive).

The Laboratory Director has full responsibility for security at Jefferson Lab and meets quarterly with key security staff to discuss collaborative development of security policies.

Implementation of security and counterintelligence has been delegated to the Associate Director for Administration. These closely related functions are managed centrally in the Facilities Management Department, except for cyber security, the central portion of which is implemented by the Computer Center, and business and personnel sensitive information that is managed by the Business Services Director and Human Resources Director respectively. Responsibilities for security and counterintelligence are clearly delineated in Jefferson Lab's DOE approved Security, Personal Property Management, and Export Control Plans and the Cyber Security Protection Plan. Additionally, Jefferson Lab has a current DOE "Facility Approval and Registration of Activities." "Foreign Ownership Control or Influence" determination are not applicable. Select contractor staff in leadership and management positions have DOE clearances sponsored by the Office of Science in order to share classified threat information.

A standard 9-foot chain link fence encloses the Accelerator, FEL, Experimental Halls and Central Helium Liquefier (CHL). These facilities are accessible only through a continuously staffed gate. Two roving patrols monitor the site 24-hours-a-day. The main "campus" is not fenced and is open during normal work hours. Buildings are locked or access controlled. After hours, locked gates block off all but the main entrance road.

Jefferson Lab has installed a personnel badging system, Central Alarm Notification System (CANS), to enhance our ability to provide access control for all entrances to and egresses from the Accelerator Site, and access to the main buildings on the campus portion of the facility. This system is integrated with the Laboratory's central personnel and visitor databases.

### *Cyber Security*

Jefferson Lab, designated as a fundamental research laboratory engaging in no classified or national security work, must provide straightforward access to its experimental data and computing resources to scientific collaborators both nationally and internationally in order to fulfill its mission. The cyber security program uses a layered approach, with strategies in place to protect the networks, provide intrusion detection, monitor and protect systems, and apply application level security as well as administrative measures. Network protection is based on a tiered model with a firewall protecting the campus network and includes protected enclaves of certain essential systems such as Business Services, HR, Financial and Accelerator controls. The full cyber security program is detailed in the DOE approved Cyber Security Program Plan (CSPP). The Laboratory recently completed a peer review of its cyber security program and implementation. The review concluded that the program is of high quality and very effective in protecting against risks, as well as being appropriately structured for the Jefferson Lab research environment.

The Laboratory uses Integrated Security Management practices with responsibility for cyber security delineated with the Lab Director, line management, and end users. The Chief Information Officer (CIO) is responsible for coordinating cyber security policy development across the Lab. The implementation of the central portion of the cyber security program is the responsibility of the Head of the Computer Center who coordinates with the CIO and thus to the Laboratory Director in matters of cyber security. Within the Computer Center there are two cyber security staff who implement the program and policies in conjunction with a team including representatives from all laboratory-computing groups. Incidents are reported directly to the Computer Incident Advisory Center and DOE by the Computer Center, as well as to management.

Cyber security is a continuously evolving activity. Projects that are currently in hand include implementing a recently procured upgrade to the site firewall and restructuring some of the protected networks. Implementation of Virtual Local Area Networks (VLANs) to provide further levels of manageability and isolation for certain network segments is also in hand. As the security environment evolves, of necessity the tools used for host monitoring and intrusion detection have to evolve and current projects include replacing some of that software, as well as the addition of new software to provide vulnerability scanning capabilities. During the coming year more effort will be focused on providing a more comprehensive training program for system administrators and in particular for users. It is essential that the program remain flexible to handle the ever-changing security environment.

## 3. INSTITUTIONAL MANAGEMENT

### A. Information Management

Modern information systems with their marriage of web-based tools and databases can be used for greatly enhanced business processes that can provide significant efficiencies and cost savings. Jefferson Lab is on an aggressive campaign to use the best management information systems (MIS) available to achieve these efficiencies, cost avoidances, and cost savings. At the same time we are providing useful management tools so that managers can have management information quickly available.

The system is based on central, site-wide, internally accessible information and data to support decision-making and daily operations. It includes information on Laboratory population, finance, budget, time reporting, buildings and building access, mail stops, telephones, property, purchases and deliveries, credit card tracking, on-line procurements, computer system access, material safety data sheets, training, Laboratory conferences, library holdings, and staff publications. During the past year a publication and publications approval system, applicant tracking system, Human Resources Information System, and Foreign National reporting system have been brought on-line. For the near-term, central systems currently under development or upgrade include EH&S tracking, travel reporting, facilities work order tracking, space management, staffing planning and budget planning.

For near-term through long-term, we are currently in the first phase of moving all of the Lab developed site-wide applications to a modern Java 2 Enterprise Edition (J2EE) environment running on Oracle. In this first phase, all of the older non web based applications are being migrated from their existing databases to the new environment. At the same time, management and user requirements are being updated and the applications are being linked to a simplified portal. With substantial overlap for the mid-term, in the second phase the third party site-wide applications will be integrated into the new environment. In the long-term and third phase, all of the applications will be brought together into a fully functional portal. We will then have MIS equal to that of companies using best business practices.

### B. Environment, Health and Safety (EH&S)

#### *EH&S Policies, Organization, and Management*

Jefferson Lab utilizes line management to achieve environment, health, and safety (EH&S) goals and objectives. The Jefferson Lab Director has the ultimate responsibility and authority for the development, oversight, and implementation of EH&S policies. Fundamental to the Laboratory's EH&S Program is the commitment that line management bears primary responsibility for EH&S issues in its areas of operation. Consequently, the EH&S effort is accomplished programmatically by line managers who have advisory input from EH&S staff distributed throughout the organization where their specific expertise is needed most.

Guidance for the implementation of EH&S policies is issued by the Directorate to the line divisions of Jefferson Lab via the *Jefferson Lab EH&S Manual*, available both on-line and in hard copy. The policies, procedures, and interfaces in the comprehensive EH&S Manual serve as the cornerstones of the Laboratory's Integrated Safety Management System (ISMS) Plan. Each line division takes full responsibility for the EH&S aspects of its operations and activities, including self-assessments. EH&S staff resources are positioned within the divisions for optimum alignment with operations. Institution-wide EH&S support, reporting, oversight activities, and internal appraisals are performed by the Office of Assessment.

### *Integrated Safety Management*

Jefferson Lab, since its inception, has considered EH&S to be primarily a line management responsibility. The Laboratory's philosophy has been that it is a better use of resources to build EH&S into functional activities than to depend on audits or inspections for results.

The Jefferson Lab ISMS Plan provides a crosswalk between the DOE/SURA contract's ISM requirements and the Laboratory's directives and practices that implement ISM. A DOE Office of Science-led ISM Verification Review was conducted successfully in 1999 at Jefferson Lab. The ISM Review Team noted that the Laboratory's safety culture and program were extremely positive**.** The Office of Science chaired January 2002 Operations Review of the CEBAF also examined the implementation status of the Lab's ISMS. This review concluded that Jefferson Lab had satisfactorily implemented its ISMS. The ES&H portion of the Review's Closeout Report noted, "Jefferson Lab has a mature, integrated and cost effective safety program."

The Office of Assessment conducts an annual review and update of the Jefferson Lab ISMS Plan. An increased emphasis has been placed on the ISM feedback component. The increased use of both internal and external lessons learned has improved ISM implementation in day-to-day work activities**.** A Jefferson Lab lessons learned web page has provided additional emphasis to the ISM feedback component.

### *Jefferson Lab Work Smart Standards Process*

SURA, in cooperation with DOE, used the "Work Smart Standards" (WSS) process, formerly called the "Necessary and Sufficient" process, to increase the effectiveness of EH&S management of Jefferson Lab. The goal of the WSS process was to enable an EH&S system that is both effective and cost-efficient. It identified the set of laws, regulations, and standards necessary and sufficient to ensure health and safety and to protect the environment.

SURA and DOE staffs continue to work together to review the applicability of new or revised laws, regulations, standards, and DOE guidance documents. The WSS Set was most recently amended in August 2002. Joint SURA/DOE working groups review new DOE directives that may have applicability to Jefferson Lab activities. Recently such a team reviewed DOE Order 450.1, Environmental Protection Program, and developed language for incorporation into the DOE/SURA contract.

### *EH&S Performance Measures*

Environment, health, and safety are important dimensions of SURA's performance-based contract with DOE for managing and operating Jefferson Lab. Objective performance measures have been identified for evaluating Jefferson Lab's EH&S performance. The

DOE/SURA performance-based contract has two key and eight secondary EH&S performance measures. The two primary measures are SURA injury avoidance performance as measured by the DOE Injury Cost Index and environmental exceedance performance. The secondary performance measures include lost work day case rate, reportable radiation exposures, reportable hazardous substance exposures, material recycling effectiveness, hazardous/radioactive waste generation, and fire protection program effectiveness. Emergency management and radiation protection peer reviews are conducted in alternating years to measure the effectiveness of these two programs.

***EH&S Plans***

Jefferson Lab's EH&S Budget Formulation Submission (formerly called the DOE EH&S Management Plan) considers the areas of industrial hygiene, radiation protection, environmental coordination, fire protection, emergency preparedness, industrial safety, occupational medicine, and internal appraisal. Since the site is relatively new, the EH&S Budget Formulation Submission is dominated by the conduct, documentation, and continuous improvement of programs in the discipline areas listed. There are no significant cleanup or remediation needs. All required permits are in place.

Jefferson Lab has produced an annual *Site Environmental Report* (SER) since 1993. The SER provides, to the DOE and the public, information on the level of radiological and non-radiological pollutants, if any, added to the environment as a result of activities at Jefferson Lab. The SER also describes environmental initiatives, assessments, and programs for each year.

## C. Public Communications and Trust

Jefferson Lab actively maintains constructive and effective communication with the public using various methods. Whether through personal interactions in community committee meetings, civic presentations, or hosting public forums such as science-related book lectures or the Open House, Jefferson Lab staff enthusiastically promotes the Laboratory and its activities.

The Laboratory enjoys a positive partnership with the City of Newport News. Through the years, the City has supported the Laboratory's efforts to advance its programs. To further this important relationship, Laboratory personnel serve on City committees in such diverse areas as economic development, education, transportation, emergency management and recycling. Additionally, Jefferson Lab participates in the city's economic development efforts by supporting the city in attracting high technology companies to locate in the area.

This partnership extends to the City of Newport News police and fire departments. Jefferson Lab and the City host joint emergency drills to ensure that the City can respond to our unique circumstances. Both departments hold region-wide meetings using the Laboratory's facilities. These meetings keep the entire region's officers aware of Jefferson Lab and its capabilities. In 2002, the site was chosen by the State of Virginia to host regional presentations to waterworks staff on the topic of terrorism using city water supplies. Tours are conducted regularly to keep city personnel well acquainted with the site as it evolves. The Laboratory also hires off-duty police force and emergency medical technicians to staff our public Open House.

Constructive and effective relationships are developed and maintained with the general public in the local area. The **Jefferson Lab Science Series**, targeting high school-aged audiences is now in its twelfth year. This program brings enthusiastic, often high-profile scientists to Jefferson Lab to present interesting science. The series is advertised in local newspapers and schools, and to all science teachers region-wide by email and fax. New this year is a public sign up for an email list that sends notification of upcoming events. The 2001-2002 Science Series was kicked off with a well known Canadian chemist who hosts a radio chemistry call-in program. The chemistry night was extremely well attended and the series held its momentum throughout the year. Also featured during the series was a book author, also a visiting JLab scientist, Tim Smith, with his book called *Hidden Works, Hunting for Quarks in Ordinary Matter*. Finally, the series ended with a bang with a scientist from the University of Minnesota lecturing on the physics of comic books, which proved to be very popular with the attendees. The Science Series is videotaped by the local school system and is re-broadcast on the City's cable channel, further extending the reach of these outstanding programs. Videotapes of the programs can be borrowed by requesting them on the Lab's Web site. About six to ten tapes each week are distributed around the country as a result of these requests.

Jefferson Lab hosts an Open House every two years and on April 26, 2003 the Lab opened its doors to the community. Joining Jefferson Lab staff in this effort were local museums such as the Mariners' Museum, Virginia Living Museum, Air and Space Museum and for the first time Old Dominion University's Physics Department, all providing interactive, hands-on activities for attendees. On the only sunny Saturday in April, more than 5,000 community members came to the Lab to learn more about its physics and its scientists. Both emails and visitor surveys yielded the event high marks. On the off years of the Open House, Jefferson Lab staff participates in the Virginia State Fair to further its outreach activities throughout the region.

Another means of communicating with both technical and non-technical audiences, the Jefferson Lab Web site is an affordable and effective means of sharing information. It is a key component of the Laboratory's communication strategy for both internal and external audiences. The Jefferson Lab Web site promotes the Lab and enhances its image, serves as an information resource and effective channel for communication with scientific user communities, and aids in the education of the general public and potential users about the Laboratory's scientific program, technological advances and science education activities.

Two noticeable JLab web features are photographs on all public pages to chronicle the events and activities that are important to the life of the Laboratory, and a home page which offers a means of prominently displaying timely or newsworthy information. Journalists can read press releases, sign up to be on the press release list, and see information at the site's journalists' newsroom. The K-12 Science Education website has become an extremely popular site for children studying to pass the Standards of Learning test administered by the State of Virginia. JLab science education specialists have adapted old tests in the science and math sections for an online "practice" test. During testing season, this portion of the website sees high traffic volume.

At the state, regional and local levels, Jefferson Lab personnel participate in economic and technology committees to reach a different community. The Laboratory's partnership with the Virginia Physics Consortium, a statewide consortium of physics Ph.D.-granting institutions, has led to Jefferson Lab's reputation as a responsible steward of state allocated funds. Although at lower budget levels than in the past due to State budgetary shortfalls, the State continues to fund the research of four local universities in the ARC and to provide additional money for university researchers to lease Laboratory space. In addition to their contribution to the ARC, State and local governments have contributed more than $42 million to Jefferson Lab in direct appropriations over the past eleven years. Jefferson Lab also participates in the Virginia Research and Technology Advisory Commission (VRTAC), created by the Commonwealth of Virginia to coordinate activities of member research institutions.

Finally, Jefferson Lab enjoys a strong relationship with the local print and broadcast media. Reporters routinely interact with the Laboratory's public affairs staff and request information that can be used to generate news stories. The national press and Jefferson Lab also collaborate to educate the public about the importance of fundamental research. Public Affairs ensures the Department of Energy is identified in press releases about Jefferson Lab. Laboratory scientists who have actual first-hand knowledge and who are skilled in communicating to diverse audiences provide science reporters detailed information on scientific topics. These interactions have proven very successful and have led to more frequent articles in the press. An ongoing science communication committee at Jefferson Lab identifies potential science articles that can be used by the press. Efforts to encourage JLab users to promote their research is starting to yield results with news articles being published in *The Economist, USA Today, New Scientist* and *The New York Times.* This committee also worked to produce a visually appealing brochure regarding the compelling science that can be accomplished with a 12 GeV energy upgrade to the accelerator and experimental halls. This brochure is receiving compliments on being able to tell a scientific story to a non-science audience in an interesting fashion. The group will continue its efforts into the future.

## D. Education K-12

As a nuclear physics research laboratory, Jefferson Lab is a valued contributor to science education and a major resource to the local, regional, and national education communities. Jefferson Lab promotes math and science education by sharing its unique resources with students, teachers, and the general public. Over a third of the Laboratory staff and many of the Lab's scientific users participate as mentors and career role models, interacting on a regular basis with students and teachers.

In partnership with the local public school districts and the surrounding community, the Lab designs and offers programs to enhance the quality of K-12 science, math, and technology education. These programs include a week-long laboratory immersion experience for 6$^{th}$, 7$^{th}$, and 8$^{th}$ grade students (BEAMS), a four-week course in physical science for teachers (PEST), summer research internships for high school honor students, evening public lectures presented by scientists, and classroom visits and field trips tailored to the classroom teachers' needs.

The BEAMS – Becoming Enthusiastic About Math and Science – program brings classes of sixth, seventh, and eighth grade at-risk students (1800 per year) and their teachers to Jefferson Lab for science and math activities. Through the BEAMS program, Jefferson Lab works to:

- Increase the representation of minorities and women in the science and engineering workforce,
- Motivate students and strengthen their academic preparation, and
- Provide teachers with classroom activities based on the science and technology at Jefferson Lab.

Since 1991, BEAMS has involved about 18,000 students and 400 teachers. Results from the on-going evaluation of BEAMS include: (1) students attending BEAMS are significantly more positive about science and school than students not attending; (2) teachers report that BEAMS increases their awareness of hands-on science activities, applications of math and science, and careers in math and science; and (3) parents report that the BEAMS program has a positive influence on their children. Preliminary results from Virginia standardized test scores show that BEAMS is helping close the disparity gap between traditionally low scoring schools and average scoring schools. Huntington Middle School, where students attend BEAMS in grades 6, 7, and 8, showed improvements in test scores from 1998 to 2001 of 37 percentage points in mathematics and 24 percentage points in science. In comparison, the school division that includes Huntington Middle School showed increases of 23 percentage points in mathematics and 14 percentage points in science.

The Physics Enrichment for Science Teachers (PEST) program is a four-week basic refresher course in physics for middle school science teachers and includes Jefferson Lab lectures on current research. PEST includes interactive discussions and instructions on methods to improve physical science education at the middle school level. Twenty-four teachers participated during the summer of 2003.

Jefferson Lab's Summer Honors Fellowship Program provides the region's highest achieving high school students with meaningful work experience in physics and engineering and encourages their pursuit of scientific and technical careers. During the eight-week program, students work under the guidance of a Lab staff member on a math, science, or technology-based project. The students present a summary of their projects to their peers and to the Lab's scientific community at a Lab-wide poster session the final week of the program.

During the school year, classes of students can attend the Jefferson Lab Physics Fest, a presentation on the Lab's science and technology that includes hands-on demonstrations of electrostatics, cryogenics, and plasmas. Each year, the Physics Fest brings more than 3000 students to Jefferson Lab.

In the monthly Science Series, guest scientists present seminars on a wide range of scientific topics of interest to the general public. Videos of presentations are loaned to teachers for use in their classrooms. Teachers can request the videos on the Lab's Science Education web page (http://education.jlab.org). The Science Education website was created to make the Lab's expertise available to a nationwide audience of students, teachers, and the general public. During the school year, the site receives about 4000 visitors a day.

The Lab is working with the Office of Workforce Development of Teachers and Scientists within the Office of Science to define opportunities for teachers through the Laboratory Science Teacher Professional Development (LSTPD) program. With funds from the LSTPD program, JLab will enhance the PEST program and address specific national science standards that each teacher identifies as areas for improvement prior to arrival at the Lab. JLab will provide follow-up activities and grants to ensure long-term contact and support for these teachers. In addition, 8-week research fellowships will be available for high school teachers interested in working alongside a physicist for the summer. Jefferson Lab plans to support 50 LSTPD teachers each year.

## E. Graduate Education

Jefferson Lab provides graduate and undergraduate students excellent research opportunities. The Science Undergraduate Laboratory Internship (SULI) is a research program held annually each summer at Jefferson Lab. The program recruits the nation's most promising undergraduate students who plan a career in science or engineering and provides them with opportunities to work with the Lab's staff and visiting scientists on challenging projects. The Jefferson Lab experience encourages outstanding students to pursue advanced degrees in Jefferson Lab-related disciplines. Fifteen students participate each summer.. Jefferson Lab has also taken on two special roles in its community: partnerships with HBCUs and HSIs, and community outreach to local area public schools and citizens.

### *Historically Black Colleges and Universities (HBCU) and Hispanic Serving Institutions (HSI)*

Jefferson Lab has taken the initiative to make HBCUs and HSIs a vital part of its university-based research community. As part of a joint-faculty program, new faculty members are appointed to local university positions on a permanent cost-shared basis with Jefferson Lab. Jefferson Lab agrees, in these cases, to reimburse the university for one-half the salary and benefits of a faculty member. In return, the university agrees to release that faculty member to spend half time conducting research at Jefferson Lab under the supervision of a Jefferson Lab Group Leader. In a second program, Jefferson Lab pays a fraction of the salary and benefits of a new faculty member for a fixed short term (a “bridging” period). In return, the university releases this faculty member on a pro rata basis to devote time to Jefferson Lab programmatic activities (including equipment building, software development, and research). The university assumes full responsibility for this faculty member upon the expiration of the “bridge assignment.”

Partnerships with two local HBCUs were initiated in 1989 with Hampton University and in 1993 with Norfolk State University (NSU). Hampton University has added four new faculty members to its physics department, while Norfolk State University has added two new faculty members. These faculty members were hired on a long-term, cost-shared basis.

In addition to these local joint-faculty partnerships, Jefferson Lab has made bridging arrangements with non-local HBCUs and HSIs. Current partners include Florida International University (FIU) and North Carolina Agricultural and Technical State University (NCA&T).

By any reasonable measure, these partnerships are extremely successful. As an example, under the Memorandum of Understanding signed in 1989, the Hampton University Department of Physics has grown from a small department with a master's degree program and a few students into a major international player in quark and nuclear physics. With the support of Jefferson Lab, the Hampton University group working at the Laboratory received a $10M grant from the National Science Foundation in 1991. Based on their outstanding performance, this grant was renewed in 2001 for a second ten-year term. In 1992, Hampton University was certified to grant doctoral degrees in physics, making it one of only three such HBCUs in the country. The university’s experimentalists are leaders on research proposals that have been awarded one-third of the beam time in CEBAF’s Hall C, where they have focused their program. In the fall of 1996, Hampton University became the first HBCU ever to lead a major experiment at a national accelerator laboratory and currently, Hampton University joint faculty members are the spokespersons for ten approved experiments. The Hampton University Department of Physics has become a major center for education of the next generation of minority scientists and engineers. During the 2002-2003 academic year, the department had an enrollment of twelve undergraduates, four of whom received their undergraduate degrees in Physics during FY03. Post-graduate studies in physics continue to be strong with 24 doctorate students and four MS students enrolled during the 2002-2003 academic year. Hampton University awarded three doctoral degrees in physics in FY03. One of these degrees was awarded in the field of nuclear physics. Seven of the remaining 25 graduate students are currently pursuing advanced degrees at Hampton University and are active in the Jefferson Lab research program.

A second HBCU in the local area, NSU, has also benefited from its partnership with Jefferson Lab. The NSU agreement has resulted in two new joint faculty appointments in the University’s Physics Department: both in nuclear and particle physics. The Nuclear and Particle Physics Group at NSU has aggressively sought and received funds from outside sources to support its research. The Group is currently funded by DOE, NASA and NSF enabling them to support a full-time postdoctoral fellow and a part-time Jefferson Lab staff scientist. They are lead participants in the R&D for the planned inner calorimeter of the CLAS upgrade and have acquired most of the hardware for the construction of a calorimeter prototype. The NSU Group members have also contributed hardware and manpower to the Hall C experimental effort where they are involved in the construction of a lead glass calorimeter. At its present level of funding and research activities in 2003, the NSU Nuclear and Particle Physics Group is able to support at least six undergraduates per year to work part-time on Jefferson Lab research.

In 1995, Jefferson Lab entered into a bridged-type partnership with NCA&T, a regional HBCU located in Greensboro, North Carolina. NCA&T is experiencing successes comparable to Jefferson Lab's local area HBCUs. Since its partnership with Jefferson Lab, NCA&T established a physics graduate program and has produced several Master's students. In the spring of 2000, NCA&T bridged faculty members were successful in securing a DOE grant to cover student support as well as funds to begin covering their own summer research time at Jefferson Lab. The grant has made it possible for NCA&T undergraduate and graduate students to remain on-site to work on Hall C projects during 2003. The NCA&T Group is also the recipient of a large NSF grant to study the precision measurement of the neutral pion lifetime via the Primakov Effect (E02-103), a high scientific priority experiment which received an 'A' rating. As spokespersons of this experiment and members of PRIMEX Collaboration, the NCA&T Group will lead one of the major research directions of Jefferson Lab at high energies.

Similar successes also have occurred as a result of Jefferson Lab's bridged-type partnership with an HSI. In 1993, Jefferson Lab entered into an agreement with FIU, an HSI located in Miami. Since then, the FIU Physics Department has grown from 14 to 22 faculty members. In 1997, FIU received approval from the Florida Board of Regents for a Ph.D. program in Physics and in the fall of 1999, the doctoral program began receiving its first students. The FIU bridged faculty members have undertaken increasingly important leadership roles in several key experiments and have involved more than a dozen students in their work at Jefferson Lab. A large DOE grant has allowed group members to purchase additional release time in support of their Jefferson Lab research. In addition, the group is able to support an onsite post-doctoral fellow and eight Ph.D. students.

Such accomplishments do not occur overnight: five to ten years, as with Hampton University, are required to create a successful academic program. However, Jefferson Lab's other HBCU/HSI partners are also beginning to enjoy comparable successes both scientifically and in the training of the next generation of minority scientists and engineers.

### *Student Affairs Office*

In 1997, The Jefferson Lab Student Affairs office was established to provide a central office for assistance to the work of students and their advisors in their research collaboration at Jefferson Lab.

The Jefferson Lab Student Affairs Office has the principal goal of enhancing Jefferson Lab's production of trained scientific and technical manpower. Among the programs established by this office are a series of monthly seminars given principally by graduate students to inform colleagues of their work and several summer lecture series on detector development, data analysis and computing to help initiate new students into nuclear research techniques.

In addition, this office supports graduate student activities directed toward recreation and leisure and informal gatherings intended to enhance student life at the Laboratory. Support for and encouragement of a graduate student association is also provided.

The Student Affairs Office supports specific programs intended to assist students presently underrepresented in scientific fields such as the Hampton University Graduate Studies (HUGS) Program and similar programs at HBCUs and HSIs.

**Table VI-14**
**University and Science Education Program Participation**

| | FY2002 | | | FY2003 (Projection) | | |
|---|---|---|---|---|---|---|
| | **Total** | **Minorities** | **Women** | **Total** | **Minorities** | **Women** |
| PRE-COLLEGE PROGRAMS | | | | | | |
| Student Programs | | | | | | |
| BEAMS Partnership | 1650 | 1280 | 825 | 1800 | 1370 | 960 |
| High School Summer Internships | 15 | 7 | 6 | 11 | 6 | 3 |
| Science Series, CHROME, etc. | 9000 | ~4000 | ~4500 | 9500 | ~5000 | ~5000 |
| Teacher Programs | | | | | | |
| Summer Teacher Participation | 32 | 11 | 21 | 22 | 6 | 11 |
| Other Teacher Assistance | 750 | | | 800 | | |
| UNDERGRADUATE PROGRAMS | | | | | | |
| Student Programs | | | | | | |
| Undergrad Student Research | 10 | 2 | 4 | 15 | 3 | 7 |
| Technical Interns Supported by JLab | 31 | 12 | 24 | 22 | 9 | 20 |
| GRADUATE PROGRAMS | | | | | | |
| Student Programs | | | | | | |
| Lab-Funded Graduate Students | 45 | 28 | 18 | 48 | 29 | 14 |
| SURA/JLAB Graduate Fellowships | 8 | 4 | 2 | 8 | 2 | 2 |
| Other Graduate Students on-site in Research | 204 | 72 | 34 | 198 | 64 | 29 |
| POSTGRADUATE PROGRAMS | | | | | | |
| Fellowships | | | | | | |
| Lab-Funded Post-Doctoral Fellows | 39 | 7 | 10 | 42 | 11 | 10 |
| Other Post-Doctoral Fellows on-site in Research | 35 | 9 | 2 | 41 | 10 | 2 |

Note: Minority women are counted in the "Minorities" column and the "Women" column in both years

## F. Technology Transfer

The Jefferson Lab Technology Transfer Program focuses on two major activities: a) managing the Intellectual Property of the Laboratory, and b) facilitating collaborative and research activities between the Laboratory and other organizations in the public and private sectors. These activities are coordinated by the Chief Technology Officer and the Technology Review Committee (TRC). The TRC is a seven-member group, chartered by the Director's Council, with representatives from all divisions of the Laboratory and SURA corporate.

Managing the Intellectual Property starts with management's pro-active encouragement of employees to record their innovative ideas by filing Invention Disclosures (ID) with the Laboratory. The TRC then evaluates the ID, authorizes patent applications, and finally negotiates licensing of the inventions when they become patented Intellectual Property. Since 1988, a steady stream of Invention Disclosures has been generated at Jefferson Lab, at a rate of about 10 per year for a total of 158 by mid 2003, and a portfolio of 38 patents. Of the 38 patents, seven are licensed to commercial partners. Although this intellectual property ranges in applications from clever safety devices to complex SRF accelerator systems, the vast majority fall into three major technology categories: medical imaging, accelerator systems, and instrumentation/sensors.

Medical Imaging, derived from the detector systems technology used in the nuclear physics program, has the biggest success story with the scintimmamography medical imaging cameras used for early detection of breast cancer. The camera has Food and Drug Administration (FDA) approval, is in use at partner research hospitals (University of Virginia Medical School and George Washington University Medical Center), and has won the recognition of the Women's Health Office of the Department of Health and Human Services. The first commercial products are being produced by our business partner, Dilon Technologies, Inc., located in the Applied Research Center.

Nurturing research and collaborative activities between Jefferson Lab and other organizations has three aspects: 1) pro-active involvement in groups that are directly or indirectly involved in research and development; 2) Cooperative Research and Development Agreements (CRADAs) with private companies; and 3) Work For Others with private companies. In all of these activities, Jefferson Lab meets its obligations with regard to fairness of opportunity, export controls, and non-competitiveness with the public sector, in keeping with the Laboratory's public-funded status.

The first aspect of the Technology Transfer Research Collaboration is illustrated in the following table of organizations:

| Organization | JLab status |
|---|---|
| Applied Research Center (ARC)<br>http://www.jlab.org/ARC/ | Co-founder and member |
| Laser Processing Consortium (LPC)<br>http://www.jlab.org/FEL/LPC<br>also see FEL section of Inst. Plan | Founder/Organizer/Host of annual meeting |
| Hampton Roads Partnership (HRP)<br>http://www.hrp.org | Member of Board of Directors |
| Hampton Roads Research Partnership (HRRP)<br>http://www.hamptonroadsrp.org | Member of Board of Directors |
| Peninsula Alliance for Economic Development (PAED)<br>http://www.paed.org/ | Member |
| Hampton Roads Technology Council (HRTC)<br>http://www.hrtc.org | Member of Board of Directors. |

The second aspect of technology transfer research collaboration is in the form of Cooperative Research and Development Agreements (CRADAs). Jefferson Lab enters into a CRADA with another organization when three requirements are met: mutual interest in the research, Jefferson Lab has unique capabilities needed for the research (we don't compete with private sector firms that could also do the work), and the partnering organization commits at least 50% of the resources needed for the CRADA. In recent years the Laboratory has partnered in five active CRADAs.

The third aspect of technology transfer research collaboration is Work for Others. This is similar to a CRADA but is essentially contracted work performed by Jefferson Lab for an outside organization (company, university, etc.) where the organization retains all the research results and pays Jefferson Lab for the use of its unique resources.

Of all the partnerships, collaborations, and consortia that Jefferson Lab has entered into, the relationship with the City of Newport News must be ranked near or at the top in terms of enhancing research and technology development. From its inception in the 1980's, the Laboratory has always received the city's generous and farsighted support. Starting with the ARC and in collaboration with Jefferson Lab, the City is developing a 200-acre, high-technology park, The Jefferson Center for Research and Technology, located immediately adjacent to Jefferson Lab. Within this partnership, the Lab and the City cooperate in local and regional efforts to strengthen and diversify the local economy.

## VII. MAJOR ISSUES

### 1. Path Forward to a Timely Start of the 12 GeV Upgrade

The proposed energy upgrade of CEBAF has recently earned highest possible marks for scientific importance and construction readiness from the 2003 NSAC Subcommittee on Future Facilities which provided input for the development of the 20-year Office of Science facilities roadmap. The science programs associated with the energy upgrade of CEBAF have been strongly endorsed by the DOE/NSF NSAC Long Range Planning Group. NSAC's new (2002) Long Range Plan includes as one of its principle recommendations:

"We strongly recommend the upgrade of CEBAF at Jefferson Laboratory to 12 GeV as soon as possible. The 12 GeV Upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This Upgrade will provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon description of matter, and the nature of quark confinement."

Jefferson Lab would like authorization (Critical Decision or CD-0) and funding to carry out the necessary R&D, design work and prototyping to pursue the earliest possible start for the project. Approval of CD-0 will allow us to proceed with a detailed Conceptual Design Report, and pursue multinational partners and other funding agencies to provide vital equipment for the project. Foreign partners in particular will not commit resources until they are assured that a project has a high probability of proceeding.

DOE's commitment to the 12 GeV Upgrade (CD-0) is also very important to the User community that has worked enthusiastically to develop the scientific White Paper and contributions to the Long Range Planning process and is now completing a pre-Conceptual Design Report for the project. This community will work to obtain support from collaborators here and abroad in pursuit of the science they envision from the upgrade. Another time consideration for a funding profile that begins PED activities in FY05 is that we can coordinate in a cost-effective manner the trained manpower that we have acquired via our work supporting the SNS. If the project remains on its timetable, synergy exists between the ramp down of SNS-related work and the ramp up of the Upgrade effort. If such coordination is not possible, expertise critical to maintaining this core competency in advanced accelerator technology will be lost, resulting in time and cost impacts for the Upgrade project and the loss of cross-cutting accelerator R&D in the Office of Science. Furthermore, the accelerator R&D needed to build the 12 GeV Upgrade will benefit the larger scientific community by reducing the technical risk and costs for a number of proposed and planned next-generation accelerators for research.

## 2. Accelerator Operations

In section VI.1.A (Nuclear Physics: 6 GeV Experimental Program) subsections b, c, and e include a description of the CEBAF accelerator and a discussion of issues related to its operation and its continuous development. In particular, the Long Range Development Plan (LRDP) and the need to address some of our long-standing operational issues are highlighted. While CEBAF is a relatively new facility, signs of aging equipment are already visible in specific systems such as the Central Helium Liquefier (CHL) plant, the klystrons (which are almost all well beyond their rated lifetimes), original control boards, magnet systems, diagnostic elements, etc. Near-, intermediate-, and long-term plans to strengthen the aging CEBAF facility are being developed; elements of these plans are identified in the documents prepared in support of our Accelerator Improvement Project (AIP) requests and the LRDP. The AIP request calls for a continuous annual investment at more than $1M per year following a multi-year profile in specific areas (such as lasers for the source, diagnostics, RF control modules, klystrons, site cryo-capacity, etc.). The LRDP identifies major systems and subsystems that are vulnerable and needing upgrades, and also projects the necessary effort and procurements in a decade-long program.

At the FY02 Operations Review of CEBAF, the review committee recognized the need for adequate funding of the engineering effort required to support the technical infrastructure maintenance, the availability upgrades, and creation of more robust new systems. The FY03 budget was the first in several years that provided some of the funding required to begin addressing these needs. In prior years our budgets were insufficient to compensate for the effects of inflation, and the cumulative effects of that funding pattern had begun to adversely impact us in a number of critical areas. The Presidents Budget for FY04 contains funding that will allow us to continue to address these needs. With the FY03 and the hoped-for FY04 funding, the Laboratory has carefully determined those areas for which investment will best help us to meet our goals in the years ahead. These are included in the AIP request and the LRDP described above.

## 3. Strengthening the Nuclear Theory Effort for Hadronic Physics

The full realization of the scientific benefits of the Laboratory's mission to explore the structure of the nucleon and nucleus requires extensive theoretical work and simulations which are directly integrated with the experimental programs. The theoretical research carried out by the group supports both the present JLab experimental program and that envisioned for the 12 GeV upgrade. Indeed, Jefferson Lab is planning to strengthen the group and to further expand its support for the experimental program in two important ways: i) the continued growth of facilities for LQCD calculations; and ii) the establishment of an Excited-Baryon Analysis Center (EBAC).

*Advanced Computational Science: Lattice Quantum ChromoDynamics*

Within the broader initiative of the DOE SciDAC project for lattice gauge theory, a Lattice Hadron Physics Collaboration (LHPC) has been formed consisting of 24 theorists from 15 institutions led by JLab and MIT. The LHPC effort has science, software, and hardware components. The science component aims to understand quantitatively, from the underlying quark-gluon dynamics, hadron structure and interactions, such as the spectroscopy of glueballs, hybrids and baryon resonances, and moments of structure functions and generalized parton distributions. Indeed, in the past year first-generation calculations of the pion form factor and of the moments of the nucleon structure functions became available.

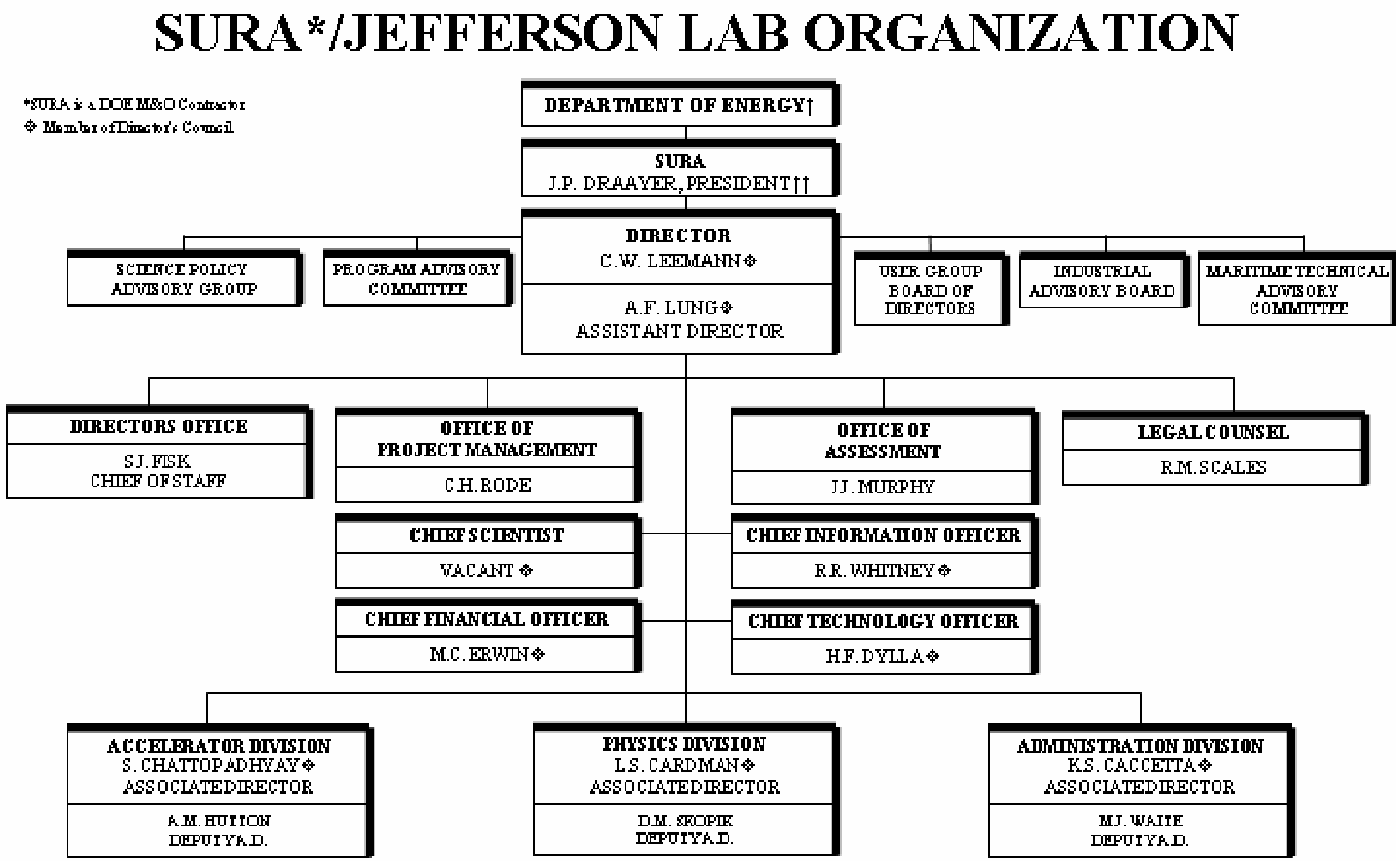
The goal of the software component of LHPC is to create a unified programming environment for achieving high efficiency on diverse multi-teraflop hardware. The goal of the hardware component is to deploy, by FY06, a distributed multi-terascale computing capability which includes sustained 8 teraflop/s ($10^{12}$ floating point operations per second) of computing at JLab; present computational capabilities yield an aggregate performance approaching 0.5 teraflop/s. Jefferson Lab has adopted a cost optimized commodity computing model based on large clusters of inexpensive nodes connected by high-speed cluster interconnects.

*Excited Baryon Analysis Center*

A significant portion of the JLab experimental program has been committed to understanding the structure of the nucleon and its excited states. Indeed, a flood of new data from the CLAS detector has made a concerted effort dedicated to their analysis and interpretation a vitally important activity, if the program is to be successful in identifying baryon resonances and in determining their associated electromagnetic couplings. This identification is crucial for providing comparisons with results of "ab initio" calculations based on LQCD and obtained within the LHPC effort at JLab, and constraints on and insights into the modeling of baryons, in particular in connection with the "missing resonance" problem.

A proposal for the establishment of an Excited Baryon Analysis Center has been submitted to the DOE. Its mission will be to develop, maintain, and update the theoretical and computational tools necessary to carry out analysis of the large body of data associated with the baryon-resonance program. There are a number of critical theoretical issues that need to be addressed and resolved, having to do, for example, with the background-resonance separation, the treatment of multi-particle final states, and the incorporation of unitarity and analytic structure in the photo- and electro-production amplitudes.

## VIII. APPENDICES




† http://www.energy.gov/engine/content.do?BT_CODE=AD_O

†† http://www.sura.org/welcome/orgchart.pdf

**APPENDIX A: SURA / Jefferson Lab Organization Chart**

## APPENDIX B: Jefferson Lab Approved Experiments – June 2003

*★ Completed ☆ Partially Completed ★/ Complete with Withdrawn Time ☆̄ Time deferred or Rejected*
** Contact person with multiple spokespersons*

### *Few Body Nuclear Properties: Approved*

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ★ | E-89-012 | C | Two-Body Photodisintegration of the Deuteron at Forward Angles and Photon Energies between 1.5 and 4.0 GeV | D. Bray<br>R. Holt* | CIT<br>ANL | 10 | A- |
| ★ | E-89-019 | A | Measurement of Proton Polarization in the d($\gamma$,p)n Reaction | R. Gilman*<br>R. Holt<br>Z. E. Meziani | Rutgers U<br>ANL<br>Temple U | 18 | B+ |
| ★ | E-89-028 | A | Polarization Transfer Measurements in the D(e,e'p)n Reaction | J. Finn*<br>P. Ulmer | W&M<br>ODU | 8 | B- |
| ★ | E-89-044 | A | Selected Studies of the $^{3}$He and $^{4}$He Nuclei through Electrodisintegration at High Momentum Transfer | M. Epstein<br>A. Saha*<br>E. Voutier | California SU<br>JLab<br>ISN | 30 | B+ |
| ☆̄ | E-91-003 | C | A Study of Longitudinal Charged Pion Electroproduction in $^{2}$H, $^{3}$He and $^{4}$He | H. Jackson | ANL | 21 | B+ |
| ★ | E-91-026 | A | Measurement of the Electric and Magnetic Structure Functions of the Deuteron at Large Momentum Transfers | J. Gomez<br>G. Petratos* | JLab<br>Kent State U | 24 | B+ |
| ★/ | E-93-017 | B | Study of $\gamma$ d $\rightarrow$ pn and $\gamma$ d $\rightarrow$ p$\Delta^0$ Reactions for Small Momentum Transfers | E. De Sanctis<br>P. Rossi* | INFN<br>INFN | 23 | B+ |
| ☆̄ | E-93-044 | B | Photoreactions on $^{3}$He | G. Audit<br>B. Berman*<br>P. Corvisiero | SACLAY<br>GWU<br>INFN | 25 | B |
| ★ | E-93-049 | A | Polarization Transfer in the Reaction $^{4}$He(e,e'p)$^{3}$H in the Quasi-elastic Scattering Region | R. Ent<br>P. Ulmer<br>J. Van Den Brand* | JLab<br>ODU<br>U of Wisconsin | 12 | B+ |
| ★/ | E-94-004 | A | In-Plane Separations and High Momentum Structure in d(e,e'p)n | M. Jones<br>P. Ulmer* | JLab<br>ODU | 29 | B |
| ★ | E-94-018 | C | Measurement of the Deuteron Tensor Polarization at Large Momentum Transfers in D(e,e'd) Scattering | E. Beise<br>S. Kox* | U of Maryland<br>ISN | 47 | A- |
| ★ | E-94-019 | B | Measuring Nuclear Transparency in Double Rescattering Processes | K. Egiyan<br>K. Griffioen*<br>M. Strikman | Yerevan<br>W&M<br>Penn State | 16 | B+ |
| ★ | E-94-102 | B | Electron Scattering from a High Momentum Nucleon in Deuterium | K. Griffioen<br>S. Kuhn* | W&M<br>ODU | 16 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| ★ E-94-104 | A | The Fundamental $\gamma\ n \rightarrow \pi^-\rho$ Process in $^2$H, $^4$He, and $^{12}$C in the 1.2 – 6.0 GeV Region | H. Gao*<br>R. Holt | Duke U<br>ANL | 18 | B+ |
| ★ E-95-001 | A | Precise measurements of the Inclusive Spin-dependent Quasi-elastic Transverse Asymmetry $A_T$ from $^2$H(e,e') at low $Q^2$ | H. Gao*<br>J. O. Hansen | Duke U<br>JLab | 15 | B |
| ★ E-96-003 | C | Two-Body Photodisintegration of the Deuteron at High Energy | R. Holt | ANL | 18 | A- |
| ★ E-97-001 | B | Electroproduction of the $pp\pi^-$ System off the Deuteron Beyond the Quasifree Region | N. Pivniouk*<br>L. VOROBYEV | ITEP<br>ITEP | 16 | B- |
| ★ E-99-008 | A | Large Angle Two-Body Photodisintegration of the Deuteron at High Energy | R. Gilman*<br>R. Holt<br>Z. E. Meziani | Rutgers U<br>ANL<br>Temple U | | B |
| ★ E-00-007 | A | Proton Polarization Angular Distribution in Deuteron Photo-Disintegration | R. Gilman*<br>R. Holt<br>Z. E. Meziani | Rutgers U<br>ANL<br>Temple U | 7 | A- |
| E-00-118 | A | Elastic Electron Scattering off $^3$He and $^4$He at Large Momentum Transfers | J. Gomez<br>G. Petratos* | JLab<br>Kent State U | 30 | A- |
| ★ E-01-020 | A | PR-01-007 and PR-01-008 Combined | W. Boeglin*<br>M. Jones<br>A. Klein<br>J. Mitchell<br>P. Ulmer*<br>E. Voutier | FIU<br>U of Maryland<br>ODU<br>JLab<br>ODU<br>ISN | 30 | A- |
| E-01-107 | C | Measurement of Pion Transparency in Nuclei | D. Dutta<br>R. Ent<br>K. Garrow* | Duke U<br>JLab<br>JLab | 14 | A- |
| E-01-108 | A | Detailed Study of the $^4$He Nuclei Through Response Function Separations at High Momentum Transfers | K. Aniol<br>S. Gilad<br>D. Higinbotham<br>A. Saha* | California SU<br>MIT<br>JLab<br>JLab | 20 | B+ |
| E-02-004 | A | A(Q) at Low Q in ed Elastic Scattering | R. Gilman*<br>X. Jiang<br>K. McCormick | Rutgers U<br>Rutgers U<br>Rutgers U | 5 | B+ |
| E-02-010 | A | The $\gamma + n \rightarrow \pi^-\ \rho$ Process from $^2$H and $^{12}$C and the $\gamma + p \rightarrow \pi^+ n$ Reaction | D. Dutta<br>H. Gao<br>R. Holt | Duke U<br>Duke U<br>ANL | 8 | B+ |
| E-02-108 | A | Measurement of $A_X$ and $A_z$ Asymmetries in the Quasi-Elastic $^3\overrightarrow{He}\ (\vec{e},e'd)$ Reaction | W. Bertozzi<br>D. Higinbotham<br>B. Norum<br>S. Sirca<br>Z. Zhou | MIT<br>JLab<br>U of Virginia<br>MIT<br>MIT | 15 | B+ |
| E-03-101 | A | Hard Photodisintegration of a Proton Pair | R. Gilman*<br>E. Piasetzky | Rutgers U<br>U of Tel Aviv | 13 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-03-104 | A | Probing the Limits of the Standard Model of Nuclear Physics with the $^4$He(e,e'p)$^3$H Reaction | R. Ent<br>R. Ransome<br>S. Strauch*<br>P. Ulmer | JLab<br>Rutgers U<br>Rutgers U<br>ODU | 18 | B+ |
| | | ***N* and Meson Properties: Approved*** | | | | |
| ☆ E-89-037 | B | Electroproduction of the $P_{33}$(1232) Resonance | V. Burkert*<br>R. Minehart | JLab<br>U of Virginia | 106 | B+ |
| ☆ E-89-038 | B | Measurements of p(e,e'$\pi^+$)n, p(e,e'p)$\pi^0$, and n(e,e'$\pi^-$)p in the Second Resonance Region | V. Burkert<br>M. Gai<br>R. Minehart*<br>R. Whitney | JLab<br>U of Conn<br>U of Virginia<br>JLab | 80 | B+ |
| ☆ E-89-039 | B | Amplitudes for the $S_{11}$(1535) and $P_{11}$(1710) Resonances from an ep $\rightarrow$ e'pn experiment | S. Dytman*<br>K. Giovanetti | U of Pittsburgh<br>JMU | 48 | B+ |
| ☆ E-89-042 | B | Measurement of the Electron Asymmetry in p(e,e'p)$\pi^0$ and p(e,e'$\pi^+$) in the Mass Region of the $P_{33}$(1232) | V. Burkert*<br>R. Minehart | JLab<br>U of Virginia | 80 | A- |
| ☆ E-91-002 | B | The Study of Excited Baryons at High Momentum Transfer with the CLAS Spectrometer | V. Burkert<br>P. Stoler*<br>M. Taiuti | JLab<br>RPI<br>INFN | 32 | B |
| ★/ E-91-008 | B | Photoproduction of $\eta$ and $\eta$' Mesons | B. Ritchie | Arizona SU | 65 | A- |
| ★ E-91-011 | A | Investigation of the N $\rightarrow$ $\Delta$ Transition via Polarization Observables in Hall A (previously titled: High-Precision Separation of Polarized Structure Function | S. Frullani<br>J. Kelly<br>A. Sarty* | INFN<br>U of Maryland<br>St. Marys | 45 | A- |
| ☆ E-91-024 | B | Search for "Missing" Resonances in the Electroproduction of Omega Mesons | V. Burkert<br>H. Funsten*<br>D. Manley<br>B. Mecking | JLab<br>W&M<br>Kent State U<br>JLab | 32 | B+ |
| ☆ E-93-006 | B | Two Pion Decay of Electroproduced Baryon Resonances | V. Burkert<br>M. Ripani* | JLab<br>INFN | 80 | B+ |
| ☆ E-93-012 | B | Electroproduction of Light Quark Mesons | M. Kossov | ITEP | 42 | B+ |
| ★ E-93-031 | B | Photoproduction of Vector Mesons at High *t* | M. Anghinolfi<br>J. Laget<br>C. Marchand* | INFN<br>SACLAY<br>SACLAY | 17 | A- |
| ★/ E-93-033 | B | A Search for Missing Baryons Formed in $\gamma$ p$\rightarrow$p$\pi^+\pi^-$ Using the CLAS at CEBAF | J. Napolitano*<br>D. Weygand | RPI<br>JLab | 65 | B+ |
| ★ E-93-036 | B | Measurement of Single Pion Electroproduction from the Proton with Polarized Beam and Polarized Target Using CLAS | R. Chasteler<br>R. Minehart<br>H. Weller* | Duke U<br>U of Virginia<br>Duke U | 42 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| ☆ E-94-005 | B | Determination of the N$\Delta$ Axial Vector Transition Form Factor $G_A^{N\Delta}$ from the $ep \rightarrow e'\Delta^{++}\pi^-$ Reaction | L. Elouadrhiri*<br>D. Heddle | JLab<br>CNU | 53 | B+ |
| ★/ E-94-008 | B | Photoproduction of $\eta$ and $\eta'$ Mesons from Deuterium | B. Ritchie | Arizona SU | 23 | B- |
| ★ E-94-012 | A | Measurement of Photoproton Polarization in the $H(\gamma,p)\pi^0$ Reaction | R. Gilman*<br>R. Holt | Rutgers U<br>ANL | 8 | B+ |
| ★ E-94-014 | C | The $\Delta$(1232) Form Factor at High Momentum Transfer | P. Stoler | RPI | 10 | B |
| ★/ E-94-015 | B | Study of the Axial Anomaly using the $\gamma\pi^+ \rightarrow \pi^+\pi^0$ Reaction Near Threshold | R. Miskimen*<br>K. Wang<br>A. Yegneswarar | U Mass<br>U of Virginia<br>JLab | 65 | A- |
| ★ E-94-016 | B | A Measurement of Rare Radiative Decays of the $\phi$ Meson | A. Dzierba*<br>J. Napolitano | Indiana U<br>RPI | 30 | A |
| ★/ E-94-103 | B | The Photoproduction of Pions | W. Briscoe<br>J. Ficenec*<br>D. Jenkins | GWU<br>VPI<br>VPI | 65 | B |
| ☆ E-94-109 | B | Photoproduction of the Rho Meson from the Proton with Linearly Polarized Photons | P. Cole*<br>J. Connelly*<br>K. Livingston | U of Texas<br><br>Glasgow U | 20 | B+ |
| ★ E-94-110 | C | Measurement of R= $\sigma_L/\sigma_T$ in the Nucleon Resonance Region | C. Keppel | Hampton U | 9 | B+ |
| ★ E-99-005 | B | Meson Spectroscopy in Few-Body Decays | G. Adams<br>C. Salgado*<br>D. Weygand | RPI<br>NSU<br>JLab | 10 | B+ |
| ☆ E-99-013 | B | Photoproduction of Omega Mesons off Protons with Linearly Polarized Photons | P. Cole<br>F. Klein* | U of Texas<br>CUA | 10 | B+ |
| ★ E-99-105 | B | Deeply Virtual Electroproduction of Vector Mesons | M. Garcon*<br>M. Guidal<br>E. Smith* | SACLAY<br>IPN ORSAY<br>JLab | 30 | B+ |
| ★ E-99-107 | B | N* Excitations at High $Q^2$ in the $p\pi^0$, $p\eta$, and $n\pi^+$ Channels | V. Burkert*<br>R. Minehart<br>P. Stoler*<br>M. Taiuti | JLab<br>U of Virginia<br>RPI<br>INFN | 30 | B+ |
| ★ E-99-108 | B | N* Excitations at High $Q^2$ in the Two-Pion Channel | V. Burkert*<br>M. Ripani | JLab<br>INFN | 30 | B+ |
| ★ E-99-117 | A | Precision Measurement of the Neutron Asymmetry $A_1^n$ at Large *x* using CEBAF at 6 GeV | J. P. Chen<br>Z. E. Meziani*<br>P. Souder | JLab<br>Temple U<br>Syracuse U | 21 | B+ |
| ★ E-99-118 | C | Measurement of the Nuclear Dependence of R= $\sigma_L/\sigma_T$ at Low $Q^2$ | A. Bruell<br>J. Dunne<br>C. Keppel* | MIT<br>MSU<br>Hampton U | 16 | B+ |
| ★ E-00-002 | C | $F_2^N$ at Low $Q^2$ | C. Keppel<br>M. I. Niculescu* | Hampton U<br>GWU | 8 | A- |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-00-116 | C | Update E97-010: Measurement of Hydrogen and Deuterium Inclusive Resonance Cross Sections at Intermediate $Q^2$ for Parton-Hadron Duality Studies | C. Keppel | Hampton U | 3 | B+ |
| ☆ E-01-002 | C | Update to E97-101: Baryon Resonance Electroproduction at High Momentum Transfer | P. Bosted<br>V. Frolov<br>M. Jones<br>V. Koubarovski<br>P. Stoler* | U Mass<br>RPI<br>U of Maryland<br>RPI<br>RPI | 25 | B+ |
| ★ E-01-006 | C | Update to 96-002: Precision Measurement of the Nucleon Spin Structure Functions in the Region of the Nucleon Resonances | O. Rondon-Aramayo | U of Virginia | 14 | B+ |
| ★ E-01-012 | A | Measurement of Neutron ($^3$He) Spin Structure Functions in the Resonance Region | J. P. Chen<br>S. Choi<br>N. Liyanage* | JLab<br>Temple U<br>U of Virginia | 18 | B+ |
| E-01-014 | A | Precision Measurement of Electroproduction of $\pi^0$ near Threshold: A Test of Chiral QCD Dynamics | J. Annand<br>D. Higinbotham<br>R. Lindgren*<br>V. Nelyubin | Glasgow U<br>JLab<br>U of Virginia<br>U of Virginia | 16 | B+ |
| ★ E-01-017 | B | Extension to E99-005: Meson Spectroscopy in Few-Body Decays | G. Adams<br>C. Salgado*<br>D. Weygand | RPI<br>NSU<br>JLab | 6 | A- |
| ★ E-01-112 | B | Photoproduction of Vector Mesons off Nuclei - Update to 94-002 | C. Djalali<br>M. Kossov<br>D. Weygand* | USC<br>ITEP<br>JLab | 18 | A- |
| E-02-012 | B | Coherent Vector Meson Production off the Deuteron | F. Klein<br>L. Kramer*<br>S. Stepanyan | CUA<br>FIU<br>ODU | 50 | A- |
| E-02-103 | B | A Precision Measurement of the Neutral Pion Lifetime via the Primakoff Effect | D. Dale<br>S. Danagoulian<br>A. Gasparian*<br>R. Miskimen | U of Kentucky<br>NCAT State U<br>NCAT State U<br>U Mass | 22 | A |
| E-02-112 | B | Search for Missing Nucleon Resonances in the Photoproduction of Hyperons Using a Polarized Photon Beam and a Polarized Target | P. Eugenio<br>F. Klein*<br>L. Todor | FSU<br>CUA<br>CMU | 20 | A- |
| E-03-004 | A | Measurement of Single Target-Spin Asymmetry in Semi-Inclusive Pion Electroproduction on a Transversely Polarized $^3$He Target | J. P. Chen<br>X. Jiang*<br>J. c. Peng | JLab<br>Rutgers U<br>U of Illinois | 24 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-03-006 | B | The GDH Sum Rule with Nearly Real Photons and the Proton $g_1$ Structure Function at Low Momentum Transfer | M. Battaglieri<br>R. De Vita<br>M. Ripani* | INFN<br>INFN<br>INFN | 20 | A |
| E-03-008 | C | Sub-threshold J/$\chi$ Photoproduction | P. Bosted*<br>J. Dunne | U Mass<br>MSU | 7 | B+ |
| E-03-012 | B | The Structure of the Free Neutron Via Spectator Tagging | H. Fenker<br>C. Keppel<br>S. Kuhn*<br>W. Melnitchouk | JLab<br>Hampton U<br>ODU<br>JLab | 25 | A- |
| E-03-105 | B | Pion Photoproduction from a Polarized Target | N. Benmouna<br>G. O'Rielly<br>I. Strakovski<br>S. Strauch* | GWU<br>U Mass<br>GWU<br>Rutgers U | 18 | B+ |
| | | ***Nucleon and Meson Form Factors and Sum Rules: Approved*** | | | | |
| ★ E-91-023 | B | Measurement of Polarized Structure Functions in Inelastic Electron Proton Scattering using the CEBAF Large Acceptance Spectrometer | V. Burkert*<br>D. Crabb<br>R. Minehart | JLab<br>U of Virginia<br>U of Virginia | 42 | A |
| ★ E-93-009 | B | The Polarized Structure Function $G_{1n}$ and the $Q^2$ Dependence of the Gerasimov-Drell-Hearn Sum Rule for the Neutron | G. Dodge<br>S. Kuhn*<br>M. Taiuti | ODU<br>ODU<br>INFN | 40 | A |
| ★ E-93-018 | C | Longitudinal/Transverse Cross Section Separation in $p(e,e'K^+)\Lambda(\Sigma)$ for $0.5<Q^2<2.0$ $(GeV/c)^2$, $W>1.7$ GeV and $t_{min}>0.1$ $(GeV/c)^2$ | O. Baker | Hampton U | 15 | B+ |
| ★ E-93-021 | C | The Charged Pion Form Factor | D. Mack*<br>R. Whitney | JLab<br>JLab | 9 | B+ |
| ★ E-93-026 | C | The Charge Form Factor of the Neutron | D. Day | U of Virginia | 60 | A |
| ★ E-93-027 | A | Electric Form Factor of the Proton by Recoil Polarization | C. Perdrisat*<br>V. Punjabi | W&M<br>NSU | 16 | B+ |
| ★ E-93-038 | C | The Electric and Magnetic Form Factors of the Neutron from the d(e,e'n)p Reaction based on PR-89-005 [originally two proposals PR-93-038 (electric) and -039 (magnetic)] | B. Anderson<br>S. Kowalski<br>R. Madey* | Kent State U<br>MIT<br>Hampton U | 60 | A |
| ★ E-93-050 | A | Nucleon Structure Study By Virtual Compton Scattering | P. Bertin<br>P. Guichon<br>C. Hyde-Wright | UCF<br>SACLAY<br>ODU | 10 | A- |
| ★ E-94-010 | A | Measurement of the Neutron ($^3$He) Spin Structure Function at Low $Q^2$ | G. Cates<br>J. P. Chen<br>Z. E. Meziani* | U of Virginia<br>JLab<br>Temple U | 31 | A- |

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ★ | E-94-017 | B | The Neutron Magnetic Form Factor from Precision Measurements of the Ratio of Quasielastic Electron-Neutron to Electron-Proton Scattering in Deuterium | W. Brooks*<br>M. Vineyard | JLab | 15 | B+ |
| ★ | E-97-103 | A | Search for Higher Twist Effects in the Neutron Spin Structure Function $g_2^n(x,Q^2)$ | T. Averett<br>W. Korsch* | W&M<br>U of Kentucky | 16 | B+ |
| ☆ | E-97-110 | A | The GDH Sum Rule and the Spin Structure of $^3$He and the Neutron Using Nearly Real Photons | J. P. Chen*<br>A. Deur<br>F. Garibaldi | JLab<br>U of Virginia<br>INFN | 18 | A- |
| ★ | E-99-007 | A | Measurement of $G_E^P$ / $G_M^P$ to $Q^2$ = 5.6 (GeV/c)$^2$ by the Recoil Polarization Method | E. Brash<br>M. Jones<br>C. Perdrisat*<br>V. Punjabi | U of Regina<br>JLab<br>W&M<br>NSU | 28 | B+ |
| ★ | E-99-114 | A | Exclusive Compton Scattering on the Proton | C. Hyde-Wright<br>A. Nathan<br>B. Wojtsekhowski* | ODU<br>U of Illinois<br>JLab | 18 | A- |
| | E-00-108 | C | Duality in Meson Electroproduction | R. Ent*<br>H. Mkrtchyan<br>G. Niculescu | JLab<br>Yerevan<br>U of Virginia | 20 | B+ |
| | E-00-110 | A | Deeply Virtual Compton Scattering at 6 GeV | P. Bertin<br>C. Hyde-Wright<br>R. Ransome<br>R. Ransome<br>F. Sabatie* | UCF<br>ODU<br>Rutgers U<br>Rutgers U<br>SACLAY | 20 | A- |
| ★ | E-01-001 | A | New Measurement of ($G_E$/$G_M$) for the Proton | J. Arrington*<br>R. Segel* | ANL<br>Northwestern U | 10 | A- |
| | E-01-004 | C | Extension to E93-021: The Charged Pion Form Factor | H. Blok*<br>G. Huber*<br>D. Mack* | Vrije U<br>U of Regina<br>JLab | 14 | A- |
| | E-01-109 | C | Measurement of $G_E^P$ / $G_M^P$ to $Q^2$ = 9 (GeV/c)$^2$ via Recoil Polarization | E. Brash<br>C. Perdrisat*<br>V. Punjabi | U of Regina<br>W&M<br>NSU | 40 | A |
| | E-01-113 | B | Deeply Virtual Compton Scattering with CLAS at 6 GeV | V. Burkert<br>L. Elouadrhiri<br>M. Garcon<br>S. Stepanyan* | JLab<br>JLab<br>SACLAY<br>ODU | 60 | A |
| | E-02-013 | A | Measurement of the Neutron Electric Form Factor $G_E^n$ at High $Q^2$ | G. Cates<br>K. McCormick<br>B. Reitz<br>B. Wojtsekhowski* | U of Virginia<br>Rutgers U<br>JLab<br>JLab | 32 | A |
| | E-02-020 | C | The $Q_{Weak}$ Experiment: A Search for Physics at the TeV Scale via a Measurement of the Proton's Weak Charge | J. Bowman<br>R. Carlini*<br>J. Finn<br>S. Kowalski<br>S. Page | LANL<br>JLab<br>W&M<br>MIT | 23 | A |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-02-109 | C | Measurement of R= $\sigma_L/\sigma_T$ on Deuterium in the Nucleon Resonance Region | M. Christy*<br>C. Keppel | Hampton U<br>Hampton U | 13 | B+ |
| E-03-003 | A | Polarization Transfer in Wide Angle Compton Scattering | A. Nathan<br>B. Wojtsekhowski* | U of Illinois<br>JLab | 7 | B+ |

***Properties of Nuclei: Approved***

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| ★/ E-89-003 | A | Study of the Quasielastic (e,e'p) reaction in $^{16}$O at High Recoil Momentum | W. Bertozzi<br>K. Fissum<br>A. Saha*<br>L. Weinstein | MIT<br>U of Lund<br>JLab<br>ODU | 20 | B- |
| ★ E-89-008 | C | Inclusive Scattering for Nuclei at x>1 and High $Q^2$ | D. Day<br>B. Filippone* | U of Virginia<br>CIT | 8 | B |
| ★ E-89-009 | C | Investigation of the Spin Dependence of the $\Lambda$N Effective Interaction in the P Shell | R. Chrien<br>E. Hungerford<br>L. Tang* | BNL<br>U of Houston<br>Hampton U | 25 | B+ |
| ★ E-89-015 | B | Study of Coincidence Reactions in the Dip and Delta-Resonance Regions: Resubmitted as PR-91-009 | H. Baghaei | U of Texas | 33 | B |
| ★ E-89-017 | B | Electro-excitation of the $\Delta$(1232) in Nuclei: Resubmitted as PR-91-009 | R. Sealock | U of Virginia | 33 | B |
| ★ E-89-027 | B | Coincidence Reaction Studies with the CLAS | W. Bertozzi<br>W. Boeglin<br>L. Weinstein* | MIT<br>FIU<br>ODU | 33 | B+ |
| ★ E-89-031 | B | Study of Multi-Nucleon Knockout with the CEBAF Large Acceptance Spectrometer: Resubmitted as PR-91-009 | F. Hersman<br>J. Lightbody<br>R. Miskimen* | U of NH<br>NSF<br>U Mass | 33 | B+ |
| ★ E-89-032 | B | Study of the Local Properties of Nuclear Matter in Electron-Nucleus and Photon-Nucleus Interactions with Backward Particle Production Using the CLAS Detector: PR-91-009 | A. Stavinskiy | ITEP | 33 | B- |
| ★/ E-89-033 | A | Measurement of Recoil Polarization in the $^{16}$O (e,e'p) Reaction with 2.4 GeV Electrons | C. Chang<br>C. Glashausser*<br>S. Nanda<br>P. Rutt | U of Maryland<br>Rutgers U<br>JLab<br>Rutgers U | 20 | B- |
| ★ E-89-036 | B | Study of Short-Range Properties of Nuclear Matter in Electron-Nucleus and Photon-Nucleus Interactions with Backward Particle Production using the CLAS Detector: PR-91-009 | K. Egiyan | Yerevan | 33 | C+ |

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ★ | E-91-013 | C | The Energy Dependence of Nucleon Propagation in Nuclei as Measured in the (e,e'p) Reaction | D. Geesaman | ANL | 24 | B- |
| ★/ | E-93-008 | B | Inclusive $\eta$ Photoproduction in Nuclei | M. Vineyard | | 23 | B |
| ★ | E-93-019 | B | Photoabsorption and Photofission of Nuclei | B. Berman*<br>N. Bianchi<br>V. Muccifora | GWU<br>INFN<br>INFN | 3 | B- |
| | E-94-107 | A | High Resolution 1p shell Hypernuclear Spectroscopy | S. Frullani<br>F. Garibaldi*<br>J. LeRose<br>P. Markowitz<br>T. Saito | INFN<br>INFN<br>JLab<br>FIU<br>Tohoku U | 24 | B+ |
| ★ | E-94-139 | C | Measurement of the Nuclear Dependence and Momentum Transfer Dependence of Quasielastic (e,e'p) Scattering at Large Momentum Transfer | R. Ent<br>R. Milner* | JLab<br>MIT | 17 | B- |
| | E-97-006 | C | Correlated Spectral Function and (e,e'p) Reaction Mechanism | I. Sick | U of Basel | 15 | A- |
| ★ | E-97-111 | A | Systematic Probe of Short-Range Correlations via the Reaction $^4$He(e,e'p)$^3$H | J. Mitchell<br>B. Reitz*<br>J. Templon | JLab<br>JLab<br>NIKHEF | 12 | B+ |
| ★ | E-98-104 | B | Measurement of the Polarized Electron Beam Asymmetry on Exclusive Reactions in Nuclei with CLAS | F. Hersman*<br>M. Holtrop | U of NH<br>U of NH | 35 | N/ |
| | E-00-101 | C | A Precise Measurement of the Nuclear Dependence of Structure Functions in Light Nuclei | J. Arrington | ANL | 12 | B+ |
| ★ | E-00-102 | A | Testing the Limits of the Single Particle Model in $^{16}$O(e,e'p): Update to E89-003 | W. Bertozzi*<br>K. Fissum*<br>A. Saha*<br>L. Weinstein* | MIT<br>U of Lund<br>JLab<br>ODU | 20 | A- |
| | E-01-011 | C | Spectroscopic Study of Lambda Hypernuclei up to Medium-Heavy Mass Region Through the (e,e'K$^+$) Reaction | O. Hashimoto*<br>S. Nakamura<br>J. Reinhold<br>L. Tang | Tohoku U<br>Tohoku U<br>FIU<br>Hampton U | 19 | A- |
| ★ | E-01-015 | A | Proposal 97-106 (update): Studying the Internal Small-Distance Structure of Nuclei via the Triple Coincidence (e,e'p+N) Measurement | W. Bertozzi<br>E. Piasetzky<br>J. Watson<br>S. Wood* | MIT<br>U of Tel Aviv<br>Kent State U<br>JLab | 23 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-01-016 | A | Precision Measurement of Longitudinal and Transverse Response Functions of Quasi-Elastic Electron Scattering in the Momentum Transfer Range 0.55 GeV/c<\|q\|<1.0 GeV/c | J. P. Chen<br>S. Choi*<br>Z. E. Meziani | JLab<br>Temple U<br>Temple U | 26 | A- |
| E-02-017 | C | Status of the $\Delta$S=1 Hadronic Weak Interaction Program: (update to 99-003) | A. Margaryan<br>L. Tang* | Yerevan<br>Hampton U | 7 | B+ |
| E-02-019 | C | Inclusive Scattering from Nuclei at $x$>1 and High $Q^2$ with a 6 GeV Beam | J. Arrington<br>D. Day<br>B. Filippone<br>A. Lung* | ANL<br>U of Virginia<br>CIT<br>JLab | 28 | A- |
| E-02-104 | B | Quark Propagation Through Cold QCD Matter | W. Brooks | JLab | 20 | B+ |
| E-02-110 | B | $Q^2$ Dependence of Nuclear Transparency for Incoherent $\pi^0$ Electroproduction | K. Hafidi*<br>M. Holtrop<br>B. MUSTAPHA | ANL<br>U of NH<br>ANL | 24 | B+ |
| E-03-103 | C | A Precise Measurement of the Nuclear Dependence of Structure Functions in Light Nuclei | J. Arrington | ANL | 10 | B+ |

### *Strange Quarks: Approved*

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ★/ | E-89-004 | B | Electromagnetic Production of Hyperons | R. Schumacher | CMU | 15 | B+ |
| ★/ | E-89-024 | B | Radiative Decays of the Low-Lying Hyperons with PR-89-004 | G. Mutchler | Rice U | 65 | B+ |
| ☆ | E-89-043 | B | Measurements of the Electroproduction of the $\lambda$ (gnd), $\lambda$*(1520) and $f_o$(975) via the $K^+ K^-$ p and $K^+ \pi^-$ p Final States | L. Dennis<br>H. Funsten* | FSU<br>W&M | 48 | A- |
| ★/ | E-89-045 | B | Study of Kaon Photoproduction on Deuterium | B. Mecking | JLab | 23 | B+ |
| ★ | E-91-010 | A | Parity Violation in Elastic Scattering From the Proton and $^4$He | J. Finn<br>P. Souder* | W&M<br>Syracuse U | 42 | A |
| ☆ | E-91-014 | B | Quasi-Free Strangeness Production in Nuclei | C. Hyde-Wright | ODU | 25 | B- |
| ★ | E-91-016 | C | Electroproduction of Kaons and Light Hypernuclei | J. Reinhold*<br>B. Zeidman | FIU<br>ANL | 21 | A- |
| ☆ | E-93-022 | B | Measurement of the Polarization of the $\phi$(1020) in Electroproduction | H. Funsten<br>P. Rubin<br>E. Smith* | W&M<br>U of Richmond<br>JLab | 15 | B+ |
| ☆ | E-93-030 | B | Measurement of the Structure Functions for Kaon Electroproduction | K. Hicks<br>M. Mestayer* | Ohio U<br>JLab | 50 | B+ |

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ☆ | E-95-003 | B | Measurement of $K^0$ Electroproduction | K. Dhuga*<br>R. Magahiz<br>R. Schumacher | GWU<br>CMU<br>CMU | 80 | B+ |
| ★ | E-98-108 | A | Electroproduction of Kaons up to $Q^2$=3 $(GeV/c)^2$ | O. Baker<br>C. Chang<br>S. Frullani<br>M. Iodice<br>P. Markowitz* | Hampton U<br>U of Maryland<br>INFN<br>INFN<br>FIU | 21 | B+ |
| ☆ | E-98-109 | B | Photoproduction of phi Mesons with Linearly Polarized Photons | P. Cole<br>J. Mueller<br>D. Tedeschi* | U of Texas<br>U of Pittsburgh<br>USC | 13 | B+ |
| ☆ | E-99-006 | B | Polarization Observables in the $^1H(e,e'K^+)\Lambda$ Reaction | D. Carman*<br>K. Joo<br>L. Kramer<br>B. Raue | Ohio U<br>U of Conn<br>FIU<br>FIU | | B |
| | E-99-115 | A | Constraining the Nucleon Strangeness Radius in Parity Violating Electron Scattering | K. Kumar*<br>D. Lhuillier | U Mass<br>SACLAY | 30 | A |
| ☆ | E-00-006 | C | $G^0$ Experiment: Forward Angle Measurements | D. Beck | U of Illinois | 70 | A |
| ★ | E-00-112 | B | Exclusive Kaon Electroproduction in Hall B at 6 GeV | D. Carman*<br>K. Joo<br>G. Niculescu<br>B. Raue | Ohio U<br>U of Conn<br>U of Virginia<br>FIU | 30 | B |
| | E-00-114 | A | Parity Violation from $^4$He at Low $Q^2$: A Clean Measurement of $\rho_s$ | D. Armstrong*<br>R. Michaels | W&M<br>JLab | 30 | A |
| | E-03-113 | B | Investigation of Exotic Baryons States in Photoproduction Reactions with CLAS | K. Hicks*<br>S. Stepanyan | Ohio U<br>ODU | 30 | A |

***Conditionally Approved***

| | Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|---|
| ★ | E-94-003 | B | Study of the $\Delta$(1232) Using Double Polarization Asymmetries | V. Burkert<br>R. Minehart<br>P. Stoler* | JLab<br>U of Virginia<br>RPI | | |
| | E-01-104 | B | Helicity Structure of Pion Photoproduction: Update of Experiment 91-015 | D. Crabb<br>M. Khandaker<br>D. Sober* | U of Virginia<br>JLab<br>CUA | 22 | B+ |
| | E-01-115 | C | Measurement of the Parity Violating Asymmetry in the N to Delta Transition | N. Simicevic<br>S. Wells* | LTU<br>LTU | | B+ |
| | E-01-116 | C | The G0 Experiment:: Backward Angle Measurements | D. Beck | U of Illinois | 60 | A |
| | E-02-101 | A | Exclusive Study of Deuteron Electrodisintegration near Threshold | W. Bertozzi<br>B. Norum<br>T. Tamae<br>K. Wang* | MIT<br>U of Virginia<br>Tohoku U<br>U of Virginia | 16 | B+ |

| Exp # | Hall | Title | Spokesperson | Institutions | Beam days | Rating |
|---|---|---|---|---|---|---|
| E-03-011 | A | Update of E00-003: Neutron Skin of $^{208}$Pb through Parity Violating Electron Scattering | R. Michaels*<br>P. Souder<br>G. Urciuoli | JLab<br>Syracuse U<br>INFN | 30 | A- |
| E-03-106 | A | Deeply Virtual Compton Scattering on the Neutron | P. Bertin<br>C. Hyde-Wright<br>F. Sabatie*<br>E. Voutier | UCF<br>ODU<br>SACLAY<br>ISN | 13 | A- |
| E-03-109 | C | Spin Asymmetries on the Nucleon Experiment (SANE) | O. Rondon-Aramayo<br>G. Warren* | U of Virginia<br>JLab | 27 | A- |

## APPENDIX C: Facilities and Infrastructure Plan

| | Project Number | SF | FY 2003 Approp. ($000) | FY 2004 Target ($000) | FY 2005 ($000) | FY 2006 ($000) | FY 2007 ($000) | FY 2008 ($000) | FY 2009 ($000) |
|---|---|---|---|---|---|---|---|---|---|
| **SITE NAME: Jefferson Lab** | | | | | | | | | |
| **1.0 Line Item Projects** | | | | | | | | | |
| CEBAF Center Addition, Phase 1 (TJNAF) | MEL-001-033 | 61,000 | 1,481 | 3,914 | 5,105 | | | | |
| CEBAF Center Addition, Phase 2 (TJNAF) | | 83,000 | | | | | | 1,055 | 8,000 |
| Test Lab Rehab | | | | | | | 800 | 6,000 | |
| **Subtotal Line Item Projects** | | **144,000** | **1,481** | **3,914** | **5,105** | | **800** | **7,055** | **8,000** |
| **2.0 General Plant Project (GPP)** | | | | | | | | | |
| Site Storm Drainage Improvements | 03-GPP-300-1 | | 550 | 295 | | | | | |
| North Connector Road | 03-GPP-300-2 | | 160 | | | | | | |
| Miscellaneous Projects | 03-GPP-300-3 | | 106 | | | | | | |
| Test Lab Fire Protection improvements | 04-GPP-300-1 | | | 50 | | | | | |
| Upgrade Accelerator Fire Detection Zones | 04-GPP-300-2 | | | 55 | 200 | | | | |
| Miscellaneous Projects | 04-GPP-300-3 | | | 60 | | | | | |
| ESR Transformer | 05-GPP-300-1 | | | | 250 | | | | |
| EEL Mods for Target Group | 05-GPP-300-2 | | | | 70 | | | | |
| Additional Site LCW | 05-GPP-300-3 | | | | 1,200 | | | | |
| Refrigeration Service Building & Utilities | 05-GPP-300-4 | 3,600 | | | 400 | 1,580 | | | |
| Technical Support Bldg Access Road | 05-GPP-300-5 | | | | 100 | | | | |
| Digital Microwave & Laser Optics R&D Lab (EEL S&R) | 05-GPP-300-6 | 3,000 | | | 570 | | | | |
| South Connector Road | 05-GPP-300-7 | | | | 200 | | | | |
| Accelerator Site Parking | 05-GPP-300-8 | | | | 50 | | | | |

| | Project Number | SF | FY 2003 Approp. ($000) | FY 2004 Target ($000) | FY 2005 ($000) | FY 2006 ($000) | FY 2007 ($000) | FY 2008 ($000) | FY 2009 ($000) |
|---|---|---|---|---|---|---|---|---|---|
| Gate House/Badge Office | 05-GPP-300-9 | | | | 250 | | | | |
| Rehab CEBAF Ctr Kitchen | 05-GPP-300-10 | | | | 200 | | | | |
| Miscellaneous Projects | 05-GPP-300-11 | | | | 110 | | | | |
| North/South Access Building Additions | 06-GPP-300-1 | 3,000 | | | | 550 | | | |
| Rehab CEBAF Center HVAC | 06-GPP-300-2 | | | | | 400 | 450 | | |
| Physics Technical Site Offices | 06-GPP-300-3 | 4,000 | | | | 900 | | | |
| Rehab CEBAF Center Kitchen Equipment | 06-GPP-300-4 | | | | | 150 | | | |
| Miscellaneous Projects | 06-GPP-300-5 | | | | | 120 | | | |
| Retention Pond (Near Physics Storage Bldg) | 07-GPP-300-1 | | | | | | 200 | | |
| FEL Transformer | 07-GPP-300-2 | | | | | | 225 | | |
| North Connector Parking Lot | 07-GPP-300-3 | | | | | | 170 | | |
| North Connector Road Extension | 07-GPP-300-4 | | | | | | 170 | | |
| Rehab Counting House HVAC | 07-GPP-300-5 | | | | | | 600 | | |
| Comms Ductbank Btw MCC & NLinac | 07-GPP-300-6 | | | | | | 125 | | |
| Site Perimeter Fence | 07-GPP-300-7 | | | | | | 650 | | |
| Test Lab Improvements | 07-GPP-300-8 | | | | | | 550 | | |
| RADCON Waste Storage | 07-GPP-300-9 | 1,000 | | | | | 120 | | |
| Tunnel Communications Improvement | 07-GPP-300-10 | | | | | | 400 | | |
| Miscellaneous Projects | 07-GPP-300-11 | | | | | | 140 | | |
| EL Additional Technical Space | 08-GPP-300-1 | 6,000 | | | | | | 1,400 | |
| Additional Experiment Setup Space | 08-GPP-300-2 | | | | | | | 1,280 | |
| Site Lighting | 08-GPP-300-3 | | | | | | | 220 | |
| Miscellaneous Projects (FY2008-2009) | | | | | | | | 1,000 | 4,000 |
| **Subtotal GPP (ALL Nuclear Physics)** | | **20,600** | **816** | **460** | **3,600** | **3,700** | **3,800** | **3,900** | **4,000** |

| | Project Number | SF | FY 2003 Approp. ($000) | FY 2004 Target ($000) | FY 2005 ($000) | FY 2006 ($000) | FY 2007 ($000) | FY 2008 ($000) | FY 2009 ($000) |
|---|---|---|---|---|---|---|---|---|---|
| **3.0 Capital Projects** | | | | | | | | | |
| Hall C Transformer (for $Q_{Weak}$ Experiment) | | | | 300 | | | | | |
| **Subtotal Non-Nuclear Physics Funded** | | | | 300 | | | | | |
| **4.0 Non NP Projects** | | | | | | | | | |
| FEL Test Cave | | 825 | | 300 | | | | | |
| FEL Addition | | 22,600 | | | 3,000 | 2,100 | | | |
| Education Center (BEAMS, etc.) | | 20,000 | | | 3,600 | | | | |
| **Subtotal Non-Nuclear Physics Funded** | | **43,425** | | **300** | **6,600** | **2,100** | | | |
| **5.0 Elimination of Excess** | **Project Number** | **Excess SF Elimated** | | | | | | | |
| CEBAF Center Addition, Phase 1 (TJNAF) | MEL-001-033 | 22,000 | | | 75 | | | | |
| Technical Support Building (Excess existing trailers) | | 9,000 | | | 30 | | | | |
| Storage Building Phase 1 (Excess existing containers) | | 14,000 | | | 20 | | | | |
| Storage Building Phase 2 (Excess existing containers) | | 5,000 | | | | | 8 | | |
| Physic Trailers | 06-GPP-300-8 | 2,000 | | | | | | 5 | |
| **Subtotal of Area Eliminated** | | **52,000** | | | **125** | | **8** | **5** | |
| **6.0 Leased Space** | | **Leased SF** | $ | | $ | $ | $ | $ | $ |
| ARC Building (Basic) | | 41,560 | 498 | 522 | 522 | 547 | 547 | 574 | 574 |
| ARC Building (Reduction) | | (16,000) | | | | | | (221) | (221) |
| ARC Building (628) | | 842 | 18 | 18 | 18 | 18 | | | |
| ARC Building (L109) | | 199 | 4 | 4 | 4 | | | | |
| Temp Office Lease (Phase 1) | | 20,000 | | | | 360 | 360 | 360 | 360 |

| | Project Number | SF | FY 2003 Approp. ($000) | FY 2004 Target ($000) | FY 2005 ($000) | FY 2006 ($000) | FY 2007 ($000) | FY 2008 ($000) | FY 2009 ($000) |
|---|---|---|---|---|---|---|---|---|---|
| Blue Crab Warehouse | | 7,000 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Middleground Warehouse | | 3,380 | 30 | 30 | | | | | |
| Hampton Crane & Rigging Warehouse (80 SF) | | 80 | 1 | 1 | 1 | 1 | | | |
| Technical Support Building | | 33,000 | | 200 | 400 | 400 | 400 | 400 | 400 |
| Shipping & Receiving/Storage | | 21,000 | | 150 | 300 | 300 | 300 | 300 | 300 |
| Storage Phase 2 | | 8,000 | | | | 60 | 60 | 60 | 60 |
| Temp Warehouse | | 20,000 | | | | | 120 | 120 | 60 |
| Federal Document Center | | | 8 | 8 | 8 | 8 | 8 | | |
| **Subtotal Leased Space** | | **139,061** | **599** | **973** | **1,293** | **1,734** | **1,835** | **1,633** | **1,573** |
| | | | | | | | | | |

## APPENDIX D: Glossary of Jefferson Lab Acronyms Used within Institutional Plan

| | |
|---|---|
| AES, Inc. | Advanced Energy Systems, Inc. |
| AIP | Accelerator Improvement Project |
| ANL | Argonne National Laboratory |
| ARC | Applied Research Center |
| AWP | Annual Work Plan |
| AY | Actual Year |
| BEAMS | Becoming Enthusiastic About Math and Science |
| BES | Basic Energy Sciences |
| BESAC | Basic Energy Sciences Advisory Committee |
| BINP | Budker Institute for Nuclear Physics |
| BNL | Brookhaven National Lab |
| BPMs | Beam Position Monitors |
| BSD | Business Services Department |
| CANS | Central Access Notification System |
| CASA | Center for Advanced Studies of Accelerators |
| CD-0 | Critical Decision 0 |
| CD-3 | Critical Decision 3 |
| CEBAF | Continuous Electron Beam Accelerator Facility |
| CHL | Central Helium Liquifier |
| CHROME | Cooperating Hampton Roads Organizations For Minorities in Engineering |
| CLAS | CEBAF Large Acceptance Spectrometer (Hall B) |
| CW | Continuous Wave |
| DC | Direct Current |
| DESY | Deutsches Elektronen-Synchrotron |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DUV | Deep Ultraviolet |
| DVCS | Deeply Virtual Compton Scattering |
| EBAC | Excited Baryon Analysis Center |
| EEL | Experimental Equipment Lab |
| EH&S | Environment, Health, and Safety |
| ELFE | Electron Laboratory for Europe |
| ELIC | Electron Light Ion Collider |
| EMC | Electron Muon Collaboration |
| e-RHIC | Electron-Relativistic Heavy Ion Collider |
| ERL | Energy Recovered Linac |
| FEL | Free-Electron Laser |
| FIU | Florida International University |
| FNAL | Fermi National Accelerator Laboratory |
| FSD | Fast Shutdown Device |
| FTE | Full Time Equivalent |
| FY | Fiscal Year |
| FZK | Forschungszentrum Karlsruhe |
| FZR | Forschungszentrum Rossendorf |
| G0 or $G^0$ | G-Zero Experiment on Strange Quark Form Factors |
| GaAs | Gallium Arsenide |
| GB | Gigabyte |
| GDH | Gerasimov-Drell-Hearn |
| GeV | Giga (or Billion) electron volts |
| GPDs | General Parton Distributions |

| | |
|---|---|
| GPP | General Plant Project |
| HBCU | Historically Black College or University |
| HENP | High Energy Nuclear Physics |
| HMS | High Momentum Spectrometer (Hall C) |
| HNSS | Hyper Nuclear Spectrometer System |
| HRIS | Human Resources Information Systems |
| HRS | High Resolution Spectrometer (Hall A) |
| HSI | Hispanic Serving Institutions |
| HUGS | Hampton University Graduate Studies |
| HVAC | Heating, Ventilation, Air Conditioning |
| IR | Infrared |
| ISM | Integrated Safety Management |
| ISMS | Integrated Safety Management System |
| JLab | Jefferson Lab |
| JLTRC | Jefferson Lab Technology Review Committee |
| JTO | Joint Technology Office |
| KEK | High Energy Accelerator Research Organization, Japan |
| LANL | Los Alamos National Laboratory |
| LHPC | Lattice Hadron Physics Collaboration |
| LPC | Laser Processing Consortium |
| LQCD | Lattice Quantum Chromodynamics |
| LRDP | Long Range Development Plan |
| LSTPD | Laboratory Science Teacher Professional Development |
| MB/s | Megabytes/second |
| Mbit/s | Megabits/second |
| MeV | Mega Electron Volts |
| MHz | Megahertz |
| MIS | Management Information Systems |
| MIT | Massachusetts Institute of Technology |
| MSU | Michigan State University |
| NAS | National Academy of Science |
| NASA | National Aeronautics and Space Administration |
| NCA&T | North Carolina Agricultural and Technical State University |
| NIST | National Institutes for Science and Technology |
| NN | Nucleon-nucleon |
| NP | Nuclear Physics |
| NRC | Nuclear Regulatory Commission |
| NSAC | Nuclear Science Advisory Committee |
| NSF | National Science Foundation |
| NSU | Norfolk State University |
| ODU | Old Dominion University |
| ONR | Office of Naval Research |
| ORNL | Oak Ridge National Laboratory |
| PAC | Program Advisory Committee |
| pCDR | pre Conceptual Design Report |
| PEST | Physics Enrichment for Science Teachers |
| PPDG | Particle Physics Data Grid |
| PPM | Parts Per Million |
| PRIMEX | Primakoff Experiment |
| QA | Quality Assurance |
| QCD | Quantum Chromodynamics |
| QED | Quantum Electro-Dynamics |
| R&D | Research and Development |
| Rf | Radio Frequency |

| | |
|---|---|
| RHIC | Relativistic Heavy Ion Collider |
| RIA | Rare Isotope Accelerator |
| RPP | Radiation Protection Program Plan |
| S&DB | Small and Disadvantaged Business |
| SC | DOE Office of Science |
| SCiDAC | Science's Discovery through Advanced Computing |
| SER | Site Environmental Report |
| SHMS | Super High Momentum Spectrometer (Hall C) |
| SM | Standard Model |
| SNS | Spallation Neutron Source |
| SOS | Short Orbit Spectrometer |
| SPAG | Science Policy Advisory Group |
| SRF | Superconducting Radio-Frequency |
| SULI | Science Undergraduate Laboratory Internship |
| SUNY | State University of New York |
| SURA | Southeastern Universities Research Association |
| TAC | Technical Advisory Committee |
| TB | Terabyte |
| TESLA | TeV – Energy Superconducting Linear Accelerator |
| THz | Terahertz |
| Ti-sapphire | Titanium Doped Sapphire Crystals |
| TPC | Total Project Cost |
| TRC | Technology Review Committee |
| UV | Ultraviolet |
| UVa | University of Virginia |
| VARC | Virginia Associated Research Center |
| VLANs | Virtual Local Area Networks |
| WSS | Work Smart Standards |