Statement of Mission Need and Project Description for

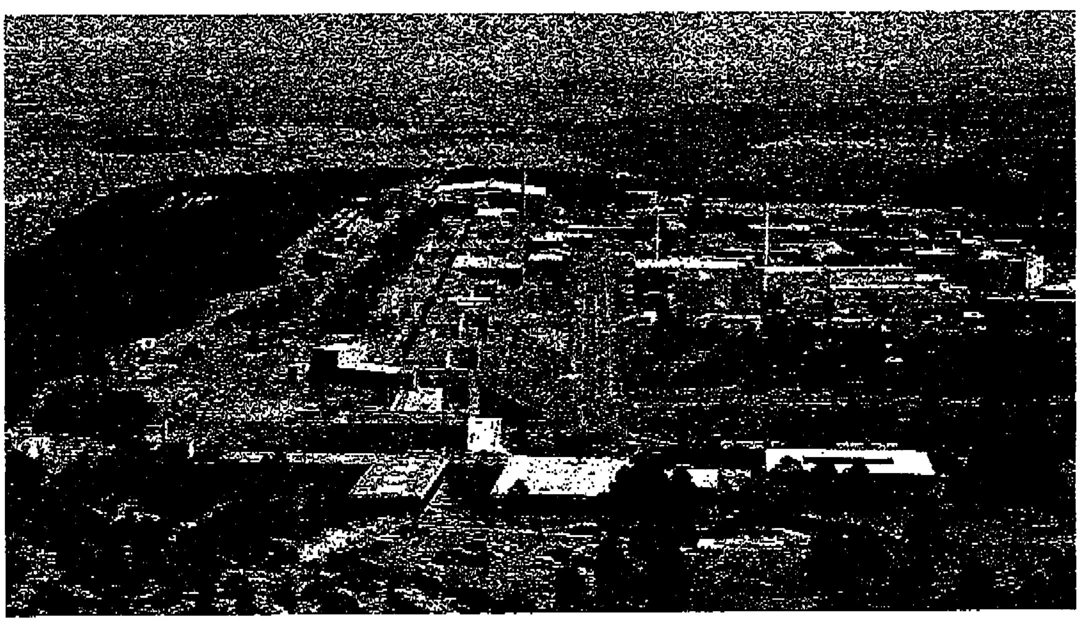
Refurbishment of the Los Alamos Neutron Science Center

LANSCE-R

Los Alamos National Laboratory

May 21, 2004

LA-UR-04-1350



NNSA

Los Alamos

Executive Summary

We propose a $138M refurbishment project to the Los Alamos Neutron Science Center (LANSCE) that will sustain reliable facility operations well into the next decade. LANSCE is a national user facility that provides pulsed protons and spallation neutrons for defense and civilian research and applications. Research and development work at LANSCE supports Defense Programs (DP) in important areas of stockpile stewardship such as robust weapon surveillance, science-based prediction, and weapons repair and remanufacture; the Office of Science (SC) through neutron scattering for condensed-matter science and engineering and nuclear physics; and the Office of Nuclear Engineering, Science, and Technology (NE) in the area of radioactive-isotope production for medical and industrial use and biomedical research. This broad array of accelerator applications has matured over 32 years of facility operation.

Over the past few years, LANSCE has become a workhorse in many areas of stockpile stewardship, and it is clear that the demand for LANSCE facilities is increasing. For example, all three offices that support research at LANSCE have affirmed the importance of having LANSCE operational as a reliable facility for the next decade and beyond. Although all of these offices share use of LANSCE, the Office of the Secretary of Energy has assigned DP with the responsibility and accountability for reliable accelerator operations in support of the overall Department of Energy (DOE) mission. LANSCE continues to be the major Los Alamos National Laboratory (LANL) experimental-science facility and is therefore a critical feature of its science-based mission. There is no foreseeable substitute for this capability. Historically, LANSCE, and its predecessor, the Los Alamos Meson Physics Facility (LAMPF), have been important in bringing exceptional talent to the entire Laboratory by way of thesis students, postdoctoral appointees, and their academic mentors. Keeping LANSCE viable will continue this process.

The first protons were accelerated by the LANSCE linear accelerator (linac) in June of 1972. Since that time, the mission has evolved, but the physical infrastructure has never been funded at a level to keep pace with evolving standards for operation of such facilities and to maintain acceptable reliability. To correct some of these problems, the National Nuclear Security Administration (NNSA) has invested in selective improvements through the Facility Infrastructure and Refurbishment Project (FIRP). Those efforts have been essential to LANSCE's operation, but additional investment is needed through this LANSCE Refurbishment (LANSCE-R) Project to prevent long non-operational periods and costly emergency expenditures.

During 2001, a bottom-up cost estimate was completed by LANSCE and reviewed by an independent team led by Klaus Berkner (retired) from Lawrence Berkeley National Laboratory. The review evaluated the annual operations funding and the refurbishment investment necessary to keep LANSCE viable. This data and review form the basis for the reinvestment decisions presented in this document. Since that time, work has been done to better define and clarify the elements of a project necessary to sustain operation. In seven years, when the $138M LANSCE-R Project is completed, the estimated $1.5B dollar replacement-cost investment at LANSCE and the security it buys will have been provided for the next decade and beyond.

Background

LAMPF was constructed with SC funding in the late 1960s and early 1970s to be a world-class, medium-energy physics machine with the primary mission of studying the production of subatomic particles called pions and their interaction with nuclei. At that time, it was evident that the nuclear weapons program needed an intense source of neutrons that the new machine could provide. As a result the accelerator was designed and constructed to have an extraordinarily flexible beam structure capable of accelerating both positive and negative hydrogen ions and delivering those beams to multiple experimental areas simultaneously.

For more than twenty years, DP, SC, and NE have invested in facilities at LANSCE by constructing and instrumenting four significant experimental areas. The Weapons Neutron Research Facility (WNR), which uses the H^- beam to produce an unmoderated source of neutrons in the keV to multiple MeV range, is the United States' (US) only broad-spectrum, intense source. The Manuel Lujan Jr. Neutron Scattering Center (Lujan Center), which uses a time-compressed proton beam to make a moderated neutron source (meV to keV range), is the premier spallation neutron source in the US. The Proton Radiography Facility (pRad), which uses the pulsed H^- beam, is unique in the world and provides time-sequenced radiographs of dynamic phenomena with billionths-of-a-second time resolution. Finally, the Isotope Production Facility (IPF), just completed in 2004, which uses the 100-MeV proton beam, is the premier source of research medical radioisototopes in the nation.

In 1996 the original accelerator complex was transferred to DP, which had initiated the development of LAMPF, to support the multiple missions of DP, SC, and NE. At that time, LAMPF was renamed the Los Alamos Neutron Science Center (LANSCE). In 2000, DOE's Office of the Secretary assigned DP with the responsibility and accountability for all projects at LANSCE. A year later the roles and responsibilities of all involved were described in a memorandum of understanding that named LANSCE as a national user facility and delegated the coordination and execution of that user program to LANL.

Mission Need

LANSCE is a unique facility in the national laboratory complex for addressing the broad suite of scientific and technical issues necessary for present and future weapons certification. Over the past half-decade, LANSCE-based research conducted by LANL, Sandia National Laboratory (SNL), and Lawrence Livermore National Laboratory (LLNL) has had significant and fundamental impacts on the three major components of NNSA's Stockpile Stewardship Program (SSP):

- **Robust weapon surveillance** (diagnosing and predicting aging-related phenomena in stockpile weapons),
- **Science-based prediction** (developing the capability to predict weapons performance and the consequences of the aging and manufacturing processes on weapons performance), and
- **Repair and remanufacture** (the capability to remanufacture, repair, and revalidate stockpile weapons).

LANSCE contributions to the SSP include the following areas: (1) research underpinning the certification of B61 cold performance for specific stockpile to target sequence (STS) requirements, (2) critical nuclear data used to rebaseline the performance of the W88 primary, and (3) materials science research used to validate component reuse in the W76 Life Extension Program. In addition, LANSCE facilities provide unique capabilities for a number of SSP campaigns (Primaries C1, Secondaries C4, Dynamic Materials Properties C2, Advanced Radiography C3, and Advanced Surveillance C8). Here, LANSCE research underpins the data and science requirements in weapons nuclear science, high-explosive science, material and actinide science, hydrodynamics and shock physics, and advanced radiography. Figure 1 schematically illustrates the ongoing weapons research utilizing LANSCE facilities.

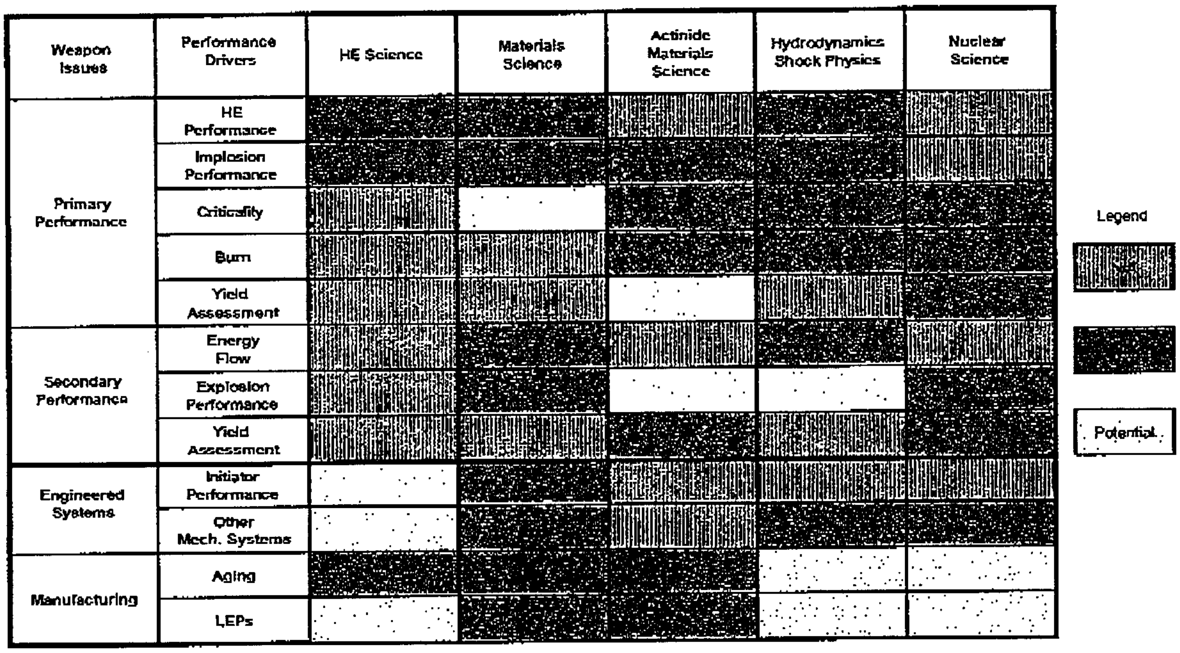


Figure 1. LANSCE facilities engage a wide range of weapons science.

The overall impact of LANSCE on the SSP is periodically reviewed by the Weapons Physics Directorate's program review process. In the most recent review (June 2002), Victor Reis, Chairman, summarized the contributions of LANSCE to the weapons program as follows:

> *"The committee was presented several examples of the role of science in supporting the weapons physics mission. Both the high energy density physics research being carried out for the NIF program and the LANSCE effort are supporting key stewardship efforts based upon excellent fundamental science. In these cases, the technical needs of the program were 'pulling' science to enable rational decision making, to reduce program costs and risks and to solve challenging problems. This is correct and healthy, in our view."*

In looking to the future, LANSCE facilities and the research utilizing those facilities will continue to have critical impacts in the SSP. The quantification of margins and uncertainties (QMU) methodology to be implemented for future weapons certification is based on the reduction of risk through scientific understanding. LANSCE will play a major and necessary role by addressing the broad range of weapons science required to form the science-based predictions that are the backbone of QMU.

Nuclear-weapons performance spans a broad range of physical conditions and scientific disciplines. The "button-to-boom" major performance drivers of a nuclear weapon include high-explosive detonation and burn, primary implosion, fission burn, boost, radiation transport, secondary implosion, secondary burn, and output effects. For each of these performance drivers, the underlying science must be understood in order to accurately predict weapons performance across the STS environment. The compilation of this broad science base forms the "weapons predictive science roadmap" that lays out the requirements for theory, modeling, experiments, and facilities.

Three major experimental facilities at LANSCE provide the most versatile defense, basic, applied, and industrial research capability in the world:

- **The Lujan Center** uses a source of moderated neutrons (with meV to keV energies) primarily for neutron-scattering research in condensed-matter physics and material science and nuclear science.
- **The WNR** uses a high-energy neutron source (100 keV to 800 MeV) for research in nuclear science and technology. The combined capabilities of the Lujan Center and WNR provide unique (in the world) access to the entire neutron spectrum of a nuclear weapon.
- **pRad** uses the 800-MeV proton beam to image (with motion pictures) dynamic systems and opens up completely new options for weapons experiments and for developing a better understanding of the aging and performance of weapons-system components.

Figure 2 schematically illustrates how the weapons-science research at LANSCE facilities ties to the weapons predictive science roadmap. It is immediately clear that LANSCE-based science addresses critical issues across almost all of the major weapon performance drivers. Specific areas of focus include the following:

- High-accuracy measurements of neutron cross sections needed to interpret archival underground nuclear tests and validate weapons performance predictions (yield and actinide inventories) based on Accelerated Strategic Computing Initiative codes;
- High-accuracy measurements of principal fission and fusion cross sections of nuclear fuels required to accurately predict weapon performance;
- Determining the constitutive properties of weapons materials, such as plutonium, under extreme conditions;
- Assessing the effect of aging on stockpile materials and performance;
- Measuring the equation of state (EOS) of stockpile metals;
- Understanding the properties of high-explosive (HE) materials, including the EOS;

- Using the unique, high-resolution, time-dependant properties of pRad to study HE burn, dynamic material properties, and hydrodynamics;
- Serving as a national user facility (including SNL and LLNL) to address stockpile issues in weapons science and Directed Stockpile Work; and for basic neutron science as related to the structure of materials and fundamental nuclear physics of weapons.

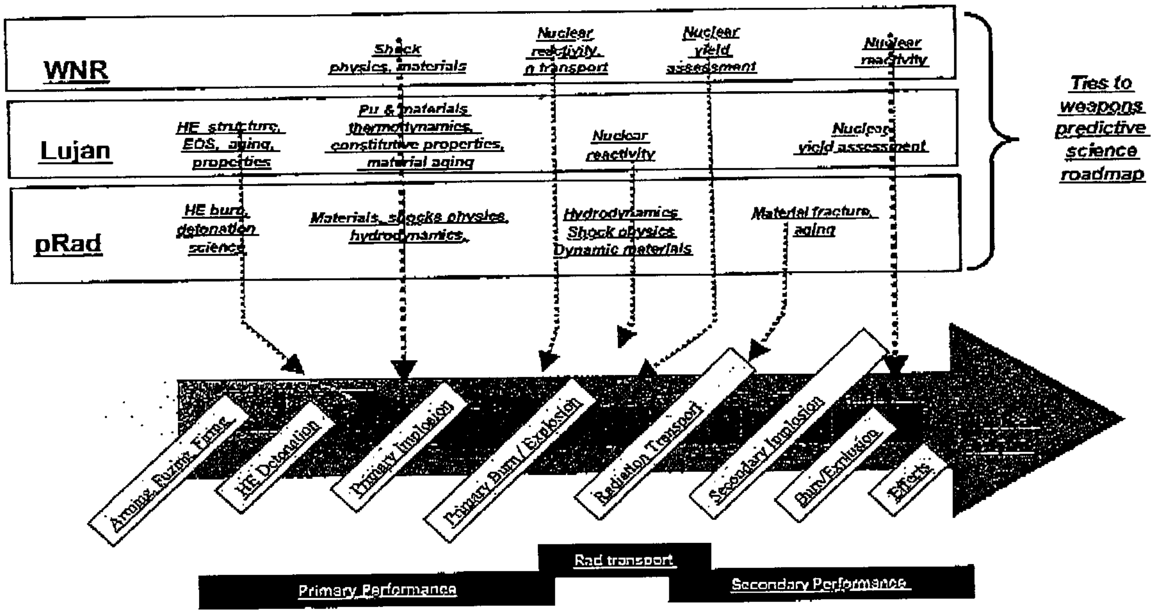


Figure 2. LANSCE capabilities are unique and will be necessary for developing to develop the science-based predictive capability for future weapons certification.

In summary, the breadth of weapons science addressed at LANSCE facilities clearly lies on the critical path to a robust science-based predictive capability for weapons certification. LANSCE facilities are the enabling elements that will allow us to meet weapons requirements and milestones over the next ten years, including replacement-warhead certification without nuclear testing by the year 2013 (a Level 1 milestone).

All the principal stakeholders, DP, SC, NE, and LANL, endorse and support the LANSCE-R Project. SC supports a growing program of users conducting neutron-scattering experiments that explore aspects of materials science and technology. Until the Spallation Neutron Source (SNS) becomes operational at design specifications (approximately 4 to 6 years from now), LANSCE is the nation's most intense neutron source, and SC would like LANSCE operating reliably at least until that time. Given the overall lack of neutron sources in the US and the projected growth of the scientific community using neutrons, it is critical that LANSCE serve the neutron scattering community for a significant period after SNS becomes fully operational.

NE has just begun operating the IPF to produce isotopes for the medical community. As the medical community begins to rely on the supply of isotopes from LANSCE, there will be increasing pressure to avoid any interruptions in that supply. Although the operating plans for IPF can accommodate normal, scheduled outages of the accelerator complex, NE has indicated that they will not be able to handle prolonged stoppages of the accelerator complex. They are planning for at least a decade of reliable operation of the IPF to justify the capital construction investment.

Los Alamos has stressed the importance of LANSCE as a significant portal to the outside scientific community and a necessary part of remaining a world-class laboratory. It is an important recruiting and retention tool. The user programs at WNR and Lujan Center attract a large number of students, faculty, and postdoctoral fellows. During the 2003–2004 operating period, there were over 1000 user visits and nearly 400 separate experiments were performed, nearly half of which supported Los Alamos programs. LANSCE is an important testbed for new technology development. Proton Radiography was developed at LANSCE and is being constantly improved. This has not only given the weapons program a new tool, but it may also point the way to major new Laboratory programs in support of our national security mission.

Research and Facility Costs

In FY03, LANSCE staff analyzed the cost of research being carried out at LANSCE by users internal and external to the division so that sponsors could better compare the facility operating costs with the research being performed. The analysis of research costs internal to LANSCE utilized actual Laboratory financial data. The analysis of external research costs used the most recent run-cycle data of experiments performed by the external research community. The external user data were sorted by funding source (e.g., DP, non-DP, SC) and user institution (e.g., university, other national laboratory, industry). The cost of a representative experiment from each category was then estimated by incorporating the following costs:

- Preparation, such as the labor cost of sample preparation, sample characterization, and x-rays;
- Travel and labor costs associated with the visit;
- Analysis of the results and publication of the paper.

These costs were then extrapolated based on detailed user data in order to arrive at an estimated total cost. Table 1 shows the summary of total LANSCE-based research costs. Two important metrics emerge from the analysis. First, total DP research, by cost, is roughly 46% of the cost of all research performed at LANSCE facilities. Second, total research cost is roughly comparable to the cost of facility operations.

Table 1. LANSCE Funding for User Support and Research

Funding Source	Totals* ($K)
Internal R&D and User Program Support	
DP Research funded inside LANSCE	$5,469
non-DP Research funded inside LANSCE	$5,076
BES User Program Support	$10,998
Subtotal	**$21,543**
External R&D	
DP Research funded outside LANSCE	$16,328
non-DP Research funded outside LANSCE	$9,672
Subtotal	**$26,000**
Total R&D and User Program Support	**$47,543**

** "Funded inside" refers to R&D performed by personnel internal to LANSCE Division. "Funded outside" refers to R&D performed by non–LANSCE Division personnel. The external user costs are only estimated. Neither internal nor external user costs include the facility/infrastructure costs associated with producing a material sample, which could be extensive for samples such as special nuclear materials. Within the Basic Energy Sciences (BES) User Program support, approximately 1/3 is in direct support of DP science. Thus of the approximately $11M in BES user program support, approximately $3.7M supports DP research.*

Project Description

The LANSCE Accelerator Facility is located in Technical Area 53 at LANL (see Figure 3). Refurbishment would occur in the existing accelerator and support buildings. No site selection action is required.

The LANSCE-R Project addresses four main rank-ordered priorities: (1) replacing facility equipment where necessary to address code compliance or end-of-life issues that could severely impact facility operations, (2) enhancing cost effectiveness by system refurbishments or improvements that stabilize decreasing facility reliability and maintainability, (3) stabilizing the overall beam availability and reliability in a manner that is sustainable over the longer term, and (4) accomplishing the above with minimal disruption to the scheduled user programs. The major project segments necessary to accomplish these priorities are described below.

There is substantial evidence that many components needed to sustain reliable operation are near end of life, are so obsolete that replacement parts can no longer be found, need replacement to comply Federal law, or have single-point failures with long lead time replacements. We give three examples of this. (1) The radio-frequency (RF) power sources, or klystrons, have a lifetime of about 35,000 hours. There are 44 of these at LANSCE with an average in-service time in excess of 100,000 hours. All 44 must be in service to operate the accelerator. There are only 11 spares left. A failure rate of one per month, which would not be unusual for a large installed base near end of life, would terminate operations after two years assuming 6 months of operations per year. (2) Chemical analysis of transformer oil is a reliable indication of impending failure from breakdown of insulating materials. Industrial databases show that the lifetime of large transformers, such as the ones at LANSCE, is typically 30 years. We expect failures within the next five years that will result in substantial outages due to long procurement lead-time. (3) There is no full-power spare available for the neutron target moderator reflector system (TMRS) presently operating at the Lujan Center. Because Lujan Center is a nuclear facility, fabrication and installation of a new TMRS takes many months. Without a spare, LANSCE is at risk of a one-year minimum downtime with no operations at the Lujan Center that would drastically affect a wide variety of weapons-program activity and SC-funded science.

Accelerator Systems

Refurbishments will be made to the ion source and injector, linac, beam transfer lines, and their ancillary systems. These are separate activities that include the following: equipment replacement for the ion source and injector; water, vacuum and beam diagnostics system refurbishments; magnet power supply replacements; accelerator structure refurbishment; and critical spares. All changes that require lengthy beam outages for the installation phases will be implemented during extended maintenance periods to minimize the impact on the user program.

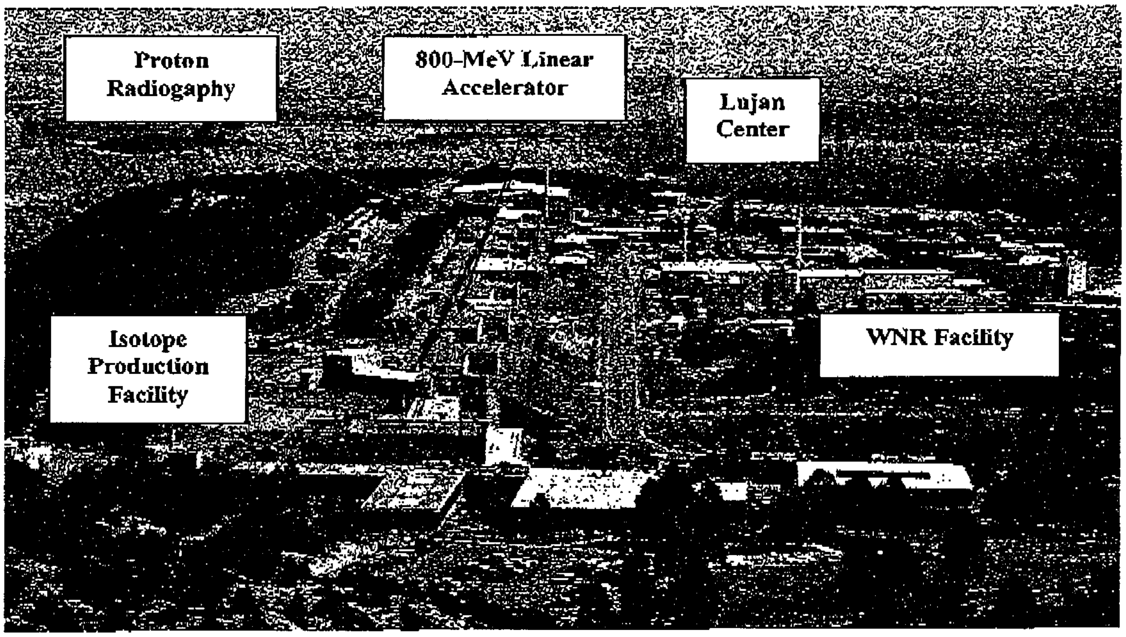


Figure 3. Technical Area 53 showing the LANSCE accelerator complex and experimental facilities.

Ion Source

The current array of power supplies and electronics for the H^- ion source and injector are, in nearly every case, outmoded, obsolete, very difficult to maintain, and/or unreliable. Many of the power supplies, such as that for the 80-keV extraction system, must be run at full capacity, and they limit the operation of the ion source and injector. Modern units whose capability, capacity, and reliability have been proven in extensive testing and operation on the LANSCE Ion Source Test Stand will replace these components.

Vacuum Systems

Accelerator beams must travel in an extremely good vacuum. Consequently, the LANSCE accelerator and beam-transport vacuum system consists of nearly two miles of vacuum enclosures. Vacuum is required from the ion source to the various target windows, the best vacuum being required in the proton storage ring.. The vacuum quality ranges from 10^{-6} torr to 10^{-9} torr. The majority of the system is ion-pumped to achieve a high vacuum. LANSCE is currently experiencing approximately 5% beam downtime because of vacuum-related system failures. The majority of this downtime is attributed to vacuum-seal failures due to age or to equipment failures due to age or inadequate system control and diagnostics.

Many of the original ion-pump power supplies are difficult to maintain because they are no longer manufactured and spare parts are not available. Replacement of these power supplies and vacuum hardware will reduce downtime and improve reliability. An adequate supply of critical spares for the vacuum system is also essential and contributes directly to the reliability, availability, maintainability, and inspectability of the LANSCE linac and beam delivery systems.

Water Systems

The LANSCE accelerator water system consists of several systems that cool the copper and iron radio-frequency accelerating cavities, beam stops, magnets, and support equipment. These systems process de-ionized water and treated water to minimize corrosion and conductivity concerns. The water-system diagnostics, such as flow meters, pressure sensors, temperature sensors, conductivity meters, mix tanks, pumps, and filtration systems, have required increasing maintenance over the last several years. Many of the original system diagnostics and flow controllers are difficult to maintain because they are no longer manufactured and spare parts are not available. Replacement of these water-system diagnostics, flow controllers, and distribution networks will reduce downtime, improve reliability, and increase predictive capability. The principal systems to be partially replaced or refurbished are the low-energy beam transport system (LEBT), linac, and beam transport systems. An adequate supply of critical spares for the water system is also essential and contributes directly to the reliability, availability, maintainability, and inspectability of the LANSCE linac, Proton Storage Ring (PSR), and beam delivery systems.

Beam Diagnostics

The essential diagnostic for assessing the operational performance of the LANSCE accelerator facility is the quality of the H^- beam as determined by appropriate beam diagnostic systems. Refurbishments, and modernization of diagnostic systems in combination with an adequate supply of critical spares contribute directly to the reliability, availability, maintainability, and inspectability of the LANSCE linac, PSR, and beam delivery systems. Replacement of substandard beam position monitors (BPMs) in the linac with current state-of-the-art BPMs will reduce linac tuning and trouble-shooting times and thus will improve LANSCE reliability and availability. Replacement of wire-scanner electronics will improve beam profile measurements and in conjunction with BPMs, current monitors, and beam-loss monitors will reduce beam loss and activation of beam-line components. Reductions in beam loss and activation will improve maintenance and inspection of the accelerator facility and result in shorter accelerator downtimes for the repair of equipment. New wire scanners will provide either new or backup capability for maintaining beam quality to the Lujan Center and WNR targets.

Some beam plugs in the beam-delivery complex are not currently in compliance with modern standards for the radiation security system because they are susceptible to beam burn-through resulting from the beam striking the beam plug for a sustained period. A fail-safe system of ion chambers and associated electronics will be provided to monitor the safety-rated beam plugs and turn the beam off if excessive beam losses are detected.

Magnet Power Supplies

The DC magnet power supply system consists of approximately 600 independent power supplies. These are high current power supplies, up to 2500 amperes, with current regulation and stability requirements for precision as stringent as 50 ppm. Approximately 70% of these units are over 25 years old. Most use the 35-year-old LAMPF-standard control electronics, which contain obsolete electronic components. The performance of these old power supplies cannot be maintained and spare-parts inventories are almost depleted. In some cases, there are no spares, particularly for bipolar shunts and steering power supplies. Many of the LAMPF-standard power supplies can be refurbished with new electronics, while retaining the high-power magnetics. Bipolar power supplies and shunts will need to be completely replaced. A spare pulsed power supply will be constructed for the two "kickers" that extract the beam from the proton storage ring; massive failure of one of these units currently represents a single-point vulnerability for the Lujan Center research programs and those WNR programs that depend on beam from the ring.

Magnets and Linac Structures

Spares will be provided for two magnets that are critical to beam delivery from the proton storage ring to research programs at the Lujan Center and WNR. Without these spares, failure of either of these magnets would result in a beam downtime lasting weeks or months.

Water erosion in the drift tubes of the 201-MHz linac has been observed to be widespread, and this caused a drift-tube failure in 1993. In all, two drift tubes were replaced in the 1990s, depleting the spares inventory, and new spares have not been constructed. While the probability of drift-tube failures is low, such an occurrence could shut off all beams for weeks or months until a spare is fabricated, tested, and installed.

Radio Frequency Systems

The existing high-power RF plant consists of klystrons and gridded tubes. The 805-MHz klystrons and associated transmitters are well beyond expected end of life and will be replaced before system reliability begins to suffer. By replacing the 201-MHz power triodes, modulators, and associated driver stages, the total number of vacuum tubes in the 201-MHz system is reduced from 24 to 7, which will improve reliability and maintainability. The accompanying low-level RF control systems will also be refurbished. This project will be carried out over the next several years and divided into several subprojects as appropriate. Conversion to the new systems will be scheduled to occur during extended maintenance periods and should not impact the user programs.

201-MHz RF System

Each of four tanks of the 100-MeV Drift-Tube Linac (DTL) at LANSCE is presently driven by a tetrode intermediate power amplifier (IPA) and a triode final power amplifier (FPA). For 35 years, these gridded electron tubes were the only devices available to generate the requisite RF power for the IPA and FPA stages. This high average power causes anode dissipation as high as 75% of the manufacturer's rating (300 kW) for some of the FPA triodes. This is 90% of our protective shutdown limit, providing a very small margin for errors.

These amplifiers have become difficult to maintain at the consistently high reliability needed for operations. The tubes themselves have become increasingly unreliable as the vendor has lost the expertise necessary to produce reliable units.

In this project we plan to replace the IPA and FPA electron tubes with modern tubes which enable a greater operating margin in duty factor and peak power. Only seven power tubes will be needed, compared with the existing 24 power tubes, which will lower AC source power and cooling requirements.

The annual cost of operation for the new 201-MHz RF system will decrease. With the reduction of electron tube types, spares inventory will only require two types as compared to five with the old system. Downtime due to replacement procedures will be reduced.

RF Feedback Control Systems

The change in the 201-MHz FPA design necessitates a change to the RF cavity field controls. In order to realize the RF control refurbishment and corresponding changes to accelerator beam quality that is realized from improved field control in the low-energy part of the accelerator, we will change field control, DTL resonance control, and RF system reference.

The DTL field control system consists of phase and amplitude control and high-power protection systems. All of the control electronics will be replaced.

The development of the new DTL field controls will be done such that the design is also applicable to the Cavity Coupled Linac (CCL) field control system. These systems are all 30+ years old and are showing the effects of aging components in terms of reduced reliability and increased maintenance requirements. A single sector of CCL RF station will be refurbished with the new control system to demonstrate and ensure the performance. The DTL resonance control system and the system reference will be replaced.

805-MHz Klystrons

The original specification of klystrons for the CCL portion of the LANSCE linac pushed the operating range into new areas for both peak and average power. The original purchase was a total of 100 klystrons to be available for the 44 operating sockets in order to minimize downtime during the operating cycle. Figure 4 shows the 805-MHz RRF power system.

The operating lifetime of the klystrons turned out to be much better than originally expected. Today's problem is that LANSCE is still operating with its original klystrons. The 44 installed klystrons have an average of over 100,000 filament operational hours and an average of over 87,000 hours high-voltage operational hours. The number of available spares at this point is 11. We are very close to the end of life for the operational klystrons.

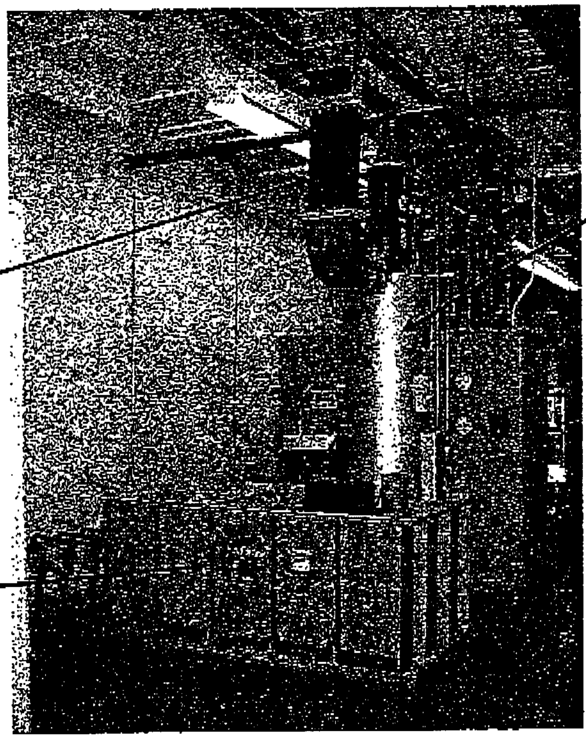


Figure 4. 805-MHz RF Power System.

The klystrons are arranged in five sectors with six klystrons each and two sectors with seven klystrons each. In this project, approximately half the klystrons for the 6-klystron sectors will be replaced. The klystrons removed from these sectors will be used as spares for the remaining sectors. Assuming we do not have excessive failures in the operational cycles prior to the replacements and that we can rebuild some of the failed klystrons, the remaining sectors should have an adequate spares base with these spares for continued operations for the next 10 years. Fifteen klystrons and four spares will be procured.

The existing klystrons have a DC-to-RF power-conversion efficiency of approximately 45%. The current commercially available klystron can now operate at 65% efficiency. This efficiency change has a significant impact on the AC power costs for the LANSCE accelerator: a savings of about $50K per klystron per year in operating costs. The replacement of 15 klystrons leads to a cost savings of $750K per year in AC power fees. Depending on the cost of the klystron and the rate of increase in electricity costs, the cost of installing the new klystrons is recovered in 5 to 8 years of operation.

High Voltage Distribution System

The existing LANSCE HV systems are in excess of 30 years old. The life expectancy of this class of high voltage equipment is between 25 and 30 years. Replacement parts are no longer available for a majority of the original distribution equipment because of changes and advancements in the hardware components. Predictive maintenance, in the form of dissolved gas analysis of the insulating oil indicates that of the seven sectors, five are indicating age-related degradation with dissolved gas levels in excess of the IEEE recommended maximums.

The maximum operating voltage of the existing HV system is 15 to 20% lower than the operating voltage required for the high efficiency klystrons discussed earlier. The high voltage system must be replaced to realize the efficiency gains in the klystrons.

Historically, the high voltage capacitor banks and associated hardware such as the crowbar have been a major source of downtime for the 805 MHz RF systems. New high voltage topologies are under consideration that would allow us to replace the capacitor banks and pulse the klystrons directly with high voltage. The direct pulsing of the klystrons would also allow us to eliminate 44 vacuum switch tubes from the existing modulator tanks. These switch tube are obsolete and the current supply of spares is diminishing.

Transmitter

The existing LANSCE klystron transmitters are more than thirty years old. Many replacement parts are obsolete. There has been considerable advancement in electronics technology and programmable logic controllers (PLCs) since the development of the LANSCE transmitters.

All of the transmitters in the five 6-klystron sectors and the transmitter in the RF test stand will be replaced to accommodate the new klystrons, for a total of 34 new transmitter systems. The removed transmitters will be used as spares for the remaining sectors, allowing for continued operation of the old transmitters for the next 10 years.

The high-voltage oil tank will be retained, but the equipment within the tank will be replaced with modern components. An original LANSCE filament transformer and its modern equivalent are shown in Figure 5.

Figure 5. An original LANSCE filament transformer and a modern SNS filament transformer.

Control Systems

This segment of the project will focus on replacing obsolete and nonmaintainable accelerator controls, data acquisition, and timing-system equipment that is critical to LANSCE operations. Software vital to the operation will be converted in association with the hardware replacement. This refurbishment will substantially reduce the risk of significant downtimes from these systems. This effort will be divided into subprojects that focus on specific subsystems and will require five years to complete.

The Remote Interface and Control Equipment (RICE) and timing-system replacement is driven by the need to replace antiquated hardware and software that has become virtually nonmaintainable. The primary criteria are to maintain existing functionality and to make improvements where economically and technically feasible. A commercially available PLC-based system will be implemented for the industrial class of hardware applications. Specialty hardware applications, mostly those related to beam diagnostics and timing, will be implemented in Experimental Physics Industrial Control System (EPICS) compliant platforms. As proposed, both software and hardware refurbishments, as proposed, will take advantage of developments in EPICS made at other DOE facilities and will provide flexibility for future changes.

Approximately half of the accelerator facility is run with software on VAX/VMS computers. The facility cannot be operated without this software. These computers are no longer manufactured, the manufacturer is no longer in business, and there is only limited support for hardware and software from the successor corporation. Following the modernization of the data-acquisition and timing-system hardware, the VAX/VMS computers can be decommissioned after approximately 40 programs and their associated support libraries are converted to run under EPICS.

Conventional Facilities
Several separate subprojects will be performed in areas that include electrical power distribution, HVAC systems, repairs to earthen radiation shielding, general structural repairs and hazard mitigation, fire protection and code compliance. All activities that require a lengthy beam outage for installation will be scheduled consistent with user program operations.

Nuclear Systems
Work will be performed to refurbish or improve the capability, reliability and monitoring of the 1L-target cooling and protection systems. Design and fabrication work will also be performed to produce a new 1L-target assembly. A spare module must be available, and we must anticipate the end of lifetime, so that we do not experience a failure during a run cycle. Should a complete failure occur without a spare TMRS, the entire run cycle (or fraction remaining) would be lost to the Lujan Center. Implementation will occur during the annual extended maintenance periods and will have little impact on the user programs.

Technical Requirements
In FY00, LANSCE surveyed the stakeholders to determine operational requirements. All of the stakeholders indicated that high availability and cost effectiveness were important. SC stated that a minimum of 85% availability was needed at an eventual 160 kW of beam power for 8 months per year of operation.

The following list contains the technical and programmatic objectives of this refurbishment project that we propose in order to meet the needs of the weapons program and to approach the requirements of the other stakeholders for a period of ten years.

The primary requirement is to enable the facility to deliver 6 to 8 months (approximately 4000–5000 hours, depending on operating funds) of beam to user programs each year with beam availability of at least 75% and no single-point failures that would result in a complete loss of operating capability for any one area during a run cycle.

Achieving this requires the following activities:

- Maintain high reliability of 805-MHz RF system by replacing klystrons, transmitters, high voltage power systems, and ancillary hardware with new and modern equivalents;
- Maintain and improve the reliability of the 201-MHz RF system by replacing power amplifier, IPA, and ancillary hardware with a modern system;
- Replace antiquated hardware and software in the accelerator controls, data acquisition, and timing systems that have become virtually nonmaintainable because of obsolescence;
- Substantially reduce the increasing amount of beam downtime contributed by failures in the vacuum and cooling systems for the accelerator and beam-transfer lines,
- Maintain reliability and provide much needed beam-tuning capabilities by refurbishments and additions to the beam-diagnostics systems;
- Remove the single-point TMRS failure point for the Lujan Center by designing and fabricating a spare;
- Maintain the reliability and monitoring of the 1L-target cooling and protection systems;

- Replace or refurbish conventional facilities including electrical power distribution, HVAC systems, and structures for which unreliability, lack of maintainability, wear-out, or code-compliance issues impact beam availability and/or cost of operation.

Technology Development

Most of the LANSCE accelerator systems were designed on the basis of technology available in the late 1960s and early 1970s. Thus, modern technologies are generally sufficient to achieve the primary objectives for the project: maintain beam availability with commensurate system reliability, eliminate obsolete systems, and enhance operational cost effectiveness. Accordingly, proven technologies can be implemented directly in most cases without the need for development and testing. The project will also benefit from research, development, and testing already completed for the SNS project. However, some development work is needed to ensure that the technologies incorporated will meet our goals for capability, reliability, and operational capacity. Development issues are nearly all straightforward; the known areas of concern already have test and evaluation programs underway as part of our normal operations program for maintaining and improving beam-delivery capabilities. For example, technical development is in progress for the new power-amplifier stages for the 201-MHz RF system. A review committee of experts from outside and within LANL evaluated and approved the design of the new system in 1997. The TH781 tetrode IPA stage is complete and tested. The TH628 Diacrode® FPA stage is still in development. Anode voltage blocking capacitors and parasitic-mode suppressors for the amplifier are in development. Additional mechanical engineering is required for the cooling design and mechanical linkages.

Acquisition Strategy

Accelerator Systems

Ion source and injector

Primary acquisition activities for the injector systems will be based on the proven performance and reliability of equipment demonstrated in the LANSCE Ion Source Test System.

Vacuum and water systems

Vacuum- and water-system installations and modifications will be determined by the LANSCE operating schedule and, consequently, will be staged to coincide with the yearly accelerator outages. As envisioned, the completion of the refurbishment of the LANSCE vacuum systems will be spread over five years.

Diagnostic system

Diagnostic-system installations and modifications will be determined by the LANSCE operating schedule and, consequently, will be staged to coincide with the yearly accelerator outages. As envisioned, LANSCE diagnostic systems will be refurbished over three or four years. Most planned refurbishments will either be extensions of systems developed for recent LANSCE projects, such as the IPF and the Switchyard Kicker, or will be duplicates of existing LANSCE systems. Items with long lead times, i.e., 10 to 12 months, will be planned for the outlying years.

Magnet power supplies

The number of magnet power supply vendors who make high-precision power supplies is very limited. The magnet power supply team will need to work closely with a coalition of suppliers to acquire this equipment.

RF Systems

Thales Electron Tubes is the only vendor that currently supplies Diacrode replacement tubes for the 201-MHz FPA. Following technical proof of concept, a first-item production FPA will be built. A production run of four complete systems for LANSCE will follow.

For klystron acquisition, a competitive procurement process will be used to select the provider of the new LANSCE tubes. We also may choose to split the order between two vendors if the costs are similar. This would develop a readily available second source, reduce schedule risk, and create competition for later orders for spare klystrons.

The transmitter and high voltage system acquisition would be based on the very successful SNS model, a performance specification and interface definition from the low bidder who meets the specification. The vendor pool would be restricted to bidders who have made similar equipment in the past and have a reputation for reliability, quality, and excellence in project management.

Control Systems

Hardware to replace the VAX computers is similar to that purchased for systems; no other hardware purchases are required.

The design cycle of the RICE and timing-system refurbishment will be greatly reduced by collaborating with the EPICS community. Development of the EPICS interface to the commercial programmable logic system (PLS) is already being tested an implemented at various accelerator facilities. Specialty hardware and accelerator-specific software application refurbishments will also make use of existing designs where available. Procurement of commercial hardware and software will be done using LANL Just-In-Time (JIT) vendors when appropriate. Fabrication of specialty hardware will be done by outside vendors using LANL specifications. All testing and installation of both hardware and software will be done by LANL.

Conventional Facilities

Design for major system refurbishments will follow standard Laboratory practices. For procurement of hardware, equipment, and other services, the acquisition strategy will concentrate on obtaining the highest-quality goods and services at the best price, on schedule, and with an acceptable level of program risk.

Nuclear Systems

Acquisition strategies for materials and services for all components of the 1L TMRS will comply with Laboratory and DOE requirements for nuclear facilities.

Resource Capability

All scientific, engineering, and technical personnel needed to accomplish this project are available in LANSCE, in the LANL workforce, in primary subcontractor to the Laboratory, or in private companies with long-standing records of successful collaboration on LANSCE projects. LANSCE has a history of successful implementation of large accelerator-design and construction projects; the most recent of these are the IPF and Switchyard Kicker projects, completed within the past year. Further, LANSCE has a several-year history of success during beam-outage periods in managing a complex set of projects for refurbishments and new capabilities together with maintenance and repair activities, all on the basis of integrated project management and tracking. The overall complexity of the LANSCE-R Project is comparable to this array of beam-outage activities. Essentially the same team of LANSCE, LANL, and subcontractor scientists, engineers, and technicians involved in these past activities will be available for the LANSCE-R Project.

Risks

An initial risk evaluation was developed by key project personnel using a subjective assessment of probability of occurrence and impact of consequences. A more rigorous and quantitative process of risk identification and assessment will be conducted in preparation of the project plan. Essentially the same team that has successfully planned and executed the array of project and maintenance activities for the last several beam outages will ensure that risks are at an acceptable level for the proposed project. Table 2 provides an overall summary of risk levels for the project, acknowledging that a high level of uncertainty is common in this phase of project planning.

Table 2. Preliminary Assessment of LANSCE-R Project Risk Categories

Risk Category	Qualitative Risk Level	Comments
Technical	Low – Moderate	Although the Lujan Center target is rather well understood, some amount of risk is associated with design changes and the Quality Assurance program required to build the new targets. The 201-MHz RF refurbishment could fail to meet the peak or average power requirements.
Programmatic	Low	The risk to the existing experimental programs is low. Much of the work will be performed during the extended maintenance periods each year. New hardware will be tested when possible prior to installation and only those components scheduled for the installation will be affected.
Schedule	Moderate – High	We need an early start to the procurement process to successfully complete a replacement TMRS.
Cost	Low – Moderate	A few items have moderate risk associated with cost. Although we have extensive experience building targets, our cost estimates are dated since they are based on the original 1996–1997 procurements. We procured many of the components for a second Lujan Center TMRS insert at the same time so there was an economy

		of scale. Estimates of software effort are notoriously difficult to make accurately, and should the present staff of VAX/VMS experts reach retirement age and depart, this will require extra costs to train new programmers on the old systems.
Procurement	Low – Moderate	For the Lujan Center TMRS, most components can be fabricated in standard machine shops. Electron-beam welding and laser welding are also readily available. However, there are some issues with capabilities for machining beryllium and cadmium plating. Also, any design changes required to implement new physics capability may require increased risk in procurement.
Environmental	Moderate	The activities proposed constitute a refurbishment of an existing, operating facility that will provide the same basic operational conditions as they currently exist. The proposed activities will be covered under the bounding conditions of the existing environmental impact statement. Refurbishment of beam line components may result in the generation of regulated waste streams, in particular low-level radioactive and low-level mixed waste. Operating experience will be combined with recognized waste minimization techniques to eliminate/reduce all waste streams. The moratorium on recycling of metals originating from locations that could have resulted in activation will result in on-site storage until disposal options are provided. Handling of lead (Pb) shielding articles, removed as a result of the refurbishment, will require additional control measures to ensure that opportunities for reuse/recycling are optimally used, as well as ensuring proper waste disposition takes place. There are no foreseeable situations that could result in generating a "no path forward" (no disposal option) waste stream. The proposed activities do not result in increased air emissions or water discharges.
Safety	Low	DOE-approved documented safety analyses (DSAs) are needed for the accelerator and nuclear facilities. Those documents are in preparation and will be approved before the start of the project. Any section of those DSA documents impacted by this project will need revision and approval by the

		DOE prior to operation. No major refurbishments to shielding are required; however, the degradation of shielding due to erosion in certain areas has been identified as a long-term concern. The facility will be operated under the same general procedures as before the project.

Preliminary Security Planning

Physical property protection already in place for the LANSCE accelerator facility is in accordance with LANL LIR 406-00-01, *General Security*, and the *FMU 4 Safeguards and Security Plan* for Technical Area 53. Access to the facility is controlled and limited to LANL or DOE badge holders and authorized visitors. Visits by foreign nationals are subject to the requirements of LANL LIR 406-00-01 Attachment 5, *Foreign Visits and Assignments*. Limited-access, secure satellite areas for classified activities are occasionally approved and set up in the LANSCE experimental areas and are not affected by the scope of this project. We foresee neither changes to security planning nor a need for security assessment funding.

Preliminary Environmental Strategy

The refurbishment of existing accelerator components and supporting infrastructure is anticipated to fall within the bounding limitations of the existing sitewide environmental impact statement. A review of project activities, conducted in the form of a NEPA Cultural and Biological screening, will be conducted to ensure that National Environmental Policy Act requirements are satisfactorily met. The results will be forwarded to DOE for review, and DOE will determine the need for further information and documentation. No other environmental issues are anticipated.

There are no specific waste-stream planning or management issues anticipated at this time. Waste minimization and pollution-prevention practices will be employed throughout the duration of the project to ensure that all appropriate opportunities to reuse and recycle materials are identified and utilized. Management of metal covered by the moratorium will be an on-going effort for the duration of the project. Waste-management activities will be included during the planning stages, as well as project execution phases, to ensure that all applicable regulatory requirements are met.

Preliminary Safety Determination

The LANSCE accelerator facility has been safely operated by LANL for over 30 years and is governed by the requirements of DOE O 420.2, *Safety of Accelerator Facilities*. The safety analysis for the accelerator is documented in the *Interim Safety Assessment Document for the LANSCE User Facility*, LANL TA-53-ISAD-007, approved by DOE in April 2002. A final safety assessment document is in progress and will be submitted to DOE by June 29, 2004.

The Lujan Center neutron-production target is a Category 3 nuclear facility per DOE STD 1027-92 and is operated under the *Basis for Interim Operation for the 1L Target*, 53-BIO-004, approved by DOE in March 2000. The basis for interim operation is being upgraded to a DSA per the requirements of 10 CFR 830 Subpart B and will be submitted to DOE by May 10, 2004.

Proposed Schedule and Cost

Preliminary Schedule Estimate

An initial schedule assessment indicates that all parts of the project can be completed by the end of FY13. In order to accomplish that goal, preliminary engineering development (PED) funding of $2.1M will be required in FY06 and that there will be a fully funded design and procurement start in early FY07. Figure 6 shows the major activities and anticipated time frames. Except during planned, annual beam outages, which are approximately four months in duration, the LANSCE beam delivery program is expected to be fully operational and supporting user programs during the entire duration of this refurbishment project.

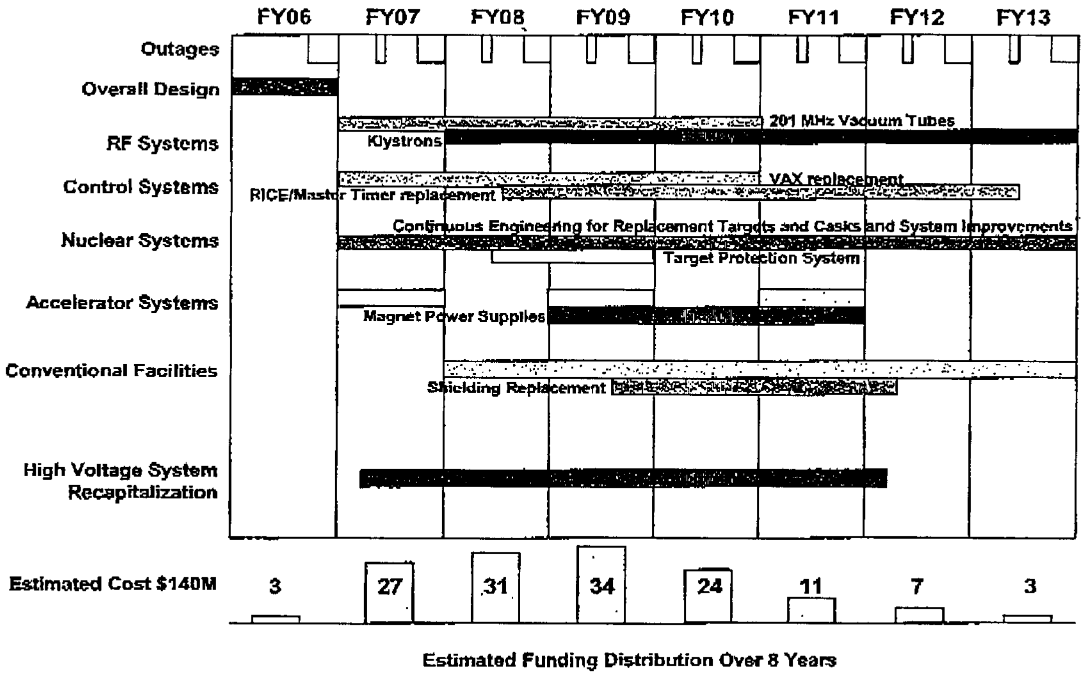


Figure 6. The LANSCE-R Project schedule, which assumes FY07 startup funding and FY06 PED funding will be available.

Preliminary Cost Estimates

An initial design cost estimate provided a total estimate at completion (TEC) of about $138M for the engineering, design, procurement, and fabrication for the various project segments. A top-level summary is provided in Table 3. These values include various levels of contingency, depending on the maturity of the technology, availability of components, and other factors. Contingency was applied to each subcost element based on experience and recent procurement and fabrication data and varied from 15% to 30%, depending on the degree of uncertainty, with an overall average of 18%. We assumed an escalation of 2.6% per year.

Table 3. Preliminary Summary of TEC

Description	Preliminary Estimate ($K)*
Accelerator Systems	$9,034
RF Systems	$37,873
Control Systems	$15,615
Conventional Facilities	$6,916
Nuclear Systems	$4,100
Burden and Escalation*	$34,416
Contingency**	$19,300
Project Management	$10,795
Total	**$138,049**

** Including 2.6% escalation* *** 18% aggregate contingency*

The table above does not include Other Project Costs (OPCs) and Preliminary Engineering & Design (PE&D) funds, which we estimate at $5.4M over the life of the project.

Organizational Interfaces

Project Oversight

The refurbishment of LANSCE will be managed with rigor appropriate to a line-item project of this magnitude. Figure 7 depicts the accountabilities for successful implementation of the LANSCE-R Project.

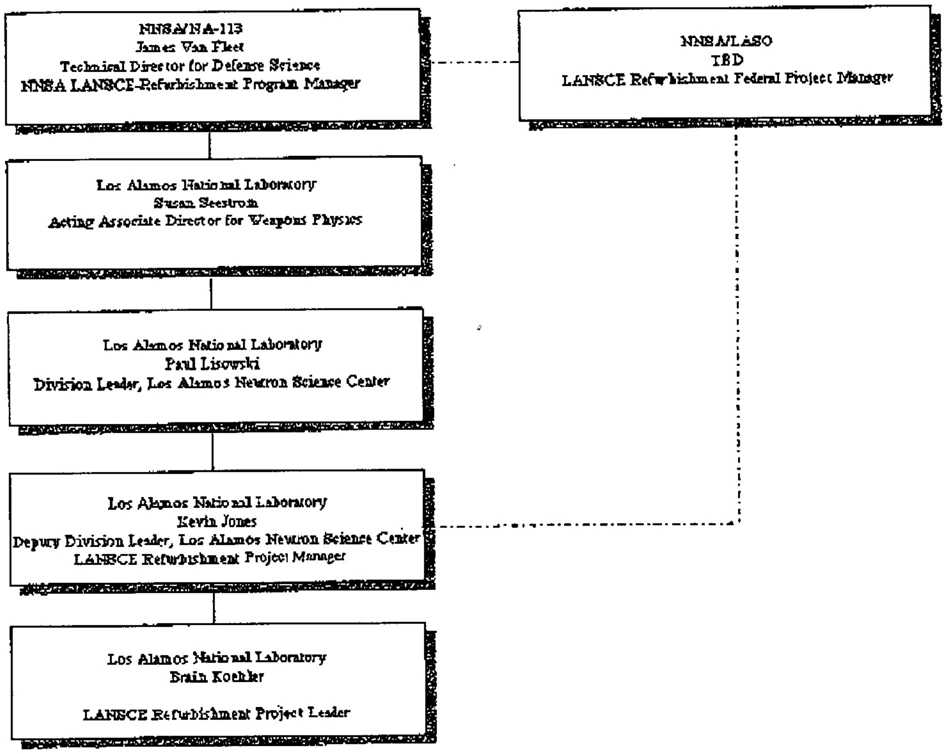


Figure 7. Primary responsibilities for management of the LANSCE-R Project.

Technical Organizational Interface

The majority of technical organizations involved in the execution of the LANSCE-R Project are within LANL. The scientific, engineering/design, and operational/installation organizations are all contained within LANSCE Division and the Facilities and Waste Operations Divisions. Environmental, safety, and health (ES&H) and safety interactions will be coordinated through the ES&H professionals in the Laboratory Health Safety and Radiation Protection Division, LANSCE Division, and the Los Alamos Site Office. The Los Alamos LANSCE-R project leader will be fully dedicated to the effort and will be the primary point of contact for the NNSA federal project manager.

ECOLOGY GROUP

LOS ALAMOS NATIONAL LABORATORY
Environmental Stewardship
ECOLOGY GROUP (ENV-ECO)
MAIL STOP M887
Los Alamos, NM 87545

Group Office Phone: (505) 665-8961
Group Office Fax: (505) 667-0731

FAX TRANSMITTAL SHEET

DATE: MAR. 2, 2005

TO: KIRK OWENS - SAIC

TO:

FAX #: 301-428-0145

FROM: SUSAN RADZINSKI - LANL

MESSAGE:

LANSCE-R

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