Jefferson Lab
Institutional Plan
FY2000-FY2004

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Jefferson Lab is managed and operated for the U.S. Department of Energy by the Southeastern Universities Research Association (SURA) under contract DE-AC05-84ER40150.

The DOE/JLab Institutional On-Site Review was held September 30, 1999, with no deficiencies noted. Office of Science approval of this plan is pending. Initiatives are provided for consideration by the Department of Energy. Inclusion in this plan does not imply department approval of or intent to support an initiative.

Thomas Jefferson National Accelerator Facility

INSTITUTIONAL PLAN

FY 2000 - FY 2004

September 1999

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EXECUTIVE SUMMARY

Jefferson Lab contributes to the Department of Energy mission to develop and operate major cutting-edge scientific user facilities. Jefferson Lab's CEBAF (Continuous Electron Beam Accelerator Facility) is a unique tool for exploring the transition between the regime where strongly interacting (nuclear) matter can be understood as bound states of protons and neutrons, and the regime where the underlying fundamental quark-and-gluon structure of matter is evident. The nature of this transition is at the frontier of our understanding of matter. Experiments proposed by 834 scientists from 146 institutions in 21 countries await beam time in the three halls. Our user-customers have been delighted with the quality of the data they are obtaining. Driven by their expressed need for energies higher than the 4 GeV design energy and on the outstanding performance of our novel superconducting accelerator, the laboratory currently delivers beams at 5.5 GeV and expects to deliver energies approaching 6 GeV for experiments in the near future.

Building on the success of Jefferson Lab and continuing to deliver value for the nation's investment is the focus of Jefferson Lab's near-term plans. The highest priority for the facility is to execute its approved experimental program to elucidate the quark structure of matter. In doing so, the lab will continue its development of SRF technology and source development to allow the facility to be upgraded to higher energies in an evolutionary way. The user community is exploring the new capabilities that they would like, convening workshops to discuss new research possibilities and to discuss the experimental equipment needs that would allow them to exploit these capabilities. Driven by the energies needed to realize these unique research opportunities, Jefferson Lab plans to build on the capabilities of its Continuous Electron Beam Accelerator Facility (CEBAF) by tripling the beam energy to 12 GeV by FY 2004 for a TPC of $100M, and to then double the energy to 24 GeV in FY 2012.

The same advances and refinements in cavity gradients and source technology that allow the CEBAF accelerator upgrade to 12 GeV provides the capabilities necessary to upgrade the free-electron laser to higher power (10 kW) and makes the ultraviolet (UV) wavelengths desired by industry accessible. The outlook for the FEL is very exciting on two fronts. First, the infrared (IR) demonstration facility provides a test bed for SRF technology development. Second, an upgrade of the IR FEL to higher power not only serves its current user community, but can be used to explore applicability to defense uses and allow a demonstration in the UV range, the regime most interesting for industrial processing.

Jefferson Lab plans to participate in the Strategic Simulation Initiative (SSI) and benefit from the scientific opportunities that it affords. Initially, the lab will contribute its expertise in simulations for nuclear theory and accelerators, data handling, and distributed systems. As part of its SSI activities, the lab is planning to enhance its expertise in lattice QCD and simulations of photon-driven materials and chemical processes. In addition, the lab is forming a collaboration with the SURA universities and other users from the nuclear physics user community and Laser Processing Consortium to participate in SSI.

Jefferson Lab continues to excel not only in its scientific and technical programs but in its administrative areas as well. Our administrative programs support the mission of the lab effectively by being proactive and looking ahead to solve problems before they arise. This approach has been incorporated into our ISMS plan and is being used in high-profile areas such as travel and security to assure that the laboratory continues to balance what is needed for an effective world-class science program with responsible stewardship.

III. LABORATORY SCIENTIFIC AND TECHNICAL VISION AND STRATEGIC PLAN

Context and Trend Analysis

The experimental program underway at Jefferson Lab fulfills a major, two-decade-old priority of the U.S. nuclear science program: the construction and scientific use of a high energy, continuous-beam (cw) electron accelerator capable of supporting a broad range of innovative research in nuclear physics. In this capacity, Jefferson Lab serves the Department of Energy mission to develop and operate major scientific user facilities. Jefferson Lab's CEBAF is a unique facility for exploring the energy region where the transition occurs between the regime where the standard picture of the nucleus as a group of protons and neutrons interacting through potentials is appropriate, and the regime where the quarks and gluons inside the nucleons must be explicitly included. At the high-energy end of this transition region, the essentially exact calculations of perturbative quantum chromodynamics (QCD) are applicable. In the lower-energy, non-perturbative region, characteristic of normal nuclear matter, an important new "strong QCD" framework is required. Elucidating the nature of this transition is one of the last frontiers in our understanding of ordinary matter.

A growing excitement is evident in the over 1600-member user group now that the experiments they have been preparing are running. A backlog of approved experiments awaits beam time in each of the three experimental halls. The accelerator is providing cw electron beams simultaneously to independent experiments exploiting the complementary capabilities of the halls' experimental equipment and we now anticipate meeting user-driven demand by achieving 5.8 GeV in 1999.

As a program-dedicated lab, we have basic research as our primary mission. To accomplish that mission, we developed key technologies that we are now sharing with industry, other labs and the military. Collaboration between universities, industry, and national laboratories is particularly important in an environment where resources are becoming scarce.

One of the biggest challenges facing all federally funded research facilities is finding support for the ongoing R&D needed to maintain our unique core competencies at the cutting edge. The synergy that comes from partnerships such as those Jefferson Lab has developed with industry in the Laser Processing Consortium and the Military provide real leverage for our efforts in SRF accelerator technology and in detector development, allowing us to advance these core competencies cost-effectively.

Vision and Goals

The vision for Jefferson Lab is to:

- Foster user-driven nuclear physics research of international significance as part of the U.S. national laboratory system.
- Leverage resources to support national goals for economic competitiveness.
- Prepare a broadly educated next generation of scientists and engineers for a globally competitive research environment and economy, including in the process traditionally underrepresented populations.
- Contribute to public science literacy through outreach and motivational/educational programs for math and science.
- Develop a world-class workforce.
- Lead responsibly by conducting environmentally sound and safe operations.

This vision translates into specific goals underlying Jefferson Lab's strategic and institutional planning:

1. Enable and conduct a physics research program of the highest scientific priority at the nuclear/particle physics interface.
   - Provide leadership and technical and theoretical support for the user-driven experimental program.
   - Maximize beam time and accelerator and experimental equipment reliability.
   - Increase the maximum beam energy toward 12 GeV (intermediate-term goal) and then to 24 GeV (long-range goal) to extend the scientific reach of the advancing experimental program.

2. Continue world leadership in underlying core competencies.
   - Superconducting radio-frequency technology.
   - Electron source development.
   - Innovative detector technologies.

3. Apply Jefferson Lab technologies to achieve Department of Energy mission and national goals.
   - High-power, energy- and cost-efficient, compact infrared/ultraviolet free-electron lasers.
   - Detectors for medical diagnostics and other applications.

4. Improve laboratory productivity and cost-effectiveness to accomplish more physics research, reduce the unit cost per running hour, and create new paradigms of effectiveness.
   - Accelerator and experimental equipment availability.
   - Business systems efficiency and effectiveness.
   - Demonstration through quantitative metrics (performance contract, DOE productivity metrics).

5. Continue as a recognized leader in environmentally sound and safe operation.
   - Recognized for good performance by regulators.
   - Continue to practice integrated safety management.

6. Serve as an asset to our community.
   - Outreach programs to increase science literacy.
   - Motivation of students in math and science through participation in science.
   - Partnerships with regional universities.

Strategic Plan

At the summary level, Jefferson Lab's Strategic Plan includes the following six elements:

- As the highest priority, conducting its internationally preeminent nuclear physics research program.
- Increasing the beam energy to 12 GeV (intermediate-term goal) and then to 24 GeV (long-range goal) as warranted by scientific priorities, a process endorsed by the DOE/NSF Nuclear Science Advisory Committee.
- Advancing Jefferson Lab's core competencies and enabling technologies, specifically superconducting radio-frequency (SRF) technology, polarized and high-intensity electron sources, and detector technologies, to support Jefferson Lab's program, other DOE missions, and potential spin-offs.
- Applying our expertise and core competencies for national benefit, symbiotic with the nuclear physics mission, with an SRF free-electron laser for scientific, industrial, and defense, applications.
- Participating in partnerships mutually beneficial to DOE, the lab, the region, and the nation.
- Engaging our diverse stakeholders and customers in discussions of their interests and needs, including preservation of environment, health, and safety, and in light of Jefferson Lab's capabilities and core competencies, developing initiatives that will create a dynamic and responsive portfolio of challenges and opportunities applicable to DOE's mission.

Table III-1 summarizes Jefferson Lab's funding and performance goals for the planning period. Table III-2 reports FY 1998 contract performance measure results.

Table III-1
Jefferson Lab Nuclear Physics Funding and Key Performance Goals

	FY1998 (Actual)	FY1999 (Projected)	FY2000 (PB)	FY2000 (Req.)	FY2001 (Req.)	FY2002 (Req.)	FY2003 (Req.)	FY2004 (Req.)
Actual, President's Budget (PB), Projected, or Requirement Budget (AY$M)	69	72	74	76	77	79	80	82
Key Performance Goals/Achieved:								
Weeks of Accelerator Running for Physics	30/31	30/30	31	33	33	33	33	33
Halls in Operation	3/3	3/3	3	3	3	3	3	3
Experiment Multiplicity[1]	2/2	2/2.4	2.1	2.4	2.4	2.4	2.4	2.4
Accelerator Availability (%)[2]	73/68	75/75	70	75	75	75	75	75

[1] Multiplicity indicates expected number of experiments running on the average
[2] Availability is averaged over all running experiments

Table III-2
FY 1997 and 1998 Contract Performance Measure Results

Performance Measure	Points Earned 1997	Points Earned 1998	Points Available
Outstanding Science and Technology	270.0	273.0	300
Reliable Operations	230.0	247.0	250
Scientific and Technical Manpower	71.2	74.5	75
Corporate Citizenship	73.2	73.6	75
Quality Performance in EH&S	97.7	97.7	100
Business and Administrative Practices	89.7	90.3	100
Responsible Institutional Management	90.0	90.3	100
Total	921.8	947.3	1000

Summary

Jefferson Lab represents a considerable investment of public funds as well as physics, engineering, and management expertise over the past decade. As a federal laboratory, we are accountable for achieving the maximum benefit for the nation from this investment in the years ahead. The scientific payoff started in 1995 as we began the approved experimental program. Effective management and stewardship of Jefferson Lab will involve a continuing commitment to excellence in all areas, beginning with the delivery of beam and the conduct of forefront physics experiments. Also important are partnerships with industry and educational institutions to help the nation capitalize in the near term on the knowledge, supporting technologies, and intrinsic excitement of Jefferson Lab's efforts. Of course, all of our efforts must be based on quality management, on employee, subcontractor, and user health and safety, and on sound environmental and business practices.

IV. SUMMARY OF MAJOR PROGRAM INITIATIVES

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

1. 5-YEAR PLANNING

A. Increasing the energy of CEBAF to 12 GeV

The physics opportunities associated with a systematic energy upgrade of CEBAF were endorsed by the 1996 Nuclear Science Advisory Committee (NSAC) Long Range Plan. This endorsement was reaffirmed by the NSAC subcommittee on "Scientific Opportunities and Funding Priorities for the DOE Medium Energy Nuclear Physics Program," chaired by J. Symons, in its September 1998 report. The scientific opportunities supported by the energy upgrade also feature prominently in the report "Nuclear Physics: The Core of Matter, the Fuel of Stars," issued by the National Academy of Sciences' Committee on Nuclear Physics chaired by J. Schiffer as part of the decadal NAS/NRC survey series *Physics in a New Era.*

The first step of the energy upgrade is well underway; the maximum energy of the accelerator has been raised from its original design value of 4 GeV to 5.5 GeV. This upgrade has been accomplished without the addition of any major new components. The maximum energy available at constant cryogenic consumption from the existing accelerator was extended through *in situ* processing of the superconducting cavities and peripherals and the development of a better understanding (and consequently relaxing) of the operational limits on the accelerator structures. This effort is having two desirable outcomes: much improved availability of the accelerator for 4 GeV operation, and the capacity to run at energies close to 6 GeV with acceptable reliability for selected, high-priority experiments. 5.5 GeV beam has already been delivered for physics experiments, and on the basis of progress to date we expect to reach 5.8 GeV by the end of 1999. As the energy is increased, the frequency of short (tens of seconds) beam interruptions increases, affecting availability. As work to remedy this situation progresses, we expect to reach a full 6 GeV reliability. Approximately $1/5^{th}$ of the approved physics program takes advantage of this increased energy capability; it permits access to higher momentum transfers (corresponding to improved spatial resolution in the nucleus) and to higher excitation energies, and it provides enhanced counting rates for many experiments that could have run at 4 GeV.

The second stage of the upgrade will raise the maximum energy available to 12 GeV. Three major new scientific capabilities drove the choice of this energy:

1) a major new physics initiative in meson spectroscopy, which will greatly enhance our understanding of QCD in the confinement regime, requiring 12 GeV;
2) the extension of our physics program to significantly higher momentum transfers, implying correspondingly finer spatial resolution; and
3) broadly enhanced access to the deep inelastic scattering (DIS) regime, which is key to understanding the quark substructure of nuclei.

Second to energy, and apart from the ongoing requirement for highly polarized beams, the most important beam requirement for physics research is high duty factor, ideally cw, operation. With regard to beam current, research needs are met by maintaining constant beam power at 1 MW; i.e. reducing the beam current as beam energy increases. The meson spectroscopy program is in fact adequately served by a few μA.

With these requirements, the accelerator needs upgrades in three major areas: increased energy gain in the accelerating sections to provide the increased energy, increased magnetic fields in the recirculation arcs and transport channels, and roughly doubled cryogenic capacity to maintain cw operation. Current magnet capability is 10 GeV, and so the upgrade to 12 GeV is a relatively modest

effort. Doubling the cryogenic capacity has been worked out conceptually and can be achieved largely through refurbishing and integration of components at hand. The main development and prototyping thrust is in the areas of cryomodules. The dual objective is to increase accelerating gradient and Q value to provide increased energy gain within the envelope of doubled cryogenic capacity. The FEL cryomodules show performance close to the desired level, and a modest ongoing program (the nominal "energy upgrade cryomodule") will demonstrate the required performance through tested prototypes.

As currently proposed, the $ 100 M upgrade project foresees 18 new cryomodules, of which ten would be placed in the existing free spaces in the linacs, two in the injector, and six would be used to replace the weakest of the existing cryomodules.

B. Free-Electron Laser (FEL) User Facility

The design of the IR Demo FEL, and the FEL User Facility described in Chapter V, allow an evolutionary expansion of the FEL to a wider wavelength range and higher powers. A proposal is under discussion with the Department of Energy and the Department of the Navy for committing FY 2000 and FY 2001 funds to upgrade the baseline IR Demo FEL to higher power (10 kilowatts in the IR) and extending the wavelengths to 60 microns in the far infrared and 0.2 microns in the deep ultraviolet. The order-of-magnitude increment in power would be of significant interest to all customers in the program. The IR Demo FEL upgrade is based on adding two cryomodules to the baseline FEL's SRF driver accelerator, extending its energy to 160 - 200 MeV using prototypes of the high gradient cryomodule developed for the CEBAF energy upgrade. An upgraded injector based on the design of the present FEL photocathode gun, and an upgraded injector cryounit will be developed. A higher efficiency IR wiggler has already been developed with one of our industrial partners (Northrop Grumman) which has collaborated with Jefferson Lab in the construction of the IR Demo. A candidate short-wavelength wiggler for kilowatt radiation in the ultraviolet range (190-350 nanometers) is in use in DOE's Advanced Photon Source. If the requested funding is available in FY 2000-2001, the planned Demo upgrade could be installed in FY 2002.

2. LONG RANGE PLANNING

A. CEBAF at 24 GeV

Studies by Jefferson Laboratory users and physicists associated with the ELFE Project in Europe have established that there is a strong physics case for constructing a CEBAF-like accelerator operating at energies in the 10-30 GeV range. We expect that early in the next decade, a widely accepted international consensus will emerge on the need for a 24 GeV electron facility.

With the R&D described in Section IV. 1.A. above, the total cost of upgrading CEBAF to a 24 GeV machine with appropriate detectors would be a fraction of the cost for a green site machine like ELFE. The cryomodule developments that are proposed should make it possible to build such a machine in the existing CEBAF tunnel in the next decade, since replacing the remaining original cryomodules in the linacs will lead to the required installed capacity of 24 GeV. With such an upgrade, Jefferson Laboratory would remain in the forefront of nuclear physics research for many years to come with only a modest investment of funds for capital improvements.

B. Scientific Simulation Initiative (SSI)

The DOE Scientific Simulation Initiative (SSI) has as its goal the application of advances in high performance computing to challenging scientific problems. As computers reach the scale of multiple tera floating point operations per second, they open the door to using simulation as a third avenue of research, complementing experiment and theory. This DOE initiative will encompass the development of scientific models or simulations in a number of scientific domains, including several of interest to Jefferson Lab. The complex platforms needed to execute the models will require technology developments in networking, data handling, visualization, and software tools such as integrated problem solving environments.

Jefferson Lab, with encouragement from DOE, plans to contribute to this initiative on a number of fronts. These include application development, technology development, and computing infrastructure development and support. The laboratory is developing collaborations with SURA universities, other DOE laboratories and other institutions to address such topics as high performance computing efficiency and optimizations, lattice QCD calculations, accelerator simulations, distributed data handling, and advanced batch systems. Within the Free Electron Laser (FEL) program, we anticipate a growing need for simulations of photon-driven materials and chemical processes.

Complementing its research program in science simulations and in computing hardware and software technology, the laboratory plans to deploy over a multi-year period a tera scale computing facility. This facility will be used as a platform for the SSI development activities of the laboratory and its collaborators, as well as for production running of science applications within the nuclear physics and FEL programs, and of a small number of approved SSI applications.

As with the CEBAF nuclear physics program and the FEL program, we anticipate that there will be tens of university based scientists for every lab scientist participating in this project. In this way the laboratory would play a key role in helping to fill the manpower needs inherent in this initiative.

Jefferson Lab
Programmatic Strategic Goals

Program	Near–Term FY 2000 - FY 2004	Mid–Term FY 2005 - FY 2009	Long–Term FY 2010 - FY 2015
Nuclear Physics	• Execute a world-class physics program that makes substantial progress toward addressing key issues in nuclear physics – complete 15-20 experiments per year, addressing a significant portion of the approved program – improve availability of accelerator (+$3M needed to meet availability goal) – continuously improve the overall program quality, through Program Advisory Committee reviews of new proposals, and mini workshops looking at the overall program – foster an awareness of and appreciation for the quality of this science in the nuclear physics community, the scientific community at large, and the public • Construct new equipment as needed to support this world-class program, including: – evolutionary upgrades to keep the existing equipment at the state-of-the-art – selected major new instruments needed to address specific, high-priority issues and/or expand our capabilities to match scientific opportunities: G^0, Compton Detector, Wide Angle Calorimeters, . . . • Determine, develop and refine (by late FY2000) the scientific case for 12 GeV, and plan the experimental equipment needed to carry out the identified key experiments (by early FY2002) • Conduct necessary cryomodule development by FY2004 to reach to 12 GeV at lowest cost • Involve the international community (and High Energy Physics) to the maximum extent possible, as a basis of support for the 12 GeV facility and a bridge to the future	• $100M construction project to reach 12 GeV and build needed new instrumentation (FY2004 - FY2006) • Launch the new physics program using this equipment and the upgraded accelerator • Decide on the next broad target of scientific opportunity for the facility (24 GeV?), by ~FY2005, then develop and refine the case for it • Foster international support for the next facility	• Move (in a manner analogous to the 12 GeV upgrade), toward the realization of the next generation facility – Doubling of energy (to 24 GeV) – International collaboration
FEL	• Deliver 1 kW of infrared light • Develop user communities • Become acknowledged and established as an operating user facility • Take advantage of university/lab/industry synergy in the Applied Research Center	• Achieve 10 kW IR/1 kW UV light • Further develop materials science interest	
SSI	• Develop an R&D program in High Performance Computing with extensive university involvement • Install and operate a highly efficient, cost optimal tera-flop scale computing facility • Considerably expand lattice QCD calculations for lab-relevant physics • Develop simulation as a useful complement to FEL-relevant material science experiments • Simulate significant design points for the CEBAF and FEL accelerator upgrades	• Develop simulation as a mature adjunct to the FEL experimental program • Perform critical comparison of nuclear theory and experiment through lattice QCD calculations • Thoroughly simulate accelerator designs for CEBAF upgrades and next generation FEL	

V. OPERATIONS AND INFRASTRUCTURE STRATEGIC PLAN

1. SCIENTIFIC AND TECHNICAL PROGRAMS

A. Physics Program

Our understanding of the fundamental 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 a fundamental understanding of their interactions – the "strong interactions" – so that now nuclear and subnuclear physics have, for the first time, a basis as solid as the theory on which atomic and molecular physics are built. There is in fact 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 quantum chromodynamics (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. CEBAF's high energy, continuous-wave electron beam is an ideal probe for the study of this transition region, since the electromagnetic interaction is well understood, the electron has no internal structure, and its electrons (with available energies up to 6 GeV) can probe distance scales ranging from the size of a large nucleus down to about $1/10^{th}$ the size of the proton.

The small cross sections of the electromagnetic interaction and the systematic nature of the required investigations mean that experiments often require months of beam time to produce meaningful results. The productivity of CEBAF's scientific program is enhanced significantly by the accelerator's ability to provide three simultaneous continuous beams of independent current and independent but correlated energy, permitting as many as three experiments to run in parallel. The availability of polarized electron beams extends the capabilities of the facility to include both spin-transfer reactions and parity violation experiments, which probe, respectively, the spin and the weak neutral current structures of the system under study.

The three experimental halls at JLab 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 4π 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 in situations 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

Initial commissioning activities in Hall A began in the spring of 1996. The hall is equipped with two optically identical, high resolution (10^{-4}) magnetic spectrometers (HRS) shown in Figure V-1; 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 in the hadron spectrometer includes a focal plane polarimeter. Commissioning of the spectrometer pair was completed in spring 1997, and the experimental program began in May 1997. The spectrometers are performing as designed, and complete data sets have been obtained for five Hall A experiments. In addition, approximately half of the desired data has (intentionally) been taken for three more experiments.

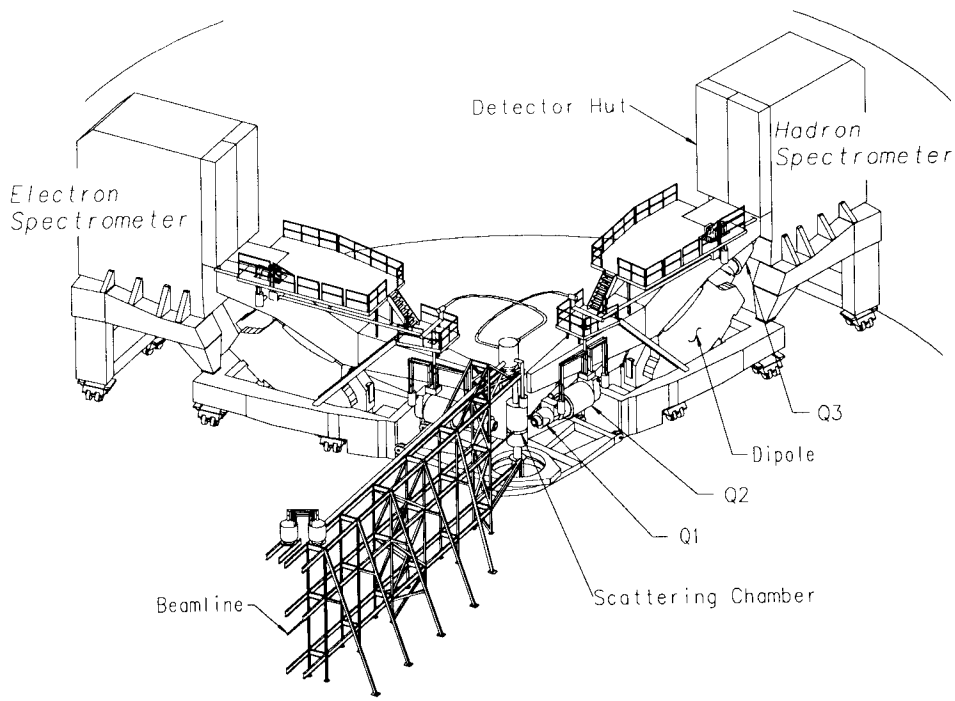


Figure V-1: The Hall A High Resolution Spectrometers (HRS).

One major focus of the research program using the Hall A spectrometers is the detailed investigation of the structure of nuclei, mainly using the $(e,e'\,p)$ and $(\vec{e},e'\,\vec{p})$ reactions. These experiments are extending the range of momentum transfers and internal nucleon momenta measured well beyond any previous work. These new data are expected to reveal the limitations of the standard (and presently adequate) picture of nuclear structure based on nucleons interacting via effective potentials. Also, experiments of this type in heavy nuclei will both expand our understanding of nuclear structure and provide information on how the nucleon's properties change when it is embedded in the nuclear medium. The first two experiments carried out in Hall A (E89-003 and E89-033) were focused on these issues.

In few-body systems, where exact calculations can be performed for interacting nucleons, the experiments proposed at JLab could, in principle, reveal a complete breakdown of the nucleon picture. It is expected from QCD that, at some point, quark models will offer a better description of the experimental data for these fundamental systems. The spectrometers in Hall A were designed to have very high resolution to be able to isolate the different reaction channels in nuclei so that a clean comparison with theory can be achieved. High absolute accuracy will be required to separate the various types of contributing electromagnetic currents. The first Hall A experiment in this category (E91-026) extended our knowledge of two of the deuteron's structure functions, $A(Q^2)$ and $B(Q^2)$, to

6 $(\mathrm{GeV}/c)^2$ and 1.4 $(\mathrm{GeV}/c)^2$, respectively, providing spatial resolution of a modest fraction of the internucleon separation and demonstrating the ability of the spectrometers to measure cross sections down to the 10^{-41} cm^2 regime.

Studies of the electromagnetic and weak neutral current structure of the nucleon will also be an important component of the Hall A program. The HRS spectrometers will measure the charge and magnetic form factors of nucleons with greatly improved accuracy. One of the first of these experiments (E93-027) used the spin transfer technique to measure the ratio of the electric to the magnetic form factors of the proton to $Q^2 \sim 3.5(\mathrm{GeV}/c)^2$. It provides a beautiful example of the quality of the data that is emerging. We now know unequivocally that the radial distribution of charge and magnetization in the proton differ significantly, and we have data on the proton electric form factor (using this experiment and the much better known magnetic form factor) that begins to distinguish among models for the proton's internal structure.

Other planned experiments in the area of nucleon structure include virtual Compton scattering, which probes both the low-energy structure of the proton and its excited states (the first of these, E93-050, is now complete). A detailed study of spin observables in the transition will also be performed. In addition, these spectrometers will be used to investigate the strange quark contributions to the charge and magnetization distributions of the nucleons via very precise parity-violating electron-scattering experiments, which will provide stringent tests for microscopic models of the strength and structure of the quark-antiquark "sea" in the proton. The first run for E91-010 demonstrated conclusively that the accelerator and experimental equipment could carry out these technically demanding parity-violation experiments at an unprecedented level of accuracy, and provided important constraints on the strangeness charge distribution in the nucleon. The results imply that the $s\bar{s}$ sea is either unexpectedly weak or that the s and $\bar{s}$ distributions are very similar so that they tend to cancel.

Hall B

Hall B, the final hall to begin physics operations, is equipped with a large acceptance (nearly 4π) detector, the CEBAF Large Acceptance Spectrometer (CLAS), which is shown in Figure V-2. 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 multiparticle 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 will be 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.

construction (the G^0 spectrometer) to investigate the proton's weak neutral current structure and possible contributions from strange quarks (E91-017). This experiment has substantial funding from both NSF and DOE, and significant foreign participation and funding as well.

Theory

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 perturbative QCD, as appropriate for a laboratory working at the interface between nuclear and particle physics. In addition to supporting the CEBAF experimental program directly, the 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 51 new papers, gave 28 invited talks at international conferences and workshops and another 35 contributed talks, and sponsored or co-sponsored four workshops on specialized topics related to the CEBAF program. Theory Group's papers continue to be so frequently cited that several have appeared on "top ten" citations lists. Theory Group continues its sponsorship of 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 on key new developments in nuclear theory.

Accelerator and Experimental Area Operations and Hours Available for Research

Jefferson Lab has a performance-based contract with DOE that emphasizes our common goal of maximizing the research productivity of the laboratory. Key metrics for the operation of the research program include the simultaneous availability of both the accelerator and the experimental equipment, the availability of the accelerator alone, the availability of the experimental equipment alone, and the total delivered physics research operations (which corresponds to the total number of hours working experimental equipment is receiving useful beam, and accounts for multiple hall operations). As we learn how to run the accelerator and the experimental equipment, the availability should increase significantly; the goals for the accelerator availability outlined in Appendix B of our contract have increased from 50% (in FY96) to 75% this year, and would go up to 80% in future years if we receive adequate funding for efficient operations. Corrections to this goal are made on an annual basis, taking into account the loss in efficiency expected when major new equipment is installed or machine capabilities are being extended substantially. Similar goals have been set for each experimental hall, with the starting year being the first year of physics operation, hall-by-hall. The average hall multiplicity should exceed two in full operation, limited by the manpower available for tearing down and re-installing specialized equipment between experiments.

We have experienced difficulties in achieving the desired availability and overall scientific productivity due to the increasing demands placed on the accelerator by the evolving research program. In the halls, we are mounting complex new experiments needing new equipment such as high power cryotargets and polarized targets, and non-destructive beam polarimeters. The needs of the experiments with the highest scientific ratings are pushing the accelerator to higher beam energies, increasing the requirements on beam quality, and demanding the delivery of highly-polarized beam and a large dynamic range of currents in multiple hall operation. Meeting these needs has strained laboratory resources. In FY98, the average operational efficiency of the accelerator was 68.4% – below our goal and well below optimum.

Our FY99 requirements budget requested a $3M/year (5%) increase in the operations budget to support a broad-ranging initiative to improve accelerator availability and to provide additional support for user-driven efforts to mount major experiment initiatives. This corresponds roughly to the level of operations funding we were able to generate in FY98 through the judicious use of one-time and non-recurring funding from alternate sources. We estimated that the $3M/year increase would permit FY99 operations with the accelerator availability raised to a nominal 70% and support

higher multiplicity operations while maintaining a 34 week operations schedule (the combination is estimated to increase the physics throughput by 1/4). A second increment of about $3M/year would permit a second 1/4 increase in physics throughput, and bring facility operations to close to optimum.

With the reduced funding actually provided in FY99, the number of weeks of running had to be cut back from 34 to 30 weeks. To minimize the impact of this reduced operations schedule we are focusing attention on correcting those accelerator operations problems that are amenable to improvement without large procurements, and we delayed scientifically important major experiment setups in Hall C for a year to increase the average multiplicity. Through these efforts we hope to be able to bring the accelerator availability up to 75% and maintain a roughly constant experiment throughput. However, this will be achieved at the expense of delaying highly rated new experiment initiatives. These steps, however, cannot be expected to sustain the laboratory's productivity, and the lack of adequate operations funding will become critical next year. Our requirements budget for FY00 includes both estimated inflation above the current budget and the first $3M above our FY98 budget discussed above, as essential to restore the laboratory's operations to a level closer to optimum scientific productivity.

New Experimental Equipment Initiatives

There has been 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 will be necessary to modify the existing equipment to improve its reliability and to keep its performance at the state-of-the-art. Eventually, it will be necessary 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. It supported the development of the t_{20} deuteron channel in Hall C, a high-power cryogenic hydrogen target for Hall A and polarized hydrogen and deuterium targets for both Halls A and C. 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 include: a photon calorimeter to be used in Compton-scattering studies and septum magnets that will allow us to use the spectrometer pair at scattering angles as far forward as 6° (for Hall A); the implementation of a level-two trigger capable of selecting trajectories in the drift chambers, a frozen spin target suitable for tagged photon experiments, and an upgrade of fire and general safety equipment (for Hall B); and the hypernuclear spectrometer and a laser-based energy measurement system (for Hall C). A number of multiyear projects are underway, the largest of which is the G^0 spectrometer for parity violation experiments in Hall C. Funds will continue to be used to improve beam-line instrumentation and to develop general-purpose infrastructure for polarized and cryogenic target development and support at the laboratory. Continued funding of this type is critical to the long-term success of the research program.

Data Acquisition, Reconstruction, and Analysis

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 Laboratory. 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 of 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, such as CORBA, guarantees continuity across platforms, as does increasing the use of platform independent technologies such as JAVA. Our support of embedded operating systems will be diversified from VxWorks to include LynxOS and Linux. We shall increase our use of model-centered, rather than code-centered, programming techniques to increase the portability and maintainability of our software.

The data reconstruction facilities have been expanded to meet the current and expected needs of the halls. The tape silo now has a full complement of eight high performance tape drives, providing an aggregate data throughput of up to 80 MB/s. The silo presently holds some 90 TB of data, the majority of which has been written by CLAS in the last few months. The combined raw data from all experiments regularly exceeds 500 GB/day. Storing this new data, and meeting the demands from the batch analysis farm for access to already stored data, means that the mass storage system moves well in excess of 1.2TB/day. Further improvements in tape access by adding more drives cannot be achieved easily in the current silo configuration without sacrificing some storage space. In view of expected access needs and the data storage requirements of currently approved experiments, it is likely that we will add a second silo equipped with second generation high-speed tape drives within the next few years. The OSM software that manages the tape media and robotics has also reached the end of its useful life. We are presently assessing software that will not only replace OSM but will also overcome some of the performance limitations of the current system and will provide a scaleable and reliable system for the next five years.

The event reconstruction farm currently has 120 CPUs, of which the majority are PC systems running Linux. The computing power provided by the farm (~ 1600 SPECint95) is somewhat more than originally planned, but has been needed to satisfy the requirements of the experiment data analysis. It is expected that the batch farm will be further augmented over the coming two years to satisfy experimenters' needs. The use of dual-processor Linux systems is an extremely cost-effective solution. In addition to the batch systems, we have also added two 4-processor Solaris systems, and have a 4-processor Linux system on order to provide interactive front-ends to the farm; they support both job preparation and interactive data analysis. These interactive facilities will expand as the experiments move into the post-event-reconstruction phase of the data analysis.

Online storage for the analysis facilities is provided by a 2.5 TB array of RAID disk used for storing frequently accessed data sets and results from the data analysis. Storage capacity will be augmented by a further 1.3 TB this summer, and will be doubled over the next two years.

Networking

The network supporting the data reduction and analysis facilities has been upgraded to include high throughput Gigabit connections where necessary. With the continuing upgrade of the general-purpose backbone network infrastructure across the site we expect to be able to provide fast network access to the central analysis systems from the desktop where necessary. Essential elements of the backbone will be Gigabit-capable this summer, with the project continuing in stages over the coming two years. As data analysis needs grow, more and more analysis will be done at collaborating institutions. There are several initiatives in place to improve wide area access to the data and analysis facilities. These include upgrading our ESnet connection and participation in Next Generation Internet (NGI) proposals to provide guaranteed bandwidth services.

The Experimental Program

CEBAF's research program was planned with the active participation of our user group, which now has nearly 1,600 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 834 scientists from 146 institutions in 21 countries are collaborators on one or more of these experiments; their home institutions are listed in the tables attached to the end of this section, and summarized in Table V-1 (immediately below). Table V-2 presents a breakdown of the approved and conditionally approved experiments by physics topic and by hall. With our present operating efficiency and 30 weeks/year of accelerator operations, the recommended beam time allocations for these experiments, shown in Table V-3 by hall, correspond to 6-7 years in Hall A, 4-5 years in Hall B, and 5-6 years in Hall C. As mentioned above, our requirements budget includes a request of incremental operations funding to address this issue by supporting work to improve accelerator availability and physics division experiment support. We anticipate that this would increase our physics output by about ¼.

Table V-1
Users On Experiments, June 1999

User Home Institution	Number of Experimenters	Number of Organizations
Universities (U.S.)	480	75
International	247	54
Other Federal Laboratories	47	16
Jefferson Lab	60	1
TOTAL	834	146

Table V-2
Approved Experiments by Physics Topic, June 1999
(including completed and partially completed experiments)

Topic	Number of Experiments			
	Hall A	Hall B	Hall C	Total
Nucleon and Meson Form Factors and Sum Rules	7	3	5	15
Few Body Nuclear Properties	12	6	5	23
Properties of Nuclei	4	8	6	18
N* and Meson Properties	6	23	6	35
Strange Quarks	4	10	5	19
TOTAL	33	50	27	110

Table V-3
Experimental Program Status, June 1999

Hall	Approved Experiments				Cond. Approved Expts
	# of Experiments Completed (full/partial × fraction)	Total Days Run	# of Expts in Queue	Days to be Run	
A	5 / 2 × ½ / 1 × ¼	148	26	553	6
B	1 /15 × .27 / 8 × .50 / 4 × .27 / 6 × .15 / 2 × .59	98	39	405	6
C	8 / 2 × ½ / 1 × ¼ / 1 × ¾	185	17	378	2
Total	14 / ~15	431	82	1,336	14

The process for 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 (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 takes 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.

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. Because many experiments were approved well before accelerator operations began, "jeopardy" is being implemented separately in the three halls; the three-year period is measured in each hall from the start of physics operations in the hall or the date of approval of the experiment, whichever is later. The jeopardy review process began with the January 1999 meeting of PAC15.

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. A second, on nucleon and meson form factors and sum rules, was held following PAC15. Future PACs will continue this process until the entire program has been examined (each workshop/review covers one

of the categories listed in Table V-2). PAC15 also initiated the process of reviewing the planning for the scientific program and equipment complement for the 12 GeV upgrade; this review will follow the precedent of PAC involvement that was so successful in defining the initial equipment complement for CEBAF. The PAC's advice on overall program direction is augmented by high-level input from our (DOE Contract-based) Science and Technology Peer Review Committee.

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 Table V-4. Running this program successfully is the laboratory's highest priority and the central focus of our near-term planning.

Table V-4
Jefferson Lab Approved Experiments

Exp #	Hall	Title
		Nucleon and Meson Form Factors and Sum Rule
E-93-024	A	Measurement of the Magnetic Form Factor of the Neutron at Large Momentum Transfers
E-93-027★	A	Electric Form Factor of the Proton by Recoil Polarization
E-94-010★	A	Measurement of the Neutron (^{3}He) Spin Structure Function at Low Q^2; a Connection between the Bjorken and GDH Sum Rules
E-94-021	A	The Electric Form Factor of the Neutron Extracted from the $^3\vec{\mathrm{He}}(\vec{e},e'n)pp$ Reaction
E-97-103	A	Search for Higher Twist Effects in the Neutron Spin Structure Function $g_2^n(xQ^2)$
E-97-110	A	The GDH Sum Rule and the Spin Structure of ^{3}He and the Neutron Using Nearly Real Photons
E-91-023☆	B	Measurement of Polarized Structure Functions in Inelastic Electron Proton Scattering using CLAS
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
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
E-93-018★	C	Longitudinal/Transverse Cross Section Separation in $p(e,e'K^+)\Lambda(\Sigma)$ for $0.5 \le Q^2 \le 2.0(\mathrm{GeV}/c)^2$, $W \ge 1.7\mathrm{GeV}$ and $f_{\min} \ge 0.1(\mathrm{GeV}/c)^2$
E-93-021★	C	The Charged Pion Form Factor + Extension
E-93-026☆	C	The Charge Form Factor of the Neutron
E-93-038	C	The Electric and Magnetic Form Factors of the Neutron from the $d(\vec{e},e'\vec{n})p$ Reaction
		Few Body Nuclear Properties
E-89-019	A	Measurement of Proton Polarization in the $d(\gamma,p)n$ Reaction
E-89-021	A	Elastic Electron ^{3}He–^{4}He Scattering at Large Momentum Transfers
E-89-028	A	Polarization Transfer Measurements in the $\mathrm{D}(\vec{e},e'p)\vec{n}$ Reaction
E-89-044	A	Selected Studies of the ^{3}He and ^{4}He Nuclei Through Electrodisintegration at High Momentum Transfer
E-91-026★	A	Measurement of the Electric and Magnetic Structure Functions of the Deuteron at Large Momentum Transfers
E-93-049	A	Polarization Transfer in the Reaction $^4\mathrm{He}(\vec{e},e'\vec{p})^3\mathrm{H}$ in the Quasi-eleastic Scattering Region
E-94-004	A	In-plane Separations and High Momentum Structure in $d(e,e'p)$
E-94-023	A	Measurement of small components of the ^{4}He wave function using $^3\vec{\mathrm{He}}(\vec{e},e'p)$ in Hall A
E-94-104	A	The Fundamental $\gamma n \to \pi^- p$ Process in ^{2}H, ^{4}He, and ^{12}C in the 1.2 – 6.0 GeV Region

★ Completed
☆ Partially Completed

		Few Body Nuclear Properties (cont.)
E-95-001★	A	Precise Measurements of the Inclusive Spin-dependent Quasi-elastic Transverse Asymmetry $A_{T'}$ from $^3\vec{\mathrm{He}}(\vec{e},e')$ at low Q^2
E-97-011	A	Initial Exploration of Semi-exclusive Scattering in $x > 1$ Region with $^{3,4}\mathrm{He}(e,e'p)$ Reactions
E-93-017	B	Study of $\gamma d \rightarrow pn$ and $\gamma d \rightarrow p\Delta^0$ Reactions for Small Momentum Transfers
E-93-043	B	Measurement of the $\Delta\Delta$ Component of the Deuteron by Exclusive Quasielastic Electron Scattering
E-93-044	B	Photoreactions on ^{3}He
E-94-019	B	Nuclear Transparency in Double Scattering Processes
E-94-102☆	B	Electron Scattering from a High Momentum Nucleon in Deuterium
E-97-001	B	Electroproduction of the $pp\pi^-$ System off the Deuteron Beyond the Quasifree Region
E-89-012★	C	Two Body Photodisintegration of the Deuteron at Forward Angles and Photon Energies Between 1.5 and 4.0 GeV
E-91-003☆	C	A Study of Longitudinal Charged Pion Electroproduction in ^{2}D,^{3}He, and ^{4}He
E-94-018★	C	Measurement of the Deuteron Tensor Polarization at Large Momentum Transfers in $\mathrm{D}(e,e'\vec{d})$ Scattering
E-96-003	C	Two Body Photodisintegration of the Deuteron at High Energy
E-97-102	C	Measurement of the $(e,e'p)$ Cross Section on Tensor-Polarized Deuterium
		Properties of Nuclei
E-89-003☆	A	Study of the Quasielastic $(e,e'p)$ Reaction in ^{16}O at High Recoil Momenta
E-89-033☆	A	Measurement of Recoil Polarization in the $^{16}\mathrm{O}(\vec{e},e'\vec{p})$ Reaction with 4 GeV Electrons
E-91-006	A	Study of Nuclear Medium Effects by Recoil Polarization up to High Momentum Transfers
E-97-111	A	Systematic Probe of Short-Range Correlations via the Reaction $^4\mathrm{He}(e,e'p)^3\mathrm{H}$
E-89-015	B	Study of Coincidence Reactions in the Dip and Delta-Resonance Regions
E-89-017	B	Electroexcitation of the $\Delta(1232)$ in Nuclei
E-89-027	B	Coincidence Reaction Studies with the CLAS
E-89-031	B	Study of Multi-Nucleon Knockout with the CLAS
E-89-032	B	Study of Local Properties of Nuclear Matter in Electro-Nucleus and Photon-Nucleus Interactions with Backward Particle Production using the CLAS
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
E-93-008	B	Inclusive η Photoproduction in Nuclei
E-93-019★	B	Photoabsorption and Photofission of Nuclei
E-89-008★	C	Inclusive Scattering from Nuclei at x>1 and High Q^2

★ Completed
☆ Partially Completed

Properties of Nuclei (cont.)

E-91-007	C	Measurement of the Nuclear Dependence and Momentum Transfer Dependence of Quasi-elastic $(e,e'p)$ Scattering at Large Momentum Transfer
E-91-013★	C	The Energy Dependence of Nucleon Propagation in Nuclei as Measured in the $(e,e'p)$ Reaction
E-97-006	C	Correlated spectral function and $(e,e'p)$ reaction mechanism
E-97-106	C	Studying the Internal Small-Distance Structure of Nuclei via the Triple Coincidence $(e,e'p+N)$ Measurement

N* and Meson Properties

E-91-011	A	High-Precision Separation of Polarized Structure Functions in Electroproduction of the Δ and Roper Resonances
E-93-050★	A	Nucleon Structure Study by Virtual Compton Scattering
E-94-012	A	Measurement of Photoproton Polarization in the $H(\gamma,\vec{p})\pi^0$ Reaction
E-94-101	A	Precision Measurement of the Neutron Asymmetry at Large x Using JLab at 6 GeV
E-96-001	A	Recoil Polarization in η Electroproduction
E-97-108	A	Exclusive Compton Scattering on the Proton
E-89-037☆	B	Electroproduction of the P_{33} (1232) Resonance
E-89-038☆	B	Measurement of $p(e,e'\pi^+)n$, $p(e,e'p)\pi^0$ and $n(e,e'\pi^-)p$ in the Second and Third Resonance Regions
E-89-039☆	B	Amplitudes for the $S_{11}(1535)$ and $P_{11}(1710)$ Resonances from an $ep \rightarrow e'p\eta$ Experiment
E-89-042☆	B	A Measurement of the Electron Asymmetry in $p(e,e'p)\pi^0$ and $p(e,e'\pi^+)n$ in the Mass Region of the P_{33} (1232) for $Q^2 < 2\ (\mathrm{GeV}/c)^2$
E-91-002☆	B	The Study of Excited Barons at High Momentum Transfer with the CLAS Spectrometer
E-91-008☆	B	Photoproduction of η and η' Mesons
E-91-015☆	B	Helicity Structure of Pion Photoproduction
E-91-024☆	B	Search for "Missing" Resonances in the Electro-production of ω Mesons
E-93-006☆	B	Two Pion Decay of Electroproduced Light Quark Baryon Resonances
E-93-012☆	B	Electroproduction of Light Quark Mesons
E-93-031☆	B	Photoproduction of Vector Mesons at High t
E-93-033☆	B	A Search for Missing Baryons Formed in $\gamma p \rightarrow p\pi^+\pi^-$ Using the CLAS and CEBAF
E-93-036☆	B	Measurement of Single Pion Electroproduction from the Proton with Polarized Beam and Polarized Target Using CLAS
E-94-002	B	Photoproduction of Vector Mesons Off Nuclei
E-94-005☆	B	Determination of the $N\Delta$ Axial Vector Transitions Form Factor $G_A^{N\Delta}$ from the $ep \rightarrow e'\Delta^{++}\pi^-$ Reaction
E-94-008	B	Photoproduction of η and η' Mesons from Deuterium
E-94-015☆	B	Study of the Axial Anomaly using the $\gamma\pi^+ \rightarrow \pi^+\pi^0$ Reaction Near Threshold
E-97-006	C	Correlated spectral function and $(e,e'p)$reaction mechanism

★ Completed
☆ Partially Completed

		N* and Meson Properties (cont.)
E-94-103☆	B	The Photoproduction of Pions
E-94-016	B	Measurement of Rare Radiative Decays of the Phi Meson
E-94-109	B	Photoproduction of the ρ Meson from the Proton with Linearly Polarized Photons
E-94-014★	C	The $\Delta(1232)$ Form Factor at High Momentum Transfer
E-96-002	C	Precision Measurement of the Nucleon Spin Structure Functions in the Region of the Nuclear Resonances
E-94-110	C	Measurement of $R = \sigma_L / \sigma_T$ in the Nucleon Resonance Region
E-93-028	C	Deformation of the Nucleon
E-97-010	C	Measurement of Hydrogen and Deuterium Inclusive Resonance Cross Sections at Intermediate Q^2 for Parton-Hadron Duality Studies
E-97-101	C	Baryon Resonance Electroproduction at High-Momentum Transfer
E-97-104	C	Measurement of the Parity Violation Asymmetry in the N to Delta Transition
		Strange Quarks
E-91-004	A	Measurement of Strange Quark Effects Using Parity-Violating Elastic Scattering from ^{4}He at $Q^2 = 0.6$ (GeV/c) ^{2}
E-91-010☆	A	Parity Violation in Elastic Scattering from the Proton and ^{4}He
E-94-107	A	High Resolution $1p$ Shell Hypernuclear Spectroscopy
E-89-004☆	B	Electromagnetic Production of Hyperons
E-89-024☆	B	Radiative Decays of the Low-Lying Hyperons
E-89-043☆	B	Measurements of the Electro-production of the Λ(gnd), $\Lambda^*(1520)$ and f_0 (975) via the K^+K^-p and $K^+\pi^-p$ Final States
E-89-045	B	Study of the Kaon Photo-production on Deuterium
E-91-014	B	Quasi-Free Strangeness Production in Nuclei
E-93-022☆	B	Measurement of the Polarization of the ϕ (1020) in Electroproduction
E-93-030☆	B	Measurement of the Structure Functions for Kaon Electroproduction
E-95-003☆	B	Measurement of K^0 Electroproduction
E-89-009	C	Investigation of the Spin Dependence of the ΛN Effective Interaction in the P Shell
E-91-016☆	C	Electroproduction of Kaons and Light Hypernuclei
E-95-002	C	Direct Measurement of the Lifetime of Heavy Hypernuclei at CEBAF
E-91-017	C	"G^0": Measurement of the Flavor Singlet Form Factors of the Proton
E-93-043☆	B	Measurement of the Delta-Delta Component of the Deuteron by Exclusive Quasielastic Electron Scattering

★ Completed
☆ Partially Completed

US 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
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 University Cyclotron Facility, Bloomington, IN
James Madison University, Harrisonburg, 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
Massachusetts Institute of Technology, Cambridge, MA
MIT Bates Linear Accelerator, Middleton, MA
MITI, Meidian Parkway, Durham, NC
NIST, Gaithersburg, MD
National Science Foundation, Washington, DC
New Mexico State University, Las Cruces, NM
Norfolk State University, Norfolk, VA
North Carolina Ag. and Tech. 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 University, Athens, OH
Old Dominion University, Norfolk, VA
Oregon State University, Corvallis, OR
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 University at New Orleans, New Orleans, LA
Stanford Linear Accelerator Center, Stanford, CA
Stanford University, Stanford, CA
Super Computer Research Institute, Tallahassee, FL
Syracuse University, Syracuse, NY
Temple University, Philadelphia, PA
Texas A&M University, College Station, TX
The College of William and Mary, Williamsburg, VA
Thomas Jefferson Natl. Accel. Facility, Newport News, VA
Triangle Universities 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 Illinois, Urbana-Champaign, IL
University of Kentucky, Lexington, KY
University of Maryland, College Park, MD
University of Massachusetts, Amherst, MA
University of Michigan, Ann Arbor, MI
University of Mississippi, University, MS
University of New Hampshire, Durham, NH
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 Texas, El Paso, TX
University of Virginia, Charlottesville, VA
University of Washington, Seattle, WA
University of Wisconsin, Madison, WI
University of Texas, Houston, TX
Virginia Polytechnic Inst. & State Univ., Blacksburg, VA
Virginia State University, Petersburg, VA
Western Kentucky University, Bowling Green, KY
Yale University, New Haven, CT

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
	TRIUMF, Vancouver, BC, Canada
	University of British Columbia, Vancouver, BC, Canada
	University of Regina, Regina, SK, Canada
	University of Saskatchewan, Saskatoon, SK, Canada
CHINA	China Institute of Atomic Energy, Beijing, China
CROATIA	Rudjer Boskovic Institute, Zagreb, Croatia
FRANCE	Institut de Physique Nucleaire, Orsay, France
	Institut des Sciences Nucleaires, Grenoble, France
	DAPNIA, C. E. N. SACLAY, Gif-Sur-Yvette, France
	SATURNE, France
	Universite Blaise Pascal, Aubiere, France
	Universite de Clermont-Ferrand, Clermont-Ferrand, France
GERMANY	Univ. of Tubingen, Tubingen, Germany
	Universitaet Giessen, Giessen, Germany
	Universitaet Mainz, Mainz, Germany
	Universitat Bonn, Bonn, Germany
ISRAEL	Birzeit University, Birzeit West Bank, Israel
	Racah Inst. of Physics, The Hebrew Univ., Jerusalem, Israel
	University of Tel Aviv, Israel
ITALY	INFN/BARI , Bari, Italy
	INFN, Sezione Lecce, Lecce, Italy
	INFN/Sanita, Roma, 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
JAPAN	Osaka Electro-Commun. University, Osaka, Japan
	Osaka University , Osaka, Japan
	Shizuoka University, Shizuoka, Japan
	Tohoku University, Sendai, Japan
	Univ. of Tsukuba, Ibaraki, Japan
NETHERLANDS	NIKHEF, Amsterdam, The Netherlands
	Rijks Universiteit Utrecht, Utrecht, The Netherlands
	Vrije Universiteit, Amsterdam, The Netherlands
	University of Utrecht, Utrecht, 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
	Inst. for Theor. & Experimental Physics, Moscow, Russia
	Joint Institute For Nuclear Research, Moscow, Russia
SOUTH KOREA	Chungnam National University, Daejeon, Korea
	Kyungpook National University, Taegu, Korea
	Seoul National University, Seoul, Korea
	Yonsei University, Seoul, Korea

Foreign Institutions with Researchers on Experiments at Jefferson Lab (cont.)

Country	Institution Name
SPAIN	Universidad de Barcelona, Barcelona, Spain
	Universidad de Valencia, Valencia, Spain
SWITZERLAND	University of Basel, Basel, Switzerland
UKRAINE	Institute for Physics and Technology, Kharkov, Ukraine
	Kharkov State University, Kharkov, Ukraine

B. CEBAF Accelerator Operations

The mission of CEBAF accelerator operations is the delivery of electron beams meeting world-class standards and users' expectations to Jefferson Lab's three nuclear physics experimental halls. During the period covered by this Institutional Plan, accelerator operations will continually improve our capability to routinely deliver reliable, simultaneous beams to three halls with individually chosen energy and current, and with beam polarization available in at least two halls, and generally three.

Performance Objectives

The CEBAF accelerator has, as its primary objective, 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 refrigerator must be operated with or without beam).

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

- steady improvements in the area of polarized beams, maintaining polarization at 75% or greater, with the capability of providing a total of up to 170 μA beam current to the Halls with acceptable cathode lifetime, and
- improvements to the multiple lasers used for independent operation of polarized beam to all three halls.

In addition, a new beam envelope limiting system is required at energies above 5 GeV to ensure that the beam parameters remain within the Operating Envelope.

Performance Enhancement

For accelerator operation, the most important figure of merit is the number of useful beam hours for physics data taking. To achieve the maximum number of beam hours, and meet user requests for higher energies, we plan for:

- running time to exceed 30 weeks per year with greater than two-hall multiplicity;
- systematic efforts to raise the accelerator availability to 80% through reductions in failure rates, shortening of time to repair, and improved instrumental and procedural support of operators for faster tuning and recovery;
- in situ cryomodule rework/conditioning to deliver beams to experimenters at 5.8 GeV and to continue preparations for 6 GeV operation; and
- cryogenic plant work to maintain cw operations and end station refrigeration capability at full beam energy.

The accelerator availability and hall multiplicity goals through FY 2000 are given in Table III-1. Currently, the main limitations to high reliability are the controls network, software (implementation of Y2K compliance), and operations procedures, all of which are receiving heavy emphasis. An additional factor is the continued work required to complete the full functionality foreseen. This means that maintenance periods are also used for completing upgrades and that recovery from maintenance periods also involves a component of commissioning. When projects are completed, the best way to operate is to try to run the accelerator for long periods, keeping the tunnel closed up as much as possible. This provides more accelerator operating weeks and tends to give higher availability. Our experience in this regard mirrors that of other laboratories.

Routine maintenance is scheduled every second week, and this is expected to continue. Some accelerators operate on the principle of "perform maintenance only when something is broken" due to the difficulties involved with accelerator start-up. We intend to continue with scheduled

maintenance, albeit with a frequency that may evolve with time, as the more predictable nature of this operating mode is preferable to our users.

The main limitation to high hall multiplicity is the availability of manpower to stage experiments. For example, every experiment would prefer to perform its annual major maintenance and large-scale new experiment installation during the annual accelerator shutdown in January. Efficient use of manpower, however, does not allow such peak efforts, and experiment installation must be staged sequentially. Additional staffing would improve the throughput and increase overall efficiency substantially.

Superconducting Radio Frequency (SRF) R&D

One of Jefferson Lab's key competencies is in SRF technology. The application of that expertise has resulted in a gradual improvement of CEBAF energy from its design value of 4 GeV to routine operation at 5.5 GeV in FY1999, and an expected 6 GeV demonstration in FY2000. It is also being successfully applied to Jefferson Lab's second major program, the Free-Electron Laser. Additionally, a substantial amount of SRF R&D is now directed toward the CEBAF Energy Upgrade.

Design studies conducted in 1998 led to a baseline concept for the 12 GeV Energy Upgrade based on a 5.5-pass machine, and on the addition of new, higher-performance cryomodules as well as the replacement of a few existing ones. This concept calls for cryomodules that, in the same length as the existing one, will be capable of providing energy gains 4 times higher than the CEBAF design with only a modest increase in the cryogenic losses. This will require the development of superconducting cavities operating at gradients of 12.5 MV/m and Q of 6.5×10^9, compared to 5 MV/m and 2.5×10^9 respectively for the CEBAF design. This R&D effort is progressing along four parallel tracks:

- First, determination of the operational limits, and operation at those limits of the existing CEBAF cryomodules. This has resulted in a continuous improvement in the CEBAF maximum energy, but also in a better understanding of the fundamental limitations of superconducting cavities in an operating accelerator. This activity was initiated in 1997 and is essentially complete
- Second, upgrade and improvement of our processing and testing facilities, as well as development of new procedures related to chemical processing, cleaning, clean room techniques leading to a reduction in particulate contamination, and high-temperature treatment of superconducting cavities. Upgrade of our facilities started in FY1998 and will be completed in FY2000
- Third, development and demonstration of prototypes of the key components of the Upgrade cryomodule. A prototype cavity successfully met the upgrade requirements in FY1998. Development of the prototype components will be completed in FY2000.
- Fourth, development of advanced control of microphonics in order to allow operation at high gradients and to reduce the rf power requirements. This activity is being initiated in FY1999.

All the above R&D activities will converge in the demonstration, with beam, of a fully operational half-length cryomodule in FY2001, and of two full-length cryomodules the following year.

In addition, a modest long-term R&D effort is directed toward challenging the assumptions that went into the selection of the baseline concept, and could result in additional options for the 12 or 24 GeV Upgrade programs.

C. Free-Electron Laser (FEL)

The Jefferson Lab Free-Electron Laser (FEL) Program developed from the laboratory's desire to exploit its unique core competency in superconducting radio-frequency (SRF) accelerator technology. SRF's capability to produce electron beams with high beam quality and high average power—two essential characteristics of CEBAF accelerator beams—afforded the opportunity to design SRF-accelerator-driven FELs as high-average-power light sources. In 1991, the laboratory formed an Industrial Advisory Board with scientists selected from major industrial research laboratories to explore the potential opportunities and requirements for SRF-driven FELs as unique tools for advanced manufacturing based on the laser processing of materials. In 1993, the group of stakeholders for the FEL Program was enlarged with the formation of the Laser Processing Consortium, which included a group of SURA universities and the Naval Post Graduate School. Specifications were developed for the design and implementation of a kilowatt-level demonstration FEL, with output in both the infrared (IR) and ultraviolet (UV) wavelength domains. Because of the synergy between industry and the Military, significant common specifications were developed. This commonality eventually led to the initial funding by the Military of the Jefferson Lab FEL Program in FY 1996.

A 1 kilowatt demonstration FEL (the IR Demo FEL) and associated User Facility was completed in 1997 and is presently (1999) in the last phase of commissioning (Figure V-4). First light was achieved on June 17, 1998 at power levels more than 14 times the previous world's record for FELs operating in the optical regime. Following the first light demonstration, the beam transport system was commissioned to allow electron beam recirculation and energy recovery. With energy recovery, the electron beam current could be raised to 4.8 mA, even though there is only sufficient RF power installed in the device to support 1.1 mA of beam current in the non-recirculated mode. In March of 1999, kilowatt class operation of the FEL was demonstrated by producing over 700 watts of IR laser output at 4.9 microns with the recirculation and energy recovery of 3.6 mA of beam current. In July of 1999, an average power output of 1.72 kilowatts was achieved at 3.1 microns in the energy recovery mode.

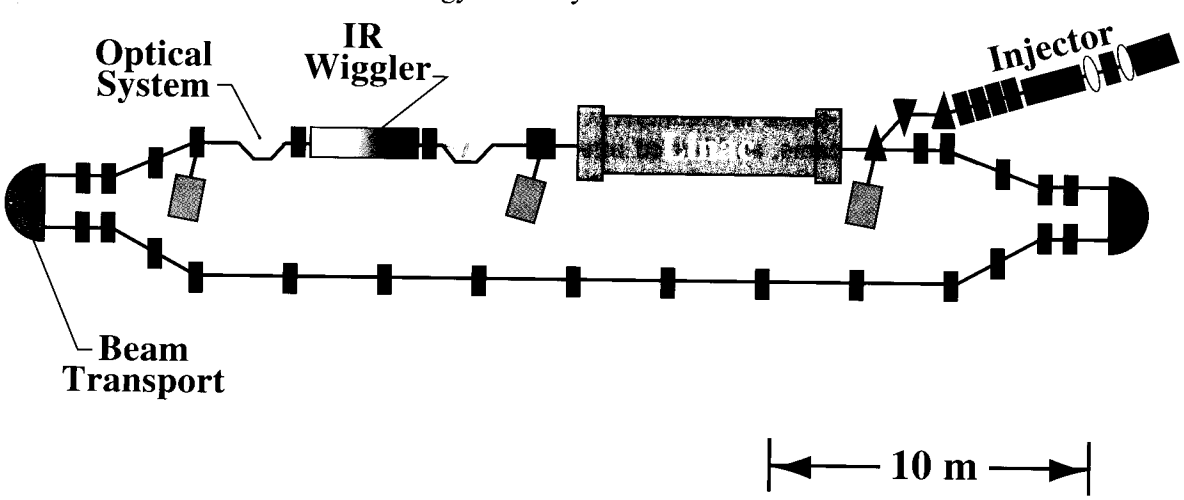


Figure V-4: The Jefferson Lab IR Demo FEL.

For the basic research community, SRF-driven FELs represent a natural extension in light-source technology that DOE has provided to the atomic physics, biophysics, chemical physics, and materials science communities: a factor of more than 10^5 increase in source brightness (at 0.1% bandwidth) in the infrared and the ultraviolet compared to the present generation of synchrotron light sources. For the industrial community, the high average power of an SRF FEL, and the broad band tunability and short pulse length for efficient coupling to materials, represent important advantages over conventional lasers for materials processing applications. For both the industrial and defense communities, the possibility of extrapolating the FEL technology from the power level of the kilowatt IR Demo to much higher power systems with lower net costs per unit of delivered power are significant design assets.

The first phase of the Jefferson Lab FEL Program began in June 1996 with the start of construction of the IR Demo FEL and the FEL User Facility on the CEBAF accelerator site. Construction was completed in September 1997, followed by commissioning activities in the succeeding year. The IR Demo project was kicked off when $8.1M of FY 1996 Navy funding was made available to the laboratory, in addition to previous dual-purpose DOE support for the injector test stand ($5.5M) and Commonwealth of Virginia funding ($5M) of the user facility building and injector prototyping. Several industrial members of the Laser Processing Consortium provided additional support (approximately $3.0M) for design and engineering of the laser and the initial fitup of equipment in the User Facility. The Department of Navy and the Commonwealth of Virginia provided over $4M of support in FY1998–1999 for commissioning of the FEL and the User Facility.

Laser Processing Consortium workshops are held annually (since 1994) to provide the laboratory with guidance on the planning and implementation of the FEL Program and, specifically, for planning initial outfitting and use of the application laboratories in the User Facility. In 1996, user working groups were formed within the consortium to focus on planning experiments on: (1) surface modification of polymers and (2) metals, (3) microfabrication, (4) electronic and (5) photovoltaic materials processing. Lead institutions have been identified in each working group and have committed themselves to underwrite the costs of the required equipment for the respective laboratories. In February 1997, the DOE Basic Energy Sciences Program Office held a review of the Jefferson Lab FEL Program to examine potential basic research applications of the planned facility. Many of the initially proposed FEL experiments can be viewed as process research or applied research. However, all of the identified industrial applications of the FEL bring with them basic research questions of interest to the scientific community. University members of the consortium have identified several of these research questions for the development of proposals to the DOE Basic Energy Sciences program office and other basic science funding agencies such as the NSF. This proposal process was initiated at the June 1997 Laser Processing Consortium workshop and continued through LPC Workshops in January 1998 and June 1999, and through participation in DOE-BES Workshops on FELs in November 1997 and January 1999. Basic science working groups have been formed for FEL research in: (1) atomic, molecular and optical (AMO) physics, (2) chemical physics, (3) materials physics and (4) laser deposition. Topics for prospective research include the fundamentals of short-pulse interactions with materials, high sensitivity spectroscopy of chemical reactions in molecular beams, and buried interfaces in semiconductor materials. These research proposals take advantage of one or more of the unique characteristics of the FEL: the broad tunability, the high-average-power, or the short pulse time structure.

2. INFRASTRUCTURE

A. Human Resources

Laboratory Personnel

As of September 30, 1998, the staff of Jefferson Lab numbered 501 employees plus 17 Commonwealth of Virginia employees. Table V-7 shows full and part-time laboratory staff composition including FEL staff and Advanced Computation, Communications Research and Associated Activities staff, excluding commonwealth employees.

Table V-7
Laboratory Staff Composition
(As of September 30, 1998)

Occupational Codes	Total #	Ph.D # (%)	MS/MA # (%)	BS/BA # (%)	AS/AA # (%)	Other # (%)
Professional Staff						
Scientists	98	92 (93.9%)	2 (2.0%)	1 (1.0%)	0 (0.0%)	3 (3.1%)
Engineers	64	3 (4.7%)	18 (28.1%)	34 (53.1%)	2 (3.1%)	7 (10.9%)
Exempt Tech.	84	0 (0.0%)	5 (6.0%)	13 (15.5%)	14 (16.7%)	52 (61.9%)
Mgmt & Admin	47	6 (12.8%)	12 (25.5%)	16 (34.0%)	4 (8.5%)	9 (19.1%)
Computer Scientists	35	4 (11.4%)	6 (17.1%)	19 (54.3%)	1 (2.9%)	5 (14.3%)
Support Staff						
Technicians	114	0 (0.0%)	2 (1.8%)	24 (21.1%)	22 (19.3%)	66 (57.9%)
All Other	59	0 (0.0%)	0 (0.0%)	6 (10.2%)	7 (11.9%)	46 (78.0%)
Totals	**501**	**105 (21.0%)**	**45 (9.0%)**	**113 (22.6%)**	**50 (10.0%)**	**188 (37.5%)**

Since Jefferson Lab is a small laboratory with many one-of-a-kind positions, our greatest staffing challenge is recruiting and selecting individuals with highly specialized scientific, technical, and managerial skills required to manage, operate, use, and/or maintain state-of-the-art accelerator systems and experimental equipment. Section VI addresses an additional challenge: Jefferson Lab's impending need to compensate for user group understaffing. The laboratory maintains an international recruiting program utilizing 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, on-the-job training, attendance at professional conferences, workshops, skill-enhancement training, and specialized training; and tuition assistance for employees in job-related degree programs.

Affirmative Action and Equal Employment Opportunity

The Affirmative Action Profile (Tables V-8 and V-9) shows that Jefferson Lab staff increased by approximately 232% between the end of FY 1987 and the end of FY 1998. During this period, the total number of minorities on the Jefferson Lab staff increased by 382% from 17 to 82, and the number of female employees increased 168% from 41 to 110. During this period, there has been significant increase in staff diversity, particularly in job groups in which minority and/or females were underutilized, such as scientists/engineers and technicians. The Affirmative Action Plan submitted annually to DOE in the first quarter of each fiscal year provides details.

TABLE V-8
AFFIRMATIVE ACTION PROFILE
FULL- AND PART-TIME EMPLOYEES
(AS OF END OF FY 1987)

Occupational Codes	Total=148		Minority Total=17		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	51 (94%)	3 (6%)	7 (13%)	0 (0%)	44 (81%)	3 (6%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	6 (11%)	0 (0%)
Mgmt & Admin	31 (66%)	16 (34%)	0 (0%)	2 (4%)	31 (66%)	14 (30%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (2%)
Support Staff														
Technicians	23 (85%)	4 (15%)	2 (7%)	0 (0%)	21 (7%)	4 (15%)	0 (0%)	0 (0%)	1 (4%)	0 (0%)	1 (4%)	0 (0%)	0 (0%)	0 (0%)
All Other	2 (10%)	18 (90%)	0 (0%)	6 (30%)	2 (10%)	12 (60%)	0 (0%)	3 (15%)	0 (0%)	1 (5%)	0 (0%)	1 (5%)	0 (0%)	1 (5%)
Totals	**107 (72%)**	**41 (28%)**	**9 (6%)**	**8 (5%)**	**98 (66%)**	**33 (22%)**	**0 (0%)**	**4 (3%)**	**2 (1%)**	**1 (1%)**	**1 (1%)**	**1 (1%)**	**6 (4%)**	**2 (1%)**

TABLE V-9
AFFIRMATIVE ACTION PROFILE
FULL- AND PART-TIME EMPLOYEES
(AS OF END OF FY 1998)

Occupational Codes	Total=501		Minority Total=82		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	215 (90.3%)	23 (9.7%)	30 (12.6%)	5 (2.1%)	185 (77.7%)	18 (7.6%)	6 (2.5%)	2 (0.8%)	3 (1.3%)	1 (0.4%)	1 (0.4%)	0 (0.0%)	20 (8.4%)	3 (1.3%)
Mgmt & Admin	63 (70.0%)	27 (30.0%)	5 (5.6%)	4 (4.4%)	58 (64.4%)	23 (25.6%)	1 (1.1%)	3 (3.3%)	3 (3.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.1%)	1 (1.1%)
Support Staff														
Technicians	93 (81.6%)	21 (18.4%)	14 (12.3%)	5 (4.4%)	79 (69.3%)	16 (14.0%)	9 (7.9%)	3 (2.6%)	3 (2.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.8%)	2 (1.8%)
All Other	20 (33.9%)	39 (66.1%)	5 (8.5%)	14 (23.7%)	15 (25.4%)	25 (42.4%)	5 (8.5%)	14 (23.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Totals	**391 (78.0%)**	**110 (22.0%)**	**54 (10.8%)**	**28 (5.6%)**	**337 (67.3%)**	**82 (16.4%)**	**21 (4.2%)**	**22 (4.4%)**	**9 (1.8%)**	**0 (0.0%)**	**1 (0.2%)**	**0 (0.0%)**	**23 (4.6%)**	**6 (1.2%)**

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 line managers' 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 accomplishment 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 (ISM) 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 the operations. Institution-wide EH&S support, reporting, oversight activities, and internal appraisals are performed by the Office of Technical Performance, which is represented on the Director's Council by an Associate Director.

Integrated Safety Management

The DOE ISM initiative has received substantial attention from SURA in the past year. 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 audit or inspection for results.

A Jefferson Lab ISMS Plan was prepared in 1997. Only four minor revisions to Jefferson Lab's practices were needed to be fully consistent with DOE P450.4, the DOE ISM guidance document. 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 on March 1-4, 1999 at Jefferson Lab. The ISM Review Team noted that the Laboratory's safety culture and program were extremely positive. The Team commended the Laboratory's safety training program and also made special note of the strong working relationship with the DOE Site Office staff. The Team's report recommended approval of Jefferson Lab's ISMS Plan, the Oak Ridge Operations Manager approved the Plan on May 24, 1999.

Jefferson Lab Work Smart Standards Process

SURA (the Southeastern Universities Research Association), in cooperation with DOE, has carried out the "Work Smart Standards" (WSS) process, formerly called the "Necessary and Sufficient" process, for more effective EH&S management of Jefferson Lab. The goal of the WSS process at Jefferson Lab was to enable an EH&S system that is both effective and cost-efficient. The WSS process was conducted between November 1995 and January 1996 in accordance with the DOE's guidance. It has identified the set of laws, regulations, and standards necessary and sufficient to ensure health and safety and to protect the environment.

As a follow-up to the WSS process, an EH&S Directives Review Team was chartered. This joint DOE Site Office/Jefferson Lab team was charged with improving the overall EH&S program at Jefferson Lab by clearly defining requirements and expectations tailored to specific mission and site characteristics.

The Team examined each of over 1500 EH&S requirements in 31 DOE EH&S and related (including quality assurance and conduct of operations) orders to recommend its inclusion or exclusion in the contract between the DOE and SURA. The Team determined which requirements were clearly needed to be specifically included in the contract. The remaining requirements are either based in law or regulation (and thus already covered in other contractual references), are not applicable to work performed at the facility, or, on the basis of a net positive benefit assessment, could not be recommended for inclusion. SURA and DOE staff are working together in an ongoing effort to review the applicability of new or revised laws, regulations, standards, and DOE guidance documents.

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 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 ES&H Budget Formulation Submission (formerly called the DOE ES&H Management Plan) considers the areas of industrial hygiene, radiation protection, environmental coordination, fire protection, emergency preparedness, industrial safety, occupational medicine, and internal appraisal. The current Jefferson Lab plan was submitted to the DOE in March 1999. Since the site is new, the ES&H 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. This SER document is prepared to provide 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 Jefferson Lab activities. The SER also describes environmental initiatives, assessments, and programs for each year.

Jefferson Lab Implementation Of 10 CFR 835

Jefferson Lab has implemented the DOE's radiation protection rule, 10 CFR Part 835, "Occupational Radiation Protection". Part 835 addresses worker safety in radiological activities. Jefferson Lab's *Radiation Protection Program* (RPP) and 10 CFR 835 *Implementation Plan* provide a programmatic approach to both evaluation and implementation of the requirements of 10 CFR 835 for Jefferson Lab radiological activities. Both current documents have received DOE approval.

The 10 CFR Part 835 Rule was amended in December 1998. The Jefferson Lab Radiation Protection Program Plan (RPP) was revised to reflect the rulemaking changes. The revised RPP was submitted for DOE review on May 26, 1999. No substantial impacts are expected to the Jefferson Lab radiation protection program as a result of the amended rulemaking.

C. SECURITY, INTELLIGENCE AND NONPROLIFERATION

Jefferson Lab is a low-hazard, non-nuclear accelerator facility chartered to conduct unclassified research into the fundamental nature of matter. As such the Lab has no classified material, special nuclear material or facilities designated as critical to the national interest. The Laboratory is categorized as a "Property Protection Facility" --- the lowest level of security considerations authorized at any DOE facility. The core technologies used to design and operate the accelerator; the Free Electron Laser or those related to use of the electron beam for research are available in open literature and are not considered "sensitive" national security technologies. However, 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 Lab management recognizes that naval and industrial interest in the Free Electron Laser (FEL) facility may lead to the development or use of sensitive technology or information at Jefferson Lab. Anticipating that possibility the Lab is implementing a "graded" approach to FEL security which includes a manned security gate, building access control, and a separate experiment room access control system.

The Lab Director has delegated implementation for security, counter intelligence and nonproliferation activities to the Associate Director for Administration. These closely related functions are managed centrally in the Plant Engineering Department. Responsibilities for security, counterintelligence and nonproliferation are clearly delineated in the Lab's DOE approved Security and Property Management Plans. Additionally, Jefferson Lab has a current DOE "Facility Approval and Registration of Activities" and a favorable "Foreign Ownership Control or Influence" determination.

A standard 9-foot chain link fence encloses the Accelerator, FEL, Experimental Halls and Central Helium Liquifier. These facilities are accessible only through a continuously manned gate. The main "campus" is not fenced and is open during normal work hours. After hours all main "campus" buildings are locked and access is monitored by three additional security guards.

Jefferson Lab is currently excluded from the provisions of DOE Order 1240.2B "Unclassified Visits and Assignments by Foreign Nationals". However, we anticipate that this exclusion may be rescinded in the near future. Jefferson Lab is installing a new personnel badging system to enhance our ability to track visitors, record all accesses and egresses from the Accelerator Site, and record after hours and weekend accesses to the main buildings on the campus portion of the facility. This system will be integrated with the Lab's central personnel and visitor database.

D. Administrative Practices

The completion of Jefferson Lab construction and the beginning of our experimental program brought new challenges for the administrative infrastructure. This timing coincided with DOE initiatives to adopt quality management practices that empower and enable individuals, focus on high performance, and seek to achieve results in a cost-effective manner. We have increasingly leveraged our limited resources in support of the lab's vision and goals as evidenced by the improvement in our research-to-support ratio in the past four years (from 2.8 in 1995 to 3.6 in 1998). While we believe that we are reaching the optimal balance of administrative support to direct research dollars, we will continue to pursue initiatives that return high value while monitoring the effectiveness and responsiveness of support to the lab.

Performance-Based Contracting

Our contract with DOE has enabled us to move toward becoming a true performance-based organization committed to clear objectives with measurable goals, focused on high customer service standards and satisfaction, and integrated with continuous system improvement. We have accordingly implemented systems that emphasize management flexibility with appropriate internal controls — the result of which has been improved performance without increasing administrative cost. The framework within which our business and administrative functions are assessed is Section 6 of Appendix B of our contract. The evaluation process is based on a key performance measure (an annual peer review by a panel of Chief-Administrative-Officer-equivalents from private industry, national labs, DOE, and the scientific community) along with a set of secondary measures. The peer review process, supported by the DOE Site Office's ongoing operational awareness, has been determined by DOE to be an innovative approach for reviewing and improving business and administrative performance. Our FY 1998 assessment resulted in a rating of 90.3 out of 100 points for an adjectival rating of *Outstanding* in Business and Administrative Practice. Table V-10 shows these results as well as the results of the FY 1999 Administrative Peer Review.

Table V-10
Peer Review Results

KEY MEASURE: PEER REVIEW	**FY98**			**FY99**		
	Available Points	Points Achieved	Adjectival Rating	Available Points	Points Achieved	Adjectival Rating
Division Office	10	10		10	9	
Business Services	20	19		*30	26.6	
Human Resources	*25	19		15	13.4	
Plant Engineering	15	14		15	14	
Public Information	Not reviewed as part of Admin Peer Review; addressed in Inst. Mgmt. Review					
Information Resource Management	Reviewed as part of Division Office above					
*Special Focus Area						
Total Peer Review	**70**	**62**	**Excellent**	**70**	**63**	**Outstanding**
SECONDARY MEASURES	Available Points	Points Achieved	Adjectival Rating	Available Points	Points Achieved	Adjectival Rating
Facilities Management	6	6		6		
Property Management & Protection	6	5		6		
Financial Management	6	6		6		
Procurement	6	6		6		
Human Resources & Services	6	5.3		6		
Total Secondary Measures	**30**	**28.3**	**Outstanding**	**30**		
TOTAL: SECTION 6	**100**	**90.3**	**Outstanding**	**100**		

Improvement Initiatives

The Administrative Peer Review Panel commended the success of the lab's business and administrative practices. Achievements have come through business process re-engineering, elimination of non-essential activities, and adoption of best business practices. Many of the initiatives originated from quality improvement teams or groups representing not only the process owners but our customers and stakeholders (including DOE) as well. Some of these initiatives are described below.

We consolidated the Finance and Procurement Departments into the Business Services Department. This change created a flatter organization, reduced support staff, and improved the department's overall efficiency. Some streamlining initiatives in this area include: revision of procurement policies to facilitate use of commercial practices; simplification of overhead rate structure; increased use of procurement credit card for micro-purchases; implementation of DOE tender agreement for relocation costs of household goods, site-wide recycled paper program, just-in-time office supplies subcontracting and electronic funds transfer program for travel reimbursement. The results of these and other streamlining efforts are evident in: a favorable cost to purchase goods and services (a cost-effectiveness measure) as compared with other labs and benchmarks; a reduction by over 55% in a five-year period in procurement cycle time (a responsiveness measure); and cash discounts in 99.3% of vendor invoice payments.

Business Services completed conversion of the Laboratory accounting system into the new Costpoint Program. Costpoint is a project based accounting system, capturing financial information in a way that allows significant flexibility for reporting functions. Additionally, this program affords Business Services the opportunity to provide desktop financial reporting to a large population of the Laboratory.

Business Services also streamlined the review of travel vouchers to reduce the level of manpower expended, while maintaining appropriate controls. Procurement personnel in Business Services developed and implemented agreements with Dell Computers and Gateway Computers to simplify procurement of standard configuration PC's; and continue to work towards implementation of a just-in-time buying program for small tools. An on-line credit card expense log has been developed and is being tested. This on-line system will provide immediate information on credit card purchases to the appropriate cost account manager.

For the past eight years in the procurement area, we have exceeded our socio-economic goals for conducting business with small, small disadvantaged, and small woman-owned businesses. DOE awarded the Secretary of Energy's Small and Disadvantaged Business Subcontracting Award to the lab for fiscal years 1990-1992, 1994, and 1998. DOE also awarded the Oak Ridge M&O Contractor of the Year Award to the Lab for fiscal years 1995, 1997, and 1998. Our socio-economic goals for FY 1999 are adjusted to reflect the move toward more commercial procurement practices such as credit card purchases, just-in-time procurement of office supplies, and leveraged buying programs (DOE consortium purchase program) where both the base of available dollars and the actual awards to small and disadvantaged businesses are affected. We continue, however, to work with DOE to set challenging socio-economic goals that reflect the lab's commitment to the DOE's diversity initiatives.

Table V-11 summarizes subcontracting and procurement expenditures for FY 1998 through those projected for FY 2001. Table V-12 summarizes procurement business in FY 1998 and FY 1999 with small and disadvantaged companies.

Table V-11
Subcontracting and Procurement

($ in Millions -- Obligated)	FY 1998	FY 1999	FY 2000	FY 2001
Subcontracting and Procurement from:				
Universities	1.5	2.0	2.3	2.5
All Others	28.2	29.7	35.9	37.3
Transfers to Other DOE Facilities	0.0	0.0	0.0	0.0
Total External Subcontracting and Procurements	**29.7**	**31.7**	**38.2**	**39.8**

Table V-12
Small and Disadvantaged Business Procurement

($ in Millions -- B/A)	FY 1998 Goal	FY 1998 Achieved	FY 1999 Goal
Procurement from S&DB	.6	1.9	.7
Percent of Annual Procurement	6%	10.8%	6%

In the human resources area, we have maintained a reasonable representation of minorities and women in the workforce and are continuing to progress toward full utilization in all job groups. This is the result of our careful monitoring of recruitment and employment activities and ongoing review with senior management. Additionally, we have increased interaction with Historically Black Colleges and Universities (HBCUs) and Minority Educational Institutions (MEIs) as well as organizational and community action programs. In FY 1998, our highly diverse student intern cooperative education program was 56% female and 33% minority, with about 43% in technical positions. We continue to promote a positive workplace climate and effective problem resolution strategies in our employee relations and communications function. The results include an enhanced performance appraisal process (including self-assessment feature) and increased communication of HR information through use of the Web and user-friendly publications (Records Management Guide, Supervisor's Guide to Effective Performance Appraisals, Employee Handbook, Annual Benefits Summary). We have implemented a comprehensive competency-based staff development and training program offering a wider range of programs and services for management and staff. An effective and proactive employee relations function which provides management consultation and intervention has resulted in no formal grievances in FY 1998. The library was relocated to the Applied Research Center Building. Library services continue to provide on-line reference searches, document delivery, and desktop, end-user search capability. A new Web/Windows-based system was installed in FY 1998. Web access through the lab homepage has allowed our participation in local and regional cooperative library and information services. Support provided by staff services for conferences and meetings and food services receives high marks from both the scientific community and internal lab users.

In the area of plant engineering, we utilize a dynamic and highly effective outsourcing program for such functions as: security, janitorial, refuse collection and disposal, pest control, materials management, meeting room setups and office moves, grounds maintenance, HVAC and mechanical maintenance, electrical (high and low voltage) maintenance, fire systems maintenance, controls systems maintenance, cooling water chemical treatment, plumbing, painting, and architect and engineering design. Many of these subcontracts are firm-fixed-price and all are very cost-effective. The lab plant engineering staff vigilantly monitor services provided through outsourcing

to ensure quality. We implemented an EH&S incentive program for construction subcontracts that DOE has recognized in successive reviews for its effectiveness in improving subcontractor safety on-site. This program provides monetary incentives to subcontractors for exemplary EH&S performance. Other accomplishments from streamlining work processes include: a property loss rate of under one percent in our latest inventory (using a sampling method instead of the labor intensive, time-consuming wall-to-wall inventory of prior years); real-time feedback to lab customers on work order status and statistical information for project managers' analysis and reporting needs with the implementation of a Web-based work order system.

In management information systems (MIS), we have developed cost-effective MIS support for administrative processes and improvement initiatives. The system is based on central, sitewide, internally accessible information and data to support decision-making and daily operations. It includes information on lab population, time reporting, buildings and building access, mailstops, telephones, property, purchases and deliveries, computer system access, material safety data sheets, training, lab conferences, library holdings, and staff publications.

Future Improvement Goals and Initiatives

Our attention to high-value, cost-effective performance results — monitored through a strong and well-established self-assessment program — dictates that we proactively target improvement opportunities. The following are our major improvement goals:

- Enhance our program for determining operational reliability of facility electrical, mechanical, and structural systems and system components through risk-cost analysis and recommend solutions to minimize downtime
- Implement the Central Alarm Notification System that integrates existing alarm systems and improves response time as well as enhances the lab's security measures and provides a new badging system
- Pursue just-in-time subcontracting and other procurement methods to streamline the procurement process in additional areas while retaining high value for dollars spent
- Continue to monitor and improve our upgrade to the financial information and reporting system that has allowed direct user access to appropriate financial data for responsible budget monitoring and reporting
- Plan and deploy a modern human resources information system
- Work with DOE toward a prudent, cost-effective, flexible, and responsible compensation system
- Continue to migrate all multi-user MIS applications to an intranet using Web technologies and standardize the information environment for administrative data systems, including sitewide applications such as word processing, spreadsheets, and database management
- Implement a 360 feedback program
- Enhance the Publications and Records Management Program
- Fully deploy an integrated Lab-wide management development program

E. Public Communications and Trust

Through a variety of means including a comprehensive but low-resource-demand public information program, Jefferson Lab actively seeks to maintain constructive, effective communication and trust with the public. In particular, the lab enjoys a high level of mutual trust with the City of Newport News. This relationship is quite important. Since well before CEBAF construction began in 1987, the city has been farsighted about the lab's significance in economic diversification and in other areas of civic life, and has therefore striven to support the lab and to advance its prospects. The most obvious examples of this support have been the city's funding for most of the land the lab is sited on, for the residence facility where visiting user-scientists stay, and for the Applied Research Center. To maintain and cultivate this mutually beneficial relationship, Jefferson Lab personnel serve on important city committees in such diverse areas as economic development, building design, education, transportation, and recycling. Both the lab and the city highly value this relationship.

This partnership also extends to police and fire protection. The city and Jefferson Lab host joint emergency drills to ensure the city can respond to our unique circumstances. Tours are conducted regularly to keep city personnel well acquainted with the site as it evolves.

Jefferson Lab has used a variety of methods to maintain constructive, effective communication with the community. Lab personnel regularly visit local civic and social organizations as guest speakers on topics relating to the lab. The Jefferson Lab Science Series, now in its eighth year, is advertised in the local newspaper and draws over 200 to 300 students, teachers, and parents each month for exposure to scientists and engineers who present science and engineering in interesting ways. High profile personalities are recruited for the science series occasionally. For example, Lawrence Krauss, author of the Science of Star Trek presented a lecture on the same topic for the public in October. Overflow seating was required to accommodate a crowd of more than 600. This series is videotaped by the local school system and is re-broadcast on the city's cable channel further broadening the exposure of the citizens to science. Lab personnel also visit local elementary school systems as guest speakers on high-technology jobs and careers. The Jefferson Lab Open House brought 4,500 guests to the lab to visit, understand our mission and see what's behind the trees. This successful event was staffed by over 280 Jefferson Lab employees and has received many positive comments from the community and the media. On the state level, Jefferson Lab expands its outreach by participating each year in the Virginia State Fair, where 200,000 people visit the lab's display booth and are treated to hands-on activities and cryogenics demonstrations over an 11-day period.

Also at the state, regional and local level, Jefferson Lab personnel participate in local and regional economic and technology committees and in partnerships such as the Virginia Physics Consortium, a statewide consortium of physics Ph.D.-granting institutions. This participation has led to a reputation of responsible stewardship of the funds allocated by the state to the lab. In part because of this reputation, the state now funds four local universities to conduct research in the Applied Research Center, and provides lease money for the laboratory space the researchers are utilizing. In addition to their contribution to the Applied Research Center, state and local governments have contributed over $40 million to Jefferson Lab in direct appropriations over the past ten years.

Similarly, a good relationship is in place with the local printing and broadcast media. Reporters and our public affairs staff know and respect each other, and the reporters routinely ask for information that can be used to generate news stories. This extends to the state level as well, and in 1998 the national press continued to play a role in helping Jefferson Lab educate the public about the importance of fundamental research. Honest communication and high-quality, specialized media kits are the key to each level of the lab's media effort, targeting particular media audiences. Additional efforts are being made this year to ensure the Department of Energy is identified strongly with Jefferson Lab. These include stronger ties in press releases, newsletter stories, and displays and more frequent mention of the Department of Energy in press interviews. The lab also cultivates its relationship with the media by arranging for direct contact with lab and user subject-matter experts-the scientists and others who have the actual first-hand technical knowledge and who are sensitive to the difficulties of communicating about it to a wide audience.

F. Education

In addition to its natural role in undergraduate and graduate education as a major national accelerator facility which supports university research, Jefferson Lab has taken on two special roles in its community: partnerships with Historically Black Colleges and Universities (HBCUs) and Hispanic Serving Institutions (HSIs), and community outreach to area public schools and citizens.

Historically Black Colleges and Universities and Hispanic Serving Institutions

The Jefferson Lab initiative to make HBCUs and HSIs a vital part of its university-based research community, and thereby to foster the education in science and technology of the next generation of minority students, has been based on two types of partnerships with various universities. Under joint-faculty arrangements, new faculty 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 of 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 type of arrangement, 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) and agrees to take over full responsibility for this faculty member upon the expiration of the "bridge."

Partnerships with local HBCUs were struck in 1989 with Hampton University (an HBCU in Hampton, about 20 minutes by car from Jefferson Lab) and in 1992 with Norfolk State University (an HBCU in Norfolk, about 40 minutes from Jefferson Lab). Hampton University has added five new faculty to its physics department, while Norfolk State University has added three faculty and intends to add one more. These faculty are all being hired on a long-term cost-shared basis.

In addition to these local joint-faculty-based partnerships, Jefferson Lab has made bridging arrangements with other non-local HBCUs and HSIs. Current partners include Florida International University, North Carolina Agricultural and Technical State University, North Carolina Central University, and New Mexico State University and its sister institution, the University of Texas at El Paso.

By any reasonable measure, these partnerships are immensely successful. Undoubtedly the best example is the oldest: Hampton University. Under the MOU 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 the laboratory, the Hampton University group working at Jefferson Lab received a $5M grant from the National Science Foundation in 1991. Based on their outstanding performance, this grant was renewed in 1996 for a second five years. 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 focused their program. Hampton faculty are the spokespersons for eleven approved and conditionally approved experiments. In the fall of 1996, Hampton University became the first HBCU ever to lead a major experiment at a national accelerator laboratory. The Hampton University Department of Physics has become a major center for education of the next generation of minority scientists and engineers. In 1998, the department has an enrollment of 21 undergraduates and 44 M.S./Ph.D. students. For the 1998-1999 academic year, the department has an enrollment of 20 undergraduates and 44 M.S./Ph.D. students. Five of the M.S./Ph.D. students graduated in December 1998 and January 1999. An additional six students are expected to receive their Ph.D. by the end of this year or early during the spring of 2000.

Such transformations do not occur overnight: five to ten years, as with Hampton University, are required to create the appropriate environment. However, Jefferson Lab has every reason to

believe that with its continued support, its other partners will enjoy comparable success both scientifically and in the training of the next generation of minority scientists and engineers.

Community Outreach

In partnership with the local school divisions and the surrounding community, Jefferson Lab is dedicated to:

- motivating students to continue learning, and
- explaining math and science to students, teachers, parents, and the general public.

Jefferson Lab's resources to achieving these goals are the staff scientists and engineers themselves. During FY 1999, about 10000 students and 750 teachers will interact with Jefferson Lab staff who shares their knowledge, experience, and enthusiasm. In FY 1998, 36% of the staff volunteered to support these programs.

The BEAMS - Becoming Enthusiastic About Math and Science - program is a vehicle to bring classes of sixth, seventh, and eighth school students with their teachers to Jefferson Lab for:

- formal interaction with Jefferson Lab staff via science and math interactive activities,
- casual interaction with staff and leadership, and
- ongoing education with the classroom teacher.

Since 1991, BEAMS has involved about 11,300 students and 305 teachers. Results from the on-going evaluation of BEAMS include: (1) students attending BEAMS are significantly more positive about science than students not attending; (2) teachers report that BEAMS increases their awareness of hands-on science, applications of math and science, and careers in math and science; and (3) parents report that the BEAMS program is a unique positive influence on their children.

Throughout the BEAMS students' middle school years, each student comes to Jefferson Lab each year - for five consecutive days in the sixth grade, three days in the seventh grade, and two days in the eighth grade. This ongoing interaction extends the initial positive influence BEAMS has shown at the sixth grade level and, at the same time, facilitates the evaluation process of obtaining students' achievement records (course selections and grades) and anecdotal information over a three year period. The FY 1999 BEAMS participants include every sixth, seventh, and eighth grade student at Huntington Middle School and every sixth grade student at Crittenden Middle School.

Evaluation results sparked the "BEAMS at Siemens" program, a replica of Jefferson Lab's BEAMS program, at Siemens, Inc. in Newport News. Siemens hosts four classes of BEAMS students each year. BEAMS has also been replicated by NASA-Goddard Space Flight Center (NASA-Goddard hosts twelve "SUNBEAMS" classes each year.)

Other community-based partnerships include:

- the monthly Jefferson Lab Science Series showcasing diverse scientific fields and topics,
- Cooperating Hampton Roads Organizations for Minorities in Engineering (CHROME), which sponsors school-based science and math clubs throughout southeast Virginia,
- summer research internships for high school students, and
- the inclusion of precollege teachers in Jefferson Lab's technical and scientific activities so they can experience applications of math and science in a high-technology workplace.

Table V-13
University and Science Education

	FY1998 Total	FY1998 Minorities	FY1998 Women	FY 1999[1] Total	FY 1999[1] Minorities	FY 1999[1] Women
PRE-COLLEGE PROGRAMS						
Student Programs						
BEAMS Partnership	1350	945	725	1260	920	605
High School Summer Internships	13	5	5	15	7	7
Science Series, CHROME, etc.	~6500	~3500	~3800	~7000	~3800	~4000
Teacher Programs						
BEAMS	60	31	42	62	29	47
Teacher Research Participation	16	5	5	5	1	3
Other Teacher Assistance	~700			~700		
UNDERGRADUATE PROGRAMS						
Student Programs						
Undergraduate Student Researchships	11	4	5	7	2	4
Technical Interns	24	9	7	16	6	8
GRADUATE PROGRAMS						
Student Programs						
Lab-Funded Graduate Students	37	15	7	38	19	8
SURA/JLAB Graduate Fellowships	8	2	2	8	2	2
Other Graduate Students on-site in Research	31	14	5	59	24	20
POSTGRADUATE PROGRAMS						
Fellowships						
Lab-Funded Post-Doctoral Fellows	17	3	2	22	5	5
Other Post-Doctoral Fellows on-site in Research	6	3	0	6	3	0

[1]Actuals to date

G. Technology Transfer

The Jefferson Lab Technology Transfer Program currently emphasizes technology development and transfer activities built upon two of the core competencies derived from our basic research mission: superconducting radio-frequency (SRF) technology and detector technology. Opportunities for commercialization of Jefferson Lab's federally funded research efforts are enhanced by leveraging our core technologies in collaboration with industry, educational institutions, and other federal agencies.

Jefferson Lab's major technology transfer effort is in its role as the lead institution in the Laser Processing Consortium (LPC), our key link to industry. The LPC was established by Jefferson Lab's Industrial Advisory Board to develop and apply free-electron laser (FEL) technology. The FEL Program and the LPC are described in Section V.1.C. This consortium meets twice yearly to provide guidance on the planning and implementation of the FEL Program and to plan initial outfitting and use of the FEL User Facility application laboratories.

A second area of concentration for Jefferson Lab's technology transfer, medical imaging, derives from the laboratory's core competency in detector technology. In a milestone achievement in 1996, Jefferson Lab negotiated a Cooperative Research and Development Agreement (CRADA) and awarded a license to a small business partner to jointly further the development of a scintimammography medical imaging device. This device, which is based on six Jefferson Lab patents and additional pending patents, has the potential for significant improvements in breast cancer detection work. This work is being conducted jointly with the University of Virginia Medical School and Johns Hopkins University Medical School, and has won the recognition of the Women's Health Office of the Department of Health and Human Services. In 1999, the imaging device won FDA approval and the first commercial product is being produced by our business partner.

Another key partnership is the lab's relationship with the City of Newport News. From the lab's start in the 1980s, it has always received the city's generous and farsighted support. With the realization that Jefferson Lab and its technology transfer development program could lead to increased economic development, the city completed building in 1998 a high profile, seven-story complex. This building, the Applied Research Center or ARC, houses lab personnel, four local university R&D efforts, and key industry partners. This building is an $18.4 million investment that the city is using to jump-start a new 200-acre high-technology business park, the Jefferson Center for Research and Technology, which is adjacent to the Jefferson Lab campus. Jefferson Lab personnel have actively participated in the design and development of both the park and the ARC building. The city counts on this support for continuing efforts to strengthen and diversify the local economy.

Intellectual property management is a significant element of the Jefferson Lab Technology Transfer Program. In 1998, SURA contributed in excess of $100,000, used by the Laboratory Invention and Patent Review Committee to fund patent reviews, applications and various other related actions. In addition, SURA established an oversight board that periodically reviews the committee's authorizations and activities. To date, Jefferson Lab has processed 77 invention disclosures, has received 18 patents, licensed 6 patents and one copyright, and currently has 14 patent applications under active consideration.

H. Site Facilities And Description

Site Description

The Jefferson Lab site, located in Newport News, Virginia (Figure V-5), includes 162 acres owned by the DOE and 8 acres owned by the Commonwealth of Virginia. SURA owns 44 acres adjacent to the site. The facilities include the accelerator complex serving three experimental halls, the Free-Electron Laser Facility, a central office building (CEBAF Center), two major laboratory buildings, and various other support structures. The replacement value of conventional facilities and utilities is $174 million.

The accelerator enclosure is a 7/8-mile racetrack-shaped concrete tunnel, 25 feet underground. The tunnel houses a 45 MeV injector, two 400 MeV linacs—one in each straight section of the racetrack—and 6 kilometers of beam transport lines. The Central Helium Liquifier (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 (MCC) houses the computer systems that control and monitor accelerator operations. The Free-Electron Laser 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 C is 150 feet in diameter, Hall A 174 feet, and Hall B 98 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, 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 recently constructed an Applied Research Center (ARC) on a site directly adjacent to the laboratory. The 121,000 square foot structure, completed in the spring of 1998, provides office and light laboratory space for lease to qualified tenants. Jefferson Lab has leased 41,600 SF. Several collaborating universities have also leased space. The ARC will be the anchor for the 200-acre Jefferson Center for Research and Technology, a technology park for high technology R&D and production activities.

Tables V-14 and V-15 and Figures V-6, V-7, and V-8 provide additional data about facilities on the site.

Site Development and Major Facility Maintenance

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 is 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.

The FEL Building was completed in late 1997. Commissioning of the FEL began in the spring of 1998. The 15,000 square foot physics storage/assembly building was completed in 1998. Plans and budgets for accelerator energy upgrades are being developed. This effort, when funded, will involve significant machine alterations and civil construction to support the increased energy operations.

The most immediate site development needs at Jefferson Lab are to provide adequate office space for the growing population of scientific users now on site, and to provide technical, staging, and storage facilities to support experiments and operations. The lab has very limited facilities of this type, and their absence has already begun to hamper laboratory productivity and user support. Relocation of Jefferson Lab staff to the ARC has provided office/work space for the majority of the visiting scientific users; however as the user population grows this problem will resurface.

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 require replacement to ensure reliability.

The current major maintenance/improvement backlog indicates that an average $1M annual expenditure will be required to keep the lab's conventional facilities sound and capable of supporting operational requirements. This amount is slightly less than 1% of the value of existing conventional facilities.

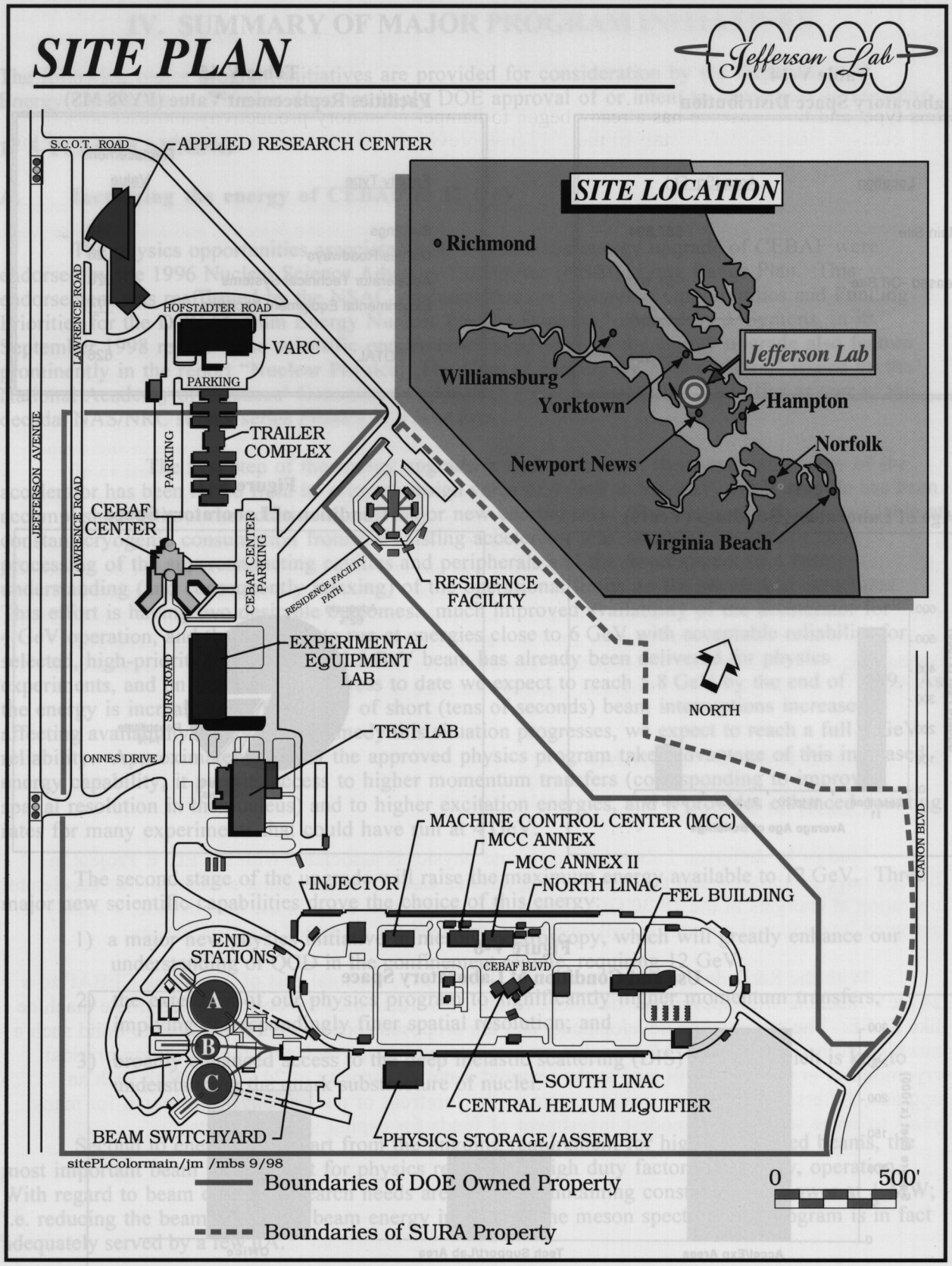


Figure V-5 Jefferson Lab Site

Table V-14
Laboratory Space Distribution

Location	Area (Sq. Ft.)
Main Site	587,894
Leased -Off Site	51,100
	638,994

Table V-15
Facilities Replacement Value (FY98 M$)

Facility Type	Replacement Value
Buildings	148
Utilities/Roadways	26
Accelerator Technical Systems	278
Experimental Equipment Facilities	174
TOTAL	626

Figure V-6
Age of Laboratory Buildings (Years)

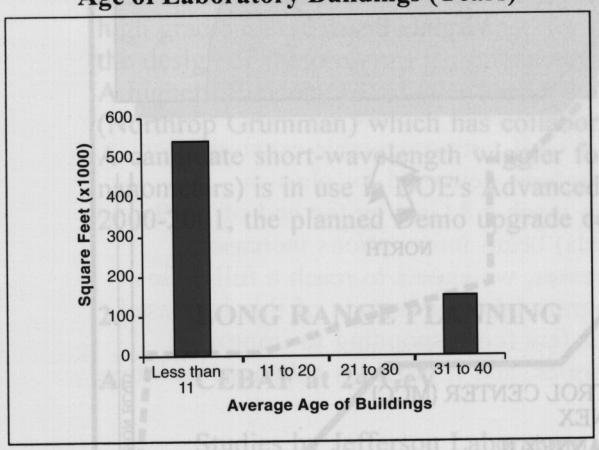


Figure V-7
Condition of Laboratory Space

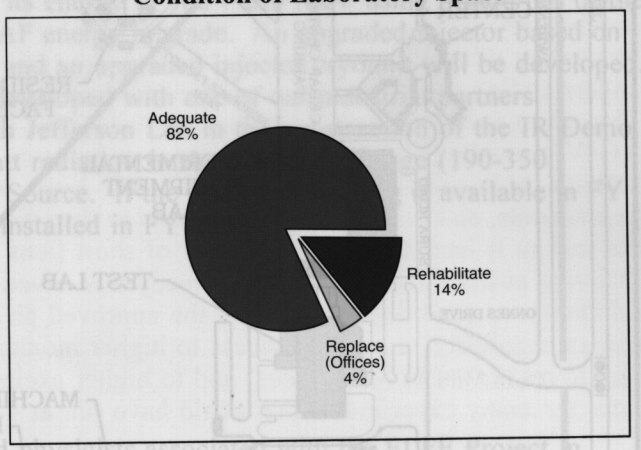
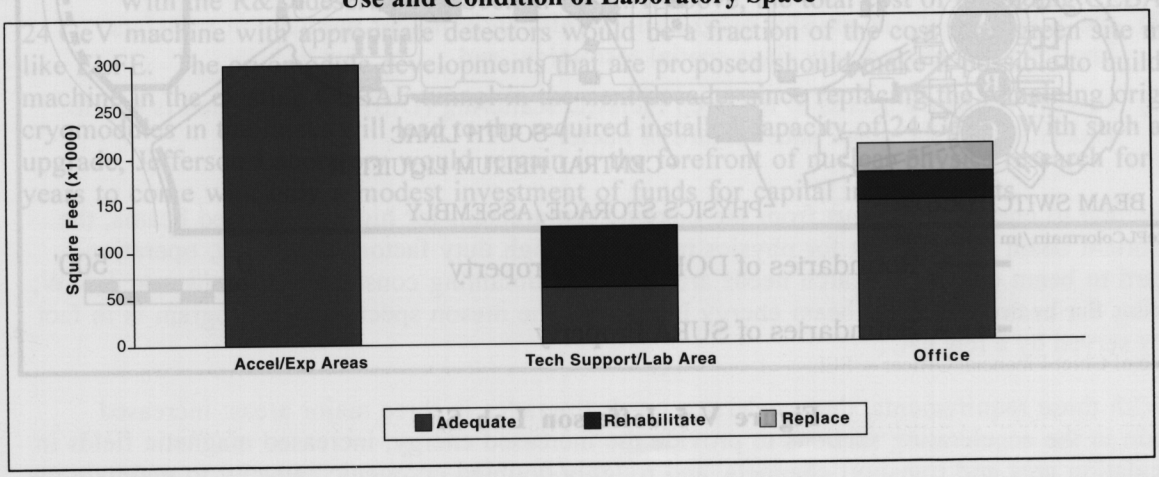


Figure V-8
Use and Condition of Laboratory Space



VI. RESOURCE PROJECTIONS

Table VI-1 reflects actual, projected, and requirements funding from the Office of Science in FY 1998 through FY 2004 for nuclear physics at Jefferson Lab. We show funding separately for operating, general-use capital equipment, experimental equipment modifications and upgrades, and GPP/AIP (General Plant Project/Accelerator Improvement Program). 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.

The table raises two important issues with regard to the funding of the laboratory and its users. First, as discussed in Section V.1.A below, the operations funding we receive is significantly below the level necessary for optimum scientific productivity. An increment of $3M/year for operating and $.2M/yer for education is included in the requirements budget for FY 2000 and beyond (with inflation each year based on OBM inflators). The increment of $3M/year in operating funds will permit us to increase the weeks of accelerator operations from 30 to 33 weeks, and to raise the accelerator operations efficiency and experiment multiplicity by an amount that will increase the scientific productivity by fully ¼. We estimate that a second increment of $3M/year in operating funds would increase the productivity by another ¼, and bring facility operations to close to optimum. The second important issue is related to the current level of staffing (Table VI-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 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 VI-1
Laboratory Funding and Performance Summary

(AY$ in Millions - BA)	FY1998 (Actual)	FY1999 (Projected)	FY2000 (Pres. Budget)	FY2000 (Req. for Eff. Ops)	FY2001 (Req. for Eff. Ops)	FY2002 (Req. for Eff. Ops)	FY2003 (Req. for Eff. Ops)	FY2004 (Req. for Eff. Ops)
WEEKS OF PHYSICS OPERATION	31	30	31	33	33	33	33	33
EXPERIMENT MULTIPLICITY[1]	2	2.4	2.1	2.4	2.4	2.4	2.4	2.4
ACCELERATOR AVAILABILITY(%)[2]	68	75	70	75	75	75	75	75
PROGRAM FUNDING								
Office of Science								
Nuclear Physics								
Operating	61.4	63.6	66.1	68.2	69.3	70.8	72.5	74.7
Capital Equipment	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1
Experimental Equipment	4.0	4.0	3.9	3.9	3.9	3.8	3.8	3.8
GPP/AIP	1.2	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Subtotal Nuclear Physics	68.9	71.7	74.0	75.6	77.2	78.5	80.2	81.9
Computational and Technology Research								
SSI				1.0	2.0	3.0	4.0	4.0
Technology Transfer				.1	.1	.1	.1	.1
Subtotal Comp. & Tech. Research				1.1	2.1	3.1	4.1	4.1
Basic Energy Sciences – FEL	.2							
Office of Chief Financial Officer – FEL	.1	.1						
TOTAL PROGRAM FUNDING	72.1	71.8	74.0	76.7	79.3	81.6	84.3	86.0

[1]Multiplicity indicates expected # of experiments running at the average
[2]Availability is averaged over all running experiments

The IR Demo FEL development was funded in FY 1996 and FY1997 for $16.8M by the U.S. Navy and the Commonwealth of Virginia. Matching funds and in-kind contributions totaling $14M additional to implement the industrial processing labs have been pledged by members of the Laser Processing Consortium. The city of Newport News has constructed an Applied Research Center (ARC) at a cost of $18.4M. The 121,000 SF structure was built on a site directly adjacent to the laboratory and provides office and laboratory space that house R&D activities that support the FEL program.

Table VI-2
Laboratory Manpower Summary (Average)

	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004
Total Projected Staffing	506	519	520	520	520	520	520
Others On Site							
Physics Users	110	130	150	170	190	210	230
Students	80	80	100	110	120	130	140
DOE	8	8	8	8	8	8	8
Subtotal	198	218	258	288	318	348	378
TOTAL SITE POPULATION	704	737	778	808	838	868	898

Table VI-3
Major Construction Projects

(2000$ in Millions - BA)	TPC	FY 2004	FY2005	FY2006
FUNDED CONSTRUCTION				
BUDGETED CONSTRUCTION				
PROPOSED CONSTRUCTION				
Program Line Item Projects				
12 GeV Energy Upgrade	100	20	40	40

Thomas Jefferson National Accelerator Facility

Laboratory Information - FY98

Location: Newport News, Virginia

Number of Full-Time Employees: 501

Scientific and Technical Degrees: 105 Ph.D.'s; 158 Bachelor's/Master's

Contractor: Southeastern Universities Research Association

Accountable Program Office: Office of Science

Field Office: Oak Ridge Operations Office

Web Site: http://www.jlab.org

Funding Sources - FY98

Science:	$69.20 M
Defense Programs:	.71 M
Energy Efficiency and Renewable Energy:	.11 M
Chief Financial Officer	.23 M
Non DOE: Commonwealth of Virginia	1.90 M
Misc. Work for others	.30 M
Total Funding:	$72.40 M

Description

Thomas Jefferson National Accelerator Facility, formerly known as the Continuous Electron Beam Accelerator Facility, is a national user facility for scientific research using continuous beams of high-energy (0.5-6.0 GeV) electrons to elucidate the underlying quark and gluon structure of nucleons and nuclei. The facility was constructed on a green site from 1987 through 1995 for $600 milllion. As the U.S. leader in this branch of research, complementing the planned research at the Relativistic Heavy Ion Collider being built at Brookhaven National Laboratory, the Facility offers users unique capabilities for experiments studying atomic nuclei using electrons, our best understood probe particle. Machine capabilities include energies in the multi-GeV range - providing spatial resolutions ranging from the size of a large nucleus down to about one-tenth the size of a proton; high currents - permitting the study of reactions with very small cross-sections; and continuous beam operation - supporting precision coincidence experiments. The user community includes about 1600 members, with 834 experimenters. The innovative design and technology of the accelerator allow a gradual, cost-effective upgrade to 12 GeV and then to 24 GeV. A spin-off of the Laboratory's accelerator technology is the 1-kW Infrared Free Electron Laser developed in collaboration with industrial, Navy, and university partners for industrial, defense, and research applications.

Distinctive Competencies and Major Facilities

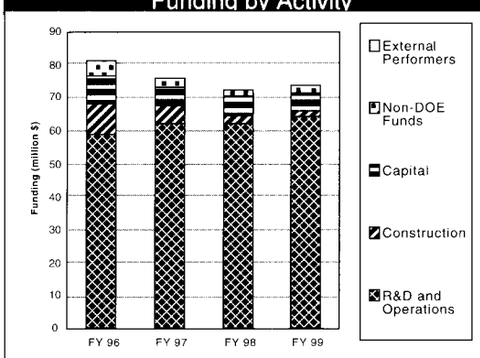
Distinctive Competencies:

- Design, execution, and analysis of precision experiments involving studies of nucleons and nuclei by both electron scattering and photon-induced reactions, and involving: state of the art simulations; the design, construction, and operation of super-conducting spectrometers, advanced detectors, and polarized and cryogenic targets; and the use of very high-rate data acquisition and analysis systems.
- Theoretical calculations in both the quantum chromodynamics and conventional nuclear physics frameworks to interpret, analyze, and plan experiments, and to project future research directions.
- Accelerator technology and accelerator physics expertise necessary to produce high brightness and highly-polarized continuous wave electron beams, including: superpconducting radiofrequency technology; very large scale 2K (superfluid) He cryogenics; large real-time control systems (>100,000 control points); and photocathode electron sources and advanced laser systems.

Major Facilities:

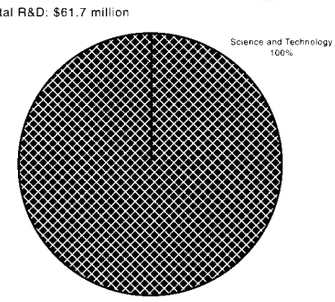
- The Continuous Electron Beam Accelerator Facility (CEBAF) provides continuous wave electron beams with energies from 0.5 to 5.5 GeV (6 GeV anticipated in FY00 and 12 GeV in 08), with currents from 100pA to 200μA (and with polarization approaching 80% to three endstations simultaneously).
- Three endstations with a set of complementary experimental equipment. Hall A has a pair of superconducting, high-resolution magnetic spectrometers
  optimized for precision electron scattering coincidence experiments. Hall B houses the CEBAF Large Acceptance Spectrometer (CLAS), a nearly 4π detector and ancillary equipment that supports studies of both electron and monochromatic photon-induced reactions with loosely-correlated particles in the final state. Hall C contains a pair of moderate resolution spectrometers (one capable of high momentum particle detection and the second optimized for the detection of short-lived reaction products) and provides additional space and infrastructure for supporting major experiment setups optimized for specific measurements that cannot be carried out using available instruments.
- The Testlab and Applied Research Center (ARC), providing a state of the art surface science and superconducting radiofrequency research and development and production capability.
- The Infrared Free Electron Laser (IFEL), designed to provide 1 kW of infrared light with picosecond pulse length, transform limited bandwidth, and diffraction limited emittance.

Funding by Activity



DOE R&D Footprint

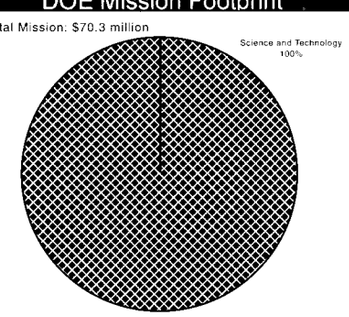
Total R&D: $61.7 million



Note: Based on FY98 funding data; contributing non-DOE funds included; site remediation funds excluded

DOE Mission Footprint

Total Mission: $70.3 million



Note: Based on FY98 funding data; contributing non-DOE funds included; site remediation funds excluded

Thomas Jefferson National Accelerator Facility

Key Research and Development Activities

Science and Technology Mission

- **Nuclear Physics**: The Continuous Beam Accelerator Facility and associated experimental equipment are addressing major open questions in nuclear physics; how the nucleons and mesons are constructed from the quarks and gluons of quantum chromodynamics; understanding the quantum chromodynamic origins of the strong interation between the nucleons; and investigating the structure of atomic nuclei with an emphasis on identifying the transition between the standard neutron plus proton picture to the underlying quark structure.

- **Accelerator Physics and Technology**: Develop and refine processing and assembly techniques for superconducting cavities; refine cavity, coupler, and cryostat designs; integrate results into upgraded cryomodules operating at > 15MV/m and high Q values for applications in an upgrade of CEBAF to 12 GeV, 24 GeV, and high power free electron lasers; refine photocathode technology, radiofrequency modulated lasers to produce intense (200uA) beams of highly (80%) polarized electrons for nuclear physics research.

- **Free Electron Laser Development**: Increase energy to extend wave length range: 1 kW in the deep ultraviolet (190 nm) for industrial applications; increase source capabilities to reach 10 kW in the infrared for defense-related research and applications.

- **Information Technology**: Provide petabyte scale data acquisition and analysis with associated high-end simulation systems; develop and deploy 100,000 element scale real-time control systems.

- **Detectors**: Provide state-of-the-art particle detector systems.

Significant Accomplishments

Infrared Free Electron Laser Delivers Record-breaking Performance: 1998—An infrared Free Electron laser based on the superconducting radiofrequency technology used in Jefferson Lab's Nuclear Physics accelerator, delivered first light in June 1998 at 15 times the previous world's record for a laser of this type. The laser has reached a power level of 311 watts and is on track to deliver 1 kW of infrared light in CY99.

Jefferson Lab began three hall operation for physics research: 1998—Jefferson Lab began three-hall operation of its three complementary experimental halls to explore the origins of quark confinement and structure of atomic nuclei. The Lab has already produced results in several world-class experiments including T20 (structure of the deuteron) and HAPPEX (a parity violation experiment on the strangeness structure of the nucleon)

Medical imaging clinical tests: 1998—Clinical tests begin at John's Hopkins of medical imaging equipment using advanced detector technology developed for Jefferson Lab's Nuclear Physics program. The device offers higher resolution at lower costs than current methods for breast and other diagnostic imaging.

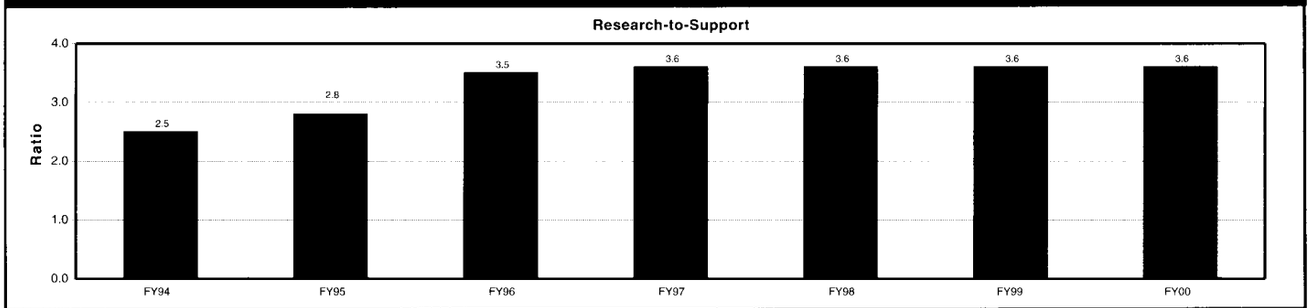
On cost, on schedule delivery of largest-scale application of SRF technology: 1995—The Continuous Electron Beam Accelerator Facility (CEBAF, later dedicated Thomas Jefferson National Accelerator Facility) was completed on cost and on schedule, and delivered 4 GeV (Spec energy) beam to the first of its three experimental halls to come on-line.

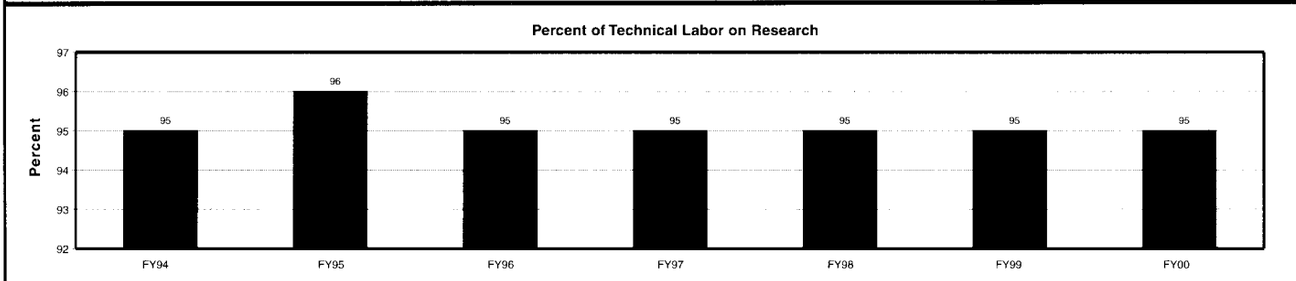
Thomas Jefferson National Accelerator Facility

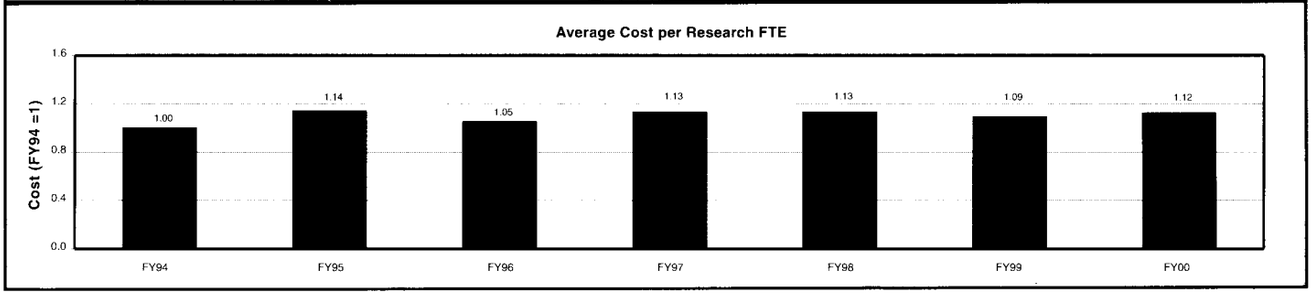
Major Partnerships, Collaborations, and CRADAs

Category/Mission	Partner	Description
Science and Technology	User Community	Jefferson Lab international user community, currently over 1600 users from 277 institutions and 21 countries. Nuclear physics, Free Electron Laser
	Universities	Universities, including minority institutions, with an emphasis on the Southeastern region. Nuclear physics, medical diagnostics, Free Electron Laser
	National Science Foundation	Nuclear physics
	NASA	Detectors
	Los Alamos National Lab	Accelerator Production of Tritium
	Brookhaven National Lab	Free Electron Laser
	Commonwealth of Virginia	Nuclear physics, Free Electron Laser
	Center for Innovative Technology	Nuclear physics, Free Electron Laser
	Industries of the Laser Processing Consortium	Free Electron Laser
National Security	DOD/U.S. Navy	Free Electron Laser

Performance Metrics

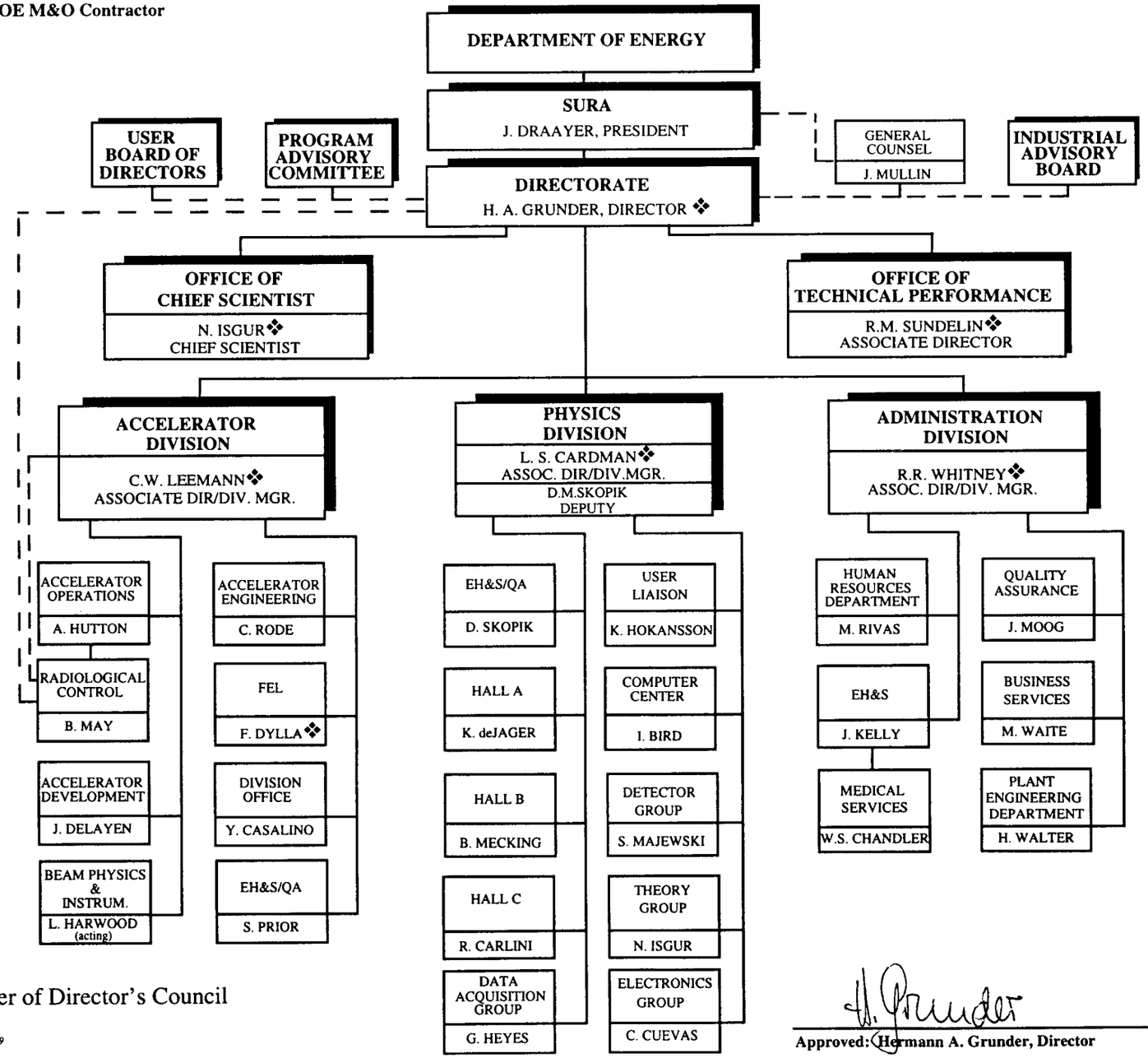






SURA*/JEFFERSON LAB ORGANIZATION

*SURA is a DOE M&O Contractor



❖Member of Director's Council

H. Grunder 27 OCT 99

Approved: Hermann A. Grunder, Director Date

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APPENDIX

GLOSSARY OF JEFFERSON LAB ACRONYMS USED WITHIN INSTITUTIONAL PLAN

AIP	Accelerator Improvement Project
ARC	Applied Research Center
BEAMS	Becoming Enthusiastic About Math and Science
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)
CRADA	Cooperative Research and Development Agreement
DIS	Deep Inelastic Scattering
DOE	Department of Energy
EH&S	environment, health, and safety
EEL	Experimental Equipment Lab
EPIP	Environmental Protection Implementation Plan
ESnet	Energy Science Network
FEL	free-electron laser
FY	fiscal year
GPP	General Plant Project
HBCU	Historically Black College or University
HMS	High Momentum Spectrometer (Hall C)
HRS	High Resolution Spectrometer (Hall A)
HVAC	Heating, Ventilation, Air Conditioning
IR	infrared
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
JFEL	Jefferson Lab's Free Electron Laser
JLTRC	Jefferson Lab Technology Review Committee
LPC	Laser Processing Consortium
MCC	Machine Control Center
MEI	Minority Educational Institutions
MIS	Management Information Systems
MOU	Memorandum of Understanding
NGI	Next Generation Internet
NSAC	Nuclear Science Advisory Committee
NSF	National Science Foundation
PAC	Program Advisory Committee
QCD	Quantum Chromodynamics
rf	radio frequency
RPP	Radiation Protection Program Plan
SER	Site Environmental Report
SOS	Short Orbit Spectrometer (Hall C)
SRF	superconducting radio-frequency
SSI	Scientific Simulation Initiative
SURA	Southeastern Universities Research Association
UV	ultraviolet
WSS	Work Smart Standards
Y2K	Year 2000

U. S. Department of Energy's

Jefferson Lab

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

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The Southeastern Universities Research Association (SURA) operates Jefferson Lab for the U.S. Department of Energy