Department of Energy
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

Continuous Electron Beam Accelerator Facility (CEBAF)

12 GeV UPGRADE PROJECT

July 2005

EXECUTIVE SUMMARY

A Department of Energy (DOE) Office of Science (SC) status review of the Continuous Electron Beam Facility (CEBAF) 12 GeV Upgrade project at the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, Virginia, was conducted July 12-14, 2005, at the request of Dr. Dennis Kovar, Associate Director for Nuclear Physics, SC. The purpose of the 12 GeV Upgrade review was to assess all aspects of the project's conceptual design and associated plans—technical, cost, schedule, management, and Environment, Safety and Health (ES&H). This information would subsequently help in recommendations to the Acquisition Executive, Dr. Raymond Orbach, regarding the consideration of Critical Decision (CD) 1, Approve Alternative Selection and Cost Range.

Overall, the Committee was impressed with the quality of the work done so far, the quality of the documentation, and the enthusiasm and capability of the people working on the project. All of the requirements for CD-1 approval have been completed; however, there were some minor concerns expressed by the Committee and provided in this report that should be addressed by the project prior to the formal request for CD-1 approval.

The 12 GeV Upgrade will allow broad advances in four key areas of nuclear physics: the understanding of quark confinement, how nuclear building blocks are made from quarks and gluons, the physics of nuclei, and tests of the Standard Model. TJNAF is proposing to upgrade the maximum electron energy of the main accelerator from 6 GeV to 12 GeV, build a new experimental area (Hall D) dedicated to the study of gluonic excitations, and upgrade capabilities in the three existing experimental halls.

The project team presented a Total Project Cost (TPC), for the 12 GeV Upgrade, of $250 million. The TPC includes a reduction for scope of work that assumes funding from non-DOE sources. No firm commitments have been established for the non-DOE scope at this time. The TPC without reduction is $279 million—this includes a Total Estimated Cost of $256 million.

The 12 GeV Upgrade plan makes excellent use of existing equipment and expertise to double the energy of the accelerator. The Committee recognized the significant work that TJNAF has done over the years in developing the capabilities of superconducting radio frequency technology that enables the 12 GeV Upgrade, as well as other exciting projects, such as the TJNAF free-electron laser.

The conceptual design meets the nuclear physics requirements. It is evident that there has been excellent synergy between the nuclear physicists using the beams and the accelerator physicists designing the upgrade. Although the beam current was reduced from the 6 GeV maximum of 200 microamperes to stay within the same power envelope, and there is no expected change in shielding requirements, it was advised to review the radiation shielding design of the facility in light of the 12 GeV Upgrade.

The Committee was concerned about the high magnet temperatures that resulted from the decision to reuse existing magnets, and therefore encouraged the project to pursue alternatives for maintaining lower magnet temperature, such as cooling the magnet steel.

The civil construction represents a relatively small fraction (about 12 percent) of the total work included in the project. This work is approximately evenly split between modifications, additions, and improvements to the existing accelerator complex and the construction of a new experimental area (Hall D). The "additions" include: 1) relatively small additions to existing buildings at four locations (totaling 8,700 square feet); 2) modifications to the mechanical systems at five principal locations; and 3) modifications to the existing electrical systems at an additional five locations. The new experimental extraction Hall D complex work includes the extension of an existing below grade tunnel stub, an electron dump, housing for a photon dump, surface service buildings for the extracted beam, necessary radiation shielding berms, a surface experimental hall (Hall D), an associated counting house, and a small Cryo Plant service building. Also included in the Hall D area are associated site support and roads in a previously undeveloped section of the site.

The Committee recommended that the scheduled order of work at the Hall D area be reconsidered. The construction of the Hall D extraction enclosure, after the surface service building construction, complicates the enclosure construction if a retention system is required to support the new buildings during construction. The tunnel excavation, enclosure construction, and backfill should be complete prior to the construction of the neighboring surface service buildings. Consideration should be given to integrating any required earth-berm retention walls with the adjacent service building walls.

The Committee felt that the use of multiple contracts for performing similar work at approximately the same time or work in immediately adjacent regions may be needlessly complex. The Committee also noted that the in-house staff for field construction management and certified field safety professionals is probably insufficient to meet the requirements for the project, both for civil and technical construction and installation work.

At this stage of the project, costs are being developed using good methodologies; however, the Committee identified some areas of concern in the accelerator, detector, and conventional facilities. There was also concern that the apparent nine months of schedule contingency may not be adequate. In addition, installation activities are least developed and will need further attention as the resource-loaded schedule evolves.

The project intends to appoint a project manager, reporting to the project director, after CD-1 approval. The Federal Project Director role is being performed temporarily by the Site Office Manager.

ES&H issues are being properly addressed at this stage of the project.

In summary, the Committee judged that the project is essentially ready to proceed into the next stage of design. Consideration of the recommendations in this report should be part of that forward progress.

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CONTENTS

1. INTRODUCTION

The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) is the world-leading facility in the experimental study of hadronic matter. TJNAF is located on 162 acres in Newport News, Virginia and was constructed over the period FY 1987-1995 for a Total Project Cost of $513 million. CEBAF began operations in FY 1995 and is managed by the Southeastern Universities Research Association (SURA). TJNAF is proposing to upgrade the maximum electron energy of the main accelerator from 6 GeV to 12 GeV, build a new experimental area (Hall D) dedicated to the study of gluonic excitations, and upgrade capabilities in the three existing experimental Halls.

The proposed upgrade will enable CEBAF's world-wide user community to greatly expand its research horizons, and will allow breakthrough programs to be launched in three key areas:

- The experimental observation of the powerful new force fields ("flux tubes") responsible for quark confinement, one of the most spectacular physics discoveries of the twentieth century; understanding these fields is essential for understanding the force underlying the structure of the atomic nucleus;
- The measurement of the quark and gluon structure of the proton, the neutron, and other nuclear building blocks at the most basic quantum level; and
- New research domains in key areas already under investigation.

The 12 GeV Upgrade project at CEBAF is identified as a near-term priority in the Office of Science (SC) Twenty-Year Outlook. In addition, the Nuclear Science Advisory Committee (NSAC) in its 1996 Long Range Plan stated that "…the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring." In the 2002 Long Range Plan, NSAC recommends the 12 GeV Upgrade as one of its highest priorities for the Nuclear Physics program: *"The realization of the 12 GeV CEBAF Upgrade will allow broad advances in four key areas of nuclear physics: our understanding of quark confinement, how nuclear building blocks are made from quarks and gluons, the physics of nuclei, and tests of the Standard Model."*

The full scope of the proposed project is the accelerator upgrade, a new experimental hall and associated beam-line, and upgrades to the existing three experimental halls (Figure 1-1). Existing features of CEBAF make the 12 GeV Upgrade highly cost-effective. The accelerator is comprised of an inter-connected pair of anti-parallel linacs, each with 20 cryomodules, with each

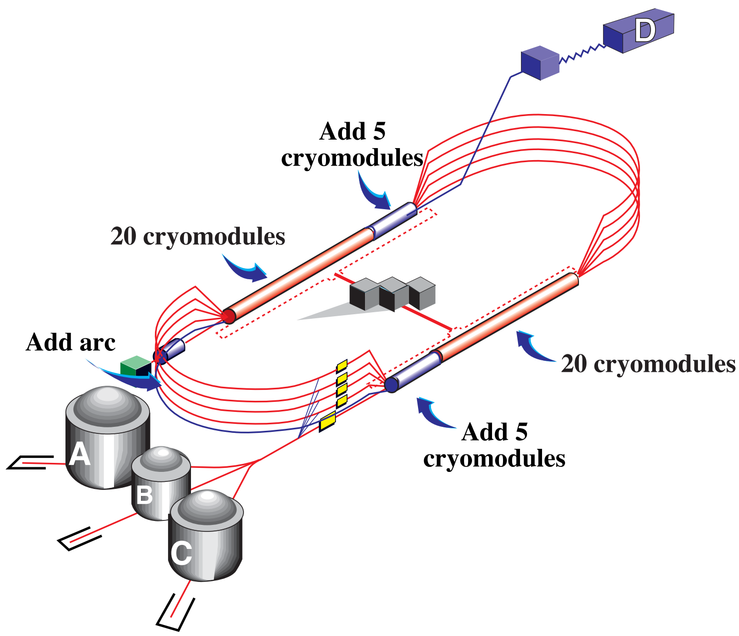

Figure 1-1. Diagram of the 12 GeV CEBAF Upgrade

cryomodule in turn containing eight superconducting radio frequency (SRF) accelerating cavities. The CEBAF tunnel "footprint" was designed so that the magnetic arcs could accommodate an electron beam of up to 24 GeV, permitting cost-effective upgrades. In the new Hall D, a tagged coherent bremsstrahlung beam and solenoid detector is proposed in support of a program aimed at testing experimentally the understanding of quark confinement. All three of the existing halls would have the upgraded capability to receive the 11 GeV beam generated in five passes of the machine. Hall A would be used for special set-up experiments and have continued use for experiments where energy resolution sufficient to separate nuclear levels is important. In Hall B, the CEBAF Large Acceptance Spectrometer (CLAS), which was designed to study multi-particle, exclusive reactions, would be upgraded to CLAS12 and optimized for studying exclusive reactions at high energy. In Hall C, a new, high-momentum spectrometer (the Super-High-Momentum Spectrometer or SHMS) would be constructed to support high luminosity experiments detecting reaction products with momenta up to the 11 GeV beam energy.

In April 2005, the Department of Energy (DOE) conducted a review of the scientific program of the new and upgraded experimental halls, to articulate the merit of the full accelerator and experimental proposed technical scope. TJNAF is exploring other non-DOE/Nuclear Physics sources of support for the construction of scientific equipment. The project received Critical Decision (CD) 0, Approve Mission Need, in March 2004.

In a May 23, 2005, memorandum (see Appendix A), Dr. Dennis Kovar, Associate Director for the Office of Nuclear Physics, SC, requested that Daniel R. Lehman, Director for Project Assessment, SC, lead a Conceptual Design Review to evaluate all aspects of the project, including technical, cost, schedule, management, and Environment, Safety and health (ES&H). The Review Committee (see Appendix B) was chaired by Daniel R. Lehman. Members were chosen on the basis of their independence from the project, as well as for their technical and/or project management expertise, and experience with building large scientific research facilities. The Committee was organized into ten subcommittees, each assigned to evaluate a particular aspect of the project corresponding to members' areas of expertise. The review was conducted on July 12-14, 2004, at Newport News, Virginia. The agenda (Appendix C) was developed with the cooperation of the 12 GeV CEBAF Upgrade Project Office, DOE/Office of Science Headquarters, and DOE Thomas Jefferson Site Office (TJSO) staff. Comparison with past experience on similar projects was the primary method for assessing technical requirements, cost estimates, schedules, and adequacy of the management structure. Although the project requires some technical extrapolations, similar accelerator projects in the United States and abroad provide a relevant basis for comparison.

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2. TECHNICAL SYSTEMS EVALUATIONS

2.1 Accelerator Physics

2.1.1 Findings and Comments

The 12 GeV Upgrade plan makes excellent use of existing equipment and expertise to double the energy of the accelerator. The Committee recognized the great work that TJNAF has done over the years in developing the capabilities of SRF technology, which enables the 12 GeV Upgrade, as well as other exciting projects, such as the TJNAF free electron laser (FEL) and other Electron Recovery Linacs (ERL). The Committee acknowledged Lia Merminga's excellent presentation in the combined breakout, and Leigh Harwood's clear and forthcoming answers to many questions.

The electron beam requirements and the design goals for the new Hall D experimental area are given in Table 2-1 (these requirements are listed in the Chapter 4, page 34 of the Conceptual Design Report (CDR) discussion for the photon beam system). In addition to the Hall D requirements, the overall design capability of the upgrade is given in Table 2-2.

Table 2-1. Comparison of the Hall D Physics Requirements with the 12 GeV Design

Parameter	Hall D Requirements	Design
Energy	12 GeV	12 GeV
Electron polarization	not required	available
Max current	3 microamps	5 microamps
Geometric Emittance (x/y)	10 nm/2.5nm	10 nm/2nm
Max energy spread(rms)	8.3×10^{-4}	2×10^{-4}

Table 2-2. 12 GeV Upgrade Beam Properties

Beam Energy:	12 GeV
Beam Power:	1 MW
Max Current to Halls A&C:	85 microamps
Max Current to Halls B&D:	5 microamps
Emittance (geometric, x/y) at 12GeV:	10 nm-rad/2 nm-rad
Energy Spread at 12 GeV:	0.02%
Simultaneous beam delivery:	Up to 3 halls

Therefore the conceptual design meets the nuclear physics requirements. It is evident that there has been excellent synergy between the nuclear physicists that would use the beams and the accelerator physicists designing the upgrade. For example, the beam optics to Hall D is designed to provide a properly sized, symmetric beam to the diamond radiator as requested by nuclear physics users to compensate for the expected x/y plane emittance ratio of 5:1. Since the beam current was reduced from the 6 GeV maximum of 200 microamperes to stay within the same power envelope, there should be no change in radiation shielding requirements.

In order to preserve the geometric relationship between the injector beam and the multipass beams in the accelerator, it is necessary to increase the injector beam energy from 67.5 MeV to 123 MeV. The increased energy is achieved by replacing the last 32 MV cryomodule in the injector with a 100 MV cryomodule, similar to the type used in the linac upgrade. There is additional effort related to upgrading the electron spectrometer and merging chicane due to the doubled injector energy. There are no physics issues connected with these changes. If anything, the higher beam energy will enhance the injector beam quality and options for future beam conditioning.

Injector simulations for the injector were performed using the space charge code PARMELA (Phase and Redial Motion in Electron Linear Accelerators), which verified the measured performance of the injector at 67.5 MeV and therefore should be an accurate prediction of the expected performance at 123 MeV. The injector performance at 123 MeV easily satisfies the requirements for the upgrade.

Simulations at higher energies for the full accelerator have been done using a beam envelope, matrix code. While this code includes the effects of incoherent synchrotron radiation, it does not include magnetic field non-uniformities discussed below, nor does it include tails generated by synchrotron radiation. Particle tracking calculations are planned to investigate these effects. The Committee strongly supported this effort, as described below.

The accelerator magnet settings were re-optimized for the 12 GeV Upgrade due to the additional arc and fifth pass through the North Linac. This 12 GeV lattice tune affects all orbits and is considered superior to and compatible with the currently used 6 GeV settings. Multiple benefits are expected from an early test of the 12 GeV setup that can be performed with the present 6 GeV machine. Using the envelope code, the emittance growth due to incoherent synchrotron radiation was computed for the 12 GeV Upgrade. The simulation gives an increased emittance at 12 GeV compared to that at 6 GeV, producing a 5:1 x-plane to y-plane emittance asymmetry at Hall D.

Thus far, the accelerator beam simulations have been done only with the beam envelope code; however, a full-beam simulation with particle tracking is still needed and is already planned by TJNAF. The Committee recommended that the tracking simulations be done with either the measured magnetic fields for the modified H-magnets or for TOSCA fields that have been benchmarked against field measurements. This is especially important because there are saturation effects of the poles which change the field shape at the poles. This may have a subtle effect on the beam quality. In addition, the tracking code should include synchrotron radiation to model details of the beam distribution. These tracking simulations will allow a more accurate estimation of beam halo and potential beam losses, as well as an improved calculation of the final emittance and energy spread.

The effects of tens of kW of synchrotron radiation in the arcs from the 12 GeV e-beam on the vacuum chamber from both heating and out-gassing were not evaluated. Nor were the effects of 100keV range gamma-rays on the radiation environment and coils of the magnets considered. This should be investigated.

The project is made cost effective by the clever re-use of the arc dipoles. In order to reach the higher magnetic fields needed for operation at 12 GeV, the dipoles will be converted from C-type to H-type frame magnets. However, neither the coils nor the poles will be changed, resulting in the following potential problems: 1) pole-edge saturation and reduction of field quality; 2) overheating of the magnet steel; and 3) possible long-term thermal drifts of the beam orbit and beam quality during the long warm-up period of approximately ten hours. In addition, a somewhat larger magnetic aperture is needed due to the increased emittance.

Calculations for the C-type dipoles have been performed with TOSCA at the 6 GeV fields, which compare very well with magnetic measurements. Given this confidence in TOSCA, the H-type dipole field was modeled at 6 and 12GeV, with the following conclusions:

1. The TJNAF analysis indicates the modified magnets meet the 12 GeV upgrade field uniformity specification.

2. The magnetic centerline of the H-type dipole is shifted by 3 to 5 mm relative to the C-type centerline. Therefore the modified magnets should be characterized and either place new alignment fiducials on each magnet or define the new centerline relative to the original fiducials. The re-definition of fiducials is already in the TJNAF plan.

3. The dipole excitation (B-field vs. current) will be non-linear due to saturation of the pole-edges.

Given these results, the Committee also observed that since the arc dipoles are powered in series, it is important to confirm that the integrated fields as a function of magnet current are identical. In addition this saturation will result in a non-linear field calibration. However, it is impractical to measure the approximately 240 dipoles being modified. Thus the Committee agreed with the TJNAF plan to statistically sample a fraction of the magnets which will be fully characterized.

Therefore, in the near term, the Committee suggested that the H-type magnetic fields be measured over a range of currents up to the full 600 amperes to experimentally investigate the saturation effects. The measured fields should be used to benchmark the TOSCA model that in turn can be used in the particle tracking simulations described above. Finally, the Committee recommended that alternative cooling schemes, such as direct cooling of the iron instead of the air, should be investigated.

There are no significant SRF physics issues since the amplitude and phase stability have been verified in tests at the TJNAF FEL in collaboration with Cornell. The Beam Breakup (BBU) threshold is at least an order of magnitude above the maximum 12 GeV current, and cryomodule development is close to demonstrating the required 100 MV/cryomodule. However, there maybe a minor issue concerning isolation of the Higher Order Mode (HOM) couplers from the fundamental accelerating mode. While a very different frequency and structure, there have been isolation problems in the Spallation Neutron Source (SNS) cryomodules. Therefore, the Committee suggested measurements of the fundamental attenuation in the HOM couplers be performed on the prototype “Renascence” cryomodule at cryogenic temperatures and the Committee supported the testing of this module with beam at the TJNAF FEL.

The 12 GeV electron beam diagnostics between the accelerator and Hall D require better definition. These diagnostics are necessary to verify the machine performance and determine the beam parameters needed for matching the beam to the coherent bremstrahlung radiator. It is especially important to have accurate measurements of the emittance, energy, and energy spread at the diamond radiator. It was suggested during Committee discussions that the energy spread could be measured in the photon-tagger magnet.

2.1.2 Recommendations

1. Experimentally investigate the 12 GeV optical solution in the 6 GeV machine since it is compatible with the normal operation and potentially improves the transport.

2. Evaluate the effects of synchrotron radiation heating and determine if dedicated absorbers are needed for the high energy arcs.

3. Evaluate the effect of synchrotron radiation quantum fluctuations on the halo formation and aperture requirements using full scale particle tracking.

4. Measure the H-magnet field along the electron trajectory for a range of currents and compare with TOSCA.

5. Use the measured or benchmarked model fields for the H-type magnets in the particle tracking simulations.

6. Refine the proposed plan for field measurements of a statistical sampling of the approximately 240 H-magnets.

7. Insure the dipole fiducials account for the good field region offsets.

8. Investigate mechanical distortion of the arcs due to the "hot" magnets on beam dynamics.

9. Consider cooling the magnet iron, instead of the air.

10. Measure RF power isolation of the fundamental mode for the Renascence cryomodule HOM at cryogenic temperatures.

11. Test Renascence cryomodule HOMs with beam at FEL.

12. Include the necessary 12 GeV diagnostics to measure the emittance, energy, and energy spread at the diamond radiator.

2.2 Superconducting Radio Frequency Cryomodules and Cryogenics (WBS 1.3.1 / 1.3.3)

The staff of the cryomodule and cryogenics groups is very knowledgeable and have current experience in successfully completing projects with similar requirements of the 12 GeV Upgrade. The level of detailed design for both these systems is well advanced, particularly for a project approaching CD-1, Approve Alternative Selection and Cost Range. Outstanding technical issues are being handled in an appropriate manner. Costs and schedules for these subsystems are quite detailed and seem reasonable. ES&H considerations have been properly integrated into the designs and processes.

2.2.1 Findings

CEBAF could be upgraded from an energy of 6 GeV to an energy of 12 GeV through the addition of five higher gradient cryomodules in each linac. The cryomodules would be inserted into existing available space at the end of each linac. Cryogenic transfer line connections exist for these additional cryomodules.

Each cryomodule will support eight, seven-cell cavities for an active length of 5.6m. To meet the upgrade energy, the ten new cryomodules must average 100 MV with less than 300 W at 2^{o}K per cryomodule. The additional high-gradient cryomodules will double the cryogenic heat load at 2^{o}K.

Two cavity designs were considered; a design best to achieve high gradient at the cost of higher dynamic losses and a low-dynamic loss design with a lower peak gradient. The low-loss design achieved the required gradient and is currently being used in prototype cryomodules.

The upgrade cryomodule has a higher packing factor. As a result, a new tuner design needed to be incorporated due to the loss of space at the end of the cavities.

The prototype cryomodules utilize a single warm-window design. The existing CEBAF cryomodules use both a warm and cold window. Two window failures in a prototype cryomodule have initiated a window R&D program. The first and second cryomodules achieved 70 MV and 80 MV, respectively. The third prototype has exceeded the required gradient in vertical dewar testing, but has yet to be tested as a cryomodule.

In order to achieve a starting point of 6 GeV, two weak CEBAF cryomodules are being refurbished per year. This activity is considered part of CEBAF operations and is not a part of the upgrade project.

TJNAF has considerable estimating, design, and construction experience for cryomodules from TJNAF, SNS, and FEL projects. In addition, three prototype 12 GeV cryomodules have been constructed and two are currently in operation. This experience has been applied to the project.

An extensive R&D program has begun to address the important cryomodule component issues. This work includes individual component and cryomodule tests. Prototype cryomodules are being tested in the FEL and Linac beam lines.

Doubling of the cryogenic refrigeration capacity will be required to support the upgrade. In order to reduce costs, the existing spare 2^{o}K cold box will be utilized. As a result, only a 4.5^{o}K cold box and associated compressors will be required. The long-lead time for procuring and installing a cryogenic refrigeration system requires that funds for the system be secured early in the project. The spare 2°K cold box is currently in operation to support TJNAF operation. The original 2°K cold box is currently being modified to add a fifth stage of cold compression, repair cold leaks, and controls upgrade. This is being accomplished using operating funds.

The existing Central Helium Liquifier (CHL) is operating to support 6 GeV CEBAF operation with a very small margin; eight percent at 2^{o}K and three percent at 50^{o}K. After the 12 GeV Upgrade, the CHL #1 will have a margin of 15 percent at 2^{o}K and 33 percent at 50^{o}K. CHL #2 will have a margin of seven percent at 2^{o}K due to the addition of the FEL. Additional ancillary systems that will be required in the cryogenic system include two, 30,000-gallon gas storage tanks and one 20,000 gallon liquid nitrogen storage dewar.

The two CHLs will be configured such that CHL #1 will support the North Linac and CHL #2 will support the South Linac, as well as the FEL. The existing transfer line design was calculated to be able to support operation at double the current flow rate.

The new 4.5^{o}K cold box and compressor controls will be commercial Programmable Logic Controller (PLC) based and interfaced to Experimental Physics and Industrial Control System (EPICS), similar to that used in the SNS project. Existing cryogenic plant controls are being upgraded to this system, but is outside the scope of the 12 GeV Upgrade project.

The existing Stand-By Refrigerator (SBR) is used to keep the cryomodules at 4.5^{o}K in the event of a CHL shutdown. This is to prevent a thermal cycle of the cryomodules. With the addition of ten cryomodules, the SBR will no longer be able to support all the cryomodules at 4.5^{o}K. The SBR will be used to maintain one linac at 4.5^{o}K in the event that one CHL is inoperable. During the long installation shutdown, the existing forty CEBAF cryomodules will be kept cold to avoid thermal cycling.

2.2.2 Comments

The cost estimates for the cryogenic refrigeration systems are based on previous TJNAF and SNS procurements, conversations with vendors, and engineering experience. The costs include the utilities required for acceptance testing of this element. The level of detail is particularly high for a project approaching CD-1. The Committee found these estimates to be well founded and the contingencies appear to be appropriate.

The cost estimates associated with cryomodules have drawn on recent SNS experience and three 12 GeV cryomodule prototype constructions. As a result, the Committee found these estimates to be well founded and the contingencies appear to be appropriate.

No significant technical problems have been identified outside of those already being addressed through R&D.

There have been valuable cryomodule production and commissioning experiences with the SNS project that should be used to describe how any identified problems will be avoided by, or are not relevant to, the 12 GeV Upgrade project.

All the cryomodules for CEBAF had eight cavities (although the number of cells per cavity has changed). Renascence is the third eight-cavity cryomodule to use the spaceframe; SL21 (installed in FY 2003) and FEL03 (installed in FY 2004) were the first two. The entire SNS cryomodule production also used a spaceframe.

A strong emphasis has been given to engineering the necessary safety systems associated with the handling of hydrofluoric acid used in cavity processing. Safety issues associated with the cryogenic refrigerators have been well planned and suitably addressed.

Existing cryomodule and cryogenic staff concurrently supported CEBAF operation, as well as the SNS project. The scope of the 12 GeV upgrade is less than the SNS project. The Committee felt that both of these elements are properly staffed.

2.2.3 Recommendations

1. Prepare a written review of lessons learned from SNS cryomodule production and commissioning. Incorporate the relevant lessons into the 12 GeV program.

2. Conduct beam testing of the HOM couplers in order to fully assess their performance and need.

3. Perform an integrated failure mode analysis as recommended by the cryomodule review committee.

2.3 Accelerator (WBS 1.3.2 / 1.3.4 / 1.3.5)

2.3.1 Findings

This report section deals with Work Breakdown Schedule (WBS) element 1.3.2 (Power Systems, including the RF and magnet power systems); WBS 1.3.4 (Beam Transport, which is a major set of systems including the injection line, upgrading of all arcs, installation of a tenth arc, modifications to the transport lines to Halls A, B, and C, and construction of the transport line to Hall D); and WBS 1.3.5 (Extraction systems, primarily the RF separators that allow interleaved bunches to be delivered to Halls A, B, and C). The costs assigned by the project to these WBS elements are shown in Table 2-3.

Table 2-3. 12 GeV Upgrade Project Accelerator Costs (Thousand Dollars)

WBS	Title	Base Cost in FY05	Contingency	Contingency $	TOTAL
1.3.2	Power Systems	15,715	26%	4,100	19,814
1.3.4	Beam Transport	10,058	25%	2,520	12,578
1.3.5	Extraction	1,147	26%	293	1,440

In evaluating the various methods used to achieve twice the energy of the existing CEBAF, several alternatives were considered. Ultimately, the project has chosen to reuse as much of the existing facility as possible. In those areas where additional magnets or supplies are needed, existing designs will be used. Except for the new RF systems that are needed for the newly designed higher power cryomodules, the designs in these WBS elements are mature and based on TJNAF experience.

Because of the decision to reuse magnets, many magnets in the arcs and beamlines will be required to run at twice the field to accommodate the upgrade. The primary way for dealing with this is to power the magnets at (approximately) twice the current, and to handle the saturation (in the dipoles) by adding extra steel to the magnet body (C-magnet are transformed to

H-magnet). It is understood by the project that these magnets will run at approximately four times the power, requiring upgrades to the cooling water system and the tunnel air handling. In spite of this, many dipoles in the arcs will run at temperatures that exceed safety standards for skin contact with metal. This has led to the need for safety considerations when accesses are needed shortly after the magnets have been powered. TJNAF in concerned about magnet heating, both from the safety and reliability standpoint. Thermal cycling tests have been performed, indicating that there are no problems with reliability related to thermal cycling.

To power these magnets, some power supplies will need to be upgraded, and in other cases new supplies will be procured. Where the above scheme does not work, particularly in the new arc, new magnets will be built.

Where ever possible, components are being reused. There are many locations where new components will be built for the highest energy beam-lines or arcs and the components that were there will be moved to the lower energy lines. There is no plan to do any refurbishment on these components, and the project believes there is little risk involved in moving these components. The extraction system is upgraded to 12 GeV (WBS 1.3.5) primarily through additional components of existing designs. This includes the deflecting RF cavities (and associated RF hardware), septa and dipoles, and a coil modification to the three-way lambertson.

2.3.2 Comments

The Committee (like the project) was concerned about the high magnet temperatures that resulted from the decision to reuse existing magnets, and therefore encouraged the project to pursue alternatives for maintaining lower magnet temperature, such as cooling the magnet steel. The project should continue to closely monitor the increased demands on all of the low conductivity water (LCW) systems (power systems, as well as magnets) to ensure that the necessary capacities will be available.

The conversion of the C-magnets to effective H-magnets is an innovative idea and can be done effectively without R&D leading to significant cost savings. An existing C-magnet should be retrofitted with the additional steel piece and a complete field map at full current should be done as early as reasonably possible to demonstrate achieving the required field strength and transverse field uniformity. The Committee advised the project to do lifetime tests of the magnets at the elevated temperature in addition to the thermal cycling.

The Committee concurred with the project that the risk to Extraction System Components is moderate, and the cost estimate and contingency are reasonable. However, this area is congested and installation and alignment time may be longer than that estimated.

Most of the new power supplies are built from existing designs. These designs are relatively new; the 20 amp power supplies are taken from a SNS design (also used at the TJNAF FEL), and the 10 amp trims are recent upgrade designs at TJNAF. The supplies that need to be upgraded to higher currents and voltages use a technique previously used on some CEBAF supplies when the accelerator was upgraded from 4 GeV to 6 GeV. The Committee concurred that the risk in this area is moderate, and the cost and contingency is adequate.

The only extensive development work being done in these WBS elements are the new RF systems that require more power than the existing systems. TJNAF is working with a vendor through a Small Business Innovative Research (SBIR) agreement to develop the klystron. The Committee suggested that extra vigilance be given to this process. Until the klystron is developed and its properties are known, other system components cannot be designed. The Committee suggested that the project maintain awareness of developments in the utilization of one klystron per multiple cryomodules, and if this technology becomes viable in the time scale of this project, then it should be explored.

The project should evaluate build versus buy scenarios.

The idea of developing a new digital low level radio frequency (LLRF) controller is a sound engineering decision and it will provide the increased level of robustness and flexibility for LLRF control for RF amplitude and phase.

The effect of Lorentz detuning should be better understood. The calculated detuning as presented in a graph shows a non-single value and tilt that makes it harder to recover from an off-resonance frequency. The Committee suggested performing measurements to quantify this effect and compare it to calculated detuning profile.

It may be prudent to develop sound technical specifications for RF subsystems such as pre-amplifers, new digital LLRF boards, and other components and outsource the construction to qualified vendors. It is important to pay attention to the development of hardware and packaging of the LLRF Controls and the high level integration and software development to assure its compatibility with the current EPICS configuration.

The Committee identified several areas where the contingency should be increased, including: increased cooling for magnets; potentially more effort for installation; and for uncertainties in the design of the high-power RF system. The cost sheet was adjusted to reflect these concerns. Considerable efficiencies can be realized by aligning the two shutdowns so that the impact on the Nuclear Physics program will be minimized. This comment applies not only to accelerator component installation, but to the scheduling of the civil construction.

2.3.3 Recommendations

1. Explore additional ways of cooling the magnets.

2. Reevaluate the effort that will be needed to complete installation activities.

2.4 Control Systems and Instrumentation (WBS 1.3.6)

2.4.1 Findings

The Controls and Instrumentation cost element for the CEBAF 12 GeV Upgrade project is a small WBS element that includes beam instrumentation, the Personnel Safety System (PPS) and traditional accelerator Instrumentation and Control (I&C) for vacuum, power supplies, etc., as well as the network that ties them together. The scope of this WBS explicitly excludes controls for cryogenic systems including the planned cryogenic plant expansion (CHL) and for RF control systems. The interface to the controls subsystem is at the input to standard CAMAC Input-Output (I/O) crates for the older systems or to VME crates for more recently installed or upgraded subsystems. Cables that “touch” these crates and their installation are included in the scope.

Almost all of the work for the upgrade is simply “more of the same” as is in use on the current machine. It is estimated that 90 percent of the controls components, both hardware and software, will be “clones” of existing equipment and software now in use on the 6 GeV machine. Beam Instrumentation for the new arc (Arc 10) has the same components and configuration as that for existing Arc 8, and the planned instrumentation for the transfer line to Hall D is based on that for Hall B, in each case providing the same physics measurements.

The PPS will be based upon new “safety-rated” Programmable Logic Controllers (PLC) and this will require the use of new programming tools. Some allowance has been made in the contingency estimate for this requirement. In addition to access control for the new areas (Hall D and transfer line) the main impact on the PPS system is the addition of several new operating modes—the logic must include all combinations of up to three beams delivered to four endstations. This doubles the number of modes and the complexity of the logic. A small number of new Oxygen Deficiency Hazard (ODH) monitor heads, for the expanded CHL and counting rooms in Hall D, is also included.

The estimated total cost presented is $5.4 million, including an average contingency estimate of 23 percent. This represents approximately seven percent of the cost of the accelerator systems which is within normal “rules-of-thumb”. The estimate is divided almost equally between the three major components: Beam Instrumentation; PPS; and Controls I&C. Because the estimate is based on “cloning” of existing equipment—80 percent on recent experience with identical hardware and software and 20 percent on catalog prices—the estimate is very solid. The conceptual design is based 90 percent on “cloning” existing systems and is therefore already demonstrated to meet technical performance requirements.

Staffing for the control system will be matrixed from the operations organization, and the operations controls team will supply software support to those areas outside WBS 1.3.6 requiring that help (such as the cryogenic system controls). The Assistant Program Manager for this WBS has been assigned half time to the project. (The other half is Deputy Operations Manager.) It is always difficult to make a matrixed organization work because of conflicting loyalties and priorities, but the right talent is available and with good will the management and organizational model should be successful.

With the exception of new programming tools for safety-rated PLCs for the PPS system, the estimate is firmly based on recent experience and costs for similar systems. The technical scope is determined by the scope of the project itself.

In response to the growing obsolescence of many of the components on which the cost estimate depends, alternative designs are already underway under the operating budget to use more modern (and available) parts. These new designs are likely to be more economical to build than the older designs on which the estimate is based.

Although at an average of 23 percent the contingency is low for new control system projects at this stage, in this case the low contingency is acceptable because of the use of existing designs with known costs.

Staffing for the control system will be matrixed from the operations organization, and the operations controls team will supply software support to those areas outside WBS 1.3.6 requiring that help—cryogenic system controls and possibly to the power supply group. Assistance is already provided to those areas. The Assistant Program Manager for this WBS has been assigned half time to this activity. It is always difficult to make a matrixed organization work because of conflicting loyalties and priorities, but the right talent is available and with good will the management and organizational model should be successful.

ES&H and Integrated Safety Management (ISM) are part of the culture of the controls team, and this WBS is itself responsible for deployment of the PSS and therefore has an increased level of awareness.

2.4.2 Comments

There seems to be no reason, other than historical, to separate the Cryogenic controls effort from the rest of the system. The cryogenic systems use the same hardware and software technology as the other I&C systems. Software support is provided by the controls team. If integrated into controls, the cryogenic group would have access to a pool of support when required, and standardization of practice would be more easily achieved.

The RF group is experimenting with embedded processors for LLRF controls. This is a useful and forward-looking experiment. However, the new design may not guarantee standardization of the operating system. Care should be taken to assure seamless integration with the rest of the control system—each LLRF system should look to applications like any other IOC and the operating system should be compatible with EPICS. This will require close collaboration with the controls team. Achieving full integration is not difficult, but it is even easier to produce an integration nightmare.

The advantage of 90 percent cloning is that it puts the cost estimate on very solid ground and eliminates the need for (and cost of) new design effort. The disadvantage is that it implies the use of very old technology in an arena where technology famously becomes rapidly obsolete. The project understands that some components are becoming obsolete and require redesign, and some of this redesign effort (e.g., parts of the BPM system) is already in progress. The cost estimate assumes that these redesigns will be complete before 12 GeV systems are deployed. There could be both cost and schedule risks if this assumption is not valid.

The larger beam size in some parts of the upgraded machine may require more sophisticated transverse feedback ("locks") than is currently used. The development of "cascaded locks" and/or similar applications might require an effort in application program development larger than can be accommodated in the software manpower estimate presented. Applications are where you get the payoff from a solid control system infrastructure—do not short-change them!

2.4.3 Recommendations

1. Continue to review the designs of equipment to be reused for the upgrade with a view to identifying components that either already are or may soon become obsolete. Track the progress of redesigns and determine a mitigation strategy in each case.

2. Continue to track accelerator physics requirements with a view to early determination of any new or changed application program requirements. Work closely with the Accelerator Physics Group to assure that adequate resources are available for application program development.

2.5 Detector (WBS 1.4 / 1.5 / 1.8.2)

Detector and beamline upgrades are planned in the three existing experimental halls. In addition, a new photon beam and new detector are planned for the new experimental hall, Hall D. New superconducting magnets are needed in Halls B and C. The detectors are a large fraction of the overall project costs—nearly one-half of the Total Estimated Cost (TEC). They are technically diverse subprojects.

2.5.1 Findings and Comments

Detector Systems—General

The conceptual design of the experimental equipment in each hall is appropriate. It will address the technical requirements. It is based on alternatives analysis at both the hall level and subsystem level. It does not entail undue technical risks. Generally, technical risks associated with the conceptual designs are small. No new detector technologies are used. Subsystem designs generally draw upon past TJNAF experience. Appropriate use is made of existing equipment and common electronics and software solutions, wherever possible. Conceptual designs have been guided by numerous TJNAF reviews within the last year.

The cost estimating methodology is systematic and appropriate. The level of breakdown of the WBS is appropriate; however, the bases of estimate are not available in the cost book.

Although a comprehensive review of cost estimates was not possible, the examples presented and discussed were supported by detailed bases of estimate, resulting in estimates that are quite thorough and reasonable for this conceptual design phase of project.

Cost estimates of many WBS items are based upon prior TJNAF experience. Basing cost estimates on prior experience leads to reliable cost estimates for labor if the cost experience from the past is mapped to present costing methodology, i.e., if costs of all technical effort, including that which was off-project in the past, is accounted for in present estimates.

The cost of some scientists who are not performing technical tasks (i.e., those tasks traditionally performed by engineers and technicians) has been included in the TEC. The cost of scientists is typically not included in the project costs of DOE Nuclear Physics/High Energy Physics projects unless they are performing technical tasks usually performed by engineers or technicians.

The project management cost of detector activities in each hall is included in the cost of other detector elements (e*.g.*, the cost of Hall C project management is included in WBS 1.4.3.1.1, Quadrupoles). Project management costs are difficult to review because they are not shown in dedicated WBS entries. WBS items in which project management costs are embedded are also made more complicated to review. All of these activities are likely to be difficult to sensibly track.

Contingency estimates were generally assigned following a simple procedure based upon the degree of maturity of each design. Items that are conceptual designs are assigned a contingency of 35 percent. Items that are "designed" are assigned a contingency of 25 percent. A few items have been assigned contingency higher than the "conceptual design" value. These estimates are applied to both labor and procurement. Cost estimates are not unreasonable for the conceptual design phase. This contingency estimating procedure drives the contingency assignments to a predefined value of approximately 30 percent. This value seems low for this conceptual design stage, particularly for items with a large fractional labor component. Labor is intrinsically difficult to estimate and depends upon many factors. The contingency estimating procedure does not take into account factors, such as the degree of technical risk of the chosen design or whether or not an item is on the critical path, that are accounted for by more complex procedures used by some other projects. Contingency assignments are likely to be five percent low for magnets and major infrastructure components and ten percent low for other subsystems and components.

Schedules are not yet detailed; however, they are sufficiently detailed to establish that the overall project schedule is reasonable. The degree of activity scheduled in parallel in Halls B, C and D may overload TJNAF staff. A resource-loaded schedule can establish whether or not this fact will affect schedule and/or cost.

The schedule contingency between commissioning and CD-4 in Halls B and C is six months; it is about nine months in Hall D. Overall schedule contingency of six months, or even nine months, is small for projects of approximately six years duration, particularly considering the firm deadlines imposed by CD-4. Schedule contingency of approximately twelve months would be more appropriate.

Hall A (WBS 1.4.1)

The Hall A upgrade consists of upgrading beam line instrumentation to measure beam energy and polarization up to 11 GeV. The existing pair of High Resolution Spectrometers (HRS) will be maintained. One of the HRS will have an electronics upgrade as part of the 6 GeV program, and the other will have an electronics upgrade as part of the 12 GeV Upgrade. The TEC for the Hall A upgrade is $0.9 million (FY 2005 million dollars direct).

Hall B: CLAS12 (WBS 1.4.2)

The Hall B upgrade consists of a new detector, CLAS12, based upon the existing CLAS detector. CLAS12 employs only one new detector technology, the Silicon Vertex Tracker (SVT). A 50 percent contingency is allocated for this subsystem. The other detector subsystems are based upon CLAS and other Hall B detectors. The CLAS12 detector collaboration is just forming; consequently, institutional responsibilities are not yet defined.

The TEC for the Hall B upgrade is $25 million (FY 2005 million dollars direct), of which $6.8 million is for magnets, $12 million is for detectors, $1.3 million is for computing, $1.6 million is for electronics, $1.1 million is for beam line upgrades, and $1.5 million is for new infrastructure. It is encouraging that the overall detector cost is reduced by a factor of approximately two by using existing experimental equipment.

The SVT conceptual design is not yet fully developed. More engineering detail is needed at the overall subsystem level, for instance regarding support structure and overlap of detectors. More detail is also needed at the sensor/electronics level, for instance conceptual design of sensors and of electrical interconnects. Simulation studies of tracking, both pattern recognition and momentum resolution, would aid the conceptual design. Several important issues would benefit from such studies, including sufficiency of three SVT layers, angle between stereo views, justification for complication of double-sided detectors, and possible advantages of employing the same strip width in all layers.

Hall C (WBS 1.4.3)

The Hall C upgrade consists of adding a SHMS capable of analyzing the higher energy particles from the 11 GeV beam. In addition, the existing High Momentum Spectrometer (HMS) will have an upgraded data acquisition system.

The limited space in Hall C requires using a combined function (CF) magnet, consisting of both a quadrupole and a dipole, as well as using two modified quadrupoles. The SHMS will have a momentum resolution of 0.02 percent at the central momentum, compared to 0.1 percent for the HMS. The stated margin on SHMS momentum resolution was a factor of two. The SHMS detector system will consist of scintillators, wire chambers, Ar/Ne and C_4F_{10} Čerenkov counters, and a lead glass calorimeter.

The TEC for the Hall C upgrade is $20 million (FY 2005 million dollars direct), of which $10 million is for magnets, $6.5 million is for the mechanics for spectrometer (the support and detector shield house), $1.9 million is for the detector to instrument the spectrometer, $0.8 million is for electronics, and $0.7 million is for beam line upgrades.

No new computing costs and no spares are included in the Hall C cost estimate. The current computing system is considered to be sufficient, although it would need upgrades along the way to stay current. Spares are considered unnecessary for commissioning because they could be obtained by removing them from other pieces of equipment if necessary. This planning may underestimate electronics costs.

Hall D: GlueX (WBS 1.5)

The Hall D detector is a new detector named GlueX. GlueX reuses the Large Aperture Supercondcuting Solenoid (LASS) solenoid, resulting in considerable cost savings. Hall D also includes a photon beam.

The GlueX conceptual design will address the technical requirements. It is based upon several years of development with physics goals in mind by the GlueX collaboration. Reviews organized by TJNAF (e.g., Detector Review, 2004) have provided useful input to the design. Detector R&D for GlueX is well advanced in most areas. The collaboration and institutional responsibilities are reasonably mature for the conceptual design phase. The Level 3 farm and 200 kHz trigger capability are not part of the initial scope.

The TEC for Hall D is $29 million (FY 2005 million dollars direct), of which $0.8 million is for the magnet, $13 million is for detectors, $3.4 million is for computing, $6.4 million is for electronics, $3.3 million is for the beam line, and $2.1 million is for infrastructure.

The barrel calorimeter is based on lead-scintillating fiber technology. It requires photodetectors, and it resides within the solenoidal magnet. Two photodetector options are being considered. An option based upon conventional photomultiplier tubes (PMT) would require routing of fiber light guides out of the solenoid and shielding the PMTs. This option is not yet fully developed. An option based upon silicon photomultipliers (SiPM) would obviate the need to route fibers out of the solenoid because SiPMs function in a magnetic field. SiPMs also have other attractive properties. However, large-area SiPMs are not a mature technology.

A plan for the option of reading out the barrel calorimeter with photomultiplier tubes needs to be developed in case silicon photomultipliers do not prove to be a practical and cost-effective solution. The plan should include fiber routing, end iron configuration, shielding, and cost estimate.

The large amount of scintillating fiber needed for the barrel calorimeter is a long-lead time item.

Experiment Magnets

The magnets are evolutionary designs from those presently in use. There is a conservative conceptual design. There is a TJNAF report detailing lessons learned with the previous magnet systems in the detectors. A detailed analysis placing a probability on each type of magnet event or fault was constructed and consideration of this data will be integrated into the new specifications.

The major new superconducting magnets are in Halls B and C. The new magnets are required due to the upgrades in the detectors in each of these halls and are evolutionary in design from magnets used in the present experimental areas. Hall D will use a rebuilt solenoidal magnet first constructed at SLAC in the early 1970s. The rebuilding is presently taking place at Indiana University.

Hall B, which currently houses the CLAS detector, will be upgraded to CLAS12. This upgrade will require a new toroid, as well as a solenoid to reduce soft particles reaching the detectors. The new toroid is somewhat smaller to allow space for the detectors and solenoid magnet. A design and build procurement is proposed. Costs presented to the Committee were based on scaling estimates from laboratory staff.

The Hall C upgrade will add a new SHMS to the existing HMS. Two of the focusing quadrupoles are slightly higher gradient modifications of the quadrupoles in the HMS. The last quadrupole and the spectrometer dipole are proposed to be built as a combined function magnet. A budgetary estimate for the quadrupoles was obtained from the engineering group that designed the present quadrupoles. TJNAF also commissioned a feasibility study by the Budker Institute in Russia, as well as a cost study by MagTec Engineering. This combined magnet is the biggest cost element in the upgrade at about $6.5 million.

TJNAF has benefited by obtaining surplus SSC superconducting cable from the Office of High Energy Physics. This cable is in house and has been qualified for use in this project. All cable will be soldered into a copper stabilizer and the overall design of the magnets will be cryostable.

Design and build procurements are proposed; however, there are market issues. The procurement process of the magnets will have to be well planned and executed. Vendor qualification is a necessity. In addition it is recommended that an independent design review of the vendor's design be a requirement prior to the start of fabrication.

2.5.2 Recommendations

1. Seek guidance from the DOE Nuclear Physics Program Office regarding costing of scientific labor on projects.

2. Allocate separate WBS numbers to project management activities.

3. Revisit contingency estimates.

4. Rework schedules to provide more schedule contingency between the present date and the planned completion date.

5. Advance the conceptual design of the CLAS12 SVT and provide more engineering details.

6. Study the CLAS12 SVT conceptual design via simulation.

7. Perform further simulation to set limits on field inhomogeneities in the combined function magnet of Hall C, in order that momentum resolution can be assured.

8. Develop a plan for readout of the GlueX barrel calorimeter based upon conventional photomultiplier tubes.

9. Conduct a preliminary procurement survey for superconducting magnets.

10. Carefully define the magnet procurement process, including required oversight and reviews during design and fabrication.

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3. CONVENTIONAL FACILITIES (WBS 1.6)

3.1 Findings

The civil construction of the 12 GeV Upgrade project represents a relatively small fraction (about 12 percent) of the total work included in the plant line of the project. As estimated by facilities management for this review, this slightly exceeded FY 2005 $20 million at this time. This work is approximately evenly split between modifications, additions, and improvements to the existing the Accelerator complex and the construction of a new experimental area (Hall D). The "additions" include relatively small additions to existing buildings at four locations (totaling 8700 square feet), modifications to the mechanical systems at five principal locations, and modifications to the existing electrical systems at a further five locations. The new experimental extraction Hall D complex work includes the extension of an existing below grade tunnel stub, a electron dump, housing for a photon dump, surface service buildings for the extracted beam, necessary radiation shielding berms, a surface experimental hall (Hall D), an associated counting house, and a small Cryo Plant service building. Also included in the Hall D Area are associated site support and roads in a previously undeveloped section of the TJNAF site.

This total work, valued at $20 million, was compared by project staff as similar (except for the Hall D extraction enclosure) to approximately $15 million in civil work designed and constructed on the TJNAF site over the previous five years.

Most of the conceptual work to date has been done in-house with the support of an architect/engineer (A/E) consultant to develop the cost estimate for the Hall D Area. The stated intention of management is to develop almost all of the "additions" design (approximately one-third of the total design work) and contract documents in- house (the only significant exception being to use A/E assistance for the addition to the CHL Building). The four additions to existing buildings are specifically additions to the North and South Access Buildings, an addition to the Beam Switchyard Service Building, and an addition to the CHL. The proposed additions to the Access Buildings are modifications of two additions previously designed but not constructed, and thus do not involve significant new design efforts. The addition to the Switchyard building is minimal, except for two new penetrations to the accelerator tunnel. The addition to CHL is similar to two previous additions to the CHL building and will include A/E design support.

The modifications to both the existing mechanical systems and the electrical systems are similar to modifications designed and managed in-house in the past by the present staff. This work is not planned to utilize A/E support for design. Staff proposed to execute the additions and modifications to the accelerator and CHL by as many as seven contracts for approximately $10 million estimated work.

The design of the Hall D complex in an undeveloped area is a more significant amount of design work. The design will be led by an A/E consultant. Engineering and design for Hall D is estimated by staff as ten percent of the $10 million construction cost.

In general the building construction includes only the shell and utilities up to the walls. Except for LCW equipment, the building user groups are responsible for all utilities and equipment inside the buildings.

All construction management is being performed by in-house staff. The dedicated staff is small (one), augmented by term hires. There is no project-dedicated certified safety professional. Engineering of the LCW system for Hall D is being done by laboratory staff. They have designed and installed a nearly identical system in the test laboratory for SNS work.

The schedule for the construction of the Hall D Area presented at this review showed the construction of the underground tunnel enclosure addition after the construction of the neighboring surface service buildings, possibly requiring the design and utilization of a retention system for the newly constructed buildings during excavation for the tunnel.

The Hall D Area work was proposed to be executed in three contracts.

The design of the convection cooling system in the accelerator arcs is specified to cool the area (to 98° F) for occupancy after one hour. As an ancillary result, the ambient temperature during operations will be 120° F. If the arc magnets were independently cooled, this system would be less stressed, although LCW demands would be increased. As presently planned, there is no conventional facilities work planned for the existing experimental halls A, B, and C.

3.2 Comments

The scheduled order of work at the Hall D Area should be reconsidered. The construction of the Hall D extraction enclosure after the surface service building construction complicates the enclosure construction if a retention system is required to support the new buildings during construction. The tunnel excavation, enclosure construction, and backfill should be complete prior to the construction of the neighboring surface service buildings. Consideration should be given to integrating any required earth-berm retention walls with the adjacent service building walls.

The use of multiple contracts for performing similar work at approximately the same time or work in immediately adjacent regions may be needlessly complex.

Cooling the magnets in the arc sections directly to remove heat at the source, thereby reducing the ambient temperature and the demands on the convection cooling system, could reduce the requirements of the convection cooling system and improve the environment of equipment in the arc sectors. If the temperatures are going to rise significantly in the tunnel arcs during accelerator operations, the performance of fire suppression and detection systems should be carefully evaluated, especially near the magnets.

The ten percent estimate for the Hall D Area cost of design seems low.

The in-house staff for field construction management and certified field safety professionals is probably insufficient to meet the requirements for the project, both for civil and technical construction and installation work.

It would be worthwhile to review once more the radiation shielding requirements. This would include operational and accidental beam losses to ensure that the earth shielding requirements in the Hall D Area, which now require importing additional earth, are reasonable. It would similarly be appropriate to review the original Hall B shielding design to ensure that it is adequate for the X10 luminosity increase associated with the 12 GeV Upgrade project. At a future review it would be advisable to include a breakout session on the topic of radiation shielding.

The civil conceptual design is reasonable for this stage of development. Interaction with the technical staff has been adequate for this level of specification.

There is abundant time in the schedule for the completion of the conventional facilities. The schedule could be accelerated. The cost estimate for construction is based upon generally accepted references such as Means to a large extent, but backed by relatively recent TJNAF experience for similar work. Value engineering is scheduled as part of the detailed design.

3.3 Recommendations

1. Reconsider the schedule for the construction of the Hall D beam extraction tunnel.

2. Consider integrating the entire Hall D Area work into a single construction contract.

3. Consider integrating the "additions to existing buildings" (North and South Access Building Additions, Beam Switchyard Service Building Addition, CHL Building Addition) into a single construction contract.

4. Review with the appropriate accelerator staff the question of directly cooling the magnet elements in the arc segments.

5. Consider increasing the Hall D Area design estimate to 15 percent of the construction cost estimate.

6. Consider increasing the construction estimate by $0.5 million to provide for increased field construction management staff and for a dedicated project certified safety manager.

7. Review the radiation shielding specifications throughout the project.

4. COST ESTIMATE

4.1 Findings

The project team presented a Total Project Cost (TPC) for the 12 GeV Upgrade of $279 million in as-spent dollars, as shown in Table 4-1. The project team proposed that the DOE TPC and project scope could be reduced for scope of work which assumes funding from non-DOE sources. No firm commitments have been established for the non-DOE scope at this time, but the project estimated this potential contribution to be approximately $29 million.

Table 4-1. 12 GeV Cost Estimate (as-spent dollars in millions of dollars)

WBS	Scope	Cost
1.2	PED	16
1.3	Accelerator Systems	68
1.4	Upgrade Hall A, B & C	44
1.5	Hall D	27
1.6	Civil	20
1.7	Project Management	6
TEC Subtotal		**181**
Escalation		20
Contingency		55
TEC TOTAL		**256**
1.0	CDR	1
1.1	R&D	5
1.8	Pre-Ops	5
1.9	ACD	3
OPC Subtotal		**14**
Escalation		1
Contingency		8
OPC TOTAL		**23**
TPC Subtotal		195
Escalation		21
Contingency		63
TPC TOTAL		**279**
Potential non-DOE Scope w/cont & esc		(29)

The project cost estimate has been escalated using standard DOE escalation rates. A general and administrative (G&A) rate of ten percent for procured materials and services and staffing resources has been applied across the project. For procurement actions, the G&A charges are applied against the first $50,000.

The detailed cost estimates, (including contingencies) are developed by the Assistant Project Manager/Cost Account Manager (CAM) at WBS Level 3 or lower and identifies the labor type, labor hours, material, or vendor costs. The detailed estimates are then provided to the Project Office, which applies labor rates, escalation, and G&A. The majority of the cost and pricing are based on experience from initial CEBAF project, the SNS project, and the FEL project. Basis of the detailed estimates are: vendors estimates (15 percent), catalog pricing (13 percent), previous TJNAF experience (53 percent), engineering judgment (13 percent) and miscellaneous (five percent).

The project has performed an alternative analysis that includes the following options: 1) do nothing; 2) construct a new facility; or 3) upgrade the existing CEBAF from 6 GeV to 12 GeV. Since there are no facilities in the world that have or are capable of upgrading to the proposed 12 GeV project capabilities, option 3 was selected.

The project has developed a Risk Management Plan and Conceptual Design Report that includes a risk summary table at WBS Level 3. The risk summary table is a roll-up of more detailed risk analysis performed by the CAM staff.

4.2 Comments

At this stage of the project, costs are being collected using good methodologies; however, the Committee identified some areas of concern in the accelerator, detector, and conventional facilities. An assessment of potential impacts (approximately $9 million) by the Committee is included in Appendix D.

In addition, the project office relies heavily on G&A cost to support the finance and procurement functions. In developing a detailed resource-loaded schedule in support of CD-2, Approve Performance Baseline, management should ensure that adequate resources are identified for all project support functions: quality assurance, ES&H, integration, finance, procurement, and DOE compliance and documentation.

A credible and sufficient alternative analysis was performed; however, as required by the DOE M 413.3-1, *Project Management for the Acquisition of Capital Asset*, a life-cycle analysis of the alternatives needs to be included in the Acquisition Strategy.

The CDR risk summary table should be consistent with the contingency approach. For example, some WBS elements have a low-risk rating and yet a higher contingency assigned, while other elements have a moderate-risk rating and a lower assigned contingency. Risk ratings, along with the contingency assessments should be reconciled to represent actual risk.

Appropriate site-specific escalation factors should be applied in lieu of the DOE rates, as they will more accurately reflect actual site conditions.

Currently, the project is charged a ten percent G&A rate. The project should formalize this agreement so that this rate can be maintained over the life of the project.

4.3 Recommendations

1. Address the Committee's cost concerns noted in this report in support of the request for CD-1.

2. Formalize the G&A rate for the project as soon as possible.

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5. SCHEDULE and FUNDING

5.1 Findings

A summary schedule and initial list of milestones were presented by the project team. The proposed Level 1 milestones are shown in Table 5-1. Additional milestones, the summary schedule, and proposed funding profile (by fund-type) are included in Appendix E.

Table 5-1. Level 1 Milestones

Level and Number	Milestone Description	Completion Date
	Level 1a	
1-0a	CD-0 (Approve Mission Need)	Mar 2004 (A)
1-1a	CD-1 (Approve Preliminary Baseline Range)	Sep 2005
1-2a	CD-2A/3A (Approve Performance Baseline and Construction of Long Lead Procurements)	Mar 2007
1-3a	CD-2B (Approve Performance Baseline	Sep 2007
1-4a	CD-3B (Approve Start of Construction	Jun 2008
1-5a	CD-4 (Approve Project Completion and Start of Operations	Dec 2012

A high-level unloaded schedule has been completed (approximately 150 items). Additional lower level milestones and activities will be identified during the development of the resource-loaded schedule. When completed, the detailed resource-loaded schedule is expected to have on the order of 5,000 activities. This schedule will be prepared over the next six months using P3e software. The goals for the schedule are to have activities in the $50,000-$200,000 range with durations less than six months wherever possible.

A rough resource profile has been completed indicating that there are not likely to be any significant staffing problems with currently available resources. In a few cases, contract personnel may need to be procured. This profile will be refined with the development of the resource-loaded schedule.

The current preliminary schedule indicated a critical path that runs through the second CHL 4.5°K cold box and the Hall D area. Based on the CD dates shown above, there would be approximately nine months of schedule contingency in the schedule prior to CD-4, Approve Start of Operations. Halls B and C are not on the critical path until after November 2011. The project schedule incorporates a phased CD-2 and CD-3, in support of the long-lead procurements for the second CHL 4.5°K cold box and the below grade construction activities in Hall D.

5.2 Comments

The process of developing the detailed, resource-loaded schedule is underway and the goals and efforts appear to be on track for the scope and level of complexity of this project. However, the Committee was concerned that the apparent nine months of schedule contingency may not be adequate at this stage of the project. In addition, installation activities are least developed and will need further attention as the resource-loaded schedule evolves.

TJNAF is essentially a single-purpose/single-program laboratory, so it is reasonable to assume that adequate resources will be focused on this upgrade as the top lab priority. However, careful coordination will be required during the construction and installation activities, which are scheduled in parallel to avoid possibly straining resources.

The expected critical path through the cold box and Hall D construction should be verified as soon as possible with a detailed resource-loaded schedule to determine the precise amount of schedule contingency and, therefore, the need and extent for the long-lead procurements funding. Project contingency with respect to CD-4 should be optimized as soon as possible. There is a relatively uniform distribution of these milestones over the lifetime of the project and over the Level 1 WBS subsystems.

It was noted in the cost worksheets that FY 2012 and FY 2013 were combined. Consequently, there is no precise breakout of costs, resources, etc. for each year. This led to some confusion in the presentation materials. This should be changed in support of preparation of the cost baseline and the resource-loaded schedule.

Planned expenditures in the early years assume little contingency is needed to solve problems. Additional contingency may be necessary to maintain progress on critical path items, and the project team should identify non-critical activities that could be deferred until later years to maintain schedule.

Project contingency is currently a common funding pool for both TEC and Other Project Costs (OPC). In preparation for CD-2, the project should identify the adequate and separate contingency budgets for each scope of work.

5.3 Recommendations

1. Review the overall schedule and milestones in light of the Committee's concerns with overall contingency.

2. Reconcile planned work with available funding to ensure adequate contingency is available for critical path activities.

3. Assign contingency funds to the TEC and OPC separately.

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6. MANAGEMENT (WBS 1.7)

6.1 Organization and Staffing

6.1.1 Findings

TJNAF has in-house, highly qualified, dedicated people who are clearly able to work well together. This bodes very well for the success of the project. The Laboratory Director regards this project as the key to the Laboratory's future and he understands in a very concrete manner how the Laboratory must fully support the project for it to succeed.

TJNAF worked hard and did a good job involving users in making hard choices about project scope and goals. The project is organized and adequately staffed to begin the next phase, advanced conceptual design or preliminary design. The organization approach of the project is appropriate to support the project through construction to a successful completion. The management is planning to bring on board the remaining key management personnel needed to guide the project to a successful completion.

The project intends to appoint a project manager, reporting to the project director, after CD-1 approval. The current Federal Project Director role is being performed by the Site Office Manager. The current project organization does not have provision for a quality assurance (QA) officer responsible to oversee and monitor the implementation of the QA plan. The Safety Officer for the project is now on-board in "as needed" basis. The plan is for a part-time Safety Officer during the PED and construction phases.

TJNAF has a mature and well-developed set of management tools that are an important asset for the project. The TJNAF's project management office staff is also a substantial asset. Although much optimization of performance vs. cost and system integration has been done so far, it does not appear that the formal systems engineering has yet been considered to any significant degree. As planning for the project proceeds, this needs to be addressed.

The project plans to use current Hall leadership and staff to handle 6 GeV operations and 12 GeV project activities in parallel (except Hall D which is full part of 12 GeV project) with 6 GeV activities ramping down as project ramps up.

TJNAF is setting up external Science, Accelerator, and Experimental Advisory Committees.

6.1.2 Comments

The Committee agreed that successful completion of this project is the key to TJNAF's future and applauded the Director's commitment to the success of the project and perspective about what must be done to make this a reality.

The position of Federal Project Director is a key position for the success of the project that should be filled on a permanent basis as soon as possible. In light of the Federal Project Director's significant responsibilities related to the stakeholders (the Laboratory management, the funding agency, the users, etc.), the Contract Project Manager should be technically very strong with experience in hands-on management of a complex technical project so that he/she has the capability needed to direct the project's technical and construction activities.

It is essential to the success of the project that the Integrated Project Team functions effectively. This requires team members (both DOE and Laboratory personnel) work well together with a high degree of respect and communication.

The project needs more planning for manpower and organizational aspects for project-specific safety in the context of the overall Laboratory Safety program and manpower. This should be done in support of the advanced conceptual design. There is a serious concern that the organizational approach of sharing of manager between the project activities in the Halls and 6 GeV operations runs the risk of insufficient focus of management personnel on the project. The project should consider appointing full-time, assistant project managers for the Hall B and C project scope.

The Committee endorsed the importance of external advisory committees and suggested that TJNAF consider appointing an outsider as chair of the Science Advisory Committee.

6. 2 Requirements, Deliverables, and Costs

6.2.1 Findings

The project has prepared an alternatives and requirements analysis, conceptual design, acquisition strategy, evaluation of project risks, and hazards analysis, and they are appropriate and adequate to support CD-1 approval. However, the Project Execution Plan (PEP) should be strengthened in the area of change control and baseline management and should clarify the roles and responsibilities of the Assistant Project Managers and the Senior Team Leaders.

The CD-4 deliverable for the accelerator has no requirements for beam current or emitance. There is no statement that everything will be in place for 12 GeV capable of meeting the long-term, full-operational objective. The CD-1 deliverables for the experimental halls involve key magnets operating at below full design field.

With the exception of the lack of a position for a QA officer, the size of the project management office is generally appropriate for a project of this size and complexity. The cost estimate for Project Management is generally consistent with the project office staff size. However, the cost estimate should be increased to account for additional needed staff; e.g., the QA officer, a construction safety professional, and systems engineering.

There seems to be confusion between TJNAF and the Program Office as to the proper method for accounting for the support of scientists performing construction tasks.

It is apparent that the appropriate cost range for this project is somewhat higher than that at CD-0, Approve Mission Need.

6.2.2 Comments

The CD-4 deliverables should reflect realistic performance levels at the end of the construction period. The project management cost estimate should be increased to account for needed additional staff.

The proper method of accounting for scientists performing construction tasks should be clarified in discussions between TJNAF and the Program Office.

Management of non-DOE funded contributions, as well as university-supplied labor must be part of the overall management of the project. Use of proven tools such as a Memorandum of Understanding, signed by high-level institution officials is essential. To provide the needed traceability, project documentation should recognize and acknowledge contributions from universities, and other agencies and nations.

6.3 Recommendations

1. The Laboratory Director should take a direct role to assure that a qualified project manager is brought on board to support advanced conceptual design.
2. The DOE should establish a permanent position of Federal Project Director for the project in conjunction with the CD-1 approval and appoint a highly qualified person

as soon as possible.

3. A QA officer should be appointed, reporting to the Project Director in order to assure independence. The QA officer should develop and own the project specific QA plan.

4. TJNAF should revise CD-4 deliverables for review and approval by the Nuclear Physics Program office.

7. ENVIRONMENT, SAFETY and HEALTH

7.1 Findings

ES&H issues are being properly addressed at this stage of the project. ISM is a part of TJNAF's management structure. The ES&H manual and various management manuals and training documents convey ISM requirements. Construction contractors are required to follow the TJNAF policies and procedures and ISM.

7.2 Comments

The ES&H team is experienced, and the staff to support the project is available at TJNAF. Current plans are to provide ES&H subject matter experts from the TJNAF to support the project. An experienced Safety Manager is assigned to the project, reporting directly to the Project Director.

The ES&H team has identified the critical ES&H issues for this project, and has a plan to address each issue in a timely fashion that supports the Project Schedule. Documents that will be required to support the project have been identified and a credible schedule to develop the documents does exist. The Preliminary Hazards Analysis is comprehensive and is the first step in addressing ES&H hazards and controls. The NEPA process is understood and plans exist for completion of the documentation. An Environmental Assessment Determination for the TJNAF site (including the 12 GeV Upgrade) was approved in April 2005 so that work can begin on the Environmental Assessment (EA). There is a milestone in the preliminary PEP or submittal of the EA. The Safety Assessment Document (SAD) will be modified to address the new requirements of the 12 GeV Upgrade, and the schedule to complete this task is credible. The Accelerator Safety Envelope (ASE) will be modified to address the new requirements of the 12 GeV Upgrade.

The ES&H staff addressed prediction of the magnitude of significant operational hazards (e.g., ionizing and non-ionizing radiation) in the12 GeV-Preliminary Hazard Assessment. Modeling will ensure adequacy of integrated safety controls, such as shielding and enhanced ventilation. Efforts should be extended to other hazards such as thermal and ozone.

It is noteworthy that the staff is reviewing lessons learned from other DOE projects and adopting successful ES&H practices such as use of special safety incentives for contractor personnel. The staff was aware of the application of lockout/tagout to hazardous all energy sources, not just electrical energy, an important lesson learned from construction at Center for

Nanoscale Materials at Argonne National Laboratory.

7.3 Recommendation

1. Model or predict the magnitude of ES&H hazards such as thermal and ozone resulting from the 12 GeV Upgrade to ensure controls are integrated into the project design and add this information to the Preliminary Hazard Assessment.

2. Add milestones to the preliminary PEP for submittal of the SAD, and ASE with approval authority identified as the Federal Project Director.

APPENDIX A

CHARGE MEMORANDUM

DOE F 1325.8
(08-93)

United States Government Department of Energy

memorandum

DATE: May 23, 2005

REPLY TO ATTN OF: Office of Nuclear Physics, SC-26

SUBJECT: Office of Science Conceptual Design Review of the CEBAF 12 GeV Upgrade Project

TO: Daniel R. Lehman, Director
Office of Project Assessment

I would like to request that you organize and lead an Office of Science (SC) Conceptual Design Review of the Continuous Electron Beam Facility (CEBAF) 12 GeV Upgrade Project at Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, Virginia, on July 12-14, 2005. The purpose of this review is to assess all aspects of the project's conceptual design and associated plans -- technical, cost, schedule, management, and ES&H. This information will subsequently help me in my recommendations to the Acquisition Executive, Dr. Raymond Orbach, regarding the consideration of Critical Decision 1 (CD-1, Approve Alternative Selection and Cost Range). The CEBAF 12 GeV Upgrade project was identified as a near-term priority in the SC 20-Year Facilities Plan and was awarded CD-0 approval in 2004. The CD-1 is planned for the fourth quarter of FY 2005.

In carrying out its charge, the review committee should respond to the following questions:

1. Is the conceptual design sound and likely to meet the technical performance requirements? Have technical performance requirements been appropriately and sufficiently defined for this stage of the project to support the proposed technical scope?

2. Are the proposed project cost, schedule and technical scopes reasonable, credible and sufficiently defined for this stage of the project to support preliminary cost and schedule estimates?

3. Has a credible and sufficient alternatives analysis been performed that supports the proposed technical, cost and schedule scopes?

4. Are the cost and schedule contingencies consistent with an appropriate risk analysis and adequate to address identified risks? Are the accelerator and instrumentation R&D plans reasonable, credible and supported by the preliminary risk analysis?

5. Is the project being managed (i.e., properly organized, adequately staffed) as needed to begin Preliminary Design and support the project through construction to a successful completion?

6. Are ES&H aspects being properly addressed given the project's current stage of development? Are Integrated Safety Management Principles being followed?

In addition to the above, it would also be helpful if the committee would evaluate drafts of project documentation that will be considered for CD-1 (e.g., Acquisition Strategy, Preliminary Project Execution Plan, Preliminary Hazard Analysis Report, Preliminary Risk Assessment Report).

The CEBAF 12 GeV Upgrade Program Manager, Jehanne Simon-Gillo, on my staff, will work closely with you as necessary to plan and carry out this review. I would appreciate receiving your Committee's report within 60 days of the review's conclusion.

/signed/
Dennis G. Kovar
Associate Director of the Office of Science
for Nuclear Physics

cc:
Steve Tkaczyk, SC-1.3
Brad Tippens, SC-26.1
Jehanne Simon-Gillo, SC-26.2
Christoph Leemann, TJNAF
Allison Lung, TJNAF
James Turi, TJNAF Site Office

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy Review of the CEBAF 12 GeV Upgrade Project
July 12-14, 2005

Daniel R. Lehman, DOE, Chairperson

SC1
Accelerator Physics

* Dave Dowell, SLAC
Vladimir Litvinenko, BNL

SC2
SRF Cryomodules and Cryogenics (WBS 1.3.1/1.3.3)

* John Weisend, SLAC
Bruce Strauss, DOE/SC
Jay Theilacker, FNAL
Ray Fuja, ORNL

SC3
Accelerator (WBS 1.3.2/1.3.4/1.3.5/1.8.1)

* Rod Gerig, ANL
Bill Weng, BNL
Ali Nassiri, ANL

SC4
Control Systems and Instrumentation (WBS 1.3.6)

* Dave Gurd, ORNL

SC5
Detector (WBS 1.4/1.5/1.8.2)

* Andy Lankford, UCI
Peter Denes, LBNL
Bill Louis, LANL
[Bruce Strauss, DOE/SC]

SC6
Conventional Facilities (WBS 1.6)

* Dixon Bogert, FNAL
Jerry Hands, SNL
Lewis Keller, SLAC (retired)

SC7
Cost and Schedule

* Mark Reichanadter, SLAC
Steve Tkaczyk, DOE/SC
Kin Chao, DOE/SC

SC8
Project Management and ES&H (WBS 1.7)

* Jay Marx, LBNL
Greg Bock, FNAL
Randy Ogle, ORNL
Les Price, DOE/OR
Don Rej, LANL

Observers

Dennis Kovar, DOE/SC
Jehanne Simon-Gillo, DOE/SC
Brad Tippens, DOE/SC
James Turi, DOE/TJSO
Steve Dierker, BNL

LEGEND

SC Subcommittee
* Chairperson
[ ] Part Time
Count: 25 (excluding observers)

APPENDIX C

REVIEW AGENDA

Department of Energy Review of the
CEBAF 12 GeV Upgrade Project

AGENDA

Tuesday, July 12, 2005—CEBAF Center (Building 12), Room L-102/104

8:00 am	DOE Executive Session	D. Lehman
9:00 am	Welcome	C. Leemann
9:10 am	12 GeV History and Science Overview	A. W. Thomas
9:20 am	12 GeV Upgrade Overview	A. Lung
10:00 am	Break	
10:20 am	Project Management Overview (WBS 1.7.1)	C. Rode
10:50 am	Accelerator Technical Overview (WBS 1.3/1.8.1)	L. Harwood
11:20 am	Physics (Experimental Equipment) Technical Overview (WBS 1.4, 1.5, 1.8.2)	W. Brooks
11:50 am	Civil Technical Overview (WBS 1.6)	R. Yasky
12:15 pm	Lunch	
1:00 pm	Tour (Test Lab, Machine, Experimental Hall A)	
2:30 pm	Technical Breakout Sessions	
5:00 pm	DOE Executive Session	D. Lehman
6:30 pm	Adjourn	

Wednesday, July 13, 2005

8:00 am	Technical Breakout Sessions	
12:00 pm	Lunch	
1:00 pm	Subcommittee Executive Sessions	
3:00 pm	DOE Executive Session	D. Lehman

Thursday, July 14, 2005

8:00 am	Subcommittee Executive Sessions	Committee
10:30 am	Closeout Dry Run	Committee
12:00 pm	Lunch	
1:30 pm	Closeout Presentation to 12 GeV Management	
2:30 pm	Adjourn	

APPENDIX D

COST
TABLE

12 GeV Cost Estimate & Contingency Comparison Cost in FY05$ Direct
(matches breakout session presentation costs)

12 GeV Project Cost Estimate						Review Committee Assessment				Note
			Contingency				Contingency			
WBS Number	WBS Title	Base Cost (FY05$K Direct)	Percent	$K	Total ($K)	Base Cost (FY05$K Direct)	Percent	$K	Total ($K)	
1.2	**PED**									
1.2.1	Accelerator Systems	7,221	25%	1,826	9,047	7,221	25%	1,826	9,047	
1.2.2	Upgrade Hall A, B & C	3,226	27%	873	4,100	3,226	27%	873	4,100	
1.2.3	Hall D	2,298	23%	533	2,831	2,298	23%	533	2,831	
1.2.4	Conventional Facilities	224	15%	34	257	224	15%	34	257	
1.2.5	Project Management (+ Management Reserve)	1,003	24%	241	1,244	1,003	24%	241	1,244	
1.2.6	Accelerator Systems Commissioning Planning	239	25%	60	299	239	25%	60	299	
1.3	**Construction Accelerator**									
1.3.1	Cryomodules	16,333	29%	4,815	21,148	16,333	29%	4,815	21,148	
1.3.2	Power Systems	15,715	26%	4,100	19,814	15,715	**29%**	**4,600**	**20,315**	**A**
1.3.3	Cryogenics	17,364	20%	3,551	20,915	17,364	20%	3,551	20,915	
1.3.4	Beam Transport	10,058	25%	2,520	12,578	10,058	**30%**	**3,020**	**13,078**	**B**
1.3.5	Extraction	1,147	26%	293	1,440	1,147	26%	293	1,440	
1.3.6	Instrumentation, Controls, and Safety Systems	4,439	23%	1,041	5,481	4,439	23%	1,041	5,481	
1.4	**Construction Upgrade Hall A/B/C**									
1.4.1	Construction Hall A	740	24%	174	915	740	24%	174	915	
1.4.2	Construction Hall B									
1.4.2.1	Magnet	6,324	30%	1,904	8,228	6,324	**35%**	**2,213**	**8,537**	**C**
1.4.2.2	Detectors	11,302	32%	3,656	14,959	11,302	**42%**	**4,747**	**16,049**	**C**
1.4.2.3	Computing	1,162	29%	334	1,496	1,162	**39%**	**453**	**1,615**	**C**
1.4.2.4	Electronics	1,571	28%	437	2,008	1,571	**38%**	**597**	**2,168**	**C**
1.4.2.5	Beamline	940	37%	350	1,290	940	**47%**	**442**	**1,382**	**C**
1.4.2.6	Infrastructure	1,192	31%	370	1,562	1,192	**36%**	**429**	**1,621**	**C**
1.4.3	Construction Hall C									
1.4.3.1	Magnet	9,522	34%	3,194	12,716	9,522	**39%**	**3,714**	**13,236**	**C**
1.4.3.2	Detector	1,733	20%	340	2,073	1,733	**30%**	**520**	**2,253**	**C**
1.4.3.3	Computing	-	n/a	-	-	-		-	-	**C**
1.4.3.4	Electronics	784	20%	158	941	784	**30%**	**235**	**1,019**	**C**
1.4.3.5	Beamline	715	17%	123	837	715	**27%**	**193**	**907**	**C**
1.4.3.6	Infrastructure	6,208	20%	1,216	7,423	6,208	**25%**	**1,552**	**7,760**	**C**
1.5	**Construction Hall D**									
1.5.1	Solenoid	772	27%	206	978	772	**32%**	**247**	**1,019**	**C**
1.5.2	Detectors	11,896	26%	3,082	14,978	11,896	**36%**	**4,283**	**16,178**	**C**
1.5.3	Computing	2,889	22%	637	3,525	2,889	**32%**	**924**	**3,813**	**C**
1.5.4	Electronics	5,724	26%	1,510	7,234	5,724	**36%**	**2,061**	**7,785**	**C**
1.5.5	Beamline	2,947	28%	820	3,767	2,947	**38%**	**1,120**	**4,067**	**C**
1.5.6	Infrastructure	2,070	44%	915	2,985	2,070	**49%**	**1,014**	**3,084**	**C**
1.6	**Construction Civil**									
1.6.1	Accelerator	5,956	15%	893	6,850	5,956	15%	893	6,850	
1.6.2	CHL	3,989	17%	685	4,674	3,989	17%	685	4,674	
1.6.3	Hall D	10,045	25%	2,464	12,509	10,045	**30%**	**2,464**	**13,009**	**D**
1.7	**Construction Project Management**									
1.7.1	Project Office (+ Management Reserve)	3,402	90%	3,073	6,476	3,402	**105%**	**3,073**	**6,975**	**E**
1.7.2	Office of Project Management	2,144	18%	386	2,530	2,144	18%	386	2,530	
1.10	$20M FY05 Direct Non-DOE Contribution	(20,000)	25%	(5,000)	(25,000)	(20,000)	25%	(5,000)	(25,000)	
	Total Estimated Cost (FY05 Direct)	153,293	27%	41,814	195,107	**153,293**		**49,306**	**202,599**	
	Overhead	7,333				**6,615**				
	Total Estimated Cost (Overheaded)	160,626				**160,907**				
	Escalation	17,518				**18,191**				
	Total Estimated Cost (as spent)	178,144	28%	49,356	227,500	**179,098**		**57,138**	**236,236**	
	Other Project Costs									
1.0	CDR	913	0%	0	913	913	0%	0	913	
1.9	ACD	2,449	12%	284	2,733	2,449	**32%**	**784**	**3,233**	**F**
1.1	R&D	4,997	24%	1,195	6,192	4,997	24%	1,195	6,192	
1.8	Pre OPS	4,605	106%	4,872	9,478	4,605	106%	4,872	9,478	
	Total Other Project Costs (FY05 Direct)	12,963	49%	6,352	19,315	**12,963**		**6,851**	**19,814**	
	Overhead	1,003				**1,029**				
	Total Other Project Costs (Overheaded)	13,966				**13,992**				
	Escalation	984				**1,009**				
	Total Other Project Costs (as spent)	14,950	50.5%	7,550	22,500	**15,002**		**8,081**	**23,082**	
	Total DOE Project Cost (as spent)	**193,094**	**29.5%**	**56,906**	**250,000**	**194,100**	**34%**	**65,219**	**259,318**	

Notes:

A Increase due to Design uncertainty

B Magnet cooling/installation needs development

C Increase due to Design uncertainty

D Additional Construction Management

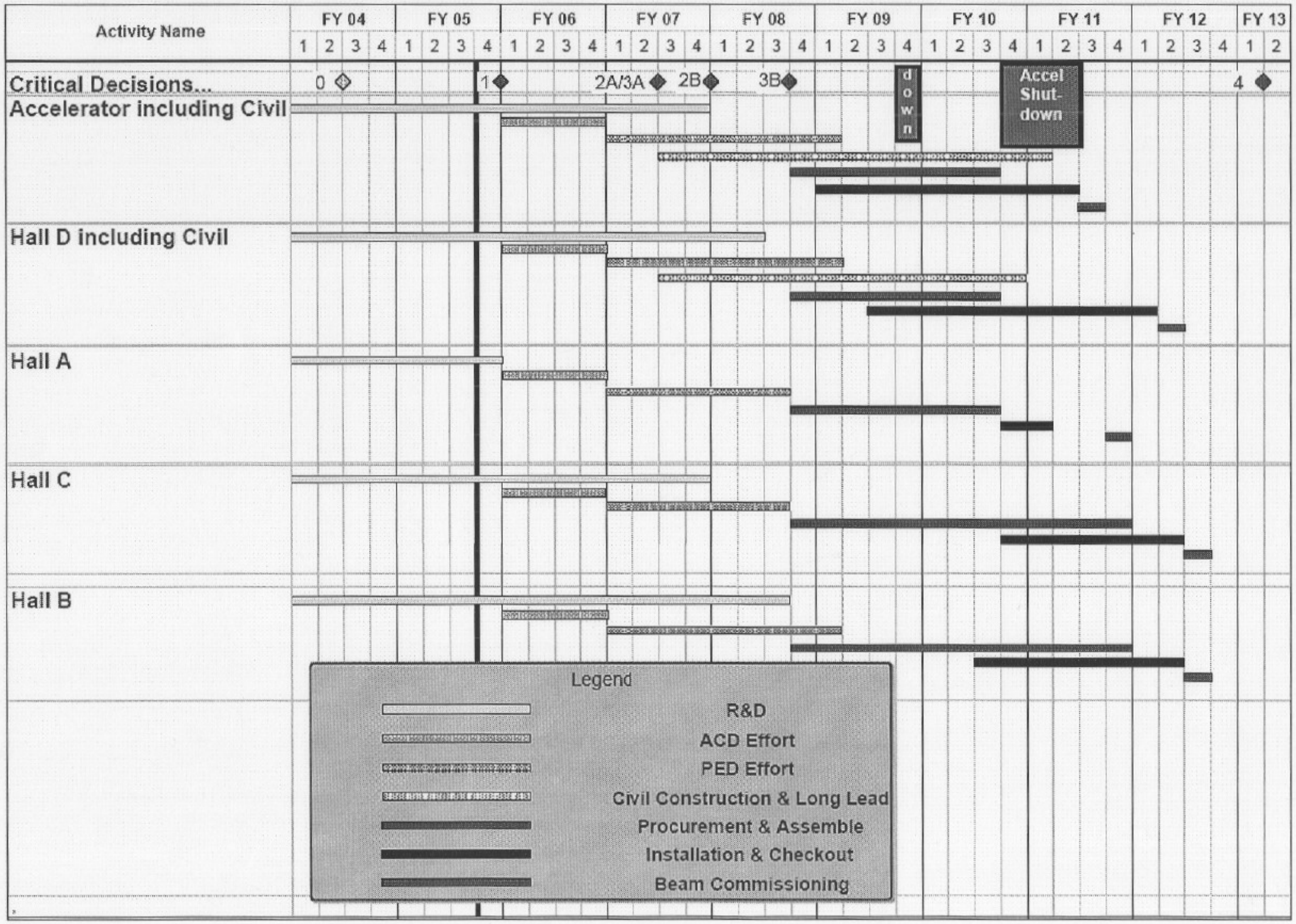
E Addition of a QA officer

F Additional Hall D design effort

APPENDIX E

SCHEDULE CHART

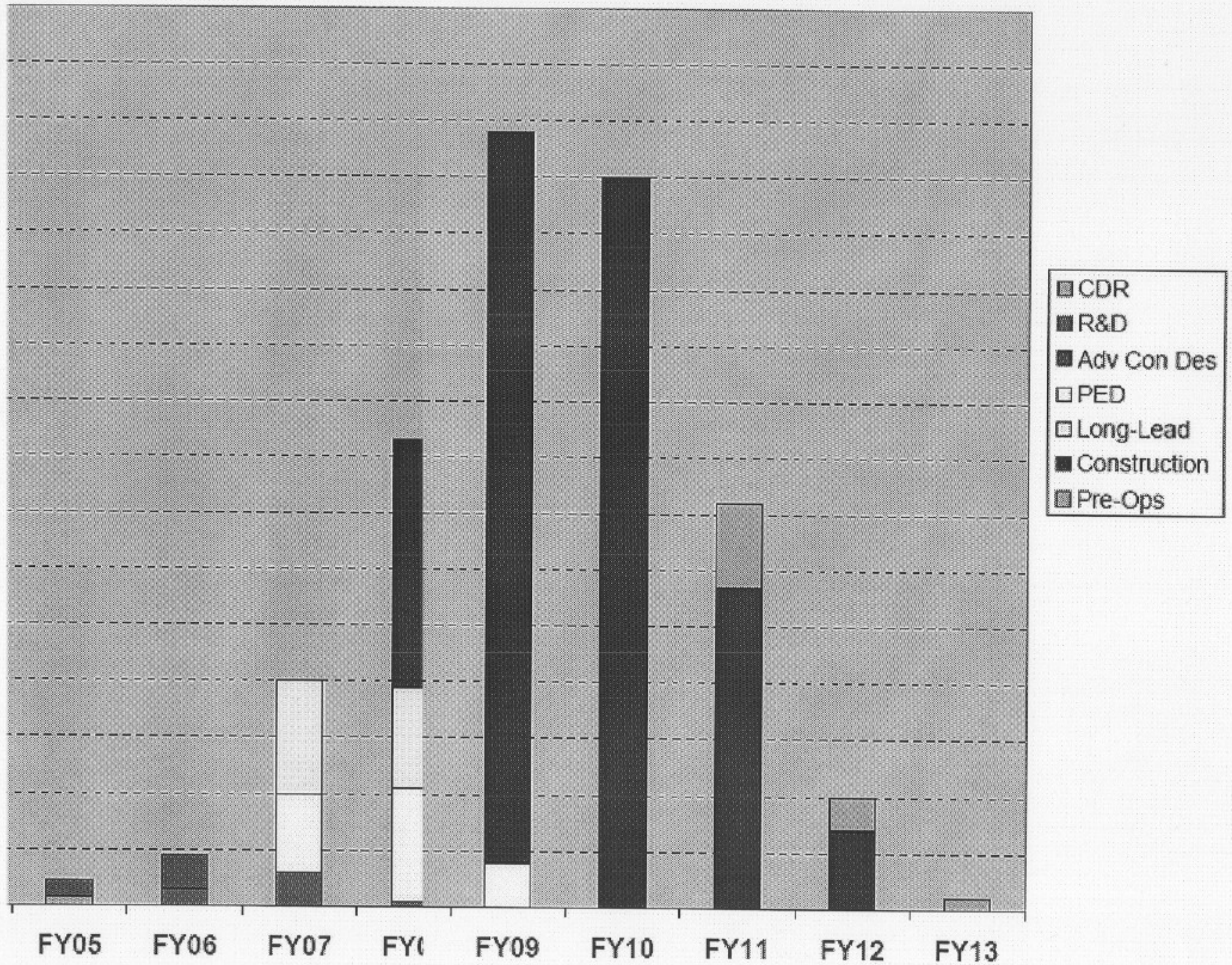
12 GeV UPGRADE SCHEDULE



APPENDIX F

FUNDING TABLE

DOE TPC Funding Profile



APPENDIX G

MANAGEMENT CHART

SURA*/Jefferson Lab Organization

*SURA is a DOE M&O Contractor
❖ Member of Director's Council