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1.0 INTRODUCTION

Operations in Tech Area IV commenced in 1980 with the construction of Buildings 980 and 981 and the Electron Beam Fusion Accelerator, which at the time was a major facility in SNL's Inertial Confinement Fusion Program. The Electron Beam Fusion Accelerator was a third-generation fusion accelerator that followed Proto I and Proto II, which were operated in Tech Area V. Another accelerator, the Particle Beam Fusion Accelerator I, was constructed in Tech Area IV because there was not enough room in Tech Area V, a highly restricted area that contains SNL's reactor facilities.

In the early 1980s, more fusion-related facilities were constructed in Tech Area IV. Building 983 was built to house a fourth-generation fusion accelerator, the Particle Beam Fusion Accelerator II, now called Z Machine, and Buildings 960 and 961 were built to house office space, electrical and mechanical laboratories, and highbay space for pulsed power research and development.

In the mid 1980s, Building 970 was constructed to house the Simulation Technology Laboratory. The main facility in the Simulation Technology Laboratory is the High-Energy Radiation Megavolt Electron Source (HERMES) III, a third-generation gamma ray accelerator that is used primarily for the simulation of gamma rays produced by nuclear weapons. The previous generations, HERMES I and HERMES II, had been located in Tech Area V.

In the late 1980s, Proto II was moved from Tech Area V to the Simulation Technology Laboratory and modified to function as an x-ray simulation accelerator, and construction of Buildings 962 and 963 began. These buildings comprised the Strategic Defense Facility, which was initially intended to support the nation's Strategic Defense Initiative or "Star Wars" program. It was to house a variety of pulsed power-related facilities to conduct research in such areas as directed-energy weapons (electron beams, lasers, and microwaves) and an earth-to-orbit launcher. With the reduction of the Strategic Defense Initiative budget in the early 1990s, however, many of these programs were discontinued and some, such as the High Power Microwave Laboratory and the Repetitive Pulsed Power Laboratory, were established.

By 1990, all the Tech Area V accelerators had either been moved to Tech Area IV or decommissioned, and Tech Area IV had become the center for SNL's pulsed power sciences activities. The early 1990s saw an infusion of programs into Tech Area IV that support DOE goals in defense, industrial competitiveness, and the environment. A computer sciences group moved into Building 980, and a group that prepares rocket payloads for flight tests moved into one of the highbays in Building 963. A robotics group moved into Building 966, and a number of diverse groups occupy office and laboratory space in Building 962.

The operations and activities taking place in Tech Area IV are diverse. Although the dominant activity is related to pulsed power technology, other areas of activity include computer science, flight dynamics, satellite processing, and robotics. All Tech Area IV capabilities fall into the basic categories of scientific research, development, and testing. More specifically, these capabilities include the following:

- Ability to integrate experimentation and computational simulation in support of radiation effects testing, radiation transport, diagnostics, and analyses to certify that electronic components and weapons systems will operate in hostile radiation environments over time as the stockpile ages.
- Reliability, survivability, and performance testing of nuclear weapon systems by generating short bursts of x-rays and gamma rays to simulate environments that would be produced by nuclear weapon detonation.
- Advanced materials research, development, testing, and evaluation through studies of x-rays effects in test materials and electronics.
- Weapons and defense systems improvements.
- Physical simulations of conditions (for example, exoatmospheric environments) to evaluate the design and development of navigation, guidance, and control systems that enhance both the accuracy and survivability of nuclear weapon delivery systems.
- Research on robots that are vital in the manufacture of new nuclear weapon components and the cleanup of radioactive and hazardous waste at former DOE nuclear weapons sites.
- Research facilities to enhance satellite surveillance capabilities in hostile radiation environments, whether encountered in space or created by nuclear detonations.
- Research and development of new commercial and defense-related applications, such as material processing, waste and product sterilization, mine detection, and food purification.
- Advanced pulsed power development, including the design and qualification of pulsed power components; target diagnostics; and the operation, maintenance, and technology advancement of pulsed power facilities.
- Characterization and demonstration of the utility of pulsed power-generated soft x-ray sources for weapons physics and inertial confinement fusion experiments to ensure the reliability and performance of nuclear weapons without underground testing.

Generally, accelerators are devices that electromagnetically accelerate atomic-size particles such as electrons, protons, and ions. The accelerators used in Tech Area IV are based on pulsed power technology and are called pulsed power accelerators. Pulsed power accelerators are single-shot devices that accelerate large numbers of particles in a very short period of time. Because power is defined as energy over time, these accelerators are considered high-powered. The HERMES III accelerator, for example, can generate a 350-kilojoule (kJ) pulse of electrons in 20 nanoseconds or 17 terawatts (TW) (17 x 1,012 watts) of power. However, because these machines have a low shot rate (sometimes only one per day), the average power generated is typically very low. One of the areas of research being conducted in Tech Area IV is to increase the shot rate, or repetition rate, of these accelerators for applications that require high average power.

The Tech Area IV pulsed power accelerators compress (in time) an electrical pulse by transferring a high percentage of the energy while shortening the pulse. For most accelerators in Tech Area IV, Marx generators are the primary power sources. Marx generators are arrays of capacitors that are charged in parallel and discharged in series, which allows the use of a relatively low-voltage DC power supply to generate a high-voltage pulse. The pulse generated by the Marx generator is then transferred through a chain of capacitors, pulse-forming lines, and switches that progressively shorten and shape the pulse. Finally, the pulse arrives at the "load," where it can be used for a variety of applications. In some accelerators, many of these chains are tied together in parallel, usually in a radial configuration, to get more energy to the load. Both the Z Machine and Saturn are configured in this way. HERMES III is configured in the series mode. The Repetitive High Energy Pulsed Power II accelerator uses a 750-kilowatt (kW) power supply, seven stages of magnetic pulse compression, ten stages of linear induction voltage addition, and a vacuum diode in its configuration.

The pulsed power research and development in Tech Area IV covers both the pulsed power technology itself and the applications. The desire to create controlled fusion for commercial power generation initially motivated the development of pulsed power technology. Later, the same technology was used to generate x-rays and gamma rays for weapons testing. New uses for pulsed power technology are continually being explored. Usually, any particular application will require some modification to existing devices; consequently, knowledge is added to the pulsed power technology base. Many applications such as materials hardening and sterilization have resulted in the development of high-power, high-repetition-rate accelerators. The current and planned Tech Area IV accelerators represent a range of possible future research that could occur at SNL/NM.

2.0 Z MACHINE SOURCE INFORMATION

2.1 Purpose and Need

The Z Machine is a multi-use facility supporting the Inertial Confinement Fusion Program and the High-Energy/Density Physics Program for stockpile stewardship. Operating on the principle of pulsed power, the Z Machine stores electrical energy over a period of minutes then releases that energy in a concentrated burst. The accelerator produces a single, extremely short, extremely powerful pulse of energy that can be focused on a target (Harris and Sullivan, 1996).

2.2 Description

The Z Machine, formerly known as the Particle Beam Fusion Accelerator II, is located at Tech Area IV, Building 983. The facility includes the accelerator highbay (mezzanine, 0-ft level, 10-ft level, and 25-ft level), support area highbays 983B and 983C, laser and facility support systems (12-ft level), water and oil tank farms, lowbay light labs and the control room, and the gas house (Building 983A). The Z Machine is in a tank that is 108 ft in diameter and 20 ft in height and that contains 540,000 gal of transformer oil, 600,000 gal of deionized water, and a vacuum chamber. Transfer lines for moving transformer oil from storage tanks to the accelerator are located underground nearest the tanks and in a below-grade trench that provides spill containment prior to entering Building 983.

The primary operating mode of the Z Machine produces a pulse that lasts 60 nanoseconds with approximately 3.0 megajoules (MJ) of electrical energy and a peak power of 50 TW. The mission of the Z Machine is as a multi-use facility supporting the Internal Confinement Fusion Program and the High-Energy/Density Weapons Physics Program for stockpile stewardship. The Z Machine currently has three operational modes:

- The historical radial diode mode for internal confinement fusion
- PBFA II X for extraction diode mode for internal confinement fusion
- Z for z-pinch, low-voltage, high-current mode for High Energy/Density Physics Program activities and Internal Confinement Fusion Program activities

The accelerator is located in a tank approximately 33 m (108 ft) in diameter and 6 m (20 ft) high. The tank is divided into three annular regions. The outer annulus, which is approximately 5 m (17 ft) wide, contains transformer oil. The oil is high-voltage dielectric material that prevents electrical breakdown when the accelerator is charged. The middle annulus is approximately 10 m (31 ft) wide and contains deionized water as the dielectric medium for pulse-forming components. Approximately 2,043,900 l (540,000 gal) of transformer oil and 2,271,000 l (600,000 gal) of deionized water fill the outer annulus and middle annulus, respectively.

Upgrades planned for the facility would increase the operating parameters described above, enhance the facilities utility, and ensure continuity of a high-quality experimental facility.

(Harris and Sullivan, 1996; U.S. Department of Energy, 1996)

2.3 Program Activities

Table 12-1 shows the program activities at the Z Machine.

Table 12-1. Program Activities at the Z Machine

Program Name	Activities at the Z Machine	Category of Program	Related Section of the *SNL Institutional Plan*
Experimental Activities	The PBFA II, modified in 1996 to drive a z-pinch source, is now referred to as the Z Machine. The Z Machine generates cold and warm x-ray environments to simulate exoatmospheric threat conditions. It will be used to conduct experiments on the response of materials, components, and subsystems to x-ray radiation.	Programs for the Department of Energy	Section 6.1.1.1
Performance Assessment Science and Technology	Develop advanced pulsed power sources for weapon effects testing and weapon physics experiments.	Programs for the Department of Energy	Section 6.1.1.1

Table 12-1. Program Activities at the Z Machine (Continued)

Program Name	**Activities at the Z Machine**	**Category of Program**	**Related Section of the *SNL Institutional Plan***
Inertial Confinement Fusion	The PBFA II had its first shot in early fiscal year 1986 (FY86). Until FY96, efforts were directed toward light ion fusion research. The primary effort at present and for the next ten years is to use the accelerator (renamed Z), as a 20-mega-amp (MA) z-pinch driver. Modifications made in the summer of FY96 redirected the electrical output of the 36 pulse-forming lines. The experimental program for Z addresses issues related to high-energy/density for weapon physics, weapon effects, and inertial confinement fusion. The research includes studies of pulse shaping, radiation flow, equation of state and opacity measurements, hydrodynamic instabilities, and capsule implosion physics using wire-array z-pinch loads. Future experiments may be done with deuterium to produce thermonuclear neutrons.	Programs for the Department of Energy	Section 6.1.1.2
Pulsed Power Technology	Provide high-intensity, large-area x-ray radiation environments for certification of DOE and Department of Defense systems. Also provide high-temperature, large-volume hohlraums and cold x-ray environments for weapon physics and internal confinement fusion applications. The multiprogram applications have been complementary over the years in developing a more capable pulse power source and then applying it to problems such as radiation flow in weapon systems.	Major Programmatic Initiatives	Section 7.1.6

2.4 Operations and Capabilities

The Z Machine includes the accelerator highbay (mezzanine, 0-ft level, 10-ft level, and 25-ft level), support area highbays 983B and 983C, laser and facility support systems (12-ft level), water and oil tank farms, lowbay light labs and the control room, and Building 983A, which houses specialty gas handling systems. The Z Machine consists of 36 modules arranged radially around a central experiment vacuum chamber. The accelerator is located in a tank that is approximately 108 ft in diameter and 20 ft high. The tank is divided into three annular regions. The outer annulus (approximately 17 ft wide) contains ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material that prevents electrical breakdown when the accelerator is charged. The middle annulus (approximately 31 ft wide) contains deionized water as the dielectric medium for pulse-forming components. Approximately 540,000 gal of transformer oil and 600,000 gal of deionized water fill the outer annulus and middle annulus, respectively. The vacuum insulator stack (VIS) is located at the center of the accelerator and contains magnetically insulated transmission lines (MITLs) and experimental hardware. The oil section contains 36 5.7-MV, 360-kJ Marx generators and nine 50-kilovolt (kV) Marx trigger generators. The water section contains 36 intermediate storage capacitors, 36 laser-triggered gas switches, and 36 pulse-forming lines (PFLs). The PFLs feed electrical pulses into the VIS, where the MITLs transport the energy to the diode region of the accelerator. The primary operating mode of Z produces a pulse that lasts 60 nanoseconds with approximately 3 MJ of electrical energy and a peak power of 50 TW. In radial diode mode, the ion diode is located at the exact center of the accelerator. In extraction diode mode, the ion diode is located in the basement of Building 983 directly under the VIS. During normal extraction diode and radial diode operation, the Z accelerator system produces an ion beam consisting of electrons, protons, or lithium +1 (Li+1) ions.

The routine operational work year for the Z Machine is 42 weeks. The 42-week year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 7 weeks of facility maintenance and experiment setup time. Should program requirements increase, additional staff would be required to expand the operational work year to 52 weeks. This level of operation is based on 42 weeks of operation at current power levels. If power levels are increased, this could result in changes to projected levels of operations, material inventory, and consumption.

Plans for upgrading the Z Machine are discussed below. Some of these upgrades would be to increase the outputs of specific components that have been discussed above (for example, Marx voltage and energy output). All the upgrades would involve increasing the total output energy.

The Z Machine serves as a principal experimental facility for the DOE Stockpile Stewardship Program. The intent of a modernization of the Z Machine is to ensure continuity of a high-quality experimental facility for critical weapon science experiments for validation of advanced computer models and certification of stockpile systems. In addition, the results of testing facilitated by these upgrades will support the development of specific design parameters of the X1 Accelerator. The modernization will improve the reliability of all mechanical components, upgrade the data acquisition system, and install a modern suite of diagnostics.

Many of the basic pulsed power components in the Z Machine were designed approximately 15 years ago. Using today's knowledge and understanding to modernize the Z Machine will significantly improve its utility by replacing aging components with new, more reliable components. Modernizing the pulsed power components will also enable the Z Machine to produce up to 50 MA in driving current and up to 10 MJ of x-ray energy for DOE weapons science experiments. This will also enable further temperature scaling data and more robust weapon physics and radiation effects experiments.

(Harris and Sullivan, 1996)

2.5 Hazards and Hazard Controls

2.5.1 Offsite Hazards to the Public and the Environment

The Z Machine contains a small chemical inventory and a small radioactive material inventory that cannot be dispersed outside the facility. Thus, the facility presents no potential offsite consequences to either the public or the environment from accidents (Harris and Sullivan, 1996).

2.5.2 Onsite Hazards to the Environment

The accelerator oil tank and the oil storage tank farm contain 750,000 gal of a reduced-flammability grade of transformer oil (ANSI/ASTM D3487, Type II) that is classified as a combustible liquid, having a British thermal unit (BTU) content of 19,400 BTU/lb and a flash point of 300° F. The concentration of polychlorinated biphenyls (PCB) in the oil is limited to less than 50 parts per million. Based on previous operating experience and on engineering and fire protection testing, certain design and operating criteria have been established for the Z Machine to minimize the possibility of an oil fire. In particular, all electrical connections and routing in the annular oil tank are well beneath the surface of the oil, and the oil surface is open and without any potential wicks.

2.5.3 Onsite Hazards to Workers

The following have been identified as potential worker hazards at the Z Machine:

- **Ionizing Radiation** - The Z Machine produces ionizing radiation in the diode region in the form of intense prompt radiation and activation products from beam interactions. Radionuclides produced are short-lived and typically decay by positron emission. Gamma and beta decay are very minimal. The primary activation products are zinc-65 (Zn-65), cobalt-56 (Co-56), manganese-54 (Mn-54), and sodium-22 (Na-22).

- **Marx Generators** - The prime energy storage components of the accelerator.

- **Solvents** - Used to clean accelerator parts. Includes isopropyl alcohol and hexanes (a mixture of isomeric forms of hexane).

- **Dilute Copper Sulfate Solution ($CuSO_45H_2O$)** - Used to fabricate high-power resistors for the Marx generators.

- **Sulfur Hexafluoride (SF_6)** - Used as an insulating gas in spark gaps and switches in the oil and water sections of the accelerator. Pure SF_6, although chemically and physiologically inert, does not support respiration in enclosed areas. When subjected to high-voltage discharge, some breakdown occurs and the byproducts that form are corrosive and somewhat toxic. Used SF_6 that has not been passed through a purifying reclaimer would represent a fugitive emission and inhalation hazard to personnel and could damage sensitive equipment. However, the reclaimer removes these hazards. The reclaimer filters are disposed of as hazardous waste materials on a schedule of about one per year. The majority of the SF_6 is stored next to Building 983 in torpedo tube tanks with additional amounts stored within the reclaimer, piping, gas switch, the D4 (a liquid tank) and D2 (a vapor tank), and the Marx generator. The total maximum amount on hand within each of these areas is estimated at 35,695 lb, or 3,909 ft^3.

- **Helium Fluoride (He/F_2) (95/5) Gas** - Used in individual cylinders to supply the KrF Excimer laser.

- **Argon Gas (Ar)** - Used in individual cylinders as a pressurization gas in the vacuum insulator stack.

- **Nitrogen Gas (N)** - Used for laser operations, Marx swing arms, vacuum cryocoil, and as a purge gas.

- The Laser Trigger System.

- The Laser Ionization Based on Resonant Saturation (LIBORS) System.

- The Neodymium Laser Subsystem.

2.5.4 Hazard Controls

The following are hazard controls at the Z Machine:

- **Radiation Shielding** - Protects personnel from the neutron and bremsstrahlung radiation emitted during accelerator operations. The shielding is designed to meet neutron attenuation requirements. When neutrons are to be propagated (historical radial diode mode only), high-density concrete blocks are placed in the highbay access-controlled area to shield any neutron radiation that is produced. During neutron-producing shots, access to the areas where a neutron beam would exist is controlled by means of the Z Machine access control system. During neutron shots, shielding is provided through the use of boron polyethylene, and water, and by limiting access. Additional hazards as a result of facility upgrades would be primarily in radiation output. Increasing the current output of the accelerator would increase the amount of radiation output from the machine. This hazard will be mitigated through new shielding that will be part of the facility upgrade design.

- **Access Control System** - Consists of lockable doors and gates, access stations with status indicators, rotating beacons, audible alarms, the control monitor computer (with operator interface), and the facility public address system. Access control to all areas of the facility is maintained by fences and gates with locking mechanisms, closed-circuit television, and physical inspection and clearing procedures. During the critical period of charging and firing, the accelerator systems are interlocked with the access control system such that any breach automatically disables all systems and places the accelerator in a safe state. Well-defined permissive access criteria allow access to secure areas for troubleshooting and maintenance activities while high-voltage systems are energized.

- **Electrical Safety** - Enhanced for work on the Marx generators by a manually operated mechanical shorting system. The system consists of ten vertical shorting bars that extend from the top of a hanging frame to the bottom of each Marx generator. When inserted, each vertical bar grounds the center terminal of all the capacitors in a Marx generator column. Electrical safety features would be enhanced as a component of any upgrade to the Z Machine.

- **Secondary Oil Containment System** - Any leakage from the Z Machine oil tank will be collected and contained in a series of concrete trenches that are located throughout the inside of Building 983. Similarly, the concrete walls around the three aboveground oil storage tanks serve as secondary containment structures in the event of an oil storage tank rupture. The oil transfer system, with the exception of approximately 200 ft of underground pipe, is located within these secondary containment structures.

- **Confined Space Safety** - The oil and water tanks of the accelerator and the laser alcove constitute confined spaces for the Z Machine. Confined space safety is maintained by oxygen deficiency monitoring and adherence to confined space procedures. In addition, because of the toxicity associated with 5 percent fluorine in the laser alcove, a continuously ventilated gas cabinet is used for He/F2 cylinder storage.

- **Tritiated Water** - Personal communications have confirmed that analytical results of grab water samples taken in 1994 from the pulse warming network and a basement sump located in Building 983 detected low levels of tritium. Three separate laboratories confirmed these results. The average results were all determined below DOE derived concentration guidelines (DOE O 5400.5), as well as Nuclear Regulatory Commission (10 CFR 20), and State of New Mexico (20 NMAC 3) regulatory radiological activity limits. For additional information, see the Biswell (1994). IT Corporation performed the sampling for Mr. Adrian Jones, Sandia National Laboratories, Project No.301455.100.03.

(Harris and Sullivan, 1996)

2.6 Accident Analysis Summary

2.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the Z Machine and through discussions with operations personnel. The Z Machine contains only small chemical and radioactive material inventories that cannot be dispersed outside of the facility (Harris and Sullivan, 1996).

The operating events selected for qualitative risk analysis were the following:

- Worker electrocution while "safing" Marx generator capacitors
- Worker radiation exposure during accelerator operation
- Worker asphyxiation from an unexpected release of N_2 into the VIS
- Fire involving insulating oil

These events are considered to be the bounding accidents that define the safety envelope for facility operations. The accident analysis for the Z Machine also included natural phenomena event scenarios that are generic to all facilities at SNL/NM, as well as aircraft crash and external oil spill scenarios.

The facility accident analysis did not address standard industrial accidents (for example accidents that involve hazards such as cranes and hoists, forklifts, lasers, and compressed gases) that are addressed by existing consensus standards for accident prevention and mitigation.

2.6.2 Analysis Methods and Assumptions

The methodology used to perform the Z Machine accident assessment (see Mahn *et al.*, 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-2. In addition, a generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency, together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities, as provided in Mahn *et al*. (1995), were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-2. Consequence Categories and Levels of Severity

Rank	**DOE/AL 5481.1B**	**Human Impact**	**Environmental Impact**	**Programmatic Impact**
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year

Table 12-2. Consequence Categories and Levels of Severity (Continued)

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

2.6.3 Summary of Accident Analysis Results

The results of the Z Machine accident assessment are summarized in Table 12-3.

Table 12-3. Results of the Z Machine Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Unlikely (B)
Fire	Marginal (III)	Incredible (D)
Asphyxiation	Catastrophic (I)	Extremely unlikely (C)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Critical (II)	Extremely unlikely (C)
External oil spill	Critical (II)	Extremely unlikely (C)

Tables 12-4 and 12-5 were obtained from DOE/AL 5481.1B and provide definitions for terms used in "2.6 Accident Analysis Summary."

Table 12-4. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or provide a significant impact on the environment.

Table 12-5. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year		

(Harris and Sullivan, 1996)

2.7 Reportable Events

Table 12-6 lists the occurrence reports for the Z Machine over the past five years.

Table 12-6. Occurrence Reports for the Z Machine

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-1000PBFA-1993-0001	Blowout of Barnstud Water Resistivity Monitor	1F	A resistor was inadvertently left in position during a high-voltage test.
ALO-KO-SNL-1000PBFA-1993-0003	Personnel Contamination	4B	A contractor contaminated both his hands with activation products.
ALO-KO-SNL-1000PBFA-1993-0002	Near Miss Resulting from a Falling Piece of Equipment	1F	Two contractors were repairing a cathode tip from the PBFA when the 350-lb tip fell seven feet to the floor. No one was injured.

Table 12-6. Occurrence Reports for the Z Machine (Continued)

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-1000PBFA-1994-0001	Personnel Contamination	4B	A technician contaminated his hand by grabbing a piece of contaminated equipment.
ALO-KO-SNL-1000PBFA-1995-0003	Personnel Contamination	4B	A technician was contaminated in excess of 5,000 disintegrations per minute per 100 cm^2 by inappropriately entering the center section of PBFA Z.
ALO-KO-SNL-9000-1997-0011	Fluorine Ventilation System Motor Failure	1H	A fluorine ventilation system motor failed.
ALO-KO-SNL-9000-1998-0007	Incorrectly Followed Procedure Results in Fluorine Gas Release	1F, 10B	A small amount (106 mg) of fluorine gas was released into the laser alcove in Building 983.

2.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for fiscal year (FY) 1996 unless otherwise noted.

2.8.1 Activity Scenario for Test Activities: Accelerator Shots

2.8.1.1 Alternatives for Test Activities: Accelerator Shots

Table 12-7 shows the alternatives for accelerator shots at the Z Machine.

Table 12-7. Alternatives for Test Activities: Accelerator Shots

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
84 shots	150 shots	300 shots	300 shots	350 shots

2.8.1.2 Assumptions and Actions for the “Reduced” Values

The estimates of activity levels projected across each of the scenarios include a series of shots using tritium, deuterium, plutonium-239, and depleted uranium. The use of these materials would represent a new activity for the Z Machine. The remainder of the shots would not involve the use of these materials but would be in support of other experimental programs, performance assessment, and development of advanced pulsed power technology and inertial confinement fusion applications.

Over the FY2003 and FY2008 timeframes of the no action alternative, the mix for numbers of nuclear material target shots by material would be as follows:

- Tritium: 50 shots per year
- Deuterium: 75 shots per year
- Plutonium-239: 20 shots per year
- Depleted uranium: 20 shots per year

The total combined nuclear material shots per year is 165 shots; all remaining shots (approximately 135) would be in support of other experimental programs, performance assessment, and development of advanced pulsed power technology and inertial confinement fusion applications.

The 84 shots is the expected output from a minimal crew firing the accelerator two times per week for 42 weeks and would include no nuclear material target testing.

2.8.1.3 Assumptions and Rationale for the “No Action” Values

The 150 shots in the base year is an average of FY1996 and FY1997 because the facility was upgraded during FY1996 and because that year's number of shots is not representative of the full capability. The Z Machine accelerator shots are taken in support of the programs listed in “2.3 Program Activities.” For future years, the facility is expected to operate at close to full capacity. The FY2003 and FY2008 values of 300 shots assume two to three shifts for five days per week. The number of shots represented in the inventories in “2.8.2 Material Inventories,” are only a small number of the total shots at the facility. These shots will be wire-array and target shots.

Activities under the “no action” alternative include upgrades that will improve the reliability of all mechanical components, improve the data acquisition system, and provide a modern suite of system diagnostics. These upgrades will likely occur without major reconfiguration of the accelerator and without major additional funding (funding will be available through incremental annual funding). See Sections 2.3.1, 2.4.1, and 2.4.2 of *Environmental Assessment for Operations, Upgrades, and Modifications in SNL/NM Technical Area IV* (U.S. Department of Energy, 1996).

A backlighter laser system designed by Lawrence Livermore National Laboratory will also be installed during the “no action” timeframes. The backlighter laser system is an x-ray backlighting source for diagnosing targets and high energy/density experiments at the Z Machine, and it was categorically excluded from environmental assessment requirements on April 8, 1998.

2.8.1.4 Assumptions and Actions for the "Expanded" Values

The value of 350 shots in the "expanded" alternative is the maximum number expected in a year to support 24-hour per-day, seven-day-per-week operations.

The following are the projected number of shots in the expanded alternative that use nuclear material:

- Tritium: 75 shots per year
- Deuterium: 100 shots per year
- Plutonium-239: 50 shots per year
- Depleted uranium: 50 shots per year

The total combined shots per year that use nuclear material is 275; the remainder of the shots (approximately 75) would not involve the use of these materials but would be in support of other experimental programs, performance assessment, and development of advanced pulsed power technology and inertial confinement fusion applications.

Activities under the "expanded" alternative include upgrades to pulsed power components that would increase the current capacity of the Z Machine and enable the accelerator to produce up to 50 MA in driving current and 10 MJ of x-ray energy. Reconfiguration and upgrades to modernize the accelerator could require as much as $40 million in additional funding.

2.8.2 Material Inventories

2.8.2.1 Nuclear Material Inventory Scenarios

2.8.2.1.1 Nuclear Material Inventory Scenario for Tritium

Alternatives for Tritium Nuclear Material Inventory - Table 12-8 shows the alternatives for tritium nuclear material inventory at the Z Machine.

Table 12-8. Alternatives for Tritium Nuclear Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 Ci	0 Ci	1,000 Ci	1,000 Ci	50,000 Ci

Operations That Require Tritium - Tritium experiments at the Z Machine would represent a new activity. Tritium would be stored on site in targets used for Internal Confinement Fusion Program target experiments. Approximately 50 shots per year will be experiments that involve the use of tritium. No more than 1,000 Ci would be in inventory at any one time because this is the upper level for nuclear facility classification per U.S. Department of Energy (1992).

Basis for Projecting the "Reduced" and "Expanded" Values - In the "reduced" alternative, no experiments using tritium would be conducted. In the "expanded" alternative, actual target filling could be done on site so that there could be a resident tritium inventory stored on U-beds. Approximately 75 shots per year would be experiments that involve the use of tritium. Also, no more that 50,000 Ci of tritium would be in inventory at any one time. This hypothetical inventory has not considered requirements for nuclear facility hazard class 3 classification.

2.8.2.1.2 Nuclear Material Inventory Scenario for Deuterium

Alternatives for Deuterium Nuclear Material Inventory - Table 12-9 shows the alternatives for the deuterium nuclear material inventory at the Z Machine.

Table 12-9. Alternatives for Deuterium Nuclear Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 l	0 l	1,000 l	1,000 l	5,000 l

Operations That Require Deuterium - Deuterium in Internal Confinement Fusion Program target experiments (handled as a gas) would represent a new activity. Approximately 75 shots per year will be conducted that involve the use of deuterium. No more than 1,000 l of deuterium will be in inventory at any one time.

Basis for Projecting the "Reduced" and "Expanded" Values - The "reduced" value assumes no deuterium experiments; the "expanded" value assumes a full #2 cylinder in the inventory. For the "expanded" value, approximately 100 shots per year would involve the use of deuterium. No more than 5,000 l of deuterium will be in inventory at any one time.

2.8.2.1.3. Nuclear Material Inventory Scenario for Plutonium-239

Alternatives for Plutonium-239 Nuclear Material Inventory - Table 12-10 shows the alternatives for the plutonium-239 inventory at the Z Machine.

Table 12-10. Alternatives for Plutonium-239 Nuclear Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 mg	0 mg	200 mg	200 mg	200 mg

Operations That Require Plutonium-239 - Plutonium used for equation-of-state measurement experiments would represent a new activity. Approximately 40 mg of Pu-239 per shot would be used. A total of 200 mg would be in inventory at any one time. A total of 20 shots per year that use Pu-239 would be done.

Basis for Projecting the "Reduced" and "Expanded" Values - For the "reduced value," no Pu-239 experiments would be conducted. For the "expanded" value, it is expected that no more than a four-shot series amount of Pu-239 would be in inventory at any one time. A total of 50 shots per year that involve Pu-239 would be done.

2.8.2.1.4 Nuclear Material Inventory Scenario for Depleted Uranium

Alternatives for Depleted Uranium Nuclear Material Inventory - Table 12-11 shows the alternatives for the depleted uranium nuclear material inventory at the Z Machine.

Table 12-11. Alternatives for Depleted Uranium Nuclear Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 mg	0 mg	200 mg	200 mg	200 mg

Operations That Require Depleted Uranium - Depleted uranium used for equation-of-state measurement experiments would represent a new activity. Approximately 40 mg of depleted uranium per shot would be used. A total of 200 mg would be in inventory at any one time. A total of 20 shots per year that use depleted uranium would be done.

Basis for Projecting the "Reduced" and "Expanded" Values - For the "reduced" value, no depleted uranium experiments would be conducted. For the "expanded" value, it is expected that no more than a four-shot series amount of depleted uranium would be in inventory at any one time, which is equal to 200 mg. A total of 50 shots per year that use depleted uranium would be done.

2.8.2.2 Radioactive Material Inventory Scenario for Activated Hardware

2.8.2.2.1 Alternatives for Activated Hardware Radioactive Material Inventory

Table 12-12 shows the alternatives for activated hardware inventory at the Z Machine.

Table 12-12. Alternatives for Activated Hardware Radioactive Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
2,000 kg	50,000 kg	10,000 kg	10,000 kg	10,000 kg

2.8.2.2.2 Operations That Require Activated Hardware

For the base year (FY1996), the Z Machine was operating in ion diode mode in which activation was an every-shot event. The amount of radioactive material represents approximately 50,000 kg (approximately 55 tons) of material and includes accelerator center section components. In the current operating mode, activation is less frequent, and therefore a reduced inventory is already in place. The reduction from the base year to FY2003 is represented by removal of a significant portion of the hardware to storage and some likely reclassification as low-level waste.

2.8.2.2.3 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value represents two tons of material because some slight component activation is currently happening. For the “expanded” value, the experiments involving the nuclear materials discussed in “2.8.2.1 Nuclear Material Inventory Scenarios,” are taken into account. This value is still less than that of the base year because activation of components is different in the z-pinch mode than in the ion diode mode, which is represented in 1996.

2.8.2.3 Sealed Source Inventory Scenarios

The Z Machine has no sealed source inventories.

2.8.2.4 Spent Fuel Inventory Scenarios

The Z Machine has no spent fuel inventories.

2.8.2.5 Chemical Inventory Scenarios

2.8.2.5.1 Alternatives for Chemical Inventories

Table 12-13 shows the alternatives for the chemical inventories at the Z Machine.

Table 12-13. Alternatives for Chemical Inventories

Chemical	Reduced Alternative	No Action Alternative			Expanded Alternative
		Base Year	FY2003	FY2008	
Fluorine 5% in neon	4.2 lb	7.5 lb	5.1 lb	5.1 lb	10.5 lb

2.8.2.5.2 Operations That Require Chemical Inventories

The programs and operations that utilize these chemicals are described in detail in “2.2 Description,” “2.3 Program Activities,” and “2.4 Operations and Capabilities.”

2.8.2.5.3 Basis for Projecting the Values in the “No Action” Columns

Baseline values for the chemicals listed in Table 12-13 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

2.8.2.5.4 Basis for Projecting the Values in the “Reduced” Column

Baseline values for the chemicals listed in Table 12-13 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

2.8.2.5.5 Basis for Projecting the Values in the “Expanded” Column

Baseline values for the chemicals listed in Table 12-13 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in "2.8.1 Activity Scenario for Test Activities: Accelerator Shots." However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

2.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1

2.8.2.6.1 Alternatives for Bare UNO 1.1 Explosives Inventory

Table 12-14 shows the alternatives for bare UNO 1.1 explosives inventory at the Z Machine.

Table 12-14. Alternatives for Bare UNO 1.1 Explosives Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 g	0 g	1,000 g	1,000 g	1,500 g

2.8.2.6.2 Operations That Require Bare UNO 1.1

Experiments using an explosive-closing fast valve use 75 g of Detasheet C per each valve setup. Each experiment could have up to three valve setups. A maximum of 1,000 g of explosive inventory would be maintained at any one time. Approximately 50 shots per year could use the explosive fast valve setup.

2.8.2.6.3 Basis for Projecting the "Reduced" and "Expanded" Values

The "reduced" value assumes no explosive valve use. The "expanded" value assumes more than three valve setups per shot and approximately 75 shots per year that use explosive-closing fast valves. Inventory under this alternative increases from 1,000 g to 1,500 g to ensure that sufficient amounts are on hand to meet setup requirements.

2.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

2.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-15 shows the alternatives for the insulator oil inventory at the Z Machine.

Table 12-15. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
700,000 gal	700,000 gal	700,000 gal	700,000 gal	700,000 gal

2.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material (no PCBs) that prevents electrical breakdown when the accelerator is charged. The oil section of the accelerator holds approximately 540,000 gal of oil. The Marx testbed, which is used to test components prior to placing them in the oil section, holds approximately 25,000 gal of oil. The total storage capacity for the oil is 750,000 gal in three aboveground 250,000-gal tanks.

2.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

There would be no change in the required volume of oil under the “reduced” or “expanded” scenarios.

2.8.3 Material Consumption

2.8.3.1 Nuclear Material Consumption Scenarios

2.8.3.1.1 Nuclear Material Consumption Scenario for Tritium

Alternatives for Tritium Consumption - Table 12-16 shows the alternatives for tritium consumption at the Z Machine.

Table 12-16. Alternatives for Tritium Consumption

Reduced Alternative		No Action Alternative						Expanded Alternative	
		Base Year		FY2003		FY2008			
N/A pkgs	0 Ci	N/A pkgs	0 Ci	N/A pkgs	2,500 Ci	N/A pkgs	2,500 Ci	N/A pkgs	7,500 Ci

Operations That Require Tritium - See “2.8.2.1 Nuclear Material Inventory Scenarios.” Approximately 50 Ci of tritium per shot would be consumed. Because inventory is replaced, consumption and inventory need not balance; what is not consumed remains as part of inventory.

Basis for Projecting the "Reduced" and "Expanded" Values - See "2.8.2.1 Nuclear Material Inventory Scenarios." Experiments involving tritium will consume a maximum of 100 Ci per shot. Because inventory is replaced, consumption and inventory need not balance.

2.8.3.1.2 Nuclear Material Consumption Scenario for Deuterium

Alternatives for Deuterium Consumption - Table 12-17 shows the alternatives for deuterium consumption at the Z Machine.

Table 12-17. Alternatives for Deuterium Consumption

Reduced Alternative		**No Action Alternative**						**Expanded Alternative**	
		Base Year		**FY2003**		**FY2008**			
N/A pkgs	0 l	N/A pkgs	0 l	N/A pkgs	3,750 l	N/A pkgs	3,750 l	N/A pkgs	5,000 l

Operations That Require Deuterium - See "2.8.2.1 Nuclear Material Inventory Scenarios." Approximately 50 l of deuterium per shot will be used. Because inventory is replaced, consumption and inventory need not balance.

Basis for Projecting the "Reduced" and "Expanded" Values - See "2.8.2.1 Nuclear Material Inventory Scenarios." A maximum of 100 l of deuterium per shot will be used. Because inventory is replaced, consumption and inventory need not balance.

2.8.3.1.3 Nuclear Material Consumption Scenario for Plutonium-239

Alternatives for Plutonium-239 Consumption - Table 12-18 shows the alternatives for plutonium-239 consumption at the Z Machine.

Table 12-18. Alternatives for Plutonium-239 Consumption

Reduced Alternative		**No Action Alternative**						**Expanded Alternative**	
		Base Year		**FY2003**		**FY2008**			
N/A pkgs	0 mg	N/A pkgs	0 mg	N/A pkgs	800 mg	N/A pkgs	800 mg	N/A pkgs	2,000 mg

Operations That Require Plutonium-239 - The largest sample size for a Pu-239 experiment is estimated at 40 mg. Because inventory is replaced, consumption and inventory need not balance.

Basis for Projecting the "Reduced" and "Expanded" Values - See "Operations That Require Plutonium-239," above.

2.8.3.1.4 Nuclear Material Consumption Scenario for Depleted Uranium

Alternatives for Depleted Uranium Consumption - Table 12-19 shows the alternatives for depleted uranium consumption at the Z Machine.

Table 12-19. Alternatives for Depleted Uranium Consumption

Reduced Alternative		No Action Alternative						Expanded Alternative	
		Base Year		FY2003		FY2008			
N/A pkgs	0 mg	N/A pkgs	0 mg	N/A pkgs	800 mg	N/A pkgs	800 mg	N/A pkgs	2,000 mg

Operations That Require Depleted Uranium - See "2.8.2.1 Nuclear Material Inventory Scenarios." The largest sample size for each experiment using depleted uranium is 40 mg. Because inventory is replaced, consumption and inventory need not balance.

Basis for Projecting the "Reduced" and "Expanded" Values - See "Operations That Require Depleted Uranium," above.

2.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at the Z Machine.

2.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

2.8.3.4 Explosives Consumption Scenario for Bare UNO 1.1 Explosives

2.8.3.4.1 Alternatives for Bare UNO 1.1 Explosives Consumption

Table 12-20 shows the alternatives for bare UNO 1.1 explosives consumption at the Z Machine.

Table 12-20. Alternatives for Bare UNO 1.1 Explosives Consumption

Reduced Alternative		No Action Alternative						Expanded Alternative	
		Base Year		FY2003		FY2008			
N/A pkgs	0 g	N/A pkgs	0 g	N/A pkgs	11,250 g	N/A pkgs	11,250 g	N/A pkgs	37,500 g

2.8.3.4.2 Operations That Require Bare UNO 1.1 Explosives

See “2.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1.” A maximum of 75 g of Detasheet C is used for each explosive-closing fast valve. A maximum of 225 g of explosive would be used for each shot, assuming three valve setups per shot. Approximately 50 shots per year would use explosive-closing fast valve setups.

2.8.3.4.3 Bases for Projecting the “Reduced” and “Expanded” Values

See “2.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1.” The expanded value is the same as the others because the setup is the same. A maximum of 375 g of explosive would be used for each shot, assuming five valve setups per shot. For the expanded value, up to 100 shots per year would use explosive-closing fast valve setups.

2.8.4 Waste

2.8.4.1 Low-Level Radioactive Waste Scenario

2.8.4.1.1 Alternatives for Low-Level Radioactive Waste at the Z Machine

Table 12-21 shows the alternatives for low-level radioactive waste at the Z Machine.

Table 12-21. Alternatives for Low-Level Radioactive Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
12 ft^3	44 ft^3	20 ft^3	20 ft^3	28 ft^3

2.8.4.1.2 Operations That Generate Low-Level Radioactive Waste

As a byproduct of the operation of the accelerator, protons that are present on the accelerator components in the form of hydrocarbon contaminates get accelerated to thresholds high enough to be capable of activating stainless steel. In z-pinch mode, this is fixed contamination. In ion diode mode, which the waste projections from the base year reflect, some of this material gets blown off and exists in the form of loose surface contamination. In addition to protons, some neutrons are generated, but the bulk of the activation is attributable to the accelerated protons. The 44 ft^3 of waste in FY1996 represents 11 bags of 4 ft^3 of waste processed from operation of the accelerator in extraction ion diode mode. So far, in z-pinch mode, no waste has been generated because the amount of activation that occurs is small, and it decays to background rapidly. The forward-looking years represent the expected waste amounts from the use of the nuclear materials as described in “2.8.2.1 Nuclear Material Inventory Scenarios.”

2.8.4.1.3 General Nature of Waste

The residuals are activation products of stainless steel and primarily include Zn-65, Co-57, Co-56, Mn-54, and Na-22. Also included in the forward-year numbers for the “no action” alternative are tritium waste and waste that contains depleted uranium.

2.8.4.1.4 Waste Reduction Measures

Waste reduction measures at the Z Machine include taking only the minimum required amount of material into the area to complete the work.

2.8.4.1.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value assumes the production of three bags of waste per year, and the “expanded” value assumes the production of seven bags of waste per year. Both of these values are associated with the number of shots, as discussed in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots.” The FY2003 and FY2008 timeframes assume approximately five bags of waste.

2.8.4.2 Transuranic Waste Scenario

2.8.4.2.1 Alternatives for Transuranic Waste at the Z Machine

Table 12-22 shows the alternatives for transuranic waste at the Z Machine.

Table 12-22. Alternatives for Transuranic Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 ft^3	0 ft^3	8 ft^3	8 ft^3	16 ft^3

2.8.4.2.2 Operations That Generate Transuranic Waste

Experiments involving the use of special nuclear material as described in “2.8.2.1 Nuclear Material Inventory Scenarios” would create some transuranic waste. The forward-looking years assume two bags of waste production.

2.8.4.2.3 General Nature of Waste

The residuals would be Pu-239 contaminated lab trash. Depending on the amount of waste and the concentration of Pu-239, it is feasible that this waste could be low-level waste. However, for the purpose of this exercise, the assumption is made that this waste would be transuranic.

2.8.4.2.4 Waste Reduction Measures

Waste reduction measures at the Z Machine include taking only the minimum required amount of material to complete the work into the test area.

2.8.4.2.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value assumes no special nuclear material shots and therefore no transuranic waste. The “expanded” value assumes four bags of waste produced from the number of shots discussed in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots.”

2.8.4.3 Mixed Waste

2.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at the Z Machine.

2.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at the Z Machine.

2.8.4.4 Hazardous Waste Scenario

2.8.4.4.1 Alternatives for Hazardous Waste at the Z Machine

Table 12-23 shows the alternatives for hazardous waste at the Z Machine.

Table 12-23. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
400 kg	750 kg	1,000 kg	1,000 kg	1,250 kg

2.8.4.4.2 Operations That Generate Hazardous Waste

The Z Machine generates hazardous waste as part of ongoing operations.

2.8.4.4.3 General Nature of Waste

The waste is comprised of film processing chemicals, copper sulfate liquid, contaminated oils and oily rags, waste capacitors, and nonhalogenated solvent-contaminated rags. In addition, the filter from the SF_6 reclaimer is also disposed of as hazardous waste at a rate of only one per year.

2.8.4.4.4 Waste Reduction Measures

Only the amount of material necessary to perform the job is used, and nonhazardous cleaning agents are substituted for solvents whenever possible.

2.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value and “expanded” value are in relation to the number of shots discussed in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots.” The estimates were projected from the base year actuals. The relationship is not linear, and the estimates in this section are best guesses regarding the amount of waste to be generated.

2.8.5 Emissions

2.8.5.1 Radioactive Air Emissions Scenarios

2.8.5.1.1 Radioactive Air Emission Scenario for N-13

Alternatives for N-13 Emissions at the Z Machine - Table 12-24 shows the alternatives for N-13 emissions at the Z-Machine.

Table 12-24. Alternatives for N-13 Emissions

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 Ci	0.042 Ci	0 Ci	0 Ci	0 Ci

Operations That Generate N-13 Air Emissions - For the base year, the Z Machine was operating in the ion diode high-voltage mode. In this mode, the operating voltage was high enough to activate the nitrogen and oxygen in the air (greater than 10 MeV). In the z-pinch mode, the voltage (4 MeV to 6 MeV) is not high enough to activate air; therefore, for the forward-looking years it is expected that there will be no radioactive air emissions.

General Nature of Emissions - Emission of N-13 is at room temperature from ground level because there is no stack.

Emission Reduction Measures - No emission reduction measures exist.

Basis for Projecting the "Reduced" and "Expanded" Values - Operating voltages in the z-pinch mode are not high enough to activate air; therefore, no anticipated emission will occur in either the "reduced" or "expanded" alternatives.

2.8.5.1.2 Radioactive Air Emission Scenario for O-15

Alternatives for O-15 Emissions at the Z Machine - Table 12-25 shows the alternatives for O-15 emissions at the Z Machine.

Table 12-25. Alternatives for O-15 Emissions

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 Ci	0.005 Ci	0 Ci	0 Ci	0 Ci

Operations That Generate O-15 Air Emissions - For the base year, the Z Machine was operating in the ion diode high-voltage mode. In this mode, the operating voltage was high enough to activate the nitrogen and oxygen in the air (greater than 10 MeV). In the z-pinch mode, the voltage (4 MeV to 6 MeV) is not high enough to activate air; therefore, for the forward-looking years it is expected that there will be no radioactive air emissions.

General Nature of Emissions - Emission of O-15 is at room temperature from ground level because there is no stack.

Emission Reduction Measures - No emission reduction measures exist.

Basis for Projecting the "Reduced" and "Expanded" Values - Operating voltages in the z-pinch mode are not high enough to activate air; therefore, no anticipated emission will occur in either the "reduced" or "expanded" alternative.

2.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

2.8.5.3 Open Burning Scenarios

The Z Machine does not have outdoor burning operations.

2.8.5.4 Process Wastewater Effluent Scenario

The Z Machine does not generate process wastewater.

2.8.6 Resource Consumption

2.8.6.1 Process Water Consumption Scenario

The Z Machine does not consume process water.

2.8.6.2 Process Electricity Consumption Scenario

The Z Machine does not consume process electricity.

2.8.6.3 Boiler Energy Consumption Scenario

The Z Machine does not consume energy for boilers.

2.8.6.4 Facility Personnel Scenario

2.8.6.4.1 Alternatives for Facility Staffing at the Z Machine

Table 12-26 shows the alternatives for facility staffing at the Z Machine.

Table 12-26. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
50 FTEs	50 FTEs	85 FTEs	85 FTEs	115 FTEs

2.8.6.4.2 Operations That Require Facility Personnel

Z Machine research and development operations require scientists for test, evaluation, and diagnostics work and also require operations and maintenance personnel. Personnel are not routinely shared between the Z Machine and other facility operations.

2.8.6.4.3 Staffing Reduction Measures

There are no staffing reduction measures currently planned or in effect.

2.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value is the minimum number of FTEs required to maintain operational capability. The nature of the research and development activities at the Z Machine require a large number of personnel to maintain all aspects of the necessary research and development capabilities.

The “expanded” value is based on 350 shots per year and the added staff needed to support this increased level of activity.

2.8.6.5 Expenditures Scenario

2.8.6.5.1 Alternatives for Expenditures at the Z Machine

Table 12-27 shows the alternatives for expenditures at the Z Machine.

Table 12-27. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$800,000	$1.2 million	$3 million	$3 million	$4 million

2.8.6.5.2 Operations That Require Expenditures

The expenditures provided here reflect funding requirements for facility operations only and include only operational and contract labor. They do not include the program personnel, who comprise the majority of the FTEs identified in “2.8.6.4 Facility Personnel Scenario.” Funding estimates by percentage and category are as follows:

- Operational and contract labor account for 41 percent

- All other expenses (for example, consumables, overhead, service centers) account for 59 percent

The number of FTEs discussed in “2.8.6.4 Facility Personnel Scenario,” would represent an additional $60.7 million. This number is based on the following assumption:

$250,000/FTE (program individual) - $600,000 (operational and contract labor costs)

2.8.6.5.3 Expenditure Reduction Measures

There are currently no expenditure reduction measures planned or in effect.

2.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value is the minimum amount necessary to maintain the current capabilities. These expenditures only reflect salary for operations personnel. They do not reflect salary for the additional program personnel identified in “2.8.6.4 Facility Personnel Scenario.” As such, there is no correlation between the number projected for expenditures under the “reduced” alternative here and the numbers of FTEs projected under the same alternative in “2.8.6.4 Facility Personnel Scenario.” The operational and contract labor included in the funding estimate here and as a portion of the number of FTEs projected in “2.8.6.4 Facility Personnel Scenario,” represent the minimum staff that would be required to maintain operational capability under the “reduced” alternative.

The “expanded” value is that required to achieve the number of shots discussed in “2.8.1 Activity Scenario for Test Activities: Accelerator Shots” (350 shots).

3.0 HERMES III SOURCE INFORMATION

3.1 Purpose and Need

HERMES III is a major facility in the Simulation Technology Laboratory, Building 970, which has provided laboratory gamma ray effects testing capability since 1988. Applications include electronics testing for component and weapon system development, which helps ensure operational reliability of weapon systems in radiation environments caused by nuclear explosions. HERMES III may also be operated in a reverse-polarity mode to conduct:

- Extraction ion diode experiments primarily for the Inertial Confinement Fusion Program.
- Radiography research and development experiments.

(Fine, 1996; Sullivan, 1995a)

3.2 Description

The HERMES III facility, located in Building 970, is a high-energy, linear induction accelerator with a bremsstrahlung gamma-ray converter that generates gamma-ray output with a 20-mega-electron volt (MeV) endpoint voltage. It was designed and built to take advantage of short-pulse, low-inductance pulsed power to provide previously unavailable dose rate area products and has been providing a laboratory gamma-ray effects testing capability since 1988.

HERMES III has the capability to provide high-fidelity simulation over very large areas, and applications include electronics testing for component and weapon system development. This testing helps ensure operational reliability of weapon systems in nuclear explosion radiation environments.

The HERMES III accelerator facility includes the following systems and sections:

- Accelerator structure
- Energy storage systems
- Pulse-forming system
- Voltage adder section and diode
- Indoor and outdoor test cells
- Accelerator and facility support systems

Routine radiation exposures are performed in the heavily shielded indoor exposure cell. The outdoor area is also shielded and allows testing of large assemblies and entire weapon systems. Safety procedures for outdoor shots require that observers be posted to maintain temporary control of the elevated radiation area boundary and that temporary barricades be positioned to block access into the area. These control measures are in accordance with DOE O 5400.5 and are promulgated in Jow (1991).

The energy storage section consists of ten 2.4-MV, 156-kJ Marx generators arranged in two groups of five each. Each Marx generator consists of two rows of 12 100-kV capacitors, and each charges two water-dielectric intermediate storage capacitors. The 20 intermediate storage capacitors are discharged through laser-triggered gas switches to charge four water-dielectric, pulse-forming transmission lines to 2.2 MV. Each of the transmission lines supplies a 1-MV, 750-kA pulse to the magnetically insulated transmission line (MITL) adder. The MITL transports the power from the adder to the diode/converter in the exposure cell. An electron beam is generated in the single anode-cathode gap diode at the end of the MITL. A tantalum bremsstrahlung (x-ray) converter on the anode side of the diode generates the gamma-ray output from incident electrons.

(Fine, 1996)

3.3 Program Activities

Table 12-28 shows the program activities at HERMES III.

Table 12-28. Program Activities at HERMES III

Program Name	**Activities at HERMES III**	**Category of Program**	**Related Section of the *SNL Institutional Plan***
Direct Stockpile Activities	Conduct development and survivability testing of nuclear weapon subsystems and components. Test the survivability of nuclear weapon systems by simulating the gamma rays produced by a nuclear weapon detonation.	Programs for the Department of Energy	Section 6.1.1.1
Performance Assessment Science and Technology	Hostile (radiation) environmental testing of weapon components.	Programs for the Department of Energy	Section 6.1.1.1

Table 12-28. Program Activities at HERMES III (Continued)

Program Name	Activities at HERMES III	Category of Program	Related Section of the *SNL Institutional Plan*
Experimental Activities	Perform radiation testing and associated diagonostics to determine the deleterious or beneficial effects of radiation on electronic, material, and biological systems. Conduct materials research, development, testing, and engineering, including but not limited to material hardening and material surface preparation, ion diode coatings, integrated circuit radiation hardness testing, system and component radiation hardness and testing, material use in accelerator components for reliability and duration, and laser preparation of materials. Research and development of new commercial and defense-related applications for activities such a materials processing, waste and product sterilization, and food purification.	Programs for the Department of Energy	Section 6.1.1.1.
Inertial Confinement Fusion	HERMES III will be used as part of the program in the SNL/NM Pulsed Power Sciences Center to validate the IVA concept for advanced hydrodynamic radiography (AHR), a proposed method to produce high-brightness, hard x-ray radiation from a small-diameter source with the potential of using multiple pulses of radiation. If these experiments are successful, AHR with IVA will have significant potential for growth and an immediate application to address stockpile stewardship issues on the compact, cost-effective, multi-axis Advanced Hydrotest Facility, expected to be located at Los Alamos National Laboratory.	Programs for the Department of Energy	Section 6.1.1.2
Other Federal Agencies	Research and development work is performed at HERMES III under the Work for Others process for the Department of Defense and its contractors, the NSA, and the United Kingdom, in addition to other qualified users.	Work for Non-DOE Entities (Work for Others)	Section 6.2.7
Pulsed Power Technology	Activities to support new pulsed power components and designs associated with accelerators or pulsed power devices. Minor modifications to the machine to support pulsed power research, development, testing, and engineering, including but not limited to improvements or changes to energy storage systems, pulse forming systems, voltage conditioning networks, and other accelerator components that do not place accelerator operations outside the analyzed environmental impacts. HERMES III is being applied as a focused source for the Radiography Program. The pulsed power test configuration will enable development of an intense gamma beam at 1 m for stewardship applications. It has also been used for source development applicable to a linear-induction-type accelerator.	Major Programmatic Initiatives	Section 7.1.6

3.4 Operations and Capabilities

In the normal operating mode, this high-energy, linear-induction accelerator creates high-energy electrons that impact a tantalum converter to produce bremsstrahlung gamma rays having a 20-MeV endpoint voltage output. It was designed and built to take advantage of short-pulse, low-inductance pulsed power to provide previously unavailable dose rate area products. It has the capability to provide high-fidelity simulation over very large areas.

The following indicate the standard accelerator parameters:

- Peak diode voltage is 20 MV.
- Peak diode current is 750 kA.
- Total beam energy is 370 kJ.
- Power pulse width is 27 nanoseconds.
- Repetition rate is eight shots per day.

The following indicate the gamma ray environment:

- Endpoint voltage is 20 MeV.
- Pulse width is 20 nanoseconds (fwhm).
- Peak dose rate is greater than 5 x 10^{12} rads per second (Si).
- Peak dose is greater than 100 krads (Si).
- Rise time is 12 nanoseconds (10^{-90}).

The Marx generator capacitors are charged in parallel up to ±100 kV over a period of approximately 2.5 minutes by a high-voltage DC power supply. Upon command, the firing system delivers a trigger pulse to the Marx trigger amplifier (MTA). The MTA then sends a pulse to the Marx trigger generator (MTG) in each oil tank. Each of the MTGs delivers pulses to five Marx generators so that the firing system triggers all ten Marx generators. To prevent unwanted discharge of the Marx generators, the firing system remains in a safe status connected to a resistive load through a transfer switch until five seconds before the firing signal. Once the firing sequence begins, a discharge command is given, triggering the MTA, and the MTG triggers 12 spark-gap switches in each Marx generator to form a series-discharge path that provides voltage addition. The output of each Marx generator is normally connected to a resistive load by a transfer switch that also actuates with the MTG transfer switches. The Marx generators then make contact with the intermediate storage capacitors and transfer their energy at up to 2.4 MV to the intermediate storage capacitors.

During extraction ion diode experiments, light ion beams (for example, proton, deuteron, helium, lithium, boron, and carbon) are accelerated through a potential difference of up to

22 MV. Ionizing radiation could consist of alpha or beta particles, electromagnetic radiation in the form of x-rays, gamma rays, or neutrons, depending on the identity and energy of the accelerated species, the target material, and the decay mode of the resulting radioactive product.

In general, HERMES III operations consist of four activity sequences:

- Precharge activities
- Firing (charge and discharge)
- Post-shot activities
- Maintenance

The operational work year for the HERMES III facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and experiment setup time.

(Fine, 1996; Sullivan, 1995a)

3.5 Hazards and Hazard Controls

3.5.1 Onsite Hazards to the Environment

3.5.1.1 Transformer Oil

Approximately 160,000 gal of transformer oil is located in the accelerator oil tanks (or in the oil tank storage farm). The oil is used as electrical insulation in the energy storage sections. The oil is recycled and regularly filtered to maintain its breakdown strength. The primary hazard to the environment associated with the oil is a large release. The building and the concrete wall around the aboveground storage tanks acts as secondary containment. Small amounts of oil are disposed of on rags. The possibility of an environmental release is very small (Fine, 1996).

A transformer oil fire also presents an onsite environmental hazard. The accelerator tanks are filled with a reduced-flammability grade of transformer oil (ASTM-D3487, Type II) that is classified as a combustible liquid that has a BTU content of 19,400 BTU/lb and a flash point of 300°F. The concentration of PCBs in the oil is limited to less than 50 parts per million. Based on previous operating experience and on engineering and fire protection testing, certain design and operating criteria have been established for HERMES III to minimize the possibility of an oil fire. In particular, all electrical connections and routing in oil tanks are well beneath the surface of the oil, and the oil surface is open and without any potential wicks.

3.5.1.2 Annual Releases of Radionuclides

The HERMES III facility produces annual releases from the activation of air constituents, which are radioactive oxygen-15 (O-15) and nitrogen-13 (N-13). The quantity of these radionuclides is directly related to the number of accelerator shots made annually. These activation gases have very short half lives (two minutes for O-15 and ten minutes for N-13); thus, decay during plume transport greatly reduces the possible doses at receptor locations.

3.5.2 Onsite Hazards to Workers

3.5.2.1 Radiological Hazards

HERMES III produces ionizing radiation in the form of bremsstrahlung in gamma ray simulation. Test exposures are normally made with objects located in an exposure (test) cell, which is surrounded by multiple layers of radiation shielding. In another mode of operation, test objects, such as large tracked vehicles, are exposed in a courtyard just outside the test cell where thick earthworks and massive concrete shields provide protection. In addition, stringent access control measures (including locked gates and machine interlocks) supplement the shielding to ensure personnel exposure is maintained at as-low-as-reasonably-achievable (ALARA) levels. Annual personnel doses for HERMES III workers are typically in the range of 0 to 30 millirem (0.000 to 0.030 rem), well below the limit of 5 rem for radiation workers. (To put this in perspective, the average annual background radiation dose equivalent an individual receives in the state of New Mexico is 170 millirem [0.170 rem]. Thirty millirem added to the New Mexico background dose of 170 millirem totals 200 millirem; and 225 millirem is the average annual dose equivalent from background radiation alone that a person living in the state of Colorado receives.)

3.5.2.2 Hazardous Material

The release of small quantities of hazardous materials may occur during HERMES III operations and could result in minor injury to workers. Most of the small quantities of hazardous materials that will be used at the facility will be adequately removed from the atmosphere in the work area by the heating, ventilating, and air conditioning (HVAC) systems.

3.5.2.2.1 Transformer Oil (160,000 Gal Recycled)

Transformer oil is used as electrical insulation in two energy storage sections. The oil is regularly filtered to maintain breakdown strength and is periodically transferred to storage tanks. The accelerator tanks are filled with transformer oil, and the intermediate stores and pulse forming lines contain deionized water. Water leaks could contaminate the oil. Workers on catwalks above HERMES III could possibly fall into the oil, but this is extremely unlikely. Any person falling into the oil-filled tank would find it impossible to swim or float. Use of handrails and safety harnesses are important in preventing such falls. Leaked or spilled oil creates a hazard for personnel, who may slip on oily floors. The transformer oil is of a reduced flammability grade (a combustible liquid having a high flash point of 300°F). The concentration of PCBs in the Exxon Univolt N61 oil is limited to less than 50 parts per million, and inspections have shown it to be less than the limit of detection.

3.5.2.2.2 Ethanol (5 to 10 Gal per Year)

Ethyl alcohol is a solvent that is used to clean various components between test shots. It poses some degree of respiratory hazard to personnel, particularly to those working in enclosed spaces. The hazards will be mitigated by using small quantities (on rags) and proper ventilation. Cloths used for cleaning are disposed of as hazardous waste.

3.5.2.2.3 Copper Sulfate (1 Lb per Year)

Exposure to dilute concentrations of copper sulfate is possible during the fabrication of resistors; personnel injury could include skin or eye irritation. The facility impact is minimal, with possible spills limited to less than 5 gal of the solution. Spill cleanup materials are disposed of as hazardous waste.

3.5.2.2.4 Sulfur Hexafluoride (SF_6) Gas (200 Lb per Month)

SF_6 is used as the insulator gas in switching components. SF_6 gas is passed through switches under continuous pressure. Pure SF_6 is chemically and physiologically inert but does not support respiration. SF_6 leaked in an enclosed area could act as a simple asphyxiate but is not toxic. When subjected to high-voltage discharge, some breakdown occurs, and the fluorides formed are corrosive and somewhat toxic. Thus, used SF_6 that has not been passed through a purifying reclaimer is a fugitive emission that represents an inhalation hazard to personnel and that could damage sensitive equipment. A reclaimer will remove these breakdown products, which will be disposed of as hazardous waste. The supply of SF_6 is stored after purification. Leakage of SF_6 gas from the closed system is possible, but the building ventilation system immediately removes this gas to the outside and effectively dilutes it from extremely small concentrations to negligible amounts in outside air.

3.5.2.2.5 Helium/Fluorine/Argon (4 Percent) Gas and Krypton Gas (5 Lb per Year Recycled)

A 5 percent F_2 and 95 percent He gas mixture is used in the KrF laser gas chamber. This mixture is not as corrosive or toxic as pure F_2 but may cause some slight irritation to the eyes. The F_2-He mixture and several other nontoxic gases, including Ar and Kr, are hazardous in enclosed areas because they do not support respiration. Positive ventilation (and personnel respirators in emergency situations) are used to reduce the inhalation hazards. An operating procedure addresses these hazards.

3.5.2.3 Industrial Hazards

Although an exposure to the gravity or mechanical hazards of maintenance work or to the thermal hazards of hotwork could result in severe personnel injury or major facility damage or possibly have an impact on the environment, such industrial-type hazards are considered to be of a magnitude and type routinely encountered and accepted by the public. Furthermore, possibly catastrophic industrial-type accidents such as a death due to heavy equipment being dropped from an overhead crane or from electric shock that results from work involving high voltages are not expected to happen, and they pose an acceptably low level of risk.

3.5.2.3.1 Gravity Hazards

Particularly important hazards in this facility result from moving and positioning heavy pieces of apparatus in restricted spaces and from performing maintenance work in cramped areas such as inside the oil tank. Sometimes these areas may be wet or oily. In addition, not all areas can be reached from ground level. The hazard created by dropped tools or apparatus is increased by these conditions. The amount of overhead work to be performed makes the possible dangers of falling (dropped) equipment of special concern. In fact, the most likely cause of death or severe personnel injury or equipment damage would be impact during movement of heavy equipment such as a Marx generator bank. Use of hardhats and personnel exclusion zones and adherence to restrictive procedures by trained personnel are important for decreasing the chances of accidents that could occur when tools are being carried by hand overhead and when equipment is being moved by cranes and lifts. The amount of overhead work that will be required and the presence of substantial amounts of transformer oil and other liquids emphasize the potential for serious falls. Oil leaks are possible over large areas. The several inches of transformer oil remaining in the oil tank after it is drained can create slippery walking and working surfaces for maintenance personnel. The design, maintenance, and use of handrails, safety harnesses, and safety footwear are especially important. These measures and approved procedures, training, and extreme attention to housekeeping are emphasized.

3.5.2.3.2 Electrical Hazards

Electrical hazards are encountered during maintenance of accelerator electrical systems where electrical energy sources (or storage) are present (for example, maintenance activities in close proximity to a Marx generator). The electrical energy sources at HERMES III include the following:

- Marx generators
- Triggering systems
- Lasers
- Data acquisition (DAS) equipment
- High-voltage power supplies
- Power tools
- Electrical wiring and cables

Of these sources, many are common in industry and are well understood. Others, such as the Marx generators, are items designed for special accelerator applications. Electrical shielding is incorporated in the facility design where possible. However, routine maintenance between shots will require that personnel work directly on these components. The Marx generators, transfer switches, lines, and other associated equipment will be discharged routinely after firing or testing and before maintenance operations are performed. However, capacitors can maintain a residual lethal charge, and discharge procedures may not be effective if equipment has been damaged. Training and adherence to approved operating procedures reduce the risk. The Marx generators deliver up to a 2.5-MV charging pulse to intermediate storage capacitors. The nominal operating charge is 100 kV. After firing, the capacitors may retain some residual charge. Maintenance work on such apparatus could be hazardous, and extreme care must be taken to ground each capacitor. The trigger system for the accelerator may experience component failure. These components may also arc, crack, and track. Other electrical wiring and cables are standard units similar to those found widely in industry. The hazards they pose and the required safety measures are common to industrial facilities and operations, and adequate safety measures are in place. Potentially dangerous sources of high voltage at the HERMES III facility that are not unique to the pulsed power apparatus will include the AC mains and conductors and the high-voltage power supplies associated with support equipment. Building 970 has been designed with substantial shielding for high voltages. However, routine maintenance and equipment installations require attention to these sources. The computer support equipment may require maintenance in the vicinity of live circuits. Trained personnel will perform these activities using standard safety equipment and procedures. The DAS functions include controlling and monitoring the accelerator and gathering and analyzing shot-related data. Because of the number and complexity of functions performed, electrical power requirements are significant. Hardware breakdown and repair activities that may occur while other parts of the system are functioning could pose some hazard to personnel.

3.5.2.3.3 Mechanical Hazards

Mechanical hazards are most often encountered during maintenance activities involving the use of tools and work on mechanical equipment. Mechanical equipment used in the HERMES III facility is standard for heavy industrial use and includes the following:

- Motors, door hoists, elevators, cranes, and hoists
- Hand tools
- Vacuum equipment
- Power tools
- Compressed gas equipment
- Transports

The use of all mechanical equipment conforms to standard industrial safety practices. Although it is unlikely, severe injury or major damage to the facility or operation could result from the mechanical hazards associated with maintenance activities on large systems or components (for example, removal and installation of the cathode stalk). However, the majority of potential accidents would be anticipated to result in only minor injury or minor occupational illness, have a minor impact on the environment, or cause minor system or component damage.

3.5.2.3.4 Thermal Hazards

Thermal hazards include welders and cutting torches, equipment with rotating parts (cranes, hoists, tools, motors, and pumps), heaters, tools that may spark, and lighting. These sources of thermal energy could initiate fires. All sources of thermal energy are standard for industrial installations.

3.5.2.3.5 Laser Hazards

A krypton fluoride (KrF) laser and a helium neon (He-Ne) laser are sources of nonionizing radiant energy. The Class IIIb He-Ne laser is used to align the laser optics for simultaneous firing. The Class IV KrF laser is used to fire all the SF_6-insulated trigger switches. These light sources can damage unprotected eyes, and the KrF laser could also damage equipment. Because high DC voltage levels are used, the lasers present an electrical and an optical hazard to personnel. The laser work areas are suitably shielded and contain no reflective surfaces. Operating procedures address the laser hazards associated with this frequently performed operation.

3.5.2.3.6 Confined Space Hazards

Potential anoxia-producing accidents may arise from working in areas where O_2 has been depleted. SF_6 or other inert gases may, in some circumstances, displace air sufficiently to deprive personnel of oxygen and cause asphyxiation. Operation of the HVAC system (including circulation fans) and use of equipment to monitor oxygen deficiencies are important in preventing and identifying low oxygen conditions. The buddy system is required, and onsite personnel are trained in cardiopulmonary resuscitation.

3.5.2.3.7 Fire

The probability of fire at the HERMES III facility is low because of the way Building 970 is designed and because of requirements that are set forth in the operating procedures. However, the potential severity of the fire is significant because personnel could be injured, and the facility could be seriously damaged or destroyed. The building is of concrete and metal construction and has built-up bituminous roofing, and the likelihood of occurrence of a serious fire is significantly reduced by the presence of an automatic foam suppression system in the accelerator area of the building. The types and quantities of flammable materials throughout the building are strictly controlled. Combustibles are kept to a minimum, the use of flammable liquids is strictly controlled, and combustible waste is kept in covered metal cans. Throughout SNL, smoking is prohibited except in designated outdoor smoking areas. A full-time, paid fire department is on duty at Kirtland Air Force Base at all times and can respond to a fire within five minutes. The fire department can also provide a crew to stand by upon request. The most likely causes of a fire would be overheated equipment, overheated wiring, or ignition of flammable solvents, oil soaked rags, or absorbent materials. Less likely, but of serious consequence, would be the ignition of the high-flash-point dielectric transformer oil. Because the fuel loading, other than the transformer oil, is very low and the building is constructed of noncombustible materials, a fire that did not ignite the transformer oil would result in minimal structural damage. The transformer oil used in HERMES III, Exxon Univolt N61, has a BTU content of 19,400 BTU/lb and a flashpoint of 300°F. Based on previous SNL accelerator experience and on engineering and fire protection testing performed by SNL, certain design and operating criteria have been established to minimize the possibility of an oil fire. For example:

- All electrical connections and routing in oil tanks are well beneath the surface of the oil.

- The oil surface is open and without any potential wicks (no screen wire).

- Foam is included in the building fire protection system.

- Operating procedures and supervision emphasize housekeeping so the possibility of oil contamination is minimized.

- Oil spills are soaked up immediately with an oil-absorbent cleaning compound, particulate vermiculite, which is removed promptly and disposed of as hazardous waste.

3.5.3 Hazard Controls

3.5.3.1 Radiation Protection

All areas of the facility have access control maintained by fences and gates with locking mechanisms, closed-circuit television (CCTV), and physical inspection and clearing procedures. Visual warning devices (beacons and lights) and audible warning devices that indicate the state of the facility are located in all areas. During the critical period of charging and firing, the accelerator systems are interlocked with access control such that any breach automatically disables all systems and places the accelerator in a safe state within two seconds. Confinement barriers are provided to protect personnel and equipment from the effects of any generated radiation. These barriers include:

- Shielding walls and a roof for the exposure cell.

- Shielding on two sides of the outdoor exposure area for open-air shots, and an earth berm shield for the third side.

- Shielding walls between the exposure cell and areas that could be occupied by personnel during HERMES III shots.

- Additional outside shielding walls to mitigate exposures to skyshine x-rays during outdoor shots.

Additional protection measures ensure that exposure of personnel to radiation is as low as reasonably achievable. These measures include:

- Use of personnel dosimeters.

- Periodic monitoring and surveys.

- Rapid venting of radioactive gases following a shot.

3.5.3.2 Heating, Ventilating, and Air Conditioning Systems and Special Exhaust Systems

Activation of Building 970 HVAC systems during accelerator operations ensures removal of noxious or hazardous gases and gaseous products. In addition, the test cell is equipped with a high-volume air exhaust system to vent the room air during and after accelerator operation.

3.5.3.3 Public Address System

A loudspeaker paging/public address system is provided throughout the facility. This system enhances personnel safety through announcements of preshot procedures and emergency evacuation procedures.

3.5.3.4 Oxygen Deficiency Monitor System (ODMS)

The oxygen deficiency monitor system (ODMS) is a stationary, high-sensitivity oxygen monitoring and alarm network. It provides continuous monitoring of the oxygen concentration of the ambient air in the trenches of Building 970 and the tunnel to Building 970A. Audible and visual alarms are generated when the oxygen concentration of the ambient air falls below the set value of 19.5 percent by volume. Periodic inspections of the system help ensure its proper operation.

3.5.3.5 Fire Protection

The fire protection systems include an automatic wet-pipe sprinkler system, an aqueous foam system, fire hydrants, and hose stations. Photocell smoke detectors are located in the highbay, the screen room, and the return air duct. For ease of identification, all exterior fire protection-related control valves, water motor alarm and gongs, fire department connections, and sprinkler system drains through walls are painted “fire protection red.” Risers to the ceiling line or to the first horizontal run for the interior sprinkler system, alarm valves, and any other related accessories are also painted fire protection red.

3.5.3.6 Exits

Building exits allow evacuation should an event such as seismic activity trigger subsequent emergencies (for example, a fire). Fire exits (emergency doors) are kept free of obstructions and are clearly marked to reduce the potential for severe injuries to personnel. All fire doors and hardware for these doors comply with NFPA standards. Fire stairways are isolated from adjoining building areas.

3.5.3.7 Fall Protection

Stairways, roof walkways, and ladders comply with OSHA standards. Guardrails are provided on exterior stairways and walkways and on elevated interior walkways. Ladders have required rung spacing and strength and are caged where necessary.

(Fine, 1996; Sullivan, 1995a)

3.6 Accident Analysis Summary

3.6.1 Introduction

The HERMES III accelerator is a radiation simulator that produces gamma rays under controlled conditions using extremely high voltages and current pulses of electrical energy. Because of the nature of the facility, the potential consequences of accidents could be severe; therefore, the facility was designed to minimize hazards, and fail-safe and redundant design features were incorporated where possible. Furthermore, the combination of design features with protection and monitoring systems, administrative programs, approved procedures, surveillance, and timely maintenance are used to control and mitigate the hazards.

The HERMES III accident analysis characterized and quantified potentially hazardous events, materials, and energy sources and used a systematic approach to identify components and operations where risk was relatively high. The objectives of the analysis were the following:

- To identify all significant hazards.
- To demonstrate that the hazards have been controlled through use of engineering controls or administrative actions.
- To demonstrate reasonable assurance that HERMES III operations can be conducted in a manner that precludes undue risks to the health and safety of the public and employees and adequately protects property and the environment.

3.6.2 Methodology

Fault Hazard Analysis (FHA) is a systematic engineering procedure that identifies the specific ways (modes) in which a piece of equipment might fail to perform its intended function. The procedure also determines, for each mode, the key causative factors, failure mode effects, mitigative measures, and the expected risk that such a failure mode might impose. FHA is a standard tool used throughout industry and government projects to develop an information base for inputs to various safety and reliability assessments and to provide detailed information for the design and operation of complex systems. In this latter regard, FHA provides information to managers and designers necessary for formulating decisions and developing any corrective measures that may be necessary. For each hazard and failure mode identified, the consequences of failure are rated in terms of relative severity, and an estimate of the relative probability of occurrence is assigned. The mitigative or preventive measures that are already in place (or those measures that still may be needed) to reduce the risks to an acceptable level are considered. For example, when the effects of a hazard cannot be eliminated through design, then safety and warning devices, periodic inspection and maintenance, training, or other administrative controls such as operating procedures are applied and are noted in the analyses. For the accident analysis of HERMES III, the FHA methodology was used to develop both a failure modes and effects analysis (FMEA) and an operating and support hazard analysis (O&SHA).

3.6.3 Selection of Accidents Analyzed in Safety Documents

Hazardous conditions were assessed by means of an FMEA to identify potential system and equipment failures and an O&SHA to identify potential human performance errors. These particular techniques are suited to evaluation of “single-event” scenarios. As a consequence, all credible single-event scenarios were considered in the analysis.

3.6.4 Analysis Methods and Assumptions

The FMEA for HERMES III focuses on component and system failures. Each subsystem at the facility has been systematically evaluated in the context of its particular function in a system and its interfaces with other subsystems. The effects of preventive and mitigative measures are considered in assessing the risk associated with each subsystem or component failure.

The standard FMEA format was used for this assessment. For each subsystem and component, the manner (or mode) in which failure has occurred or could occur is listed. Failure modes are determined by examining maintenance records and logs and, for those subsystems that have no failure history, by analyzing the subsystem input and output functions identified in diagrams of the system.

For each failure mode, the possible reasons for the failure are postulated and listed. These causes, which are at the component level, describe fundamental failures or defects. In general, no attempt is made to identify causes down to the failure mechanism level of detail. Associated with each failure mode/cause combination is an effect or consequence. For each failure mode, accident severity and probability categories are assigned using the accident severity and probability criteria presented in AL 5481.1B. Combinations of accident severity codes (I, II, III, IV) and probability codes (A, B, C, D) were used to represent the risk associated with specific failure modes.

The FMEA results for HERMES III are documented in Appendix A of Fine (1996). The FMEA tables identify the facility controls that will either prevent the occurrence of or mitigate the effects of the failure. A comment column in each of the tables provides explanations that are relevant to the analysis but that do not otherwise fit into the table. When possible, specific mitigating administrative controls are cited in the comment columns.

The O&SHA focuses on human interaction, operator errors, and problems associated with deviations of plant operations from design specifications. For each facility subsystem, hypothetical hazardous events (scenarios) are postulated and systematically evaluated in terms of credibility, effects, and associated risk. Similar to the FMEA, the effects of preventive and mitigative measures were considered in assessing the risk associated with each event. The following is the format for the O&SHA results contained in Appendix B of Fine (1996):

- **Description** - Hypothetical hazardous events are described for each subsystem and component. These events were developed either by expanding the basic FMEA failure modes into events that are deviations from normal operations or by projecting a human interaction, such as operator error or the mere presence of personnel, into the hazardous condition.

- **Hazard** - The primary hazards associated with each hazardous event are identified (for example, confined space, and radiation exposure).

- **Effect** - As with the FMEA, the possible consequences of the event are listed.

- **Severity** - Similar to the FMEA, accident severity categories are assigned using the criteria of AL 5481.1B.

- **Probability** - Similar to the FMEA, accident probability categories are assigned using the criteria of AL 5481.1B.

- **Prevention or Mitigation** - The O&SHA tables identify the facility controls that will either prevent the occurrence of or mitigate the effects of the hazardous event.

- **Comments** - Similar to the FMEA tables, this column in the O&SHA table provides explanations that are relevant to the analysis but that do not otherwise fit into the table.

3.6.5 Summary of Accident Analysis Results

For some of the Tech Area IV accelerator facilities, a scenario evaluation methodology was used to perform the facility accident analyses. For these facilities, a set of "generic" events for evaluation was established by examining sources of energy, radiation, and hazardous materials in the facility. These selected events represent the major contributors to overall facility accident risk. The results of the HERMES III accident assessment are summarized in Table 12-29 in terms of these "generic" events.

Table 12-29. HERMES III Accident Assessment Results

Event	Severity	Probability
Electric shock	Critical (II)	Unlikely (B)
Radiation exposure	Catastrophic (I)	Extremely unlikely (C)
Gravity (dropped heavy equipment)	Catastrophic (I)	Extremely unlikely (C)
Fire	Catastrophic (I)	Extremely unlikely (C)
Asphyxiation	Catastrophic (I)	Extremely unlikely (C)
Earthquake	Marginal (III)	Unlikely (B)
Tornado	Critical (II)	Extremely unlikely (C)
High winds	Marginal (III)	Unlikely (B)
Flood	Marginal (III)	Extremely unlikely (C)
Aircraft crash	Catastrophic (I)	Extremely unlikely (C)

Tables 12-30 and 12-31 were obtained from AL 5481.1B and provide definitions for terms used in "3.6 Accident Analysis Summary."

Table 12-30. Qualitative Accident Hazard Severity, Hazard Categories, and Consequences to the Public, Workers, or the Environment

Hazard Category	Consequence	Explanation
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or provide a significant impact on the environment.

Table 12-31. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

(Fine, 1996)

3.7 Reportable Events

HERMES III has had no reportable events over the past five years.

3.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials

3.8.1.1 Alternatives for Test Activities: Irradiation of Components or Materials

Table 12-32 shows the alternatives for irradiation of components or materials at HERMES III.

Table 12-32. Alternatives for Test Activities: Irradiation of Components or Materials

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40 shots	262 shots	500 shots	500 shots	1,450 shots

3.8.1.2 Assumptions and Actions for the “Reduced” Values

The HERMES III facility is a high-energy, linear-induction accelerator with a bremsstrahlung gamma-ray converter that generates gamma-ray output with a 20-MeV endpoint voltage. It was designed and built to take advantage of short-pulse, low-inductance pulsed power to provide a laboratory gamma-ray effects testing capability. HERMES III provides high-fidelity simulation over very large areas, and applications include but are not limited to electronics testing for component and weapon system development. The HERMES III accelerator can also operate in other modes, including reverse polarity and internal confinement fusion modes; however, the operations in these alternative modes is enveloped by the HERMES III gamma-ray effects testing.

The programs that use the HERMES III accelerator and the activities associated with those programs are provided in “3.3 Program Activities.” Because HERMES III’s production of an accelerated endpoint (diode) voltage is fundamental to each of the listed programmatic activities, the values for the various scenarios are essentially the same. Therefore, the following analyses of values consider one basic scenario, which is the firing of the HERMES III accelerator. Furthermore, there is the underlying assumption that the effects or values such as those for materials in inventory, material consumed, and wastes generated are directly proportional to the number of times the machine fires (“shots”).

HERMES III must be fired about once per week to keep the accelerator in a state of operational readiness. Therefore, 40 shots per year are required for the “reduced” alternative, which is 0.15 times the activity level reported in the base year (40 shots / 262 shots = 0.15).

3.8.1.3 Assumptions and Rationale for the "No Action" Values

The following are assumptions and rationale for the “no action” values:

- Base year: The base year value indicates the 262 HERMES III shots in calendar year 1997.

- FY2003 and FY2008 projections: A maximum of 500 HERMES III shots per year is expected in the ten-year period of 1999 to 2008. The FY2003 and FY2008 projections for 500 shots per year are approximately 1.9 times the base year value (500 shots / 262 shots = 1.9).

The HERMES III accelerator can operate in additional modes, which include the reverse polarity and internal confinement fusion modes; however, operations in these alternative modes are bounded by the activities assessed in the HERMES III gamma-ray effects testing.

3.8.1.4 Assumptions and Actions for the "Expanded" Values

HERMES III can fire a maximum of 1,450 times per year, based on the theoretical maximum of four shots per day for 362 days. The expanded value of 1,450 shots is approximately 5.5 times the base year value (1,450 shots / 262 shots = 5.5).

3.8.2 Material Inventories

3.8.2.1 Nuclear Material Inventory Scenarios

HERMES III has no nuclear material inventories.

3.8.2.2 Radioactive Material Inventory Scenario for Activated Hardware

3.8.2.2.1 Alternatives for Activated Hardware Radioactive Material Inventory

Table 12-33 shows the alternatives for activated hardware inventory at HERMES III.

Table 12-33. Alternatives for Activated Hardware Radioactive Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	**FY2003**	**FY2008**	
0 kg	0 kg	0 kg	0 kg	0 kg

3.8.2.2.2 Operations That Require Activated Hardware

No radioactive materials are used in HERMES III operations, and no radioactive materials inventory is maintained at the HERMES III accelerator facility; however, some small amount of short-lived activation products may be present in the facility at any time.

The interaction of up to 20-MeV bremsstrahlung gamma rays with machine components and test apparatus can generate radioactive materials. Machine components and other objects in close proximity to the radiation source could become activated, depending on their composition. Using components and apparatus fabricated of material that has a low activation potential and short half-life minimizes the possibility of creating a radiation hazard.

3.8.2.2.3 Basis for Projecting the “Reduced” and “Expanded” Values

No radioactive materials are used in HERMES III operations.

3.8.2.3 Sealed Source Inventory Scenario for Kr-85

3.8.2.3.1 Alternatives for Kr-85 Sealed Source Inventory

Table 12-34 shows the alternatives for the Kr-85 sealed source inventory at HERMES III.

Table 12-34. Alternatives for Kr-85 Sealed Source Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
3.3 x 10^2 µCi	3.3 x 10^2 µCi	3.3 x 10^2 µCi	3.3 x 10^2 µCi	3.3 x 10^2 µCi

3.8.2.3.2 Operations That Require Kr-85

The Kr-85 is the sealed calibration source for the HERMES III exposure cell exhaust stack monitor.

3.8.2.3.3 Basis for Projecting the “Reduced” and “Expanded” Values

Both volume and activity within sealed sources remains relatively static.

3.8.2.4 Spent Fuel Inventory Scenarios

HERMES III has no spent fuel inventories.

3.8.2.5 Chemical Inventory Scenarios

3.8.2.5.1 Alternatives for Chemical Inventories

Table 12-35 shows the alternatives for chemical inventories at HERMES III.

Table 12-35. Alternatives for Chemical Inventories

Chemical	Reduced Alternative	No Action Alternative			Expanded Alternative
		Base Year	FY2003	FY2008	
Oxazine 720 perchlorate solution	0.3 l	5 l	3.8 l	3.8 l	11 l
Sulforhodamine 640 solution	0.3 l	2 l	3.8 l	3.8 l	11 l
Helium 95% / fluorine 5%	0.375 lb	2.5 lb	4.75 lb	4.75 lb	13.75 lb

3.8.2.5.2 Operations That Require Chemical Inventories

The programs and operations that utilize these chemicals are described in detail in “3.2 Description,” “3.3 Program Activities,” and “3.4 Operations and Capabilities.”

3.8.2.5.3 Basis for Projecting the Values in the “No Action” Columns

Baseline values for the chemicals listed in Table 12-35 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

3.8.2.5.4 Basis for Projecting the Values in the “Reduced” Column

Baseline values for the chemicals listed in Table 12-35 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

3.8.2.5.5 Basis for Projecting the Values in the “Expanded” Column

Baseline values for the chemicals listed in Table 12-35 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

3.8.2.6 Explosives Inventory Scenarios

HERMES III has no explosives inventories.

3.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

3.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-36 shows the alternatives for insulator oil inventory at HERMES III.

Table 12-36. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
160,000 gal	160,000 gal	160,000 gal	160,000 gal	160,000 gal

3.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material (inspections have shown the PCB concentration to be less than the limit of detection) that prevents electrical breakdown when the accelerator is charged. The oil section of the accelerator holds 160,000 gal of oil. The total storage capacity for the oil is 500,000 gal in two aboveground 250,000-gal tanks that are shared with the other accelerators in Building 970.

3.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

There will be no more or no less oil required in the “reduced” or “expanded” scenarios.

3.8.3 Material Consumption

3.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at HERMES III.

3.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at HERMES III.

3.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

3.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at HERMES III.

3.8.4 Waste

3.8.4.1 Low-Level Radioactive Waste Scenario

3.8.4.1.1 Alternatives for Low-Level Radioactive Waste at HERMES III

Table 12-37 shows the alternatives for low-level radioactive waste at HERMES III.

Table 12-37. Alternatives for Low-Level Radioactive Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.04 ft^3	0.25 ft^3	0.48 ft^3	0.48 ft^3	1.38 ft^3

3.8.4.1.2 Operations That Generate Low-Level Radioactive Waste

The interaction of up to 20-MeV bremsstrahlung gamma rays with machine components, test apparatus, and the air in the exposure cell can generate radioactive materials. Machine components and other objects in close proximity to the radiation source could become activated, depending on their composition. Using components and apparatus fabricated of material that has a low activation potential and short half-life minimizes the possibility of creating a radiation hazard.

3.8.4.1.3 General Nature of Waste

No radioactive material inventory is maintained at the HERMES III accelerator facility; however, some small amount of short-lived activation products may be present in the facility at any time (components or test items). The following are estimated primary residuals of the activation products:

- Zinc-65 (Zn-65)
- Cobalt-57 (Co-57)
- Manganese-54 (Mn-54)
- Sodium-22 (Na-22)

3.8.4.1.4 Waste Reduction Measures

The test item may be cleaned and reused, moved to a low-level storage area, or removed from the site as waste.

3.8.4.1.5 Basis for Projecting the "Reduced" and "Expanded" Values

See "3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Material."

3.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at HERMES III.

3.8.4.3 Mixed Waste

3.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at HERMES III.

3.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at HERMES III.

3.8.4.4 Hazardous Waste Scenario

3.8.4.4.1 Alternatives for Hazardous Waste at HERMES III

Table 12-38 shows the alternatives for hazardous waste at HERMES III.

Table 12-38. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
25 kg	167 kg	316 kg	316 kg	915 kg

3.8.4.4.2 Operations That Generate Hazardous Waste

HERMES III generates hazardous waste as part of ongoing operations.

3.8.4.4.3 General Nature of Waste

The waste is comprised primarily of photochemicals, copper sulfate liquid, contaminated oils and oily rags, waste capacitors, and nonhalogenated solvent-contaminated rags.

3.8.4.4.4 Waste Reduction Measures

Waste management for ongoing activities is conducted in accordance with Sandia National Laboratories (1999). Nonhazardous cleaning agents are substituted for solvents whenever possible.

3.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

See “3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” The amount of waste produced is proportional to the operational activity (number of “shots”).

3.8.5 Emissions

3.8.5.1 Radioactive Air Emissions Scenarios

3.8.5.1.1 Radioactive Air Emission Scenario for N-13

Alternatives for N-13 Emissions at HERMES III - Table 12-39 shows the alternatives for N-13 emissions at HERMES III.

Table 12-39. Alternatives for N-13 Emissions

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
1×10^{-4} Ci	6.55×10^{-4} Ci	12.45×10^{-4} Ci	12.45×10^{-4} Ci	36.03×10^{-4} Ci

Operations That Generate N-13 Air Emissions - The National Emissions Standards for Hazardous Air Pollutants (NESHAP) quality assurance plan for HERMES III describes the process for complying with 40 CFR 61, Subpart H. The main focus of the plan is to describe quality assurance procedures and policies for implementing the guidelines of the U.S.

Environmental Protection Agency standard, including 40 CFR 61, Appendix B, Method 114, Section 4, “Quality Assurance Methods.”

The NESHAP quality assurance plan for HERMES III applies to the monitoring of the airborne radionuclide emissions produced by the interaction of HERMES III’s gamma ray output with the air in its shielded exposure (test) cell. The plan supplements Sandia National Laboratories (1999), Chapter 17, Section E, “Radionuclide National Emissions Standards For Hazardous Air Pollutants (NESHAP),” which provides SNL's basic procedures for achieving and maintaining compliance with NESHAP. The reporting requirements for abnormal or unplanned releases of airborne radioactive material are covered under the SNL Accident, Incidents and Occurrence Reporting Program. Subpart H to 40 CFR 61 is concerned only with effective dose equivalent to members of the public outside of facility boundaries from routine airborne radionuclide emissions.

At HERMES III, an exhaust stack ventilates the test cell after each shot (the air volume is exchanged in less than 10 minutes). All airborne activation products exit through the stack and fresh air is drawn in through openings at the floor level of the cell (for example, under the doors) and thus the concentration is reduced during ventilating. The activation products decay with time due to the short half-lives of the radionuclides (N-13 and O-15), which also reduces the concentration.

The HERMES III monitoring system is capable of continuous operation; however, emissions are only produced during a “downline” shot, and periodic sampling can be used to determine total emissions over a period (total emissions = number of shots x emissions/shot). Continuous monitoring is not required by 40 CFR 61, Subpart H because the dose to the nearest receptor for HERMES III is less than 0.1 mrem per year. Therefore, only periodic measurements of the air emissions are required. The monitoring system, which has a detector installed in the exhaust stack, allows periodic measurements during routine HERMES III operations.

General Nature of Emissions - The HERMES III facility produces annual releases from the activation of air constituents, which are radioactive N-13 and O-15. The quantity of these radionuclides is directly related to the number of accelerator shots made annually. These activation gases have very short half lives (two minutes for O-15 and ten minutes for N-13); thus, decay during plume transport greatly reduces the possible doses at receptor locations.

Emission Reduction Measures - Unplanned releases are extremely unlikely because emissions are only produced during a shot, all shots are planned using the required shot approval form, and numerous operating procedures are followed (including access control and authorization). Procedures are followed after the shot that indicate radiation production. These include:

- A radiation survey at the converter to determine activation level.
- Thermoluminescent dosimeter dose measurements at the converter yielding a dose x area product.
- A reference Compton diode radiation detector which provides a temporal signal to determine pulsewidth and dose rate.

Unusually high readings from any one of these could identify a possible problem. Before the accelerator is fired, the system is checked and placed on line to perform the emissions measurement for the next shot and all subsequent shots until the readings return to normal. This activity is documented in the system log and noted in the next data report.

Actions to reduce excessive releases include releases above and within a predefined safety envelope that states maximum operating parameters for the accelerator and limits radiation output. This is a condition of operation, and deviation requires DOE approval (see Chapter 5, “Safety Envelope,” Fine, 1996).

Basis for Projecting the "Reduced" and "Expanded" Values - The annual emission rate for routine operations is 2.5 µCi/shot for N-13.

The calculation for base year N-13 emissions is as follows:

$$2.5 \text{ x } 10^{-6} \text{ Ci/shot x } 262 \text{ shots} = 12.45 \text{ x } 10^{-4} \text{ Ci}$$

The FY2003 and FY2008 projections for N-13 emissions are calculated as follows:

$$2.5 \text{ x } 10^{-6} \text{ Ci/shot x } 500 \text{ shots} = 12.45 \text{ x } 10^{-4} \text{ Ci}$$

The “reduced” projection for N-13 emissions is calculated as follows:

$$2.5 \text{ x } 10^{-6} \text{ Ci/shot x } 50 \text{ shots} = 1 \text{ x } 10^{-4} \text{ Ci}$$

The “expanded” projection for N-13 emissions is calculated as follows:

$$2.5 \text{ x } 10^{-6} \text{ Ci/shot x } 1{,}450 \text{ shots} = 36.03 \text{ x } 10^{-4} \text{ Ci}$$

3.8.5.1.2 Radioactive Air Emission Scenario for O-15

Alternatives for O-15 Emissions at HERMES III - Table 12-40 shows the alternatives for O-15 emissions for HERMES III.

Table 12-40. Alternatives for O-15 Emissions

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
1E x 10^{-5} Ci	6.55 x 10^{-5} Ci	12.45 x 10^{-5} Ci	12.45 x 10^{-5} Ci	36.03 x 10^{-5} Ci

Operations That Generate O-15 Air Emissions - See “Operations That Generate N-13 Air Emissions.”

General Nature of Emissions - See “General Nature of Emissions” for N-13 air emissions.

Emission Reduction Measures - See “Emission Reduction Measures” for N-13 air emissions.

Basis for Projecting the "Reduced" and "Expanded" Values - The annual emission rate for routine operations is 0.25 µCi/shot for O-15.

The calculation for base year O-15 emissions is as follows:

$$0.25 \times 10^{-6} \text{ Ci/shot} \times 262 \text{ shots} = 12.45 \times 10^{-5} \text{ Ci}$$

The FY2003 and FY2008 projections for O-13 emissions are calculated as follows:

$$0.25 \times 10^{-6} \text{ Ci/shot} \times 500 \text{ shots} = 12.45 \times 10^{-5} \text{ Ci}$$

The “reduced” projection for O-15 emissions is calculated as follows:

$$0.25 \times 10^{-6} \text{ Ci/shot} \times 50 \text{ shots} = 1 \times 10^{-5} \text{ Ci}$$

The “expanded” projection for O-15 emissions is calculated as follows:

$$0.25 \times 10^{-6} \text{ Ci/shot} \times 1{,}450 \text{ shots} = 36.03 \times 10^{-5} \text{ Ci}$$

3.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

3.8.5.3 Open Burning Scenarios

HERMES III does not have outdoor burning operations.

3.8.5.4 Process Wastewater Effluent Scenario

HERMES III does not generate process wastewater.

3.8.6 Resource Consumption

3.8.6.1 Process Water Consumption Scenario

HERMES III does not consume process water.

3.8.6.2 Process Electricity Consumption Scenario

HERMES III does not consume process electricity.

3.8.6.3 Boiler Energy Consumption Scenario

HERMES III does not consume energy for boilers.

3.8.6.4 Facility Personnel Scenario

3.8.6.4.1 Alternatives for Facility Staffing at HERMES III

Table 12-41 shows the alternatives for facility staffing at HERMES III.

Table 12-41. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
10 FTEs	12 FTEs	15 FTEs	15 FTEs	22 FTEs

3.8.6.4.2 Operations That Require Facility Personnel

Personnel are required for ongoing operations of the facility, including operational readiness and firing the accelerator for support of programs.

3.8.6.4.3 Staffing Reduction Measures

HERMES III is presently on a shared crew basis with the operations of the Saturn, Short-Pulse High Intensity Nanosecond X-Radiator (SPHINX), and Sandia Accelerator and Beam Research Experiment (SABRE) accelerators, which represents the minimum required to maintain the present capability.

3.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

See “3.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.”

3.8.6.5 Expenditures Scenario

3.8.6.5.1 Alternatives for Expenditures at HERMES III

Table 12-42 shows the alternatives for expenditures at HERMES III.

Table 12-42. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
\$1.98 million	\$2.4 million	\$3.0 million	\$3.0 million	\$4.4 million

3.8.6.5.2 Operations That Require Expenditures

Operations that require expenditures include FTEs, maintenance equipment, and consumables.

3.8.6.5.3 Expenditure Reduction Measures

Expenditure reduction measures include reduction of FTEs and consumables as the number of shots vary.

3.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

Historically, HERMES III costs $3 million per year for the “no action” category (500 shots). The projections were determined by ratioing the cost according to the number of FTEs (for example, $3 million x 10/15 = $2 million for the “reduced” column).

4.0 SATURN SOURCE INFORMATION

4.1 Purpose and Need

The Saturn accelerator produces x-rays to simulate the radiation effects of nuclear bursts on electronic and material components. Areas of application include the following:

- Satellite systems
- Electronic and materials devices, components, and subsystems
- Reentry vehicle and missile subsystems

The Saturn facility also maintains a capability for doing hohlraums weapons physics testing. Scientists working in the Saturn facility were responsible for developing this technique. However, hohlraums testing is now predominantly a Z Machine activity. Similarly, while the Saturn facility is also capable of operating in the z-pinch mode, this too is now primarily done at the Z-Machine facility (Sullivan, 1995b).

4.2 Description

The Saturn facility, located in Building 981, consists of a laboratory building (including a highbay, office space, shop areas, light labs, a mechanical room, radiation exposure cell, and basement) and storage tanks and transfer systems for large quantities of transformer oil and deionized water. Transfer lines for moving transformer oil from storage tanks to the accelerator are located just below grade in spill-containment trenches that follow the exterior course of the lines until they enter Building 983. Transformer oil from these tanks is shared between Saturn and the National Ignition Facility switch research operations located in Building 961. The oil transfer lines to Building 961 are located underground.

Deionized water does evaporate and may also be lost through leaks in the circulating system (the facility has a ground discharge permit to cover accidental leaks), but deionized water is not discharged to the SNL/NM sewage system as a wastewater.

The accelerator is a circumferentially symmetric, parallel-current driver consisting of 36 identical pulse-compression and power-flow modules. The 36 modules are arranged like the spokes of a wheel and can easily be configured to drive either annular electron-beam bremsstrahlung diodes or z-pinch plasma loads. The pulsed power components are housed in an open-air tank that is 96 ft in diameter and 14 ft high. The tank is divided into energy storage, pulse compression, power flow, and power combination sections. The concrete- and earth-shielded exposure cell is located in a basement room beneath the accelerator. The cell contains a 10-ton hydraulic lift for lifting large experimental and test equipment to the x-ray source.

The energy storage section of the tank includes 36 Marx generators, each of which consists of 32 capacitors that store 7.0 MJ of energy at 2.9 MV. The Marx generators transfer their energy to the intermediate storage capacitors through high-voltage feedthroughs in barriers between the oil and water tanks. The accelerator compresses pulses to 35 nanoseconds in two stages. The first stage consists of a coaxial water-dielectric intermediate storage capacitor and a triggered gas switch. The second stage consists of a charged transmission line and self-breaking water switches. Transmission lines and the vacuum insulator stack (VIS) feed the 35-nanosecond pulse of 800 kJ at 1.8 MV to the diode.

(Fine, 1988)

4.3 Program Activities

Table 12-43 shows the program activities at Saturn.

Table 12-43. Program Activities at Saturn

Program Name	Activities at Saturn	Category of Program	Related Section of the *SNL Institutional Plan*
Direct Stockpile Activities	Conduct development and survivability testing of nuclear weapon subsystems and components. Test the survivability of nuclear weapon systems by simulating the x-rays produced by a nuclear weapon detonation.	Programs for the Department of Energy	Section 6.1.1.1
Experimental Activities	Simulate the x-ray radiation effects of nuclear weapons on nonnuclear components of United States' strategic systems. May be used in hot x-ray or cold x-ray mode, depending on the type of source. Applications include testing of satellite systems, reentry vehicles, and missile subsystems.	Programs for the Department of Energy	Section 6.1.1.1

Table 12-43. Program Activities at Saturn (Continued)

Program Name	Activities at Saturn	Category of Program	Related Section of the *SNL Institutional Plan*
Performance Assessment Science and Technology	Provide hostile radiation environmental testing of weapon components. Conduct weapon physics experiments for x-ray simulations.	Programs for the Department of Energy	Section 6.1.1.1
Inertial Confinement Fusion	The 2-MV Saturn facility was previously Particle Beam Fusion Accelerator (PBFA) I (with initial operation in 1980), the forerunner of PBFA II. Saturn is a 36-module, 5-MJ stored energy accelerator, configured for parallel (current) addition. The first full-power shot in the new configuration occurred September 1987. The facility has a multi-ring diode geometry to provide bremsstrahlung sources for radiation effects testing of electronic subsystems by the SNL/NM Applied Physics Center (9300). Although the facility is critical to SNL/NM Center 9300 for the radiation effects portion of the Core Stockpile Stewardship Programs, the design of Saturn intentionally incorporated the versatility to also drive z-pinch plasma loads for inertial confinement fusion and weapon physics research by the SNL/NM Pulsed Power Sciences Center (9500). Z-pinch-driven hohlraum experiments for weapon physics studies began in FY1995. In FY1996, radiography proof-of-principle experiments relevant to stockpile stewardship began; these experiments will be continued with HERMES III.	Programs for the Department of Energy	Section 6.1.1.2
Pulsed Power Technology	Provide high-intensity, large-area x-ray radiation environments for certification of DOE and Department of Defense systems. Also provide high-temperature, large-volume hohlraums and cold x-ray environments for weapon physics and internal confinement fusion applications. The multiprogram applications have been complementary over the years in developing a more capable pulse power source and then applying it to problems such as radiation flow in weapon systems.	Major Programmatic Initiatives	Section 7.1.6
Other Federal Agencies	Saturn provides work for other entities such as the Department of Defense agencies and their subcontractors, the NSA, the United Kingdom, and other qualified users.	Work for Non-DOE Entities (Work for Others)	Section 6.2.7

4.4 Operations and Capabilities

The Saturn accelerator facility is a modular, high-power, variable-spectrum, x-ray simulation source that can be operated with two different bremsstrahlung diodes or any one of several plasma radiation sources. The diodes and sources provide x-ray radiation environments with enhanced simulation fidelity based on fast rise time, short pulse duration, and tailored spectral content.

In the bremsstrahlung mode, the accelerator is normally operated with a medium-area diode of 500 cm^2. A large-area diode (3,000 cm^2) is also available. Both diodes consist of three nested, triaxial diodes that are electrically isolated from one another. Each triaxial diode produces an annular current ring in which the electrons strike a thin tantalum anode, where electrical power is converted into x-ray power. The three current rings create a uniform, intense x-ray source. Both of the Saturn diodes can be operated over a range of anode-cathode gap settings in order to change the electron endpoint voltage and the x-ray photon output spectrum. In addition, the pulsed power portion of the accelerator can be operated at one-half or one-third of its full power, allowing reliable operation of low-voltage, high-spectral, and temporal-fidelity modes. The medium- and large-area bremsstrahlung diodes generate x-rays with endpoint voltages varying from 800 keV to 2 MeV, which allow good spectral fidelity over test areas from 500 cm^2 to greater than 10,000 cm^2.

Saturn can also be configured to provide 10 MA of current to z-pinch plasma radiation sources. Total x-ray yields from those sources range from 300 kJ to 500 kJ. Thin films are used to eliminate the ultra-violet and soft x-ray components.

The following are the standard accelerator parameters:

- Peak diode voltage is 1.8 MV.
- Power pulse width is 40 nanoseconds.
- Peak diode current is 12 MA (bremsstrahlung) or 10 MA (plasma radiation source).
- Total beam energy is 1.5 kJ.
- Total power is 36 TW.
- Repetition rate is two shots per day.

The operational work year for the Saturn facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and experiment setup time.

(Fine, 1988; Sullivan, 1995b)

4.5 Hazards and Hazard Controls

4.5.1 Offsite Hazards to the Public and Environment

The Saturn facility contains a small chemical inventory and a small radioactive material inventory that cannot be dispersed outside the facility. There are two accident scenarios (electric shock and aircraft crashes) in which the severity of an accident could be catastrophic. However, the probability is remote or extremely improbable. Therefore, accidents at this facility present no potential offsite consequences to either the public or the environment (Fine, 1988).

Approximately 300,000 gal of transformer oil is located in the accelerator oil tank (or in the oil tank storage farm). The oil is used as electrical insulation in the energy storage sections. The oil is recycled and regularly filtered to maintain its breakdown strength. The primary hazard to the environment associated with the oil is a large release. The building as well as the concrete wall around the aboveground storage tanks acts as secondary containment. Small amounts of oil are disposed of on rags. The possibility of an environmental release is very small. Transfer lines for moving transformer oil from storage tanks to the accelerator are located just below grade in spill-containment trenches that follow the exterior course of the lines until they enter Building 983. Transformer oil from these tanks is shared between the Saturn and the National Ignition Facility switch research operations located in Building 961. The oil transfer lines to Building 961 are located underground.

4.5.2 Onsite Hazards to the Environment

A transformer oil fire also presents an onsite environmental hazard. The accelerator tank is filled with reduced-flammability grade of transformer oil (ASTM-D3487, Type II) that is classified as a combustible liquid with a BTU content of 19,400 BTU/lb and a flash point of 300°F. The PCB concentration in the oil is limited to less than 50 parts per million. Based on previous operating experience and on engineering and fire protection testing, certain design and operating criteria have been established for Saturn to minimize the possibility of an oil fire. In particular, all electrical connections and routing in oil tanks are well beneath the surface of the oil, and the oil surface is open and without any potential wicks. Saturn draws transformer oil from 250,000-gal storage tanks located in Tech Area IV via underground piping.

4.5.3 Onsite Hazards to Workers

4.5.3.1 Radiological Hazards

Saturn is designed to produce an intense burst of x-rays, and high exposures are possible anywhere in the basement. A person standing on the basement floor directly beneath the diode during a shot could receive a major (greater than 25 rem) prompt radiation effective dose; however, a person standing directly on top (and at the center) of the accelerator would receive a negligible (less than 1 rem) dose. Access to the basement and to the entire highbay is rigorously controlled. Shielding provided by the accelerator, coupled with the personnel exclusion equipment, ensure that personnel are not exposed to hazardous levels of ionizing radiation. Furthermore, radioactive materials are not deliberately made or dispersed by the Saturn accelerator. Some reactions in beryllium-copper materials are possible, but the level of activation would be below 2 mCi/gm, and other surrounding materials would not become activated as a result of these reactions or machine operations.

4.5.3.2 Hazardous Material

The release of small quantities of hazardous material may occur during Saturn operations and could result in minor injury to workers. Most of the small quantities of hazardous material that will be used at the facility will be adequately removed from the atmosphere in the work area by the HVAC systems. Any chemical waste requires special handling and is disposed of in accordance with an approved activity-specific ES&H SOP for the use and disposal of hazardous chemicals at the Saturn Facility, Building 981. Disposal is in accordance with EPA regulations on hazardous waste.

4.5.3.2.1 Transformer Oil (300,000 Gal Recycled)

Transformer oil is used as electrical insulation in the energy storage section. The oil is regularly filtered to maintain breakdown strength and is periodically transferred to storage tanks. The circular accelerator tank is filled with transformer oil, and the intermediate stores and pulse-forming section contains deionized water. Water leaks could contaminate the oil. Workers on catwalks above Saturn could possibly fall into the oil, but this is extremely unlikely. Any person who falls into the oil-filled tank would find it impossible to swim or float. Use of handrails and safety harnesses are important in preventing such falls. Leaked or spilled oil creates a hazard for personnel, who may slip on oily floors. Oil leaks in the transformer oil storage tanks and supply system generate a liquid waste that requires treatment. Liquid waste sumps are strategically located throughout the highbay and storage tank farm to catch any oil spills. Once in the sumps, the oil is pumped to a location where the oil can be skimmed off the top of waste water and pumped to a waste oil storage tank. The waste oil storage tank is periodically drained and then trucked to an oil reclamation center. This drainage and transport for disposal of oil is not a part of routine operations. Small oil spills are absorbed on particulate vermiculite. Because oil-soaked vermiculite particles are considered flammable, this waste is cleaned up and collected in red, fire-safety-approved closed containers located throughout the building.

4.5.3.2.2 Ethanol (5 to 10 Gal per Year)

Ethyl alcohol is a solvent that is used to clean various components between test shots. It poses a minor respiratory hazard to personnel, particularly to those working in enclosed spaces. The hazards will be mitigated by using small quantities (on rags) and proper ventilation. Cloths used for cleaning are disposed of as hazardous waste.

4.5.3.2.3 Copper Sulfate (5 Lb per Year)

Exposure to dilute concentrations of copper sulfate is possible during the fabrication of resistors, and personnel injury could include minor skin or eye irritation. The facility impact is minimal, with possible spills limited to less than 5 gal of the solution. Spill cleanup materials are disposed of as hazardous waste.

4.5.3.2.4 Sulfur Hexafluoride (SF_6) Gas (200 Lb per Month)

SF_6 is used as the insulator gas in switching components. SF_6 gas is passed through switches under continuous pressure. Pure SF_6 is chemically and physiologically inert but does not support respiration. SF_6 leaked in an enclosed area could act as a simple asphyxiate but is not toxic. When subjected to high-voltage discharge, some breakdown occurs and the fluorides formed are corrosive and somewhat toxic. Thus, used SF_6 that has not been passed through a purifying reclaimer is a fugitive emission that presents an inhalation hazard to personnel and that could damage sensitive equipment. A reclaimer will remove these breakdown products, which will be disposed of as hazardous waste. The supply of SF_6 is stored after purification. Leakage of SF_6 gas from the closed system is possible, but the building ventilation system immediately removes this gas to the outside and effectively dilutes it from extremely small concentrations to negligible amounts in air. The total maximum SF_6 on hand at any one time is estimated at 200 lb.

4.5.3.2.5 Beryllium

In the plasma radiation source mode, some tests involve the installation of beryllium filters or shields that can be damaged during a shot. This causes beryllium particulate to be released into the diode vacuum chamber, which presents a potential health hazard because beryllium is a suspected human carcinogen, and it can also cause beryllium intoxication and contact dermatitis. The potential hazards result from inhalation of particulate and skin contact. Activities where particulate beryllium may be encountered include cutting of foils and decontamination of test hardware following beryllium test article failure. Skin contact is a continuous hazard when handling beryllium test articles and wastes.

Experience with beryllium testing at Saturn indicates that beryllium contamination sources are extremely small and that decontamination procedures work well. The Saturn test chamber is ventilated following each beryllium test, and a high-efficiency particulate air (HEPA) filter filters the exhaust. After several beryllium tests, the HEPA filter was assayed, but no beryllium particulate was detected. It can be concluded that airborne beryllium is generated in only very small amounts at most. After a particularly harsh test, beryllium contamination was found on surfaces in the immediate vicinity of the test articles. Contamination of 0.2 µg per cm^2 was measured. Following standard decontamination procedures, the contamination was reduced to levels below detection limits. The same report contained results of samples taken in the test preparation area, which showed no contamination was present. Samples taken for a number of other beryllium tests consistently resulted in the same low-level results. Even in the absence of active forms of protection, the potential for health effects or environmental damage due to the beryllium hazard is very slight. (Tests involving the beryllium filters constitute less than 20 percent [range of 5 percent to 20 percent] of Saturn’s annual operations, and exposures are carefully controlled to levels as low as reasonably achievable, which is well below the established exposure limits.)

4.5.3.3 Industrial Hazards

Although an exposure to the gravity or mechanical hazards of maintenance work or to the thermal hazards of hotwork could result in severe personnel injury or major facility damage or possibly have an impact on the environment, such industrial-type hazards are considered to be of a magnitude and type routinely encountered and accepted by the public. Furthermore, possibly catastrophic industrial-type accidents such as a death due to heavy equipment being dropped from an overhead crane or from electric shock that results from work with high voltages are not expected to happen and pose an acceptably low level of risk.

4.5.3.3.1 Gravity Hazards

Particularly important hazards in this facility result from moving and positioning heavy pieces of apparatus in restricted spaces and from the need to perform maintenance work in cramped areas such as inside the oil tank. Sometimes these areas may be wet or oily. In addition, not all areas can be reached from ground level. The hazard created by dropped tools or apparatus is increased by these conditions. The amount of overhead work to be performed makes the possible dangers of falling (dropped) equipment of special concern. In fact, the most likely cause of death or severe personnel injury or equipment damage would be impact during movement of heavy equipment such as a Marx generator bank. Use of hard hats and personnel exclusion zones and adherence to restrictive procedures by trained personnel are important for decreasing the chances of accidents that could occur when tools are being carried by hand overhead and when equipment is being moved by cranes and lifts. The amount of overhead work that will be required and the presence of substantial amounts of transformer oil and other liquids augment the potential for serious falls. Oil leaks are possible over large areas. The several inches of transformer oil that remain in the oil tank after it is drained can create slippery walking and working surfaces for maintenance personnel. Facility design and maintenance and use of handrails, safety harnesses, and safety footwear are especially important for fall protection. These measures and approved procedures, training, and extreme attention to housekeeping are emphasized.

4.5.3.3.2 Electrical Hazards

Electrical hazards are encountered during maintenance of accelerator electrical systems where electrical energy sources (or storage) are present (for example, maintenance activities in close proximity to a Marx generator). The electrical energy sources at Saturn include the following:

- Marx generators
- Triggering systems
- Lasers
- Data acquisition (DAS) equipment
- High-voltage power supplies
- Power tools
- Electrical wiring and cables

Of these sources, many are common in industry and are well understood. Others, such as the Marx generators, are items designed for special accelerator applications. The Marx generators, transfer switches, lines, and other associated equipment are discharged routinely after firing or testing and before maintenance operations are performed. However, capacitors can maintain a residual lethal charge, and discharge procedures may not be effective if equipment has been damaged. Maintenance work on such apparatus could be hazardous, and extreme care must be taken to ground each capacitor. The trigger system components for the accelerator may fail and may also arc, crack, and track. Training and adherence to approved procedures reduce the risk. Other electrical wiring and cables are standard units similar to those found widely in industry. The hazards they pose and the required safety measures are common to industrial facilities and operations, and adequate safety measures are in place. The computer support equipment may require maintenance in the vicinity of live circuits. Trained personnel perform these activities using standard safety equipment and procedures. The DAS controls and monitors the accelerator and gathers and analyzes shot-related data. Because of the number and complexity of functions performed, electrical power requirements are significant. Hardware breakdown and repair activities that may occur while other parts of the system are functioning could pose some hazard to personnel.

4.5.3.3.3 Mechanical Hazards

Mechanical hazards are most often encountered during maintenance activities involving the use of tools and work on mechanical equipment. Mechanical equipment used in the Saturn facility is standard for heavy industrial use, and this equipment includes motors, door hoists, elevators, cranes, and hoists, power tools, hand tools, compressed gas equipment, vacuum equipment, and transports. The use of all mechanical equipment conforms to standard industrial safety practices. Although it is unlikely, severe injury or major damage to the facility or operation could result from the mechanical hazards associated with maintenance activities on large systems or components. However, the majority of potential accidents would result in only minor injury or minor occupational illness or minor impact on the environment or minor system or component damage.

4.5.3.3.4 Thermal Hazards

Thermal hazards include welders and cutting torches, equipment with rotating parts (cranes, hoists, tools, motors, and pumps), heaters, tools that may spark, and lighting. These sources of thermal energy could initiate fires. All sources of thermal energy are standard for industrial installations.

4.5.3.3.5 Confined Space Hazards

Potential anoxia-producing accidents could arise from working in areas where O_2 has been depleted. SF_6 or other inert gases may, in some circumstances, displace air sufficiently to deprive personnel of oxygen and cause asphyxiation. Operation of the HVAC system (including circulation fans) and use of equipment to monitor oxygen deficiencies are important in preventing and identifying low oxygen conditions. The buddy system is also required. At Saturn, such an asphyxiation event is only remotely possible and is not expected to occur during the life of the facility.

4.5.3.3.6 Fire

The probability of fire at the Saturn facility is low because of the way Building 981 is designed and because of requirements that are set forth in the operating procedures. However, the potential severity of the fire is significant because personnel could be injured and the facility could be seriously damaged or destroyed. The building is of concrete and metal construction and has built-up bituminous roofing, and the likelihood of occurrence of a serious fire is significantly reduced by the presence of an automatic foam suppression system in the accelerator area of the building. The types and quantities of flammable materials throughout the building are strictly controlled. Combustibles are kept to a minimum, the use of flammable liquids are strictly controlled, and combustible waste is kept in covered metal cans. Throughout SNL, smoking is prohibited except in designated outdoor smoking areas. A full-time paid fire department is on duty at Kirtland Air Force Base at all times that can respond to a fire within five minutes. Also, the fire department can provide a crew to stand by upon request. The most likely causes of a fire are overheated equipment, overheated wiring, or ignition of flammable solvents, oil soaked rags, or absorbent materials. Less likely, but of serious consequence, is the ignition of the high-flash-point (300°F) dielectric transformer oil.

4.5.4 Hazard Controls

4.5.4.1 Radiation Shielding

The annular oil and water tanks shield those who occupy ground-level areas surrounding Saturn from x-rays that stream radially from the diode during accelerator operation. The stainless-steel tips of the magnetically insulated transmission lines (MITLs) provide sufficient shielding to limit skyshine radiation from x-ray streaming out of the vacuum insulator stack (VIS) to less than 1 rem per year.

4.5.4.2 Access Control

Access control to all areas of the facility is maintained by access control systems, closed circuit television, and physical inspection and clearing procedures. The primary access control system consists of the following:

- A facility public address system
- Audible alarms
- Rotating beacons
- Lockable doors and gates with position sensors
- Access stations with status indicators

- An operator control panel (Should a primary access control system intrusion or fault occur, an audible alarm is sounded and the door or gate that was opened or has a fault is visually indicated.)

- A redundant access control system, which includes:

    - Redundant position sensors on all doors and gates in the highbay that permit direct access to the accelerator or basement exposure cell

    - An operator control panel

    - Warning lights that are color-coded to permit ready identification of hazardous conditions by facility personnel

    - The Building 981 roof access ladders, which have a cage around them with a padlocked gate

    - Three video cameras strategically located on the building highbay roof that allow the entire highbay roof to be seen on monitors at the accelerator control console

4.5.4.3 Electrical Safety

Marx generator energy can be safely dissipated into a resistive load in the oil section if a shot is aborted. During physical sweeps of the access-controlled areas, personnel activate a series of key-operated switches at test alert stations at each of the highbay doors or gates, which enables the high-voltage interlock system. Personnel must activate all test alert station switches before the accelerator triggering system can be operated.

4.5.4.4 Secondary Oil Containment System

Building 981 includes a secondary containment trench system, which is located just inside the exterior walls of the highbay. In the event of a large oil leak, the trenches channel the oil to the basement area, where it is stored until it can be reclaimed. In the event of a catastrophic failure of the outer wall of the annular oil tank, oil flows to the lower pit floor level by way of the personnel tunnel. Dikes around the aboveground oil storage tanks serve as secondary containment structures in the event of an oil tank rupture.

4.5.4.5 Confined Space Safety

Oxygen deficiency monitoring and adherence to confined space procedures help to maintain confined space safety. Ventilation, respirators, and the two-person rule ensure worker protection in confined spaces.

(Fine, 1988; Sullivan, 1995b)

4.6 Accident Analysis Summary

4.6.1 Selection of Accidents Analyzed in Safety Documents

The fault hazard analysis (FHA) technique was used to develop both the system hazard analysis (SHA) and the O&SHA for the Saturn facility. These particular analyses are suited to evaluation of single-event scenarios. As a consequence, all credible single-event scenarios were considered in the analysis.

4.6.2 Analysis Methods and Assumptions

The FHA is a systematic means of identifying the following:

- Key causative factors
- Specific ways in which a piece of equipment might fail to perform its intended function
- Effects of the failure
- Information related to the expected risk that such a failure might impose

In the SHA, each system and subsystem in a facility is systematically evaluated in the context of its particular function and its interfaces with other systems and subsystems. The SHA identifies component hazards and failure modes critical enough to be addressed in more detail.

For each hazard and failure mode that the SHA identifies, the unmitigated consequences of failure are rated in terms of relative severity using the criteria provided in AL 5481.1B. An estimate of the relative probability of occurrence is assigned based on the probability that a hazard will occur during the planned life expectancy of the system, as shown in Table 12-44. The severity-probability pairings (risks) for each hazard and failure mode are then rated in terms of criticality as shown in Table 12-45. When the criticality of the risk is determined to fall within an unacceptable or undesirable range, the hazard requires additional evaluation.

Table 12-44. Hazard Probability

Failure Category	Level	Description	Description	Failure Rate
Frequent	A	Likely to occur	One or more system failures per shot	Continually experienced $P_e > 10^{-2}$
Reasonably probable	B	Will occur several times in the life of an operation or item	One system failure in two or more shots, fewer component failures per shot	Will occur several times $P_e = 10^{-2}$ to 10^{-3}
Occasional	C	Likely to occur sometime in the life of an operation or item	One system failure in several shots, maximum of one component failure per shot	Will occur several times $P_e = 10^{-3}$ to 10^{-4}
Remote	D	Unlikely to occur during the life of an operation or item	Unlikely but can reasonably be expected to occur	Unlikely to occur but possible $P_e = 10^{-4}$ to 10^{-5}
Extremely improbable	E	So unlikely that it can be assumed that this hazard will not be experienced	Unlikely to occur but possible	Can be assumed that although possible, it will not be experienced $P_e = 10^{-5}$ to 10^{-6}
Impossible	F	Physically impossible to occur	Physically impossible to occur	Will not be experienced

P_e = Probability of event occurring per year.

Table 12-45. Risk Criticality

Probability	Severity			
	I	II	III	IV
A	Unacceptable	Unacceptable	Unacceptable	Acceptable with management review
B	Unacceptable	Unacceptable	Undesirable*	Acceptable with management review
C	Unacceptable	Undesirable*	Acceptable with management review	Acceptable without review
D	Undesirable	Undesirable*	Acceptable with management review	Acceptable without review
E	Acceptable with management review	Acceptable with management review	Acceptable with management review	Acceptable without review
F	Acceptable without review	Acceptable without review	Acceptable without review	Acceptable without review

*May be inescapable for an experimental high-energy facility.

When the criticality of the risk falls into the unacceptable or undesirable categories of Table 12-45, a system hazard analysis form is completed. This form includes additional information on hazard detection and prevention or mitigation features and recommendations for reducing risk. The analyst assigns a residual risk, taking into consideration the effect of recommended risk reduction measures. The SHA results for Saturn are documented in Appendix A of Fine (1988).

In the O&SHA, each major component in a facility is systematically evaluated in the context of its particular function in the subsystem and system, and the analysis includes personnel involvement. Unmitigated consequences, relative probability of occurrence, and risk criticality are determined as indicated above for the SHA. When the criticality of the risk falls into the unacceptable or undesirable categories of Table 12-45, an operating and support analysis form is completed. This form includes additional information on hazard detection and prevention or mitigation features and recommendations for reducing risk. The analyst assigns a residual risk, taking into consideration the effect of recommended risk reduction measures. The O&SHA results for Saturn are documented in Appendix B of Fine (1988).

4.6.3 Summary of Accident Analysis Results

For some of the Tech Area IV accelerator facilities, a scenario evaluation methodology was used for the facility accident analysis. For these facilities, a set of “generic” events for evaluation was established by examining sources of energy, radiation, and hazardous materials in the facility. These selected events represent the major contributors to overall facility accident risk. The results of the Saturn accident assessment are summarized in Table 12-46 in terms of these generic events.

Table 12-46. Summary of Saturn Accident Assessment Results

Event	Severity	Probability
Electric shock	Catastrophic (I)	Remote (D)
Radiation exposure	Critical (II)	Extremely improbable (E)
Fire	Critical (II)	Remote (D)
Asphyxiation	Marginal (III)	Occasional (C)
Earthquake	Marginal (III)	Reasonably probable (B)
Tornado	Critical (II)	Remote (D)
High winds	Marginal (III)	Frequent (A)
Flood	Marginal (III)	Remote (D)
Aircraft crash	Catastrophic (I)	Extremely improbable (E)

Adjusting the probability categories of the above methodology to the criteria in AL 5481.1B produces the residual risk results in Table 12-47.

Table 12-47. Probability Categories Adjusted to Criteria in AL 5481.1B

Event	Severity	Probability
Electric shock	Catastrophic (I)	Extremely unlikely (C)
Radiation exposure	Critical (II)	Extremely unlikely (C)
Fire	Critical (II)	Extremely unlikely (C)
Asphyxiation	Marginal (III)	Unlikely (B)
Earthquake	Marginal (III)	Unlikely (B)
Tornado	Critical (II)	Extremely unlikely (C)
High winds	Marginal (III)	Likely (A)
Flood	Marginal (III)	Extremely unlikely (C)
Aircraft crash	Catastrophic (I)	Extremely unlikely (C)

Tables 12-48 and 12-49 were obtained from AL 5481.1B and provide definitions for terms used in “4.6 Accident Analysis Summary.”

Table 12-48. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or significantly affect the environment.

Table 12-49. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

(Fine, 1988)

4.7 Reportable Events

Table 12-50 lists the only occurrence report for the SATURN accelerator over the past five years.

Table 12-50. Occurrence Report for the Saturn Accelerator

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-14000-1996-0001	Contaminated Welding Fixture Parts Exceed the Threshold for a Non-Contaminated Controlled Area	1D	A survey of welding fixture parts located inside cabinets in Building 891 indicated contamination levels in excess of the reporting threshold.

4.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials

4.8.1.1 Alternatives for Test Activities: Irradiation of Components or Materials

Table 12-51 shows the alternatives for irradiation of components or materials at Saturn.

Table 12-51. Alternatives for Test Activities: Irradiation of Components or Materials

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40 shots	65 shots	200 shots	200 shots	500 shots

4.8.1.2 Assumptions and Actions for the “Reduced” Values

The Saturn accelerator facility is a modular, high-power, variable-spectrum, x-ray simulation source. Saturn can be operated with two different bremsstrahlung diodes or any one of several plasma radiation sources. Saturn is used to simulate the radiation effects of nuclear countermeasures on electronic and material components and is also used as a pulsed-power and radiation source and as a diagnostic test bed.

The programs that use the Saturn accelerator and the activities associated with those programs are provided in “4.3 Program Activities.” Because Saturn's controlled production of x-rays is fundamental to each of the listed programmatic activities, the values for material inventory, consumption, and waste generation would be essentially the same under each scenario. Therefore, the following considers one basic scenario, which is the firing of the Saturn accelerator. Furthermore, there is the underlying assumption that the related values are directly proportional to the number of times the machine fires (“shots”).

For the “reduced alternative,” Saturn must be fired about once per week to keep the accelerator in a state of operational readiness. Therefore, 50 shots are required during the 40-week operating year for the “reduced” alternative. This value is approximately 0.6 times that reported in the base year (40 shots / 65 shots = 0.6).

4.8.1.3 Assumptions and Rationale for the “No Action” Values

The following are assumptions for the “no action” alternative:

- The base year value is the actual number of 65 shots in CY1997. (The 65 shots were taken during about six months of actual operations. If Saturn had been operating the entire year, a projected 130 shots would have been taken.)

- Current projections for level of activity are based on current funding and program requirements. The value for FY2003 is approximately three times the value reported in the base year (200 shots / 65 shots = 3.08).

- Current projections for the level of activity are based on current funding and program requirements. The value for FY2008 is approximately three times the value reported in the base year, or approximately 200 shots per year (200 shots / 65 shots = 3.08).

4.8.1.4 Assumptions and Actions for the “Expanded” Values

The Cold War level of activity for Saturn was approximately 250 to 260 shots per year; current estimates for expanded operations are one shot per day for 40 weeks (minus holidays and maintenance time), which equals 200 shots. Some customers request two shots per day, which is possible in a ten-hour work day. A split shift would increase the workday by four hours per day and would enable an extra shot per day (three shots per day every other day), which equals a maximum of 480 shots annually.

The expanded value of 500 shots is approximately 7.7 times the value reported in the base year approximately (500 shots / 65 shots = 7.69).

4.8.2 Material Inventories

4.8.2.1 Nuclear Material Inventory Scenarios

Saturn has no nuclear material inventories.

4.8.2.2 Radioactive Material Inventory Scenarios

Saturn has no radioactive material inventories.

4.8.2.3 Sealed Source Inventory Scenarios

Saturn has no sealed source inventories.

4.8.2.4 Spent Fuel Inventory Scenarios

SATURN has no spent fuel inventories.

4.8.2.5 Chemical Inventory Scenarios

4.8.2.5.1 Alternatives for Chemical Inventories

Table 12-52 shows the alternatives for chemical inventories at Saturn.

Table 12-52. Alternatives for Chemical Inventories

Chemical	Reduced Alternative	No Action Alternative			Expanded Alternative
		Base Year	FY2003	FY2008	
Sulfuric acid	30 l	30 l	30 l	30 l	30 l
Acetone	0.7 gal	1 gal	3 gal	3 gal	7.7 gal
Methyl alcohol	0.7 gal	1 gal	3 gal	3 gal	7.7 gal

4.8.2.5.2 Operations That Require Chemical Inventories

The programs and operations that utilize these chemicals are described in detail in “4.2 Description,” “4.3 Program Activities,” and “4.4 Operations and Capabilities.” The inventory of sulfuric acid is not related to Saturn operations. The Chemical Information System assigned this material to the Saturn facility because it is in the same building.

4.8.2.5.3 Basis for Projecting the Values in the “No Action” Columns

Baseline values for the chemicals listed in Table 12-52 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

4.8.2.5.4 Basis for Projecting the Values in the “Reduced” Column

Baseline values for the chemicals listed in Table 12-52 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

4.8.2.5.5 Basis for Projecting the Values in the “Expanded” Column

Baseline values for the chemicals listed in Table 12-52 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

4.8.2.6 Explosives Inventory Scenarios

Saturn has no explosives inventories.

4.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

4.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-53 shows the alternatives for insulator oil inventory at Saturn.

Table 12-53. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
300,000 gal	300,000 gal	300,000 gal	300,000 gal	300,000 gal

4.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material which prevents electrical breakdown when the accelerator is charged. (Inspections have shown that PCB concentrations are below the level of detection.) The oil section of the accelerator holds approximately 300,000 gal of oil. The total storage capacity for the oil is 500,000 gal in two aboveground 250,000-gal tanks.

4.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

There will be no more or no less oil required in the “reduced” or “expanded” scenarios.

4.8.3 Material Consumption

4.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at Saturn.

4.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at Saturn.

4.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

4.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at Saturn.

4.8.4 Waste

4.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at Saturn.

4.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at Saturn.

4.8.4.3 Mixed Waste

4.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at Saturn.

4.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at Saturn.

4.8.4.4 Hazardous Waste Scenario

4.8.4.4.1 Alternatives for Hazardous Waste at Saturn

Table 12-54 shows the alternatives for hazardous waste at Saturn.

Table 12-54. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
100 kg	167 kg	501 kg	501 kg	1,286 kg

4.8.4.4.2 Operations That Generate Hazardous Waste

Saturn generates hazardous waste as part of ongoing operations.

4.8.4.4.3 General Nature of Waste

The waste is comprised of copper sulfate liquid (contained in resistors), contaminated oils and oily rags, waste capacitors, and nonhalogenated solvent-contaminated rags.

4.8.4.4.4 Waste Reduction Measures

Waste management for ongoing activities is conducted in accordance with Sandia National Laboratories (1998), Chapter 19, "Waste Management." Nonhazardous cleaning agents are substituted for solvents whenever possible.

4.8.4.4.5 Basis for Projecting the "Reduced" and "Expanded" Values

See "4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials." The amount of waste is proportional to the operational activity (number of "shots").

4.8.5 Emissions

4.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at Saturn.

4.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

4.8.5.3 Open Burning Scenarios

Saturn does not have outdoor burning operations.

4.8.5.4 Process Wastewater Effluent Scenario

Saturn does not generate process wastewater.

4.8.6 Resource Consumption

4.8.6.1 Process Water Consumption Scenario

Saturn does not consume process water.

4.8.6.2 Process Electricity Consumption Scenario

Saturn does not consume process electricity.

4.8.6.3 Boiler Energy Consumption Scenario

Saturn does not consume energy for boilers.

4.8.6.4 Facility Personnel Scenario

4.8.6.4.1 Alternatives for Facility Staffing at Saturn

Table 12-55 shows the alternatives for staffing at Saturn.

Table 12-55. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
4 FTEs	5 FTEs	10 FTEs	10 FTEs	18 FTEs

4.8.6.4.2 Operations That Require Facility Personnel

Ongoing operations of the facility, including operational readiness and firing the accelerator for the support of programs, require staff.

4.8.6.4.3 Staffing Reduction Measures

Saturn is presently on a shared crew basis with the operations of the HERMES III, SPHINX, and SABRE accelerators, which is essentially the minimum staff required to maintain the present capability.

4.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

See “4.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.”

4.8.6.5 Expenditures Scenario

4.8.6.5.1 Alternatives for Expenditures at Saturn

Table 12-56 shows the alternatives for expenditures at Saturn.

Table 12-56. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$1.2 million	$1.5 million	$3 million	$3 million	$5.4 million

4.8.6.5.2 Operations That Require Expenditures

Expenditures are required for FTEs, maintenance equipment, and consumables.

4.8.6.5.3 Expenditure Reduction Measures

Expenditure reduction measures include reduction of FTEs and consumables as the number of shots vary.

4.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

Historically, Saturn cost $3 million per year for the “no action” alternative (200 shots). The projections were determined by ratioing the cost according to the number of FTEs (for example, $3 million x 4/10 = $1.2 million for the “reduced” alternative).

5.0 REPETITIVE HIGH ENERGY PULSED POWER UNIT I SOURCE INFORMATION

5.1 Purpose and Need

The mission of the Repetitive High Energy Pulsed Power Unit I (RHEPP I) facility is to serve as a tool for the development of the technology for continuous operation of pulsed power systems that:

- Demonstrate high average power ion beam outputs at energies up to 1 MeV and power up to 45 kW.

- Suit industrial applications.

(De La O and Zawadzkas, 1995; U.S. Department of Energy, 1996)

5.2 Description

The Repetitive High Energy Pulsed Power Unit I facility, located in Building 986, includes a Marx generator, a pulse-forming line (PFL), a linear induction voltage adder (LIVA), the vacuum diode load (VDL), and a vacuum test stand for ion source testing and development. The system consists of a 150-kW power supply, four stages of linear induction voltage addition, and the vacuum diode. The 150-kW power supply serves as the prime power source.

(De La O and Zawadzkas, 1995; U.S. Department of Energy, 1996)

5.3 Program Activities

Table 12-57 shows the program activities at the Repetitive High Energy Pulsed Power Unit I.

Table 12-57. Program Activities at the Repetitive High Energy Pulsed Power Unit I

Program Name	Activities at the Repetitive High Energy Pulsed Power Unit I	Category of Program	Related Section of the *SNL Institutional Plan*
Performance Assessment Science and Technology	Develop unique pulsed power materials-processing techniques for weapon applications.	Programs for the Department of Energy	Section 6.1.1.1
Nonproliferation and Verification Research and Development	The Repetitive Pulsed Power Program will be developing advanced accelerators for applications related to biological and chemical agent defeat.	Programs for the Department of Energy	Section 6.1.3.1
Pulsed Power Technology	Repetitive High Energy Pulsed Power Unit I, the first SNL/NM RHEPP-type accelerator, was used for basic technology development of the RHEPP technical concept and is now used for applications at lower energies. It is also still used for technology development and some experimental work with materials and organic sterilization processes.	Major Programmatic Initiatives	Section 7.1.6

5.4 Operations and Capabilities

During normal operation, the accelerator system produces pulses of ions that may be stopped (creating low-level bremsstrahlung radiation). The Marx generator delivers pulses of nominally 1-microsecond duration and 250-kV amplitude to the PFL. These pulses are further compressed to 60-nanosecond waveforms by the water-filled PFL. Four stages of magnetically insulated voltage addition in the LIVA boost the pulse voltages to nominally 800 kV at 45 kA and deliver the pulses to the ion diode for generation of an ion beam for materials testing. The ion diode source and materials test chamber are located in a below-grade, radiation-shielded test cell under the LIVA.

The operational work year for the Repetitive High Energy Pulsed Power Unit I facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and test setup time.

(De La O and Zawadzkas, 1995)

5.5 Hazards and Hazard Controls

5.5.1 Offsite Hazards to the Public and the Environment

The Repetitive High Energy Pulsed Power Unit I facility contains a small chemical inventory and a small radioactive material inventory that cannot be dispersed outside the facility. Thus, there are no potential consequences to either the public or the environment from accidents at this facility (De La O and Zawadzkas, 1995).

5.5.2 Onsite Hazards to the Environment

Onsite environmental hazards include transformer oil. The Repetitive High Energy Pulsed Power Unit I oil tank contains 6,500 gal of a reduced-flammability grade of transformer oil (Shell DIALA A/AX) that is used as electrical insulation for the Marx generators, and another 1,500 gal is used in the LIVA. The oil is regularly filtered to maintain breakdown strength and is periodically transferred to a 22,000-gal storage tank located next to Building 986. The oil has a flash point of 300°F.

5.5.3 Onsite Hazards to Workers

The following are potential worker hazards at the Repetitive High Energy Pulsed Power Unit I facility:

- Small amounts of ionizing radiation, which can be produced in the form of bremsstrahlung (x-rays) at the diode located in the test cell.

- The Marx generator, which is the prime energy storage component of the accelerator.

- Ethanol, which is used in small quantities (100-ml squeeze bottles) as a solvent to clean accelerator components and other equipment.

- Dilute copper sulfate solution, which is used to fabricate high-power resistors for use in the Marx generators.

- Confined spaces, including the Marx generator oil tank, the secondary oil containment trenches, and the test cell (pit).

Repetitive High Energy Pulsed Power Unit I does not use heavier-than-air gases. Gases that may be used would be nitrogen (N) or compressed air. There is no gas switching in the repetitive pulse mode (no SF_6 use).

5.5.4 Hazard Controls

Hazard controls at the Repetitive High Energy Pulsed Power Unit I facility include:

- **Radiation Shielding** - Radiation shielding was constructed at a time when Repetitive High Energy Pulsed Power Unit I was operating at higher voltages and capable of producing higher radiation levels than those that the facility currently produces. The facility is constructed to ensure that an errant particle beam is physically intercepted before it reaches any area where personnel may be present during operations. The only entrance and exit to the test cell is a lead shield door, and the test cell itself is constructed of thick radiation shield walls.

- **Access Control** - Access control at Repetitive High Energy Pulsed Power Unit I is maintained by fences, locked doors, a locked gate, and physical inspection and clearing procedures. The test cell is a restricted area and is checked for personnel before the accelerator is operated. The lead shield door to the test cell is closed and locked to prohibit entry prior to and during a shot sequence. By procedure, evacuation sweeps are conducted prior to accelerator startup to ensure that personnel are not present in restricted areas. Accelerator operation is interlocked with the main access gate, which is locked and alarmed. If the gate is opened, the alarm alerts the operator to take safeguard actions according to facility ES&H SOPs. The gate can be opened with a key that is in the possession of the operator or by means of a panic switch in an emergency.

- **Electrical Safety** - The charging circuit for the Marx generator is solenoid operated so that a disruption or loss of power will automatically discharge the Marx bank capacitors through an electronic dump circuit. The circuit will not allow the Marx bank to recharge until the operator resets the charging switches.

- **Secondary Oil Containment System** - Building 986 has secondary oil containment in the form of a 3-ft-deep concrete trench system that will contain the oil should a catastrophic leak occur. Similarly, the concrete walls around the 22,000-gal oil storage tank located next to Building 986 serve as a secondary containment structure in the event of a rupture of the oil storage tank.

- **Confined Space Safety** - The Marx generator oil tank is a confined space that requires a permit for entry. This tank and the secondary oil containment trenches are checked for proper oxygen content prior to entrance by personnel who must wear oxygen sensors while working there. Prior to any entry to the test cell, the cell is checked for oxygen level using an oxygen monitor. Entry to the pit following any operations is also procedurally governed by the two-man rule, which requires an entrant and an observer.

(De La O and Zawadzkas, 1995)

5.6 Accident Analysis Summary

5.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the Repetitive High Energy Pulsed Power Unit I facility and through discussions with operations personnel.

Following the walk-down and qualitative survey of the facility, the operating events selected for qualitative risk analysis included the following:

- Fire involving insulating oil
- Worker electrocution while “safing” Marx generator capacitors
- Worker asphyxiation in a confined space
- Worker radiation exposure during accelerator operation

These events are considered to be the bounding accidents that define the safety envelope for facility operations. In addition, the accident analysis for Repetitive High Energy Pulsed Power Unit I included natural phenomena event scenarios that are generic to all facilities at SNL, as well as an aircraft crash scenario.

The facility accident analysis did not address standard industrial accidents (for example, accidents involving hazards such as cranes and hoists, forklifts, lasers, and compressed gases) for which accident prevention and mitigation are covered by existing consensus standards.

5.6.2 Analysis Methods and Assumptions

The methodology used to perform the Repetitive High Energy Pulsed Power Unit I accident assessment (see Mahn *et al.*, 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-58. In addition, a generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities, as provided in Mahn *et al*. (1995), were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-58. Consequence Categories and Levels of Severity

Rank	**DOE/AL 5481.1B**	**Human Impact**	**Environmental Impact**	**Programmatic Impact**
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year

Table 12-58. Consequence Categories and Levels of Severity (Continued)

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

5.6.3 Summary of Accident Analysis Results

The results of the Repetitive High Energy Pulsed Power Unit I accident assessment are in Table 12-59.

Table 12-59. Results of the Repetitive High Energy Pulsed Power Unit I Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Extremely unlikely (C)
Fire	Marginal (III)	Extremely unlikely (C)
Asphyxiation	Marginal (III)	Unlikely (B)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

Tables 12-60 and 12-61 were obtained from AL 5481.1B and provide definitions for terms used in “5.6 Accident Analysis Summary.”

Table 12-60. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or significantly affect the environment.

Table 12-61. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

(De La O and Zawadzkas, 1995)

5.7 Reportable Events

Table 12-62 lists the only occurrence report for the Repetitive High Energy Pulsed Power Unit I over the past five years.

Table 12-62. Occurrence Report for the Repetitive High Energy Pulsed Power Unit I

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-1000-1994-0002	Oil Spill at Building 986	2B and 2E	A small spill of transformer oil occurred from the oils storage tank associated with Building 986 when a gasket failed.

5.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

5.8.1 Activity Scenario for Test Activities: Accelerator Tests

5.8.1.1 Alternatives for Test Activities: Accelerator Tests

Table 12-63 shows the alternatives for accelerator tests at the Repetitive High Energy Pulsed Power Unit I.

Table 12-63. Alternatives for Test Activities: Accelerator Tests

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
100 tests	500 tests	5,000 tests	5,000 tests	10,000 tests

5.8.1.2 Assumptions and Actions for the “Reduced” Values

The number of tests (also referred to as “treatments”) projected under the “reduced” alternative represent the minimum number of shots needed to maintain operational capability. This number is based on maintaining assurance of capability in both the single and repetitive pulse modes.

The Repetitive High Energy Pulsed Power Unit I fires at 10 Hz. The number of shots within a test can go as high as 1,000.

5.8.1.3 Assumptions and Rationale for the “No Action” Values

For the base year projection, Repetitive High Energy Pulsed Power Unit I has averaged approximately 500 tests per year over 1996 and 1997.

The projected increase in Repetitive High Energy Pulsed Power Unit I operations for the FY2003 and FY2008 projections is based on an average of 25 tests per day over a 40-week year (5,000 tests/40 weeks = 125 tests per week/5 days per week = 25 tests per day).

5.8.1.4 Assumptions and Actions for the “Expanded” Values

Projections under the “expanded” alternative are based on the maximum anticipated number of tests per day (50) over a 40-week year that the facility would reasonably be expected to do (10,000 tests/40 weeks = 250 tests per week/5 days per week = 50 tests per day).

5.8.2 Material Inventories

5.8.2.1 Nuclear Material Inventory Scenario for Depleted Uranium

5.8.2.1.1 Alternatives for Depleted Uranium Nuclear Material Inventory

Table 12-64 shows the alternatives for depleted uranium at the Repetitive High Energy Pulsed Power Unit I.

Table 12-64. Alternatives for Depleted Uranium Nuclear Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 µg	0 µg	10 µg	10 µg	100 µg

5.8.2.1.2 Operations That Require Depleted Uranium

Testing that uses ion beams to melt and resolidify near-surface material on small amounts of depleted uranium represents a new activity for the Repetitive High Energy Pulsed Power Unit I facility. The tests would be performed on approximately 5-µg amounts of depleted uranium called “coupons.” Because this represents a new activity, a value of zero has been provided under the base year of the “no action” alternative. At present, only a minimal number of tests are anticipated (approximately two per year). Inventory projections are based on maintaining enough depleted uranium for two shots, or 10 µg.

5.8.2.1.3 Basis for Projecting the “Reduced” and “Expanded” Values

Projections under the “reduced” alternative are estimated at 0 µg. Given the small percentage of overall facility activity represented by depleted uranium testing, no reduction in Repetitive High Energy Pulsed Power Unit I operational capability would occur.

The projection under the “expanded” alternative assumes that depleted uranium testing would take on a greater importance, and that the number of tests increase from two per year under the FY2003 and FY2008 timeframes to 20 per year under the “expanded” alternative. Under this alternative, enough depleted uranium for 20 shots would be maintained in inventory (100 µg).

5.8.2.2 Radioactive Material Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit I has no radioactive material inventories.

5.8.2.3 Sealed Source Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit I has no sealed source inventories.

5.8.2.4 Spent Fuel Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit I has no spent fuel inventories.

5.8.2.5 Chemical Inventory Scenarios

5.8.2.5.1 Alternatives for Chemical Inventories

Table 12-65 shows the alternatives for chemical inventories at the Repetitive High Energy Pulsed Power Unit I.

Table 12-65. Alternatives for Chemical Inventories

Chemical	Reduced Alternative	No Action Alternative			Expanded Alternative
		Base Year	FY2003	FY2008	
Acetone	0.5 gal	1 gal	5 gal	5 gal	7.4 gal

5.8.2.5.2 Operations That Require Chemical Inventories

The programs and operations that utilize these chemicals are described in detail in "5.2 Description," "5.3 Program Activities," and "5.4 Operations and Capabilities."

5.8.2.5.3 Basis for Projecting the Values in the "No Action" Columns

Baseline values for the chemicals listed in Table 12-65 were obtained from the SNL Chemical Information System. In most cases, the values for the "no action," "reduced," and "expanded" alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in "5.8.1 Activity Scenario for Test Activities: Accelerator Tests." However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

5.8.2.5.4 Basis for Projecting the Values in the “Reduced” Column

Baseline values for the chemicals listed in Table 12-65 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “5.8.1 Activity Scenario for Test Activities: Accelerator Tests.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

5.8.2.5.5 Basis for Projecting the Values in the “Expanded” Column

Baseline values for the chemicals listed in Table 12-65 were obtained from the SNL Chemical Information System. In most cases, the values for the “no action,” “reduced,” and “expanded” alternatives were derived by adjusting the base year information in proportion to the changes in activity levels provided in “5.8.1 Activity Scenario for Test Activities: Accelerator Tests.” However, where facility managers used process knowledge to estimate chemical applications, this more specific information was used instead.

Projections for highly toxic chemicals or those used in large quantity may have deviated from this methodology and used estimated values if deemed appropriate by the facility representatives.

5.8.2.6 Explosives Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit I has no explosives inventories.

5.8.2.7 Other Hazardous Material Inventory Scenarios

5.8.2.7.1 Other Hazardous Material Inventory Scenario for Insulator Oil

Alternatives for Insulator Oil Inventory - Table 12-66 shows the alternatives for insulator oil inventory at the Repetitive High Energy Pulsed Power Unit I.

Table 12-66. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
6,000 gal	6,000 gal	6,000 gal	6,000 gal	6,000 gal

Operations That Require Insulator Oil - Insulator oil is required as dielectric insulation for Marx tank high voltage (PCB concentrations, if any, would be less than the 50 parts per million regulatory limit). The level of oil remains constant due to machine requirements.

Basis for Projecting the "Reduced" and "Expanded" Values - The level of oil remains constant regardless of operational requirements.

There are no plans at present to use the accelerator to perform tests on any biological agents.

5.8.3 Material Consumption

5.8.3.1 Nuclear Material Consumption Scenario for Depleted Uranium

5.8.3.1.1 Alternatives for Depleted Uranium Consumption

Table 12-67 shows the alternatives for depleted uranium consumption at the Repetitive High Energy Pulsed Power Unit I.

Table 12-67. Alternatives for Depleted Uranium Consumption

Reduced Alternative		No Action Alternative						Expanded Alternative	
		Base Year		FY2003		FY2008			
0 pkgs	0 µg	0 pkgs	0 µg	2 pkgs	10 µg	2 pkgs	10 µg	20 pkgs	100 µg

5.8.3.1.2 Operations That Require Depleted Uranium

As stated in "5.8.2.1 Nuclear Material Inventory Scenario for Depleted Uranium," depleted uranium is used in testing where ion beams melt and resolidify near-surface material on 5-µg depleted uranium coupons. This represents a new activity at the Repetitive High Energy Pulsed Power Unit I; as such, a value of 0-µg is provided for the base year portion of the "no action" alternative.

Projections for FY2003 and FY2008 are based on the receipt of two 5-µg packages on an annual basis.

5.8.3.1.3 Basis for Projecting the “Reduced” and “Expanded” Values

Projections of 0-µg under the reduced alternative are consistent with those provided previously in “5.8.2.1 Nuclear Material Inventory Scenario for Depleted Uranium.” Additional background and rationale for this projection is provided within that section. Projections provided under the “expanded” scenario are also consistent with the “5.8.2.1 Nuclear Material Inventory Scenario for Depleted Uranium,” inventory scenarios (the receipt of 20 5-µg packages on an annual basis).

5.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at the Repetitive High Energy Pulsed Power Unit I.

5.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

5.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at the Repetitive High Energy Pulsed Power Unit I.

5.8.4 Waste

5.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at the Repetitive High Energy Pulsed Power Unit I.

5.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at the Repetitive High Energy Pulsed Power Unit I.

5.8.4.3 Mixed Waste

5.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at the Repetitive High Energy Pulsed Power Unit I.

5.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at the Repetitive High Energy Pulsed Power Unit I.

5.8.4.4 Hazardous Waste Scenario

5.8.4.4.1 Alternatives for Hazardous Waste at the Repetitive High Energy Pulsed Power Unit I

Table 12-68 shows the alternatives for hazardous waste at the Repetitive High Energy Pulsed Power Unit I.

Table 12-68. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 kg	0 kg	5 kg	5 kg	10 kg

5.8.4.4.2 Operations That Generate Hazardous Waste

All operations have the potential to generate hazardous waste, depending on the type of solvents used for cleaning. Currently, no regulated solvents are used for the operation. In CY1997, from which the above base year value comes, 590 kg of nonregulated waste was generated.

5.8.4.4.3 General Nature of Waste

The waste includes solvent- and oil-contaminated rags.

5.8.4.4.4 Waste Reduction Measures

No waste reduction measures exist.

5.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value is based on no facility operation. The “expanded” value is based on some possible waste generation. The projections provided are intended to accommodate any potential use of a regulated chemical that is not used currently.

5.8.5 Emissions

5.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at the Repetitive High Energy Pulsed Power Unit I.

5.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

5.8.5.3 Open Burning Scenarios

The Repetitive High Energy Pulsed Power Unit I does not have outdoor burning operations.

5.8.5.4 Process Wastewater Effluent Scenario

The Repetitive High Energy Pulsed Power Unit I does not generate process wastewater.

5.8.6 Resource Consumption

5.8.6.1 Process Water Consumption Scenario

The Repetitive High Energy Pulsed Power Unit I does not consume process water.

5.8.6.2 Process Electricity Consumption Scenario

The Repetitive High Energy Pulsed Power Unit I does not consume process electricity.

5.8.6.3 Boiler Energy Consumption Scenario

The Repetitive High Energy Pulsed Power Unit I does not consume energy for boilers.

5.8.6.4 Facility Personnel Scenario

5.8.6.4.1 Alternatives for Facility Staffing at the Repetitive High Energy Pulsed Power Unit I

Table 12-69 shows the alternatives for facility staffing at the Repetitive High Energy Pulsed Power Unit I.

Table 12-69. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
2 FTEs	5 FTEs	8 FTEs	8 FTEs	10 FTEs

5.8.6.4.2 Operations That Require Facility Personnel

Repetitive High Energy Pulsed Power Unit I operations require personnel for facility operations, test evaluation, and diagnostics support.

5.8.6.4.3 Staffing Reduction Measures

There is no routine sharing of facility operation staff with other accelerators.

5.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The projection provided under the “reduced” alternative is based on the minimum required staffing to maintain operational capability. The “expanded” alternative value is based on estimated increases in operational and scientific staff, who will provide additional evaluation and diagnostics of test results.

5.8.6.5 Expenditures Scenario

5.8.6.5.1 Alternatives for Expenditures at the Repetitive High Energy Pulsed Power Unit I

Table 12-70 shows the alternatives for expenditures at the Repetitive High Energy Pulsed Power Unit I.

Table 12-70. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$750,000	$1.5 million	$2.5 million	$2.5 million	$5.5 million

5.8.6.5.2 Operations That Require Expenditures

Repetitive High Energy Pulsed Power Unit I operations require expenditures for operational and research scientists, consumables, and laboratory support services. Program staff costs are estimated at $250,000 per FTE and are included in the cost estimates above.

The base year value under the “no action” alternative is based on the known funding level for that year. Projections for FY2003 and FY2008 are based on the estimated increase in funding (facility operations and staffing) to sustain the increased level of activity of the FY2003 and FY2008 timeframes.

5.8.6.5.3 Expenditure Reduction Measures

No routine sharing of staff among accelerators occurs.

5.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

The projections for the “reduced” alternative is based on funding estimates for sustaining operational capability (facility and staffing). The “expanded” alternative projection is based on funding estimates to support increased operations (facility and staffing).

6.0 REPETITIVE HIGH ENERGY PULSED POWER UNIT II SOURCE INFORMATION

6.1 Purpose and Need

The Repetitive High Energy Pulsed Power Unit II is a DOE user facility that is available for the development of radiation-processing applications using high-dose-rate electron or x-ray beams. The Repetitive High Energy Pulsed Power Unit II accelerator is also a test bed for the continued development of high-power magnetic switches and repetitive, magnetically insulated transmission lines (MITLs) (U.S. Department of Energy, 1996; Weber and Zawadzkas, 1996a).

6.2 Description

The Repetitive High Energy Pulsed Power Unit II facility, located in Building 963, contains the Repetitive High Energy Pulsed Power Unit II accelerator, a 2.0-MeV, 25-kA, pulsed accelerator. Accelerator components include the microsecond pulse compressor (MPC), a water-insulated pulse forming line (PFL), the linear induction voltage adder (LIVA), and a high-power electron beam diode. The system consists of a 750-kW power supply, seven stages of magnetic pulse compression, ten stages of linear induction voltage addition, and a vacuum diode. The 750-kW power supply serves as the prime power source.

(U.S. Department of Energy, 1996; Weber and Zawadzkas, 1996a)

6.3 Program Activities

Table 12-71 shows the program activities at the Repetitive High Energy Pulsed Power Unit II.

Table 12-71. Program Activities at the Repetitive High Energy Pulsed Power Unit II

Program Name	Activities at the Repetitive High Energy Pulsed Power Unit II	Category of Program	Related Section of the *SNL Institutional Plan*
Performance Assessment Science and Technology	Develop pulsed power technology and applications in Defense Programs and Work for Others.	Programs for the Department of Energy	Section 6.1.1.1
Initiatives for Proliferation Prevention	The program will be developing advanced accelerators for biosterilization.	Programs for the Department of Energy	Section 6.1.3.5
Nonproliferation and Verification Research and Development	The program will be developing advanced accelerators for biosterilization.	Programs for the Department of Energy	Section 6.1.3.1
Pulsed Power Technology	The Repetitive High Energy Pulsed Power Unit II is used for basic magnetic switching technology development and as a DOE User Facility for high-energy per pulse applications. RHEPP technology has been used for Ion Beam Surface Treatment (IBEST) to harden material surfaces and for advanced research that supports sterilization projects for organic materials (for example, food products and lumber). Development of these and other applications continue.	Major Programmatic Initiatives	Section 7.1.6

6.4 Operations and Capabilities

The MPC delivers pulses of nominally one-microsecond duration and 250-kV amplitude to the PFL. The PFL compresses the MPC output to a 60-nanosecond duration, which is then delivered to the LIVA. Ten stages of magnetically insulated voltage addition in the LIVA boost the pulse voltages to nominally 2.0 MeV at 25 kA and deliver the pulses to the VDL, which is located in a below-grade, radiation-shielded test cell under the LIVA. The VDL generates an electron beam, which may be extracted through a thin foil window or deposited onto a tungsten converter that stops the electron beam and creates bremsstrahlung x-rays. The electron beam or x-rays are directed into a chamber in which the target (for example, medical waste and food products) are located.

The operational work year for the Repetitive High Energy Pulsed Power Unit II facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and experiment setup time.

(Weber and Zawadzkas, 1996a)

6.5 Hazards and Hazard Controls

6.5.1 Offsite Hazards to the Public and the Environment

The Repetitive High Energy Pulsed Power Unit II facility contains a small chemical inventory that cannot be dispersed outside the facility. Thus, there are no potential consequences to either the public or the environment from accidents at this facility (Weber and Zawadzkas, 1996a).

6.5.2 Onsite Hazards to the Environment

Onsite environmental hazards at the Repetitive High Energy Pulsed Power Unit II facility include a commonly available industrial transformer oil that is routinely used by the power distribution industry. The MPC, the PFL, and the LIVA contain approximately 20,000 gal of a reduced-flammability grade of transformer oil (Shell DIALA A/AX), which is used as electrical insulation. The oil is regularly filtered to maintain breakdown strength and is periodically transferred to the Building 966 oil storage tank. The oil has a flash point of 300°F.

6.5.3 Onsite Hazards to Workers

The following are potential worker hazards at the Repetitive High Energy Pulsed Power Unit II facility:

- Ionizing radiation, which can be produced in the form of electrons or bremsstrahlung (x-rays) at the diode located in the test cell.
- The MPC, which is the prime energy storage component of the accelerator.
- Confined spaces, including the MPC tank, the secondary oil containment trenches, and the test cell.
- Ethanol, which is used in small quantities to clean accelerator components and other equipment.

The Repetitive High Energy Pulsed Power Unit II does not use heavier-than-air gases.

6.5.4 Hazard Controls

The hazard controls at the Repetitive High Energy Pulsed Power Unit II facility include:

- **Radiation Shielding** - The radiation test cell is located in a basement below the level of the floor of the highbay, and all entries to the basement are constructed with serpentine passages and thick radiation shield walls. The facility is constructed to ensure that errant radiation is physically intercepted before it reaches any area where personnel may be present during operations. The only entrance and exit to the test cell is a lead shield door, and the test cell itself is constructed of thick radiation shield walls.

- **Access Control** - Access control at the Repetitive High Energy Pulsed Power Unit II is maintained by fences and gates with locking mechanisms and physical inspection and clearing procedures. The test cell is a restricted area and is checked for personnel before the accelerator is operated. By procedure, evacuation sweeps are conducted prior to accelerator startup to ensure that personnel are not present in restricted areas. Accelerator operation is interlocked with the access gates, and any breach of the gates automatically disables all systems and places the accelerator in a safe state. Emergency stop buttons at strategic locations in the facility disable the accelerator immediately when the buttons are pushed.

- **Electrical Safety** - The charging circuit for the MPC will automatically discharge the MPC to ground through a dump resistor upon a disruption or loss of power.

- **Secondary Oil Containment System** - Building 963 includes a secondary containment trench system that is located just inside the exterior walls of the building and that completely surrounds oil-filled tanks and equipment. The accelerators in this building also use an oil transfer and processing system that is housed in Building 966. Transfer piping between the buildings is double-walled, welded steel pipe that is sloped to drain into a concrete-lined catch basin associated with the Building 966 oil storage tank. A leak detection system detects leaks of inner pipes.

- **Confined Space Safety** - The MPC tank and the secondary oil containment trenches are checked for proper oxygen content before personnel may enter them, and personnel must wear oxygen sensors while working in this confined space.

(Weber and Zawadzkas, 1996a)

6.6 Accident Analysis Summary

6.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the Repetitive High Energy Pulsed Power Unit II facility and through discussions with operations personnel. The operating events selected for qualitative risk analysis were the following:

- Fire involving insulating oil
- Worker electrocution while “safing” MPC capacitors
- Worker asphyxiation in a confined space
- Worker radiation exposure during accelerator operation

These events are considered to be the bounding accidents that define the safety envelope for facility operations. In addition, the accident analysis for the Repetitive High Energy Pulsed Power Unit II included natural phenomena event scenarios that are generic to all facilities at SNL, as well as an aircraft crash scenario.

The facility accident analysis did not address standard industrial accidents (for example, accidents involving hazards such as cranes and hoists, forklifts, lasers, and compressed gases) for which accident prevention and mitigation are covered by existing consensus standards.

6.6.2 Analysis Methods and Assumptions

The methodology for the Repetitive High Energy Pulsed Power Unit II accident assessment (see Mahn *et al*., 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-72. In addition, a generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities as provided in Mahn *et al.* (1995) were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-72. Consequence Categories and Levels of Severity

Rank	**DOE/AL 5481.1B**	**Human Impact**	**Environmental Impact**	**Programmatic Impact**
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months

Table 12-72. Consequence Categories and Levels of Severity (Continued)

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

6.6.3 Summary of Accident Analysis Results

The results of the Repetitive High Energy Pulsed Power Unit II accident analysis are summarized in Table 12-73.

Table 12-73. Results of the Repetitive High Energy Pulsed Power Unit II Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Unlikely (B)
Fire	Marginal (III)	Extremely unlikely (C)
Asphyxiation	Marginal (III)	Unlikely (B)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

Tables 12-74 and 12-75 were obtained from AL 5481.1B and provide definitions for terms used in “6.6 Accident Analysis Summary.”

Table 12-74. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or significant impact on the environment.

Table 12-75. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

(Weber and Zawadzkas, 1996a)

6.7 Reportable Events

The Repetitive High Energy Pulsed Power Unit II has had no reportable events over the past five years.

6.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

6.8.1 Activity Scenario for Test Activities: Radiation Production

6.8.1.1 Alternatives for Test Activities: Radiation Production

Table 12-76 shows the alternatives for radiation production at the Repetitive High Energy Pulsed Power Unit II.

Table 12-76. Alternatives for Test Activities: Radiation Production

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40 tests	80 tests	160 tests	160 tests	800 tests

6.8.1.2 Assumptions and Actions for the "Reduced" Values

Projections under the reduced alternative assume eight weeks of operations during the year and are based on maintaining minimum operational capability for diagnostic development and radiation characterization. Reduced alternative testing would take place at a rate of one test per day for eight weeks over the course of the year (5 tests per week x 8 weeks = 40 tests).

6.8.1.3 Assumptions and Rationale for the "No Action" Values

The Repetitive High Energy Pulsed Power Unit II operations are based on "operational five-day work weeks" that take place over the course of a given year. During the base year, the Repetitive High Energy Pulsed Power Unit II facility only operated for 16 weeks. The remainder of that year the facility was shut down for maintenance, or staff were preparing for tests scheduled within the 16 operational weeks of the 1996 base year, or the facility was idle. Over the 1996 16-week operational period, 80 tests were conducted at a rate of 1 test per day (5 tests per week x 16 weeks = 80 tests).

Projections provided under the FY2003 and FY2008 timeframes assume a 40-week operational year in which testing would take place at a rate of four tests per week for 40 weeks (4 tests per week x 40 weeks = 160 tests).

6.8.1.4 Assumptions and Actions for the "Expanded" Values

Projections under the "expanded" alternative assume a 40-week operational year and are based on achieving maximum anticipated capacity for the facility. Testing under this scenario would take place at a rate of 4 tests per day (20 tests per week) for the 40-week operational year (20 tests per week x 40 weeks = 800 tests).

6.8.2 Material Inventories

6.8.2.1 Nuclear Material Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no nuclear material inventories.

6.8.2.2 Radioactive Material Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no radioactive material inventories.

6.8.2.3 Sealed Source Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no sealed source inventories.

6.8.2.4 Spent Fuel Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no spent fuel inventories.

6.8.2.5 Chemical Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no inventories of chemicals of concern.

6.8.2.6 Explosives Inventory Scenarios

The Repetitive High Energy Pulsed Power Unit II has no explosives inventories.

6.8.2.7 Other Hazardous Material Inventory Scenarios

6.8.2.7.1 Other Hazardous Material Inventory Scenario for Insulator Oil

Alternatives for Insulator Oil Inventory - Table 12-77 shows the alternatives for insulator oil inventory at the Repetitive High Energy Pulsed Power Unit II.

Table 12-77. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
5,000 gal	5,000 gal	5,000 gal	5,000 gal	5,000 gal

Operations That Require Insulator Oil - The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material that prevents electrical breakdown when the accelerator is charged (PCB concentrations, if any, are less than the 50 parts per million regulatory limit). The oil section of the accelerator holds approximately 5,000 gal of oil.

Basis for Projecting the "Reduced" and "Expanded" Values - There will be no more or less oil required for either the reduced or expanded scenarios.

6.8.2.7.2 Other Hazardous Material Inventory Scenario for Contaminated Meat Products

Alternatives for Contaminated Meat Products Inventory - Table 12-78 shows the contaminated meat product inventory at the Repetitive High Energy Pulsed Power Unit II.

Table 12-78. Alternatives for Contaminated Meat Products Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 lb	100 lb	100 lb	100 lb	100 lb

Operations That Require Contaminated Meat Products - Packaged meat products contaminated with pathogens are shipped to SNL/NM where they are irradiated at the accelerator and then shipped offsite (in appropriate packaging) to the originator (for example, Iowa State University). It is anticipated that no more than 100 lb of these packaged meat products would be irradiated in a year.

6.8.2.7.3 Basis for Projecting the "Reduced" and "Expanded" Values

There is currently no great demand for this activity; as such, the projections remain the same across all alternatives with the exception of the "reduced" alternative, which assumes no testing of contaminated meat products.

6.8.3 Material Consumption

6.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at the Repetitive High Energy Pulsed Power Unit II.

6.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at the Repetitive High Energy Pulsed Power Unit II.

6.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

6.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at the Repetitive High Energy Pulsed Power Unit II.

6.8.4 Waste

6.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at the Repetitive High Energy Pulsed Power Unit II.

6.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at the Repetitive High Energy Pulsed Power Unit II.

6.8.4.3 Mixed Waste

6.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at the Repetitive High Energy Pulsed Power Unit II.

6.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at the Repetitive High Energy Pulsed Power Unit II.

6.8.4.4 Hazardous Waste Scenario

6.8.4.4.1 Alternatives for Hazardous Waste at the Repetitive High Energy Pulsed Power Unit II

Table 12-79 shows the alternatives for hazardous waste at the Repetitive High Energy Pulsed Power Unit II.

Table 12-79. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 kg	0 kg	1 kg	1 kg	1 kg

6.8.4.4.2 Operations That Generate Hazardous Waste

During the base year (1996 and 1997), no regulated hazardous waste was generated at the facility. A total of 5 kg of nonregulated waste was generated. Depending on the kind of solvents used for cleaning, future maintenance activities could generate some hazardous wastes. As a result, projections under FY2003 and FY2008 reflect some minimal waste generation to accommodate the potential use of a regulated chemical that is not currently in use.

6.8.4.4.3 General Nature of Waste

Waste includes solvent- and oil-contaminated rags.

6.8.4.4.4 Waste Reduction Measures

Waste reduction measures include the reuse of materials and use of nonregulated substances such as microbial parts cleansers.

6.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

No regulated hazardous waste was generated during the base year. As such, no waste generation would be anticipated under a “reduced” alternative. For the “expanded” alternative, a small amount of waste generation could reasonably be expected with increased operations. Projections reflect some minimal generation to accommodate the potential use of regulated chemicals that are not currently in use.

6.8.5 Emissions

6.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at the Repetitive High Energy Pulsed Power Unit II.

6.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

6.8.5.3 Open Burning Scenarios

The Repetitive High Energy Pulsed Power Unit II does not have outdoor burning operations.

6.8.5.4 Process Wastewater Effluent Scenario

The Repetitive High Energy Pulsed Power Unit II does not generate process wastewater.

6.8.6 Resource Consumption

6.8.6.1 Process Water Consumption Scenario

The Repetitive High Energy Pulsed Power Unit II does not consume process water.

6.8.6.2 Process Electricity Consumption Scenario

The Repetitive High Energy Pulsed Power Unit II does not consume process electricity.

6.8.6.3 Boiler Energy Consumption Scenario

The Repetitive High Energy Pulsed Power Unit II does not consume energy for boilers.

6.8.6.4 Facility Personnel Scenario

6.8.6.4.1 Alternatives for Facility Staffing at the Repetitive High Energy Pulsed Power Unit II

Table 12-80 shows the alternatives for facility staffing at the Repetitive High Energy Pulsed Power Unit II.

Table 12-80. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.45 FTEs	0.9 FTEs	1.4 FTEs	1.4 FTEs	3 FTEs

6.8.6.4.2 Operations That Require Facility Personnel

The Repetitive High Energy Pulsed Power Unit II staffing requirements include operational technicians to maintain and operate the facility and research scientists to set up and conduct experiments. Staffing costs are estimated at $250,000 per FTE.

6.8.6.4.3 Staffing Reduction Measures

The Repetitive High Energy Pulsed Power Unit II does not routinely share operational staff among other accelerators.

6.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” and “expanded” values are directly proportional to the number of weeks of operation and reflect part-time duties of personnel.

6.8.6.5 Expenditures Scenario

6.8.6.5.1 Alternatives for Expenditures at the Repetitive High Energy Pulsed Power Unit II

Table 12-81 shows the alternatives for expenditures at the Repetitive High Energy Pulsed Power Unit II.

Table 12-81. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$126,000	$252,000	$353,000	$353,000	$754,000

6.8.6.5.2 Operations That Require Expenditures

The Repetitive High Energy Pulsed Power Unit II requires minimal expenditures to provide for operational and research scientist staff, estimated at $250,000 per FTE, and additional expenses for consumables and SNL/NM laboratory support services.

6.8.6.5.3 Expenditure Reduction Measures

Sharing of operational staff is not routinely done among accelerators.

6.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” and “expanded” values are directly proportional to the number of weeks of operations. These expenditure estimates are as reasonable as can be made at this time.

7.0 SANDIA ACCELERATOR & BEAM RESEARCH EXPERIMENT SOURCE INFORMATION

7.1 Purpose and Need

The Sandia Accelerator & Beam Research Experiment (SABRE) facility is a pulsed power particle accelerator that supports the Inertial Confinement Fusion Program for advanced extraction ion diode research and for target and focusing studies. The accelerator can also be configured for radiography experiments and used as the driver that provides a flash radiography source.

7.2 Description

SABRE is a pulsed accelerator located within the Simulation Technology Laboratory, Building 970, in SNL/NM's Tech Area IV. Two other accelerators, HERMES III and PROTO II (currently inactive), as well as STF, a pulse power device, are also housed within the confines of Building 970.

The SABRE accelerator facility includes the following:

- An accelerator oil tank
- A lead- and concrete-shielded test cell
- Work areas
- The gated portion of the 13-ft trench occupied by the diode capacitor banks
- A Class 3a alignment laser
- Three local screen rooms
- Two small cryogenic systems
- The STL screen room access

The 30,000-gal accelerator oil tank contains the following:

- One 3.6-MeV, 230-kJ Marx generator
- Two electrically triggered gas switches
- The high-voltage distribution for twenty pulse-forming lines (PFLs), which feed into cavities on the outside of the oil tank and deliver the power pulse to an magnetically insulated transmission line (MITL), which delivers the power pulse to the diode
- One 50-kV miniature Marx generator
- Two intermediate storage capacitors

SABRE subsystems include anode and cathode capacitor banks and two trigger generators located adjacent to the oil tank.

7.3 Program Activities

Table 12-82 shows the program activities at SABRE.

Table 12-82. Program Activities at SABRE

Program Name	Activities at SABRE	Category of Program	Related Section of the *SNL Institutional Plan*
Direct Stockpile Activities	Conduct development and survivability testing of nuclear weapon subsystems and components.	Programs for the Department of Energy	Section 6.1.1.1
Performance Assessment Science and Technology	Develop pulsed power technology to provide advanced radiographic characterization techniques that may be applied to Dual-Axis Radiographic Hydrotest (DARHT) or Advanced Hydrotest Facility (AHF).	Programs for the Department of Energy	Section 6.1.1.1
Inertial Confinement Fusion	SABRE is the workhorse of the light ion program for investigating extraction diodes and magnetically insulated transmission line coupling; for testing surface and subsurface cleaning, improved vacuum conditions, and advanced ion sources; and for studying lithium ion transport. It uses the inductive voltage adder (IVA) technology also used on HERMES III. New high-magnetic-field capability was tested in FY96 as part of the advanced hydrodynamic radiography (AHR) program in the SNL/NM Pulsed Power Sciences Center (9500).	Programs for the Department of Energy	Section 6.1.1.2

7.4 Operations and Capabilities

When configured in support of the Inertial Confinement Fusion Program, SABRE is a 10-MV, 250-kA, positive polarity, pulsed accelerator used as a driver for advanced extraction ion diode research as well as target and focusing studies. When configured for radiography experiments, SABRE is a 12-MV, 120-kA, negative polarity, pulsed accelerator used as the driver that provides a flash radiography source.

SABRE's radiography configuration, operating in the negative polarity mode, was first tested using a 95-kV charge in basic, or positive, configuration with the acceleration cavities reversed. While the voltage remained low, the MITL was the normal (positive mode) 40-ohm MITL. The current radiography mode uses a 100-ohm impedance MITL. The net effect is that the MITL reduces the current while allowing the required increase in voltage for the radiography. In general, radiation at the diode of SABRE is proportional to the current and target material's atomic number, but increases by a factor of 2.8 with increases in voltage.

Although the current was reduced by more than half in the negative polarity mode, which will reduce radiation output by a similar amount, the voltage was theoretically increased from 10 to 12 MeV. Therefore, radiation output will predictably decrease for SABRE radiography experiments.

Changing of the target material (for example, to carbon, titanium, tungsten, or copper) will proportionally alter radiation output, with the higher-atomic-numbered elements producing the higher radiation.

This negative polarity mode of operation, while used to support radiography, could also be used for gamma-ray simulation experiments, but this has not been done to date. This mode of operation will not change the safety envelope.

The SABRE accelerator consists of an oil tank, a test cell, and a control console. The 4,000-ft^3 (30,000-gal) oil tank contains a 3.6-MV, 230-kJ Marx generator (three arrays with 12 capacitors each), one 50-kV miniature Marx generator (12 small capacitors used to trigger the main generator), two intermediate storage capacitors, two electrically-triggered gas switches, and the high-voltage distribution network for twenty PFLs. The PFLs feed into cavities on the outside of the tank. An MITL delivers the power pulse into the diode. SABRE subsystems include anode and cathode capacitor banks, an alignment laser (Class IIIa), a 125-kV trigger generator (TG-125) located adjacent to the oil tank, and a 70-kV trigger generator (TG-70) located adjacent to the oil tank on the raised PFL platform of SABRE.

Table 12-83 shows the standard accelerator parameters for SABRE.

Table 12-83. Standard Accelerator Parameters for SABRE

Ion Beam Radiography	Positive Polarity	Negative Polarity
Peak diode voltage	10 MV	12 MV
Peak diode current	250 kA	120 kA
Total beam energy	125 kJ	60 kJ
Power pulse width	50 nanoseconds	20 nanoseconds
Repetition rate (norm)	5 shots per week	8 to 10 shots per week

The operational work year for the SABRE facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and experiment setup time.

7.5 Hazards and Hazard Controls

7.5.1 Offsite Hazards to the Public and the Environment

The SABRE facility contains controlled radioactive sources and chemical inventories that cannot be dispersed outside the facility. The test cell contains four sodium-22 (Na-22) sealed sources (the largest of which produces 1.31 mCi) that have a combined source strength of less than 1.63 mCi. The facility contains only small chemical and radioactive material inventories that cannot be dispersed outside of the facility. The facility presents no potential for offsite consequences to either the public or the environment from accidents (Knowles and Zawadzkas, 1995).

7.5.2 Onsite Hazards to the Environment

Onsite hazards to the environment include transformer oil. The SABRE oil tank contains 30,000 gal of a reduced-flammability grade of transformer oil (Shell DIALA A/AX), which has a flash point of 300°F and a PCB concentration of less than 50 parts per million. The oil is regularly filtered to maintain breakdown strength and is periodically transferred to a 500,000-gal storage tank farm, which is shared with the other accelerators in Building 970.

7.5.3 Onsite Hazards to Workers

Potential worker hazards at the SABRE facility include:

- **Ionizing Radiation** - Produced at the diode within the test cell. A person standing in the exposure area (at the diode) could receive a negligible (less than 1 rem) dose of radiation during a shot. Activation products generate only a low level of radioactivity, such that a 30-minute waiting period may be required before a worker wearing gloves removes any items from the diode. Generally, within a few hours or days activated items can be cleaned for reuse, moved to a more permanent low-level storage area, or removed from the site as mixed waste.

- **Marx Generator** - The prime energy storage component of the accelerator. The 230-kJ Marx generator consists of three arrays of 12 capacitors each, while the miniature Marx generator consists of 12 small capacitors that are used to trigger the main generator.

- **Solvents** - Includes propanols and hexanes, which are used in small quantities to clear various components between test shots.

- **Dilute Copper Sulfate Solution** - Used to fabricate high-power resistors for use in the Marx generators.

- **SF_6** - Used as the insulator gas in switching components. Pure SF_6, although chemically and physiologically inert, does not support respiration in enclosed areas. When subjected to high-voltage discharge, some breakdown occurs, and the byproducts formed are corrosive and somewhat toxic. Used SF_6 is passed through a reclaimer located adjacent to Building 970, where the breakdown products are filtered out so that the SF_6 can be recycled. After the reclaimer has removed these breakdown products, they would be disposed of as hazardous waste. Used SF_6 that has not been passed through a purifying reclaimer would be a fugitive emission and represent an inhalation hazard to personnel and could damage sensitive equipment.

  The supply of SF_6 is stored after purification. Leakage of SF_6 gas from the closed system is possible, but the building ventilation system immediately removes this gas to the outside and effectively dilutes it from extremely small concentrations to negligible amounts in the outside air.

- **Confined Spaces** - Includes all trenching under and around SABRE. The basement beneath the accelerator is not designated a “confined space” but is equipped with oxygen alarm devices.

7.5.4 Hazard Controls

Hazard controls at the SABRE facility include:

- **Radiation Shielding** - Provided by the concrete and lead test cell, which ensures that personnel are not exposed to harmful levels of ionizing radiation during accelerator operation.

- **Access Control** - Access to the Building 970 highbay and mezzanine areas is controlled through doors with cipher locks. Administrative controls require operators to conduct a sweep of the test cell and other potential radiological areas, lock gates, and clear any temporary restricted areas before charging or firing the accelerator. When an area cannot be physically locked out, then radiological worker personnel equipped with radios are posted to ensure these areas remain clear of all personnel during a shot. During the critical period of charging and firing, the accelerator systems are interlocked with access control so that any breach of the access controls automatically disables all systems and places the accelerator in a safe condition.

- **Electrical Safety** - The charging circuit for SABRE is solenoid-operated so that a disruption or loss of power will automatically discharge the Marx bank capacitors through an electronic dump circuit. This circuit will not allow the Marx bank to recharge when power is restored until the operator resets the charging switches.

- **Secondary Oil Containment** - Building 970 is designed with secondary oil containment, and the oil storage tank farm located adjacent to Building 970 is also designed with secondary containment.

- **Confined Space Safety** - Operation of the Building 970 HVAC system, the physical size of the highbay, and the use of equipment to monitor oxygen deficiencies are important in preventing and identifying low oxygen conditions.

7.6 Accident Analysis Summary

7.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the SABRE facility and through discussions with operations personnel.

Following the walk-down and qualitative survey of the facility, the operating events selected for qualitative risk analysis were the following:

- Worker electrocution while “safing” Marx generator capacitors
- Worker radiation exposure during accelerator operation
- Worker asphyxiation in a confined space

These events are considered to be the bounding accidents that define the safety envelope for facility operations. In addition, the accident analysis for SABRE included natural phenomena event scenarios that are generic to all facilities at SNL, as well as an aircraft crash scenario.

The facility accident analysis did not address standard industrial accidents (for example, accidents involving hazards such as cranes and hoists, forklifts, lasers, and compressed gases) for which accident prevention and mitigation are covered by existing consensus standards.

7.6.2 Analysis Methods and Assumptions

The methodology for the SABRE accident assessment (see Mahn *et al.*, 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-84. In addition, a generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities, as provided in Mahn *et al.* (1995), were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-84. Consequence Categories and Levels of Severity

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

7.6.3 Summary of Accident Analysis Results

The results of the SABRE accident assessment are summarized in Table 12-85.

Table 12-85. Results of the SABRE Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Unlikely (B)
Asphyxiation	Critical (II)	Extremely unlikely (C)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

Tables 12-86 and 12-87 were obtained from AL 5481.1B and provide definitions for terms used in “7.6 Accident Analysis Summary.”

Table 12-86. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or significantly affect the environment.

Table 12-87. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

7.7 Reportable Events

SABRE has had no occurrences over the past five years.

7.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

7.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials

7.8.1.1 Alternatives for Test Activities: Irradiation of Components or Materials

Table 12-88 shows the alternatives for irradiation of components or materials at SABRE.

Table 12-88. Alternatives for Test Activities: Irradiation of Components or Materials

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 shots	187 shots	225 shots	225 shots	400 shots

7.8.1.2 Assumptions and Actions for the “Reduced” Values

SABRE is a very small facility (approximately 5 percent of the size of HERMES III). The amount of time spent to restart would be essentially the same whether SABRE is fired a minimal number of times or not at all. The cost benefit from not firing at all is the primary consideration.

When configured in support of the Inertial Confinement Fusion Program, SABRE is a 10-MV, 250-kA, positive polarity, pulsed accelerator used as a driver for advanced extraction ion diode research as well as target and focusing studies. When configured for radiography experiments, SABRE is a 12-MV, 120-kA, negative polarity, pulsed accelerator used as the driver that provides a flash radiography source.

The programs that use SABRE and the activities associated with those programs are provided in “7.3 Program Activities.” Because a SABRE “shot” is fundamental to each of the listed programmatic activities, the impacts of various scenarios are essentially the same. Therefore, the following values consider one basic scenario, which is the firing of the SABRE accelerator. Furthermore, there is the underlying assumption that the values are directly proportional to the number of times the machine fires (“shots”).

For the “reduced” alternative, SABRE need not be fired to keep the accelerator in a state of “near” operational readiness; only a minimal amount of general maintenance will be required. Therefore, in this standby mode, no environmental impacts are expected.

7.8.1.3 Assumptions and Rationale for the “No Action” Values

The following are assumptions for the “no action” alternative:

- The base year value indicates 187 shots in CY1997.
- For the FY2003 and FY2008 projections, 225 shots per year are expected in the ten-year period of FY1999 through FY2008. This value is approximately 1.2 times the base year value (225 shots / 187 shots = 1.2).

7.8.1.4 Assumptions and Actions for the “Expanded” Values

The value for the “expanded” alternative of 400 shots is based on two shots per day during a five-day week over the 40-week operational work year. This value is approximately 2.1 times the base year (400 shots / 187 shots = 2.1).

7.8.2 Material Inventories

7.8.2.1 Nuclear Material Inventory Scenarios

SABRE has no nuclear material inventories.

7.8.2.2 Radioactive Material Inventory Scenario for Activated Hardware

7.8.2.2.1 Alternatives for Activated Hardware Radioactive Material Inventory

Table 12-89 shows the alternatives for activated hardware radioactive material inventory at SABRE.

Table 12-89. Alternatives for Activated Hardware Radioactive Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 kg	0 kg	0 kg	0 kg	0 kg

7.8.2.2.2 Operations That Require Activated Hardware

No radioactive material inventory is maintained at SABRE; however, some small amount of short-lived activation products may be present in the facility at any time.

SABRE downline shots with an ion diode load (especially lithium) may generate radioactive materials within the diode assembly (located inside the confines of the test cell). The test materials are reviewed by the SABRE Machine Safety Committee, are stored within the confines of the “permanent contaminated” area in the NE corner of SABRE under the HP criterion, are often cleaned and reused, and are controlled through appropriate permits and procedures. The levels of radioactivity are low enough that procedure may require a 30-minute waiting period before removal of any items from the diode using gloves. Any activated item, even at a very low level, is placed on the table inside a designated contamination area within the test cell itself. Normally, within a few hours or days and with HP approval and radiological survey, these items can be cleaned for reuse, moved to a more permanent low-level storage area, or removed from the site as low-level waste.

7.8.2.2.3 Basis for Projecting the “Reduced” and “Expanded” Values

See “7.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.”

7.8.2.3 Sealed Source Inventory Scenarios

7.8.2.3.1 Sealed Source Inventory Scenario for Cm-244

Alternatives for Cm-244 Sealed Source Inventory - Table 12-90 shows the alternatives for the Cm-244 sealed source inventory at SABRE.

Table 12-90. Alternatives for Cm-244 Sealed Source Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.0 µCi	8.54 µCi	8.54 µCi	8.54 µCi	8.54 µCi

Operations That Require Cm-244 - This source was added to the inventory for calibration of magnetic spectrometer pin diodes.

Basis for Projecting the “Reduced” and “Expanded” Values - This source is not dependent on operational activity. In the “reduced” scenario, it will no longer be necessary to hold the source on site.

7.8.2.3.2 Sealed Source Inventory Scenario for Na-22

Alternatives for Na-22 Sealed Source Inventory - Table 12-91 shows the alternatives for the Na-22 sealed source inventory at SABRE.

Table 12-91. Alternatives for Na-22 Sealed Source Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.0 µCi	1.620 x 10^{-1} µCi	1.62 µCi	1.62 µCi	1.62 µCi

Operations That Require Na-22 - SABRE contains carefully controlled radioactive materials (sources) that are not allowed outside the facility. The test cell contains four Na-22 sealed sources, the largest of which produces 1.31 µCi. The combined capability of the four sources is 1.62 µCi, or 0.677 percent of the 240-Ci threshold for hazard category 3 in U.S. Department of Energy (1992). This amount of "sealed-source" radiation is well below the amount specified for a nuclear facility designation. The sealed sources are used inside Screen Room 1 to check diagnostic materials used in the SABRE accelerator. The sources are contained in a locked cabinet with limited access to the keys, and radiation surveys are conducted frequently by radiation protection personnel.

Basis for Projecting the "Reduced" and "Expanded" Values - The inventory of sources is independent from the level of activity (number of shots). The sources will not be required in the "reduced" alternative.

7.8.2.4 Spent Fuel Inventory Scenarios

SABRE has no spent fuel inventories.

7.8.2.5 Chemical Inventory Scenarios

SABRE has no inventories of chemicals of concern.

7.8.2.6 Explosives Inventory Scenarios

SABRE has no explosives inventories.

7.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

7.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-92 shows the alternatives for insulator oil inventory at SABRE.

Table 12-92. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
30,000 gal	30,000 gal	30,000 gal	30,000 gal	30,000 gal

7.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material which prevents electrical breakdown when the accelerator is charged. (Inspections have shown the PCB concentration to be less than the limit of detection.) The oil section of the accelerator holds 30,000 gal of oil. The total storage capacity for the oil is 500,000 gal in two aboveground 250,000-gal tanks.

7.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

There will be no more or no less oil required in the “reduced” or “expanded” scenarios.

7.8.3 Material Consumption

7.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at SABRE.

7.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at SABRE.

7.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

7.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at SABRE.

7.8.4 Waste

7.8.4.1 Low-Level Radioactive Waste Scenario

7.8.4.1.1 Alternatives for Low-Level Radioactive Waste at SABRE

Table 12-93 shows the alternatives for low-level radioactive waste at SABRE.

Table 12-93. Alternatives for Low-Level Radioactive Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.0 ft^3	4.0 ft^3	4.8 ft^3	4.8 ft^3	8.4 ft^3

7.8.4.1.2 Operations That Generate Low-Level Radioactive Waste

SABRE downline shots with an ion diode load (especially lithium) may generate radioactive materials within the diode assembly (located inside the confines of the test cell). The test materials are reviewed by the SABRE Machine Safety Committee, are stored within the confines of the “permanent contaminated” area in the northeast corner of SABRE under the HP criterion, are often cleaned and reused, and are controlled through appropriate permits and procedures.

7.8.4.1.3 General Nature of Waste

The levels of radioactivity are low enough that procedures may require a 30-minute waiting period before removal of any items from the diode using gloves. Any activated item, even at a very low level, is placed on the table inside a designated contamination area within the test cell itself. Normally, within a few hours or days and with HP approval and radiological survey, these items can be cleaned for reuse, moved to a more permanent low-level storage area, or removed from site as waste.

7.8.4.1.4 Waste Reduction Measures

The waste is minimal.

7.8.4.1.5 Basis for Projecting the “Reduced” and “Expanded” Values

The quantity of waste generated at the facility is proportional to the level of activity projected (see “7.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials,” for activity descriptions).

7.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at SABRE.

7.8.4.3 Mixed Waste

7.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at SABRE.

7.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at SABRE.

7.8.4.4 Hazardous Waste Scenario

7.8.4.4.1 Alternatives for Hazardous Waste at SABRE

Table 12-94 shows the alternatives for hazardous waste at SABRE.

Table 12-94. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0 kg	63 kg	76 kg	76 kg	132 kg

7.8.4.4.2 Operations That Generate Hazardous Waste

SABRE generates hazardous waste as part of its ongoing operations.

Some SF_6, when subjected to high-voltage discharges during accelerator shots, breaks down, and the fluorides formed are corrosive and somewhat toxic. Used SF_6 that has not been passed through a purifying reclaimer is an inhalation hazard to personnel and could damage sensitive equipment. A reclaimer will remove these breakdown products, which will be disposed of as hazardous waste.

7.8.4.4.3 General Nature of Waste

The waste is comprised primarily of copper sulfate liquid, contaminated oils and oily rags, waste capacitors, and nonhalogenated solvent-contaminated rags.

7.8.4.4.4 Waste Reduction Measures

Waste management for ongoing activities is conducted in accordance with Sandia National Laboratories (1999), Chapter 19, “Waste Management.” Nonhazardous cleaning agents are substituted for solvents whenever possible.

7.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

See “7.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.” The amount of waste produced is proportional to the operational activity (number of “shots”).

7.8.5 Emissions

7.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at SABRE.

7.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency’s *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

7.8.5.3 Open Burning Scenarios

SABRE does not have outdoor burning operations.

7.8.5.4 Process Wastewater Effluent Scenario

SABRE does not generate process wastewater.

7.8.6 Resource Consumption

7.8.6.1 Process Water Consumption Scenario

SABRE does not consume process water.

7.8.6.2 Process Electricity Consumption Scenario

SABRE does not consume process electricity.

7.8.6.3 Boiler Energy Consumption Scenario

SABRE does not consume energy for boilers.

7.8.6.4 Facility Personnel Scenario

7.8.6.4.1 Alternatives for Facility Staffing at SABRE

Table 12-95 shows the alternatives for facility staffing at SABRE.

Table 12-95. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.5 FTEs	4.0 FTEs	5.0 FTEs	5.0 FTEs	6.0 FTEs

7.8.6.4.2 Operations That Require Facility Personnel

Operations that require facility personnel are the ongoing operations of the facility, including operational readiness and firing the accelerator for support of programs.

7.8.6.4.3 Staffing Reduction Measures

SABRE is presently on a shared crew basis with the operations of the HERMES III, Saturn, and SPHINX accelerators. This is essentially the minimum staffing level to maintain the present capabilities.

7.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

See “7.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.”

7.8.6.5 Expenditures Scenario

7.8.6.5.1 Alternatives for Expenditures at SABRE

Table 12-96 shows the alternatives for expenditures at SABRE.

Table 12-96. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$80,000	$640,000	$800,000	$800,000	$960,000

7.8.6.5.2 Operations That Require Expenditures

Operations that require expenditures include FTEs, maintenance equipment, and consumables.

7.8.6.5.3 Expenditure Reduction Measures

Expenditure reduction measures include reduction of FTEs and consumables as the number of shots vary.

7.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

Historically, SABRE costs $800,000 per year for the “no action” alternative (225 shots). The projections were determined by ratioing the cost according to the number of FTEs (for example, $800,000 x 0.5 / 5 = $80,000).

8.0 SHORT-PULSE HIGH INTENSITY NANOSECOND X-RADIATOR SOURCE INFORMATION

8.1 Purpose and Need

The Short-Pulse High Intensity Nanosecond X-Radiator (SPHINX) accelerator is a high-voltage, high-shot-rate bremsstrahlung and electron beam accelerator that is used primarily to measure:

- X-ray-induced photo currents from short, fast-rise-time pulses in integrated circuits.

- Thermostructural response in materials.

8.2 Description

The SPHINX accelerator facility, located in a concrete-shielded enclosure adjacent to the SATURN accelerator in Building 981, consists of the following:

- An 18-stage, low-inductance Marx generator
- Two oil pulse forming lines (PFLs)
- A vacuum PFL
- Radiation barriers, which include the following:
  - A concrete-shielded enclosure
  - A movable skyshine shield attached to the top of the transmission line/diode
  - An alternate, portable skyshine shield

8.3 Program Activities

Table 12-97 shows the program activities at SPHINX.

Table 12-97. Program Activities at the Short-Pulse High Intensity Nanosecond X-Radiator

Program Name	Activities at SPHINX	Category of Program	Related Section of the *SNL Institutional Plan*
Experimental Activities	SPHINX is applied as a high-shot-rate, hot x-ray effects simulator capable of testing piece parts or components that require small-area exposure. The electron beam mode is used to study the thermostructural response of materials to pulsed radiation. It has high usage to support development work in support of tactical and strategic satellite systems.	Programs for the Department of Energy	Section 6.1.1.1
Performance Assessment Science and Technology	Provides short, high-intensity x-ray and electron beam sources for weapon effects studies.	Programs for the Department of Energy	Section 6.1.1.1

Table 12-97. Program Activities at the Short-Pulse High Intensity Nanosecond X-Radiator (Continued)

Program Name	Activities at SPHINX	Category of Program	Related Section of the *SNL Institutional Plan*
Other Federal Agencies	Research and development work is performed at the SPHINX through the Work for Others mechanism for the Department of Defense (for example, Defense Special Weapons Agency and the Air Force) and its contractors (the NSA, the United Kingdom, and other qualified users).	Work for Non-DOE Entities (Work for Others)	Section 6.2.7

8.4 Operations and Capabilities

The primary purpose of SPHINX is to provide radiation environments for testing DOE components of nuclear weapons and for confirming codes used in the certification of nuclear weapons components. SPHINX can operate in two distinct modes—as a bremsstrahlung x-ray source and as an electron beam source. In the bremsstrahlung (x-ray) mode, researchers study the response of electronics to pulsed high-energy x-ray environments. The electron beam mode is used to study the thermostructural response of materials to the pulsed radiation. In the x-ray mode, experimental cassettes are placed at variable distances from a tantalum, bremsstrahlung converter (target) in order to change the dose rate incident to the cassette. The cassette is connected to a data acquisition system through a radiation-hardened cable plant. The experimenter determines what data (other than standard accelerator diagnostics) are recorded. The electronics are exposed to dose rates of about 2×10^{11} rad(Si)/s, and the responses are recorded. Generally, SPHINX is operated at a charge voltage of ±45 kV, but other voltages can be used to vary the average photon energy in the radiation spectrum. (SPHINX was designed to operate at any charge voltage from ±25 kV to ±49 kV.) In electron beam mode, the experiment is mounted inside a portion of the SPHINX accelerator and acts as a total electron stopper. The electrons are extracted from the main SPHINX vacuum transmission line and injected through a thin titanium foil into a drift region containing a variable-pressure gas fill. By adjusting the gas pressure and the distance of the internal experiment to the extraction foil, the experimenter can adjust the electron beam profile incident on the test coupon. The SPHINX anode-cathode gap is adjusted as needed to further optimize the beam profile.

The following are accelerator parameters for SPHINX:

- Accelerator type is pulsed power (single pulse).
- Particle type is electron.
- Peak diode voltage is 4 MV (open circuit).
- Total beam energy is 1,000 J (max pulse width = 14 nanoseconds).
- Radiant energy is x-ray (bremsstrahlung) or electron beam.
- Repetition rate is 12 shots per hour.
- Peak diode current is 67 kA (short circuit).
- Power pulse width is 3.5 to 14 nanoseconds (continuously variable).

The following are parameters for the x-ray environment:

- Endpoint voltage is 2.5 MeV (bremsstrahlung).
- Maximum dose rate is 4.0 x 10^{11} rad(CaF2)/s (on face plate) and 1.5 x 10^{11} rad(CaF2)/s (1.3 cm from face).
- Peak dose is 4 krads (CaF2) (on face plate).
- Rise time is 2 nanoseconds or 7 nanoseconds.

The following are parameters for the electron beam environment:

- Endpoint voltage is 2.0 MeV.
- Peak dose is 10 Mrads (Al) (on experiment plate).
- Rise time is 2 nanoseconds.
- Maximum dose rate is 1,015 rad(Al)/s (on experiment plate).

SPHINX's Marx generator is made up of 18 64-nF stages, each charged to a maximum voltage of 50 kV. It is charged in approximately one minute with electrical current limited to less than 1 ampere during that time. Upon full charge, the power supply is disconnected. The stored electrical energy is then discharged into a series of pulse compression units. The PFL is isolated from the Marx generator by a 5.5-ohm(W) series resistor and charges to a peak voltage of approximately 2.7 MV in approximately 100 nanoseconds. The impedance of this line is 25-W, and the line switches out to the second PFL via a single channel, hemispherical, self-breaking oil switch. The second PFL has a 40-W impedance and charges in approximately 10 nanoseconds. This line switches out via a 15-pin sharpening switch with prepulse suppression. There is an additional diverter switch following this to shorten the pulse from its maximum of 14 nanoseconds. The current travels through a radial, graded vacuum-oil insulator interface into a 60-W vacuum, coaxial transmission line long enough to provide transit-time isolation. This line ends in a graphite anode for emission of the electron beam. At this point the beam is either (1) incident on a reusable tantalum optimized converter to produce bremsstrahlung or (2) propagated through a 1-m long, low-pressure-gas drift chamber, and its energy is deposited in the experiment.

The shot rate is limited by the five-minute oil cleaning time between shots. As many as 60 shots have been performed in a single day.

Two bremsstrahlung diode types are available for SPHINX. One is a reusable optimized converter, whose anode-cathode gap has been optimized for a flat radiation pulse using a tantalum converter and aluminum debris/beam stop. The other type is a nonreusable converter consisting of titanium-foil anodes with a gas drift chamber that ballistically focuses the beam onto the tantalum converter. For electron beam operation, the beam is injected through a titanium window into a gas-filled drift chamber. With a maximum (unsustainable) shot rate of about one shot per five minutes, test objects in SPHINX could accumulate large doses. However, neither mode will cause activation of materials.

The operational work year for the SPHINX facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personal leave and holidays and 9 weeks of operational maintenance and experiment setup time.

8.5 Hazards and Hazard Controls

8.5.1 Offsite Hazards to the Public and the Environment

SPHINX contains no radioactive material or chemical inventories that can be dispersed outside the facility. Accidents at the facility present no potential offsite consequences to either the public or the environment (Nickerson *et al.*, 1995).

8.5.2 Onsite Hazards to the Environment

Onsite hazards to the environment include transformer oil. Approximately 1,000 gal of transformer oil are used as electrical insulation. The quality of the oil is maintained through continuous processing.

8.5.3 Onsite Hazards to Workers

8.5.3.1 Radiological Hazards

SPHINX is designed to produce an intense burst of x-rays, and high exposures are possible inside the restricted, test cell area. A person standing in the exposure area (at the diode) could receive a lethal dose. However, access to SPHINX is rigorously controlled during a shot to prevent such an accident. Shielding provided by the concrete enclosure, coupled with personnel exclusion equipment and procedures, ensure that personnel are not exposed to hazardous levels of ionizing radiation. Assuming the passive shielding remains intact with the single entry gate secured, the maximal (credible) accident involving prompt radiation would result in a negligible radiation effective dose equivalent to onsite and offsite personnel.

8.5.3.1.1 Radiological Exposures From Routine Operations

SPHINX is only capable of producing lethal ionizing radiation doses in the target area of the test cell. Evacuation and access control procedures (along with shielding, distance, time, alarms, and warning beacons) obviate the hazard. If the access control gate is breached, the accelerator is automatically deactivated (shot aborted) and no radiation is produced. The maximum number of shots allowed per year is 9,000. As an upper limit of operation, 9,000 shots ensures that the effective dose equivalent to onsite and offsite personnel remains negligible (Sandia National Laboratories, 1992).

8.5.3.1.2 Radiological Exposures From Accidents and Abnormal Events

If an individual were present in the target area of the machine during a shot, the exposure could be fatal. This is the only scenario wherein an individual could possibly receive a major dose of x-rays from the SPHINX accelerator. Periodic monitoring has confirmed the adequacy of passive shielding, and interlocks are tested prior to each shot according to an ES&H SOP. The worst-case accidental exposure would occur during a test in which one of the skyshine shields was not in use. In the extremely unlikely event someone was located above the top of the shielding and was in direct line-of-sight of the target, a maximum prompt radiation effective dose of 1 millirem is possible. In addition, because the accelerator does not produce a continuous beam over time that could be interrupted by an accident (for example, an earthquake) but only produces radiation for an instant, an accidental release of radiation to the environment or the general public is not possible.

8.5.3.1.3 Activation Products

Radioactive materials are not made or dispersed by the SPHINX accelerator.

8.5.3.2 Hazardous Materials

The release of small quantities of hazardous materials may occur during SPHINX operations and could result in minor injury to workers. Most of the small quantities of hazardous materials that will be used at the facility will be adequately removed from the atmosphere in the work area by the HVAC systems. Accidents resulting from exposure to the hazardous materials used at the SPHINX facility are considered to be of a magnitude and type routinely encountered and accepted by the public.

8.5.3.3 Industrial Hazards

Although an exposure to the gravity or mechanical hazards of maintenance work or to the thermal hazards of hotwork could result in severe personnel injury or major facility damage or possibly have an impact on the environment, such industrial-type hazards are considered to be of a magnitude and type routinely encountered and accepted by the public. Furthermore, possibly catastrophic industrial-type accidents such as a death due to heavy equipment being dropped from an overhead crane or from electric shock during work with high voltages are not expected to happen and pose an acceptably low level of risk.

8.5.3.3.1 Gravity Hazards

Particularly important hazards in this facility result from moving and positioning heavy pieces of apparatus in restricted spaces. The most likely cause of death or severe personnel injury or equipment damage would be impact during movement of heavy equipment such as a Marx generator. Adherence to restrictive procedures by trained personnel is important for decreasing the chances of accidents that could occur when equipment is being moved by cranes and lifts.

8.5.3.3.2 Electrical Hazards

Electrical hazards are encountered during maintenance of accelerator electrical systems where electrical energy sources (or storage) are present (for example, maintenance activities in close proximity to a Marx generator). The electrical energy sources at SPHINX include the following:

- Marx generators
- Triggering systems
- Electrical wiring and cables
- High-voltage power supplies
- Power tools
- Data acquisition (DAS) equipment

Of these sources, many are common in industry and are well understood. Others, such as the Marx generators, are items designed for special accelerator applications. The Marx generators and other associated equipment are discharged routinely after firing or testing and before maintenance operations are performed. However, capacitors can maintain a residual lethal charge, and discharge procedures may not be effective if equipment has been damaged. Maintenance work on such apparatus could be hazardous, and extreme care must be taken to ground each capacitor. Other electrical wiring and cables are standard units similar to those found widely in industry. The hazards they pose and the required safety measures are common to industrial facilities and operations, and adequate safety measures are in place. The computer support equipment may require maintenance in the vicinity of live circuits. Trained personnel perform these activities using standard safety equipment and procedures. The DAS controls and monitors the accelerator and gathers and analyzes shot-related data. Hardware breakdown and repair activities that may occur while other parts of the system are functioning could pose some hazard to personnel.

8.5.3.3.3 Mechanical Hazards

Mechanical hazards are most often encountered during maintenance activities involving the use of tools and work on mechanical equipment. Mechanical equipment used in the SPHINX facility is standard for heavy industrial use and includes motors, door hoists, elevators, cranes, and hoists; power tools; hand tools; compressed gas equipment; vacuum equipment; and transports. The use of all mechanical equipment conforms to standard industrial safety practices. Although it is unlikely, severe injury or major damage to the facility or operation could result from the mechanical hazards associated with maintenance activities on large systems or components. However, the majority of potential accidents would only result in minor injury, minor occupational illness, have minor impact on the environment, or result in minor system or component damage.

8.5.3.3.4 Thermal Hazards

Thermal hazards include welders and cutting torches, equipment with rotating parts (cranes, hoists, tools, motors, and pumps), heaters, tools that may spark, and lighting. These sources of thermal energy could initiate fires. All sources of thermal energy are standard for industrial installations.

8.5.3.3.5 Fire

The probability of fire at the SPHINX facility is low because of the way Building 981 is designed and because of requirements that are set forth in the operating procedures. However, the potential severity of the fire is significant because personnel could be injured and the facility could be seriously damaged or destroyed. The building is of concrete and metal construction and has built-up bituminous roofing, and the likelihood of occurrence of a serious fire is significantly reduced by the presence of an automatic foam suppression system in the accelerator area of the building. The types and quantities of flammable materials throughout the building are strictly controlled. Combustibles are kept to a minimum, the use of flammable liquids is strictly controlled, and combustible waste is kept in covered metal cans. Throughout SNL, smoking is prohibited except in designated, outside smoking areas. A full-time paid fire department is on duty at Kirtland Air Force Base (KAFB) at all times that can respond to a fire within five minutes. Also, the fire department can provide a crew to stand by upon request. The most likely causes of a fire would be overheated equipment, overheated wiring, or ignition of flammable solvents, oil soaked rags, or absorbent materials.

8.5.4 Hazard Controls

8.5.4.1 Radiation Protection

Confinement barriers are provided to protect personnel and equipment from the effects of any generated radiation. These barriers include the following:

- Shielding walls on four sides of the test cell
- A movable skyshine shield (attached to the top of the transmission line/diode)
- An alternate skyshine shield (portable)

Additional protection measures are used to ensure that personnel exposures to radiation are as low as reasonably achievable. These measures include use of personnel dosimeters, periodic monitoring and surveys, and access control features interlocked to the energy beam.

8.5.4.2 Access Control

All areas of the SPHINX facility have access control maintained by fences and gates with locking mechanisms. The SPHINX accelerator, which is located in the Building 981 highbay, is a personnel-restricted radiation zone during shots. During the critical period of charging and firing, access to SPHINX is controlled by physical inspection and clearing procedures, and systems are interlocked with access control such that any breach automatically disables all systems and places the accelerator in “safe.”

8.5.4.3 Secondary Oil Containment System

Building 981 includes a secondary containment trench system located just inside the exterior walls of the highbay. In the event of a large oil leak, the trenches channel the oil to the basement area, where it is stored until it can be reclaimed.

8.5.4.4 Other

Other safety features (including HVAC systems, warning lights, roof television monitors, auxiliary power fire protection systems, and exits) are common to the Saturn accelerator facility (Building 981).

8.6 Accident Analysis Summary

8.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the facility and through discussions with operations personnel. Following the walk-down and qualitative survey of the facility, the operating events selected for qualitative risk analysis were the following:

- Worker electrocution while “safing” Marx generator capacitors
- Worker radiation exposure during accelerator operation
- Fire involving insulating oil

These events are considered to be the bounding accidents that define the safety envelope for facility operations. In addition, the accident analysis for SPHINX included natural phenomena event scenarios that are generic to all facilities at SNL as well as an aircraft crash scenario. The facility accident analysis did not address standard industrial accidents (for example accidents that involve hazards such as cranes and hoists, forklifts, lasers, and compressed gases) that are addressed by existing consensus standards for accident prevention and mitigation.

8.6.2 Analysis Methods and Assumptions

The methodology used to perform the SPHINX accident assessment (see Mahn *et al*, 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-98. In addition, the generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities, as provided in Mahn *et al.* (1995), were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-98. Consequence Categories and Levels of Severity

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

8.6.3 Summary of Accident Analysis Results

The results of the SPHINX accident assessment are summarized in Table 12-99.

Table 12-99. Results of the SPHINX Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Incredible (D)
Insulating oil fire	Critical (II)	Extremely unlikely (C)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

Tables 12-100 and 12-101 were obtained from AL 5481.1B and provide definitions for terms used in “8.6 Accident Analysis Summary.”

Table 12-100. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or provide a significant impact on the environment.

Table 12-101. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely Unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

8.7 Reportable Events

Table 12-102 lists the only occurrence report for SPHINX over the past five years.

Table 12-102. Occurrence Report for SPHINX

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-NMFAC-1997-0008	Failure of Vital System Consisting of Backup Battery on Halon Alarm System	1E	The fan motor for the control monitor air-conditioning system overheated, causing the halon system to discharge.

8.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

8.8.1 Scenario for Test Activities: Irradiation of Components or Materials

8.8.1.1 Alternatives for Test Activities: Irradiation of Components or Materials

Table 12-103 shows the alternatives for irradiation of components or materials at SPHINX.

Table 12-103. Alternatives for Test Activities: Irradiation of Components or Materials

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
200 shots	1,185 shots	2,500 shots	2,500 shots	6,000 shots

8.8.1.2 Assumptions and Actions for the “Reduced” Values

SPHINX is a high-voltage, high-shot-rate bremsstrahlung accelerator. It was placed in operation in 1992 and is primarily used to measure the x-ray-induced photo currents from short, fast-rise-time pulses in integrated circuits.

The programs that use the SPHINX accelerator and the activities associated with those programs are provided in “8.3 Program Activities.” Because SPHINX’s controlled production of x-rays is fundamental to each of the listed programmatic activities, the values associated with such things as material inventory and consumption are essentially the same across each scenario. Therefore, the following considers one basic scenario, which is the firing of the accelerator. Furthermore, there is the underlying assumption that the consumption and generation values are directly proportional to the number of times the machine fires (“shots”).

For the “reduced” alternative, SPHINX must be operated about once per week to keep the accelerator in a state of operational readiness. Therefore, the minimal level of activity equates to 200 shots per year. The “reduced” alternative assumes that the projected value would be approximately 0.17 times that reported in the base year (200 shots / 1,185 shots = 0.17).

8.8.1.3 Assumptions and Rationale for the “No Action” Values

The following are assumptions for the “no action” alternative:

- The base year value is the actual reported number of shots in CY1998.
- A maximum of 2,500 SPHINX shots per year are expected in the ten-year period of FY1999 through FY2008. Therefore, FY2003 and FY2008 values are approximately 2.1 times the value reported in the base year (2,500 shots / 1,185 shots = 2.1).

8.8.1.4 Assumptions and Actions for the “Expanded” Values

SPHINX can fire a maximum of 6,000 times per year between now and FY2008. The projected value for the expanded alternative of 6,000 shots per year is approximately 5.1 times the value reported in the base year (6,000 shots / 1,185 shots = 5.1).

8.8.2 Material Inventories

8.8.2.1 Nuclear Material Inventory Scenarios

SPHINX has no nuclear material inventories.

8.8.2.2 Radioactive Material Inventory Scenarios

SPHINX has no radioactive material inventories.

8.8.2.3 Sealed Source Inventory Scenarios

SPHINX has no sealed source inventories.

8.8.2.4 Spent Fuel Inventory Scenarios

SPHINX has no spent fuel inventories.

8.8.2.5 Chemical Inventory Scenarios

SPHINX has no inventories of chemicals of concern.

8.8.2.6 Explosives Inventory Scenarios

SPHINX has no explosives inventories.

8.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

8.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-104 shows the alternatives for insulator oil inventory at SPHINX.

Table 12-104. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
1,000 gal	1,000 gal	1,000 gal	1,000 gal	1,000 gal

8.8.2.7.2 Operations That Require Insulator Oil

Approximately 1,000 gal of transformer oil are used as electrical insulation. The quality of the oil is maintained through continuous processing. (Inspections have shown the PCB concentration to be less than the limit of detection.)

8.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

There will be no more or no less oil required in the “reduced” or “expanded” alternatives.

8.8.3 Material Consumption

8.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at SPHINX.

8.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at SPHINX.

8.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

8.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at SPHINX.

8.8.4 Waste

8.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at SPHINX.

8.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at SPHINX.

8.8.4.3 Mixed Waste

8.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at SPHINX.

8.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at SPHINX.

8.8.4.4 Hazardous Waste Scenario

8.8.4.4.1 Alternatives for Hazardous Waste at SPHINX

Table 12-105 shows the alternatives for hazardous waste at SPHINX.

Table 12-105. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
3.6 kg	21 kg	45 kg	45 kg	107 kg

8.8.4.4.2 Operations That Generate Hazardous Waste

SPHINX generates hazardous wastes as part of ongoing operations.

8.8.4.4.3 General Nature of Waste

The waste is comprised of photochemicals, contaminated oils and oily rags, waste capacitors, and halogenated solvent-contaminated rags.

8.8.4.4.4 Waste Reduction Measures

Waste management for ongoing activities is conducted in accordance with Sandia National Laboratories (1999), Chapter 19, "Waste Management." Nonhazardous cleaning agents are substituted for solvents whenever possible.

8.8.4.4.5 Bases for Projecting the "Reduced" and "Expanded" Values

See "8.8.1 Scenario for Test Activities: Irradiation of Components or Materials." The amount of waste produced is proportional to the operational activity (number of "shots").

8.8.5 Emissions

8.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at SPHINX.

8.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

8.8.5.3 Open Burning Scenarios

SPHINX does not have outdoor burning operations.

8.8.5.4 Process Wastewater Effluent Scenario

SPHINX does not generate process wastewater.

8.8.6 Resource Consumption

8.8.6.1 Process Water Consumption Scenario

SPHINX does not consume process water.

8.8.6.2 Process Electricity Consumption Scenario

SPHINX does not consume process electricity.

8.8.6.3 Boiler Energy Consumption Scenario

SPHINX does not consume energy for boilers.

8.8.6.4 Facility Personnel Scenario

8.8.6.4.1 Alternatives for Facility Staffing at SPHINX

Table 12-106 shows the alternatives for facility staffing at SPHINX.

Table 12-106. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.5 FTEs	2.7 FTEs	3.5 FTEs	3.5 FTEs	5 FTEs

8.8.6.4.2 Operations That Require Facility Personnel

Personnel are required for ongoing operations of the facility, including operational readiness and firing the accelerator for support of programs.

8.8.6.4.3 Staffing Reduction Measures

SPHINX is presently on a shared crew basis with the operations of the Saturn, HERMES, and SABRE accelerators. This is essentially the minimum staff to maintain the present capability.

8.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

See “8.8.1 Activity Scenario for Test Activities: Irradiation of Components or Materials.”

8.8.6.5 Expenditures Scenario

8.8.6.5.1 Alternatives for Expenditures at SPHINX

Table 12-107 shows the alternatives for expenditures at SPHINX.

Table 12-107. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$70,000	$300,000	$500,000	$500,000	$710,000

8.8.6.5.2 Operations That Require Expenditures

Expenditures are required for FTEs, maintenance equipment, and consumables.

8.8.6.5.3 Expenditure Reduction Measures

Expenditure reduction measures include reduction of FTEs and consumables as the number of shots vary.

8.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

Historically, SPHINX costs $500,000 per year for the “no action” category (2,500 shots). The projections were determined by ratioing the cost according to the number of FTEs (for example, $500,000 x 0.5/3.5 = $70,000).

9.0 TESLA SOURCE INFORMATION

9.1 Purpose and Need

The mission of the Tera-Electron Volt Energy Superconducting Linear Accelerator (TESLA) facility, formerly known as the MITE accelerator facility, is to test plasma opening switches for pulsed power drivers. The name change came about from modifications to the MITE accelerator and redirected research (U.S. Department of Energy, 1996; Weber and Zawadzkas, 1996b).

9.2 Description

The TESLA accelerator facility, located in Building 961, includes the accelerator highbay, light labs, offices, and the screen room. The accelerator consists of the following:

- An oil tank
- A water tank
- A concrete-shielded test cell

The test cell includes a vacuum storage inductor, a magnetically controlled plasma opening switch, and an electron beam load. The oil tank contains 10,000 gal of transformer oil and a Marx generator, which can store a maximum of 740 kJ in 48 capacitors and which is equipped with a mechanical shorting system. The water tank contains 15,000 gal of deionized water and a 150-kJ intermediate storage capacitor. The test cell is surrounded by 2-ft-thick concrete block walls. The electron beam load consists of an electron diode with a graphite converter. The maximum possible voltage is 5 MV into a very high impedance load.

TESLA draws transformer oil from 250,000-gal storage tanks located at Tech Area IV via underground piping.

(U.S. Department of Energy, 1996; Weber and Zawadzkas, 1996b)

9.3 Program Activities

Table 12-108 shows the program activities at TESLA.

Table 12-108. Program Activities at TESLA

Program Name	Activities at TESLA	Category of Program	Related Section of the *SNL Institutional Plan*
Performance Assessment Science and Technology	No description of program activities provided by program manager.	Programs for the Department of Energy	Section 6.1.1.1

9.4 Operations and Capabilities

The primary operating mode of TESLA produces a pulse that lasts approximately 40 nanoseconds with 150 kJ of electrical energy and 700-kA peak diode current at a peak voltage of 5 MV or less. It produces ionizing radiation in the vacuum chamber region in the form of intense prompt radiation (bremsstrahlung). In the primary operating mode, an ion beam is not produced except incidentally in the plasma opening switch (Weber and Zawadzkas, 1996b).

The operational work year for the TESLA facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and test setup time.

9.5 Hazards and Hazard Controls

9.5.1 Offsite Hazards to the Public and the Environment

The TESLA accelerator facility contains no radioactive material inventory and only a small chemical inventory that cannot be dispersed outside the facility. Accidents at the facility present no potential offsite consequences to either the public or the environment (Weber and Zawadzkas, 1996b).

9.5.2 Onsite Hazards to the Environment

Onsite hazards to the environment include transformer oil. The TESLA oil tank contains 10,000 gal of ANSI/ASTM D 3487 Type II, Shell 69701 DIALA AX transformer oil, which has a flash point of 300°F.

9.5.3 Onsite Hazards to Workers

Potential worker hazards at the TESLA facility include:

- **Ionizing Radiation** - TESLA produces ionizing radiation in the vacuum storage inductor in the form of intense prompt radiation. Because TESLA operates at relatively low voltages, activation of test materials or machinery parts is not expected to occur.

- **Marx Generator** - The prime energy storage component of the accelerator.

- **Solvents** - Includes methyl alcohol and hexanes, which are used for cleaning accelerator parts. Less than 5 gal per year are used for this purpose.

- **Dilute Copper Sulfate Solution** - Used to fabricate high-power resistors for the Marx generator.

- **SF_6** - Used as an insulating gas in spark gaps and switches.

- **Confined Spaces** - The oil and water tanks as well as the building secondary oil containment trenches are designated as confined spaces.

9.5.4 Hazard Controls

Hazard controls at the TESLA accelerator facility include:

- **Shielding** - The shielding for the TESLA test cell, which limits bremsstrahlung radiation beyond the test cell walls to 1 millirem or less with each full system shot.

- **Access Control** - All areas of the facility have access control maintained by fences and gates that are physically locked and interlocked with the control console. During the critical period of charging and firing, access is controlled by physical inspection and clearing procedures, and accelerator systems are interlocked with access control so that any breach automatically disables all charging and firing systems and places the accelerator in a safe condition. There is only one access door to the test cell, and it is controlled by means of an interlock that will not allow the accelerator to be charged if the door is open.

- **Electrical Safety** - The Marx capacitors are discharged to ground, and all charging circuits must be manually reset before charging can begin again.

- **Secondary Containment** - Concrete trenches located within Building 961 provide secondary oil containment to protect the environment from oil spills.

- **Confined Space Safety** - The oil and water tanks and the secondary oil containment trenches are permit-required confined spaces. A check for adequate oxygen content is performed prior to any entry. However, the single SF_6 bottle limitation inside the building and the physical size of the highbay preclude this potential hazard in the tanks. The contents of a single SF_6 bottle dumped into the oil containment trenches would result in less than 1 in. of gas in the trench system. TESLA personnel working within a confined space wear personal oxygen monitors.

(Weber and Zawadzkas, 1996b)

9.6 Accident Analysis Summary

9.6.1 Selection of Accidents Analyzed in Safety Documents

Generic accidents were selected for qualitative analysis by examining sources of energy, radiation, and toxicological risk through a walk-down of the facility and through discussions with operations personnel. Following the walk-down and qualitative survey of the facility, the operating events selected for qualitative risk analysis were the following:

- Worker electrocution while “safing” Marx generator capacitors

- Worker radiation exposure during accelerator operation

These events are considered to be the bounding accidents that define the safety envelope for facility operations. In addition, the accident analysis for the TESLA accelerator included natural phenomena event scenarios that are generic to all facilities at SNL, as well as an aircraft crash scenario.

The facility accident analysis did not address standard industrial accidents (for example accidents that involve hazards such as cranes and hoists, forklifts, lasers, and compressed gases) that are addressed by existing consensus standards for accident prevention and mitigation.

9.6.2 Analysis Methods and Assumptions

The methodology used to perform the TESLA accelerator accident assessment (see Mahn *et al*., 1995) used the accident severity and probability criteria of AL 5481.1B. However, in this methodology the DOE/AL accident severity matrix was enhanced as shown in Table 12-109. In addition, a generic event tree was used to evaluate the likelihood of occurrence of an accident scenario. That is, each accident scenario was evaluated in terms of an initiating event frequency together with the probability that mitigating structures, systems, and worker actions fail to terminate the accident event sequence. Generic initiating event frequencies, structural failure probabilities, system failure probabilities, and human performance error probabilities, as provided in Mahn *et al*. (1995), were applied to calculate the scenario likelihood of occurrence. The combination of accident severity code (I, II, III, IV) and probability code (A, B, C, D) was used to represent the risk associated with the accident scenario.

Table 12-109. Consequence Categories and Levels of Severity

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
I	Catastrophic	• More than one death • Significant offsite injury	• Over $10 million cleanup cost • Groundwater or surface water in immediate danger of contamination	Programmatic delay greater than one year
II	Critical	• One death • Permanent disability, severed limb • Permanent paralysis or hospitalization • Minor offsite injuries	• $1 million to $10 million cleanup cost • Significant soil contamination • Likely long-term migration of contamination off site or to water source that does not pose any short-term threat to offsite or endangered animals and fauna	• Loss $1 million to $10 million • Programmatic delay between three months and one year
III	Marginal	• Mendable injury that may require surgery, hospitalization, or outpatient treatment • Moderate or less rehabilitation • Injury resulting in two or more worker days lost • No offsite injuries	• $50,000 to $1 million cleanup costs • Minor soil contamination with nearly no potential for contaminant migration	• Loss $50,000 to $1 million • Programmatic delay between one week and three months

Table 12-109. Consequence Categories and Levels of Severity (Continued)

Rank	DOE/AL 5481.1B	Human Impact	Environmental Impact	Programmatic Impact
IV	Negligible	• None to minor injuries requiring none or only little immediate medical attention • Less than two lost worker days	• Less than $50,000 cleanup cost • Small spills or spills that do not immediately enter into the soil • Contamination that is quickly and readily cleaned up with onsite or locally available technology	• Loss less than $50,000 • Programmatic delay less than one week

9.6.3 Summary of Accident Analysis Results

The results of the TESLA accident assessment are summarized in Table 12-110.

Table 12-110. Results of the TESLA Accident Assessment

Event	Severity	Probability
Electric shock	Critical (II)	Incredible (D)
Radiation exposure	Negligible(IV)	Unlikely (B)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

Two accident scenarios (tornado and aircraft crash) are identified as potentially catastrophic in nature. However, the probabilities of such events occurring are remote or extremely improbable.

Tables 12-111 and 12-112 were obtained from AL 5481.1B and provide definitions for terms used in “9.6 Accident Analysis Summary.”

Table 12-111. Qualitative Accident Hazard Severity, Hazard Categories, and/or Consequences to the Public, Workers, or the Environment

Categories	Consequences	Definitions
Category I	Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II	Critical	May cause severe injury, or severe occupational illness, or major damage to a facility operation, or major impact on the environment.
Category III	Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV	Negligible	Will not result in a significant injury, or occupational illness, or a significant impact on the environment.

Table 12-112. Qualitative Accident Probabilities

Descriptive Word	Symbol	Nominal Range of Frequency per Year
Likely	A	$P_e > 10^{-2}$
Unlikely	B	$P_e = 10^{-2}$ to 10^{-4}
Extremely unlikely	C	$P_e = 10^{-4}$ to 10^{-6}
Incredible	D	$P_e < 10^{-6}$
P_e = Probability of event occurring per year.		

(Weber and Zawadzkas, 1996b)

9.7 Reportable Events

Table 12-113 lists the only occurrence report for TESLA over the past five years.

Table 12-113. Occurrence Report for TESLA

Report Number	Title	Category	Description of Occurrence
ALO-KO-SNL-9000-1996-0003	“TESLA” Operation Without Meeting DOE Order 5480.25 Requirements Resulted in an Unusual Occurrence	1C	A total of 20 shots were made prior to obtaining the required authorization basis.

9.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

9.8.1 Activity Scenario for Test Activities: Accelerator Shots

9.8.1.1 Alternatives for Test Activities: Accelerator Shots

Table 12-114 shows the alternatives for accelerator shots at TESLA.

Table 12-114. Alternatives for Test Activities: Accelerator Shots

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40 shots	40 shots	1,000 shots	1,000 shots	1,300 shots

9.8.1.2 Assumptions and Actions for the “Reduced” Values

Shots at TESLA are for pulsed power technology development and primarily involve a plasma opening switch. Of the estimated numbers of shots projected across each of the alternatives found here, approximately half would be radiation-producing shots (electron beam into carbon load). The remaining half would be pulsed power tests into a dummy load (nonradiation-producing shots). TESLA operations do not involve the use of nuclear or radioactive materials, sealed sources, or explosives. In addition, no chemicals identified on the chemical inventory list of regulated chemicals are in use. Operational needs would not be anticipated to change under any of the scenarios projected here.

The “reduced” alternative projection reflects the minimum number of shots required to maintain operational capability at the facility. This scenario assumes one shot each week over the approximately 40-week operational year. The Tech Area IV 40-week year is based on subtracting a total of 12 weeks from the 52-week calendar year. (There are 3 weeks of annual leave and holidays and 9 weeks in which the facility is idle due to operational maintenance and experiment setup time.)

9.8.1.3 Assumptions and Rationale for the “No Action” Values

The TESLA facility was not operational during 1996. For this reason, the base year is estimated to be consistent with the “reduced” alternative of 40 shots. TESLA operations in 1997 were also at a minimum (approximately 10 shots).

Projections provided for the 2003 and 2008 alternatives assume five shots per day during a five-day week over a 40-week year (25 shots per week x 40 weeks = 1,000 shots). The numbers projected for the FY2003 and FY2008 alternatives assume that the facility operates at nearly full capability.

9.8.1.4 Assumptions and Actions for the “Expanded” Values

The projection under the “expanded” alternative assumes a level of activity of approximately 130 percent of the FY2003 and FY2008 values, which is only minimally above the FY2003 and FY2008 values because those values already approach operational capacity. To achieve this level of activity, an estimated increase of from three to five FTEs would be required.

9.8.2 Material Inventories

9.8.2.1 Nuclear Material Inventory Scenarios

TESLA has no nuclear material inventories.

9.8.2.2 Radioactive Material Inventory Scenarios

TESLA has no radioactive material inventories.

9.8.2.3 Sealed Source Inventory Scenarios

TESLA has no sealed source inventories.

9.8.2.4 Spent Fuel Inventory Scenarios

TESLA has no spent fuel inventories.

9.8.2.5 Chemical Inventory Scenarios

TESLA has no inventories of chemicals of concern.

9.8.2.6 Explosives Inventory Scenarios

TESLA has no explosives inventories.

9.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

9.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-115 shows the alternatives for insulator oil inventory at TESLA.

Table 12-115. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
10,000 gal	10,000 gal	20,000 gal	20,000 gal	20,000 gal

9.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material that prevents electrical breakdown when the accelerator is charged. (PCB concentrations, if any, are below the 50 parts per million regulatory limit.)

Projections under the base year of the “no action” alternative are based upon the capacity of the oil tank, which is approximately 10,000 gal.

Projections for FY2003 and FY2008 are based on the installation of an additional 10,000-gal tank to house another Marx generator. This additional Marx generator does not increase the output of the accelerator.

9.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

Projections under the “reduced” alternative are the same as that provided under the base year and reflect tank capacity and machine operating requirements. Projections under the “expanded” alternative assume the same rationale as that presented for the FY2003 and FY2008 timeframes.

9.8.3 Material Consumption

9.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at TESLA.

9.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at TESLA.

9.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

9.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at TESLA.

9.8.4 Waste

9.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at TESLA.

9.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at TESLA.

9.8.4.3 Mixed Waste

9.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at TESLA.

9.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at TESLA.

9.8.4.4 Hazardous Waste Scenario

9.8.4.4.1 Alternatives for Hazardous Waste at the TESLA

Table 12-116 shows the alternatives for hazardous waste at TESLA.

Table 12-116. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
2 kg	2 kg	50 kg	50 kg	65 kg

9.8.4.4.2 Operations That Generate Hazardous Waste

TESLA generates hazardous waste as part of routine operations. A multiplier of 0.05 kg has been applied to the number of projected shots to provide an annual estimate of wastes reasonably anticipated to be generated:

0.05 x number of shots = kg of hazardous waste anticipated to be generated on annual basis

Some SF_6, when subjected to high-voltage discharges during accelerator shots, breaks down, and the fluorides formed are corrosive and somewhat toxic. Used SF_6 that has not been passed through a purifying reclaimer is an inhalation hazard to personnel and could damage sensitive equipment. If these toxics are removed by a reclaimer, they would be disposed along with other hazardous waste generated at the facility.

9.8.4.4.3 General Nature of Waste

The waste is comprised of copper sulfate liquid, contaminated oils and oily rags, waste capacitors, and nonhalogenated solvent-contaminated rags.

9.8.4.4.4 Waste Reduction Measures

No waste reduction measures exist.

9.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value and “expanded” value are based on the multiplier identified above in relation to the number of shots projected in “9.8.1 Activity Scenario for Test Activities: Accelerator Shots.” For the “reduced” alternative, the minimum number of shots needed to maintain operational capability is 40. For the “expanded” alternative, the number of shots is approximately 130 percent of the FY2003 and FY2008 values (1,300 shots).

9.8.5 Emissions

9.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at TESLA.

9.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency's *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

9.8.5.3 Open Burning Scenarios

TESLA does not have outdoor burning operations.

9.8.5.4 Process Wastewater Effluent Scenario

TESLA does not generate process wastewater.

9.8.6 Resource Consumption

9.8.6.1 Process Water Consumption Scenario

TESLA does not consume process water.

9.8.6.2 Process Electricity Consumption Scenario

TESLA does not consume process electricity.

9.8.6.3 Boiler Energy Consumption Scenario

TESLA does not consume energy for boilers.

9.8.6.4 Facility Personnel Scenario

9.8.6.4.1 Alternatives for Facility Staffing at the TESLA

Table 12-117 shows the alternatives for facility staffing at TESLA.

Table 12-117. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
1 FTEs	1 FTEs	3 FTEs	3 FTEs	5 FTEs

9.8.6.4.2 Operations That Require Facility Personnel

All operations at TESLA require personnel. Personnel can provide operational, evaluation, and diagnostic support.

Projections of the number of FTEs for the FY2003 and FY2008 alternatives are based on a level of activity that places the TESLA facility at close to full operational capacity.

9.8.6.4.3 Staffing Reduction Measures

No staffing reduction measures exist.

9.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value assumes the minimum budget and associated FTEs to maintain operational capability (approximately 40 shots). The “expanded” value assumes the additional budget and associated FTEs for the expanded number of shots projected in “9.8.1 Activity Scenario for Test Activities: Accelerator Shots” (1,300 shots).

9.8.6.5 Expenditures Scenario

9.8.6.5.1 Alternatives for Expenditures at the TESLA

Table 12-118 shows the alternatives for expenditures at TESLA.

Table 12-118. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$500,000	$50,000	$1 million	$1 million	$1.6 million

9.8.6.5.2 Operations That Require Expenditures

All TESLA operations require funding. Funding is based on FTEs, infrastructure, and program operational costs.

Projections for FY2003 and FY2008 are based on the estimated level of funding to sustain the facility at nearly full operational capacity.

9.8.6.5.3 Expenditure Reduction Measures

No expenditure reduction measures are in effect.

9.8.6.5.4 Basis for Projecting the "Reduced" and "Expanded" Values

The "reduced" value assumes the minimal budget to maintain operational capability at the TESLA facility. This number is based on the estimated number of FTEs, infrastructure needs, and the minimum operational costs associated with the 40 shots projected in "9.8.1 Activity Scenario for Test Activities: Accelerator Shots." The "expanded" value assumes the total budget for the staffing level and number of shots described in that section.

10.0 RADIOGRAPHIC INTEGRATED TEST STAND SOURCE INFORMATION

10.1 Purpose and Need

SNL/NM proposes to install a new accelerator to be called the Radiographic Integrated Test Stand in place of the existing Proto II accelerator located in the Tech Area IV, Building 970 highbay. The purpose of this new accelerator, which is planned for FY1999, is to demonstrate inductive voltage adder (IVA) technology utility for advanced hydrodynamic radiography. This research, which is sponsored by the Office of Defense Programs, would support SNL/NM in a technical competition for a future $1 billion advanced hydrotest facility. The DOE Kirtland Area Office determined that the project should be granted a categorical exclusion on September 26, 1997 (U.S. Department of Energy, 1997).

The Radiographic Integrated Test Stand is an accelerator and intense electron beam testbed to develop and demonstrate the capabilities required for the national Advanced Hydrotest Facility (AHF). The AHF will provide experimental benchmarking for advanced full-physics, three-dimensional numerical models of nuclear weapon primaries. The resulting confidence in the codes will form the basis for confidence in the nuclear performance and safety of the enduring stockpile and provide critical data to qualify remanufacture technologies and lifecycle engineering.

10.2 Description

The proposed project would required the removal of the Proto II accelerator, followed by construction of the Radiographic Integrated Test Stand, a 12-MV, 100-kA, 50-nanosecond IVA accelerator. This new accelerator would have similar parameters to the existing adjacent

SABRE accelerator. The Radiographic Integrated Test Stand will occupy the same general area as Proto II (approximately 50 ft by 50 ft) and consist of a transformer oil-filled tank containing a high-voltage Marx generator and transfer capacitor, a water-filled pulse forming line, an oil-filled transmission line, and a magnetically insulated vacuum transmission line to an x-ray-generating diode load.

The Radiographic Integrated Test Stand will consist of two single-pulse, 6- to 8-MV accelerator modules capable of operating either together to generate a single 12- to 16-MV pulse, separately to generate sequential pulses, or in tandem to generate two sequential pulses applied to a common load.

The Radiographic Integrated Test Stand would be configured to provide a variety of output options, including two sequential half-voltage pulses, a single full-voltage pulse, and twin-axis, half-voltage single pulses. The x-rays generated by the Radiographic Integrated Test Stand would be characterized with a variety of standard diagnostics presently in use on SABRE and HERMES III and would be used to radiograph both static and dynamic objects within the Building 970 highbay. Other research that the Radiographic Integrated Test Stand would support includes validation of pulse power architecture (power flow), diode physics studies, weapons code validation, diagnostic development, and possible long-range research involving explosive component testing.

The x-rays would be used to radiograph both static and dynamic (explosively driven) objects within the Building 970 highbay. All explosive tests will be conducted within approved explosive containment systems similar to systems used at Los Alamos National Laboratory (LANL) explosive sites. LANL has proven designs for containment spheres rated at up to 110 kg (approximately 242 lb) of TNT-equivalent explosive. However, it is anticipated that explosive charges would be limited to approximately 66 kg (approximately 145 lb) of TNT equivalent.

10.3 Program Activities

Table 12-119 shows the program activities at the Radiographic Integrated Test Stand.

Table 12-119. Program Activities at the Radiographic Integrated Test Stand

Program Name	Activities at the Radiographic Integrated Test Stand	Category of Program	Related Section of the *SNL Institutional Plan*
Assistant Secretary for Defense Programs	Radiography of both static and dynamic objects within the Building 970 highbay, including explosive tests within approved explosive containment systems using proven designs for containment spheres rated up to approximately 110 kg of TNT equivalent explosive (approximately 242 lb). It is anticipated that explosive charges would be limited to approximately 66 kg of TNT equivalent (145 lb). Research for validating pulse power architecture (power flow), diode physics studies, weapons code validation, and system diagnostic development.	Programs for the Department of Energy	Section 6.1.1

10.4 Operations and Capabilities

The Radiographic Integrated Test Stand accelerator operations and capabilities will be very similar to the adjacent SABRE accelerator and well within the scope of the adjacent HERMES III accelerator. The possible future addition of a contained explosive firing capability will significantly modify facility operations and capabilities, and will be addressed at the time of such an upgrade proposal.

The operational work year for the Radiographic Integrated Test Stand facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays and 9 weeks of operational maintenance and test setup time.

10.5 Hazards and Hazard Controls

The Radiographic Integrated Test Stand accelerator hazards and hazard control procedures will be very similar to the adjacent SABRE accelerator and will be well within the scope of those for the adjacent HERMES III accelerator.

As the Radiographic Integrated Test Stand is being assembled, numerous pulsed power tests will be conducted on subsystem elements. These produce high voltage for which hazard controls are well established. After construction, full “accelerator shots” (counted in this metric) will begin, which form a further hazard of ionizing radiation.

The possible future addition of a contained explosive firing capability will significantly change these facility hazards and the corresponding controls, and will be addressed at the time of such an upgrade proposal.

10.6 Accident Analysis Summary

The Radiographic Integrated Test Stand is not built or even fully designed at this time. At the point when the design is complete, a safety assessment document will be prepared, and an accident analysis will be performed. See “7.6 Accident Analysis Summary,” for a summary of similar operations at SABRE.

10.7 Reportable Events

The Radiographic Integrated Test Stand is a planned facility and is not yet operational.

10.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

10.8.1 Activity Scenario for Test Activities: Accelerator Shots

10.8.1.1 Alternatives for Test Activities: Accelerator Shots

Table 12-120 shows the alternatives for accelerator shots at the Radiographic Integrated Test Stand.

Table 12-120. Alternatives for Test Activities: Accelerator Shots

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
100 shots per year	0 shots per year	400 shots per year	600 shots per year	800 shots per year

10.8.1.2 Assumptions and Actions for the “Reduced” Values

The Radiographic Integrated Test Stand is a planned rather than an existing SNL facility. As such, base year (1996) activities are zero. Estimates for the FY2003 and FY2008 timeframes under “no action,” as well as the “reduced” and “expanded” alternatives, are projected from the startup year number.

The projection under the “reduced” alternative assumes the minimum level of shots required to ensure operational capability in both the pulse power and explosive modes at a ratio of 2 to 3 percent explosive to over 97 percent made from the pulse power mode. Shots would occur at an estimated rate of one to three per week over the 40-week operational year.

10.8.1.3 Assumptions and Rationale for the “No Action” Values

For the startup year (1999-2000 estimated timeframe), the initial startup operations at the Radiographic Integrated Test Stand facility would include numerous pulsed power tests conducted on subsystem elements. A nominal startup year value for the Radiographic Integrated Test Stand is estimated at 200 shots, or roughly five shots per week over the 40-week operational year. This assumes all 200 shots are made from the pulse power mode.

As the facility becomes more reliable and user-focused, the number of shots are projected to increase incrementally at a rate of 200 additional shots over the five-year horizon (FY2003) and then 400 additional shots by the ten-year horizon (FY2008). The weekly rate of shots would be anticipated to increase from the 5 per week projected for the startup year to 10 and 15 per week, respectively, over the 40-week operational year. For the purposes of these projections, the mix of explosive to pulse power shots remains the same as that projected for the “reduced” alternative. This ratio is valid for each of the scenarios excluding the startup year.

10.8.1.4 Assumptions and Actions for the “Expanded” Values

The projection under the “expanded” alternative assumes a facility operating at full capacity, with shots occurring at a maximum rate of four shots per day over the 40-week operational year (20 shots per week x 40 weeks = 800 shots).

10.8.2 Material Inventories

10.8.2.1 Nuclear Material Inventory Scenarios

The Radiographic Integrated Test Stand would have no nuclear material inventories.

10.8.2.2 Radioactive Material Inventory Scenario for Activated Hardware

10.8.2.2.1 Alternatives for Activated Hardware Radioactive Material Inventory

Table 12-121 shows the alternatives for activated hardware inventory at the Radiographic Integrated Test Stand.

Table 12-121. Alternatives for Activated Hardware Radioactive Material Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
500 kg	0 kg	500 kg	500 kg	500 kg

10.8.2.2.2 Operations That Require Activated Hardware

Operation of the Radiographic Integrated Test Stand facility at voltages above 8 MeV would cause activation of accelerator components in the beam exposure area.

Projections for the startup year assume approximately 500 total kg of radioactive material in inventory at any one time. The 500 kg is based on an estimate of the weight of the reusable hardware in the beam exposure area.

For the FY2003 and FY2008 projections, it is expected that the 500-kg inventory will remain relatively static over time. The inventory remains static because, although activated, the performance of the component is generally not hindered. Often, the components would simply be decontaminated and normal operations would be resumed.

10.8.2.2.3 Basis for Projecting the “Reduced” and “Expanded” Values

See “10.8.2.2.2 Operations That Require Activated Hardware.”

10.8.2.3 Sealed Source Inventory Scenarios

The Radiographic Integrated Test Stand would have no sealed source inventories.

10.8.2.4 Spent Fuel Inventory Scenarios

The Radiographic Integrated Test Stand would have no spent fuel inventories.

10.8.2.5 Chemical Inventory Scenarios

The Radiographic Integrated Test Stand would have no inventories of chemicals of concern.

10.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1

10.8.2.6.1 Alternatives for Bare UNO 1.1 Explosives Inventory

Table 12-122 shows the bare UNO 1.1 explosives inventory at the Radiographic Integrated Test Stand.

Table 12-122. Alternatives for Bare UNO 1.1 Explosives Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
45 kg	0 kg	150 kg	225 kg	300 kg

10.8.2.6.2 Operations That Require Bare UNO 1.1

Operations related to explosive containment require an explosives inventory. At this time, the exact type of explosive to be used has not been determined. The bare UNO 1.1 classification is a best estimate at this point in time. Similarly, the exact amount of high explosives required for two to three shots is currently unavailable. However, a bounding amount has been estimated at approximately 45 kg or 15 kg per shot.

Explosives in support of the shots would be obtained from the Explosives Components Facility on an as-needed basis. At present, projections for the minimum inventory maintained at the Radiographic Integrated Test Stand facility at any one time are estimated at approximately 15 kg to 39 kg or quantities sufficient to support a one- to two-shot series.

Projections assume no explosive shots taken during the startup year. The FY2003 and FY2008 projections are based on up to ten explosives shots occurring out of every 400 shots taken at the facility during the 1999 to 2003 timeframe. Similarly, projections for the FY2003 to FY2008 timeframe are based on an estimate of up to 15 explosives shots occurring out of every 600 shots taken. These estimates reflect the projected number of shots in “10.8.1 Activity Scenario for Test Activities: Accelerator Shots” (that is, roughly 2 to 3 percent of all shots taken would be explosive, excluding those taken during the startup year when all shots made would be from the pulse power mode).

10.8.2.6.3 Basis for Projecting the “Reduced” and “Expanded” Values

Projections for the “reduced” alternative are based on maintaining sufficient inventory to support approximately two to three explosive shots. The projection for the “expanded” alternative is based on maintaining sufficient inventory to support approximately 20 explosive shots.

10.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

10.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-123 shows the alternatives for insulator oil inventory at the Radiographic Integrated Test Stand.

Table 12-123. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40,000 gal	0 gal	40,000 gal	40,000 gal	40,000 gal

10.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil. The oil is a high-voltage dielectric material that prevents electrical breakdown when the accelerator is charged. (PCB concentrations, if any, are below the 50 parts per million regulatory limit.) The oil will be contained in two 20,000-gal sections.

10.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

The machine reservoir would require the same amount of oil irrespective of activity levels.

10.8.3 Material Consumption

10.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at the Radiographic Integrated Test Stand.

10.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at the Radiographic Integrated Test Stand.

10.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

10.8.3.4 Explosives Consumption Scenario for Bare UNO 1.1 Explosives

10.8.3.4.1 Alternatives for Bare UNO 1.1 Explosives Consumption

Table 12-124 shows the alternatives for bare UNO 1.1 explosives consumption for the Radiographic Integrated Test Stand.

Table 12-124. Alternatives for Bare UNO 1.1 Explosives Consumption

Reduced Alternative		No Action Alternative						Expanded Alternative	
		Base Year		FY2003		FY2008			
N/A pkgs	45 kg	N/A pkgs	0 kg	N/A pkgs	150 kg	N/A pkgs	225 kg	N/A pkgs	300 kg

10.8.3.4.2 Operations That Require Bare UNO 1.1 Explosives

Sections “10.8.1 Activity Scenario for Test Activities: Accelerator Shots” and “10.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1” provide an overview of the operations at the Radiographic Integrated Test Stand that would require the use of explosives as well as the assumptions and rationale for the amount required on an annual basis. The consumption numbers provided here are consistent with the inventory numbers found in “10.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1.” The number of packages has been marked as not applicable because, at present, that value is unknown.

10.8.3.4.3 Basis for Projecting the “Reduced” and “Expanded” Values

For the “reduced” alternative, the estimate of 45 kg is based on two to three explosive shots per year at the Radiographic Integrated Test Stand facility. For the “expanded” alternative, the 300 kg estimate is based on 20 shots per year at the Radiographic Integrated Test Stand facility. Additional information on the use of explosives at the Radiographic Integrated Test Stand facility is provided in “10.8.2.6 Explosives Inventory Scenario for Bare UNO 1.1.”

10.8.4 Waste

10.8.4.1 Low-Level Radioactive Waste Scenario

10.8.4.1.1 Alternatives for Low-Level Radioactive Waste at the Radiographic Integrated Test Stand

Table 12-125 shows the alternatives for low-level radioactive waste at the Radiographic Integrated Test Stand.

Table 12-125. Alternatives for Low-Level Radioactive Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
15 kg	0 kg	60 kg	90 kg	120 kg

10.8.4.1.2 Operations That Generate Low-Level Radioactive Waste

The Radiographic Integrated Test Stand is being developed for the sole purpose of generating intense bursts of hard x-rays (5 to 10 MeV). Basic system operation, hazard control, and the radiographic purpose of the facility require the interaction of these x-rays with materials. The high-voltage portion of this x-ray distribution will phototransmute some of these interacting materials, producing low-level radioactive waste.

10.8.4.1.3 General Nature of Waste

The types of residual waste would be similar to those identified for the HERMES III accelerator, although the levels of residual waste would be significantly less for the Radiographic Integrated Test Stand. Examples of short-half-life products representative of those that could be produced include the following:

- Magnesium-52 (Mg-52) (21 minutes to 120 hours)
- Nickel-57 (Ni-57) (35.6 hours)
- Copper-67 (Cu-67) (60 hours)

10.8.4.1.4 Waste Reduction Measures

Accelerator-produced wastes typically have very short half-lives (minutes to hours), which allow significant reduction in the waste activity after short holding periods.

10.8.4.1.5 Basis for Projecting the “Reduced” and “Expanded” Values

Projected values are based on double the SABRE demonstrated values.

10.8.4.2 Transuranic Waste Scenario

Transuranic waste would not be produced at the Radiographic Integrated Test Stand.

10.8.4.3 Mixed Waste

10.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste would not be produced at the Radiographic Integrated Test Stand.

10.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste would not be produced at the Radiographic Integrated Test Stand.

10.8.4.4 Hazardous Waste Scenario

10.8.4.4.1 Alternatives for Hazardous Waste at the Radiographic Integrated Test Stand

Table 12-126 shows the alternatives for hazardous waste at the Radiographic Integrated Test Stand.

Table 12-126. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
34 kg	0 kg	136 kg	204 kg	272 kg

10.8.4.4.2 Operations That Generate Hazardous Waste

Operation and maintenance of the Radiographic Integrated Test Stand accelerator would generate hazardous waste. The values provided under these scenarios are considered conservative enough to also bound any potential explosives waste as well. During initial startup operations, the estimated 200 shots would generate 68 kg of waste.

Some SF_6, when subjected to high-voltage discharges during accelerator shots, breaks down, and the fluorides formed are corrosive and somewhat toxic. Used SF_6 that has not been passed through a purifying reclaimer is an inhalation hazard to personnel and could damage sensitive equipment. If these toxins are removed by a reclaimer, they would be disposed along with other hazardous waste generated at the facility.

10.8.4.4.3 General Nature of Waste

Waste includes solvent-contaminated rags, spent copper sulfate resistor solution, and other wastes similar to those described in the HERMES III and SABRE profiles.

10.8.4.4.4 Waste Reduction Measures

No waste reduction measures exist.

10.8.4.4.5 Basis for Projecting the "Reduced" and "Expanded" Values

Values provided for the "reduced," "expanded," and "no action" alternatives are based on SABRE waste production numbers, which are equivalent to approximately 0.34 kg of waste generated per shot. Basing estimates of potential Radiographic Integrated Test Stand waste stream types and waste generation quantities on either the HERMES III and the SABRE accelerator experience provides highly conservative waste scenarios for the Radiographic Integrated Test Stand.

10.8.5 Emissions

10.8.5.1 Radioactive Air Emission Scenario for N-13

10.8.5.1.1 Alternatives for N-13 Emissions at the Radiographic Integrated Test Stand

Table 12-127 shows the alternatives for N-13 emissions for the Radiographic Integrated Test Stand.

Table 12-127. Alternatives for N-13 Emissions

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
0.02 Ci	0 Ci	0.08 Ci	0.12 Ci	0.16 Ci

10.8.5.1.2 Operations That Generate N-13 Air Emissions

When electrons are decelerated, bremsstrahlung radiation is emitted. The bremsstrahlung radiation corresponding to the deceleration of electrons of 10.55 to 15 MeV energy will interact with air and produce N-13. Radiographic Integrated Test Stand operating parameters are expected to be as high as 15 MeV. Bremsstrahlung radiation from electrons of less than 10.55 MeV energy will not interact with air to produce radionuclides. Activation of oxygen occurs at 15.67 MeV and is not expected to happen at the Radiographic Integrated Test Stand. During startup tests of 200 shots, about 0.04 Ci of N-13 is expected to be emitted.

10.8.5.1.3 General Nature of Emissions

Emission would be through the general air exchange associated with Building 970.

10.8.5.1.4 Emission Reduction Measures

No emission reduction measures exist.

10.8.5.1.5 Basis for Projecting the “Reduced” and “Expanded” Values

Actual AIRDOS-EPA and RADRISK codes will have to be run to determine the actual amount of N-13 produced and emitted. Based on historical information from the PBFA II facility (now called Z Machine), which operates at 30 MeV for 250 shots per year, the total N-13 production was calculated to be 0.042 Ci per year. This number represents a highly conservative multiplier because the Radiographic Integrated Test Stand facility will operate at approximately one half the power of the PBFA II facility, from which this value was derived. It would be expected that the Radiographic Integrated Test Stand accelerator would generate less for 400 shots, based on the operating parameters.

10.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency’s *Industrial Source Complex Air Quality Dispersion Model, Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

10.8.5.3 Open Burning Scenarios

Outdoor burning operations would not be conducted at the Radiographic Integrated Test Stand.

10.8.5.4 Process Wastewater Effluent Scenario

The Radiographic Integrated Test Stand does not generate process wastewater.

10.8.6 Resource Consumption

10.8.6.1 Process Water Consumption Scenario

The Radiographic Integrated Test Stand would not consume process water.

10.8.6.2 Process Electricity Consumption Scenario

The Radiographic Integrated Test Stand would not consume process electricity.

10.8.6.3 Boiler Energy Consumption Scenario

The Radiographic Integrated Test Stand would not consume energy for boilers.

10.8.6.4 Facility Personnel Scenario

10.8.6.4.1 Alternatives for Facility Staffing at the Radiographic Integrated Test Stand

Table 12-128 shows the alternatives for facility staffing at the Radiographic Integrated Test Stand.

Table 12-128. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
4 FTEs	0 FTEs	6 FTEs	6 FTEs	10 FTEs

10.8.6.4.2 Operations That Require Facility Personnel

The Radiographic Integrated Test Stand is a pulsed power accelerator. The personnel estimates have been extrapolated from the adjacent SABRE and HERMES III pulsed power accelerators.

10.8.6.4.3 Staffing Reduction Measures

Operational and research staff are not expected to be shared with other Tech Area IV facilities.

10.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The initial construction period would require substantially more FTEs than the subsequent operation. “Reduced” or “expanded” operation will depend on funding and program direction changes.

10.8.6.5 Expenditures Scenario

10.8.6.5.1 Alternatives for Expenditures at the Radiographic Integrated Test Stand

Table 12-129 shows the alternatives for expenditures at the Radiographic Integrated Test Stand.

Table 12-129. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$1.75 million	$0	$2.25 million	$2.25 million	$4 million

10.8.6.5.2 Operations That Require Expenditures

Following construction of the Radiographic Integrated Test Stand (anticipated to be $6 million in FY99), routine operation will require approximately $750,000 per year, with additional funding required to maintain and upgrade diagnostics required by the evolving program, irrespective of the level of any anticipated activity at the facility.

Staffing costs are calculated at $250,000 per FTE and are included in the estimates.

10.8.6.5.3 Expenditure Reduction Measures

Operations at the Radiographic Integrated Test Stand are not anticipated to share staff with other accelerator operations.

10.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

The Radiographic Integrated Test Stand operational costs are estimated to be between those of the adjacent SABRE and HERMES III accelerators.

11.0 ADVANCED PULSED POWER RESEARCH MODULE SOURCE INFORMATION

11.1 Purpose and Need

The Advanced Pulsed Power Research Module is a relatively small, single-pulse accelerator for evaluating the performance and reliability of components that may be used in a next generation accelerator facility (Sullivan *et al.,* 1996; U.S. Department of Energy, 1996).

11.2 Description

The Advanced Pulsed Power Research Module, located in the southwest highbay of Building 963, is a single-pulse accelerator designed to evaluate the performance of new pulsed-power components and component alignments that could be used to improve the performance of future accelerators. The Advanced Pulsed Power Research Module also serves as a test bed for other scientific projects and can be used for conducting general pulsed-power research. The accelerator consists of the following:

- A Marx generator bank of 56 capacitors arranged in a series/parallel configuration within a 130,000-gal oil tank
- Two intermediate storage capacitors within a 4,000-gal tank of deionized water
- An intermediate storage, gas-insulated (SF_6) switch
- Four gas switch-controlled PFLs
- A single inductively isolated voltage adder cavity
- A magnetically insulated transmission line (MITL)

With the exception of the intermediate storage capacitors, the other pulsed power components are contained in the oil tank, with the MITL extending into a heavily shielded experiment cell.

(Sullivan *et al.,* 1996; U.S. Department of Energy, 1996)

11.3 Program Activities

Table 12-130 shows the program activities at the Advanced Pulsed Power Research Module.

Table 12-130. Program Activities at the Advanced Pulsed Power Research Module

Program Name	Activities at the Advanced Pulsed Power Research Module	Category of Program	Related Section of the *SNL Institutional Plan*
Experimental Activities	The Advanced Pulsed Power Research Module is a developmental pulsed power module that is designed for the study of power storage, high-voltage switching, and power flow for advanced applications. It is also being used to develop advanced technologies that may be applied to enhance current facility capabilities or support new designs.	Programs for the Department of Energy	Section 6.1.1.1
Performance Assessment Science and Technology	Develop advanced pulsed power sources for future incorporation into machines to be used for weapon effects and weapon physics experiments.	Programs for the Department of Energy	Section 6.1.1.1
Inertial Confinement Fusion	There is no inertial confinement fusion activity on the facility at present. However, a breakthrough in gas switch design for the Advanced Pulsed Power Research Module eliminates the shock generated in the module and has validated the application of the technology for testing the design of a potential (future) pulsed power facility, X-1.	Programs for the Department of Energy	Section 6.1.1.2

11.4 Operations and Capabilities

The Advanced Pulsed Power Research Module's Marx generator charges two water-dielectric intermediate storage capacitors, which are subsequently discharged through laser-triggered gas switches to charge four water-dielectric pulse-forming transmission lines to approximately 2.2 MV. An azimuthal transmission line balances the four-point feed to provide azimuthal symmetry of the power feed (10-MV, 100-nanosecond pulse) to the MITL, which then delivers the power to a load in the experiment cell. The power is dissipated into a carbon anode beam stop that generates x-ray (bremsstrahlung) output.

The Advanced Pulsed Power Research Module shares the oil transfer and processing equipment housed in Building 966 with the other accelerators in Building 963.

The operational work year for the Advanced Pulsed Power Research Module facility is 40 weeks. The 40-week work year is reduced from the 52-week calendar year by 3 weeks of personnel leave and holidays, and 9 weeks of operational maintenance and test setup time.

(Sullivan *et al.*, 1996)

11.5 Hazards and Hazard Controls

11.5.1 Offsite Hazards to the Public and the Environment

The Advanced Pulsed Power Research Module facility contains only a small chemical inventory that cannot be dispersed outside the facility. Accidents at this facility present no potential offsite consequences to either the public or the environment (Sullivan *et al.*, 1996).

11.5.2 Onsite Hazards to the Environment

Onsite hazards to the environment include transformer oil. The Advanced Pulsed Power Research Module oil tank is filled with a reduced-flammability grade of transformer oil (ASTM-D3487, Type II) that is classified as a combustible liquid having a BTU content of 19,400 BTU/lb and a flash point of 300°F. The PCB concentration in the oil is limited to less than 50 ppm. Based on previous operating experience and on engineering and fire protection testing, certain design and operating criteria have been established for the Advanced Pulsed Power Research Module to minimize the possibility of an oil fire. In particular, all electrical connections and routing in the oil tank are well beneath the surface of the oil, and the oil surface is open and without any potential wicks.

11.5.3 Onsite Hazards to Workers

Potential worker hazards at the Advanced Pulsed Power Research Module facility include:

- **Ionizing Radiation** - The Advanced Pulsed Power Research Module produces only small amounts of x-radiation. It is primarily a test bed for the Jupiter accelerator energy storage and transmission line systems, not a radiation-simulating facility. (The “beam stop” that the electron beam strikes is made of a low “Z” material.) The worst-case accidental exposure would occur in the extremely unlikely event of a beam dump, in which the accelerated electrons accidentally strike the wall of the MITL with someone located just outside the experiment cell. The maximum prompt radiation effective dose under these circumstances would be approximately 50 millirem, which results in a negligible health consequence.

- **Marx Generator** - The prime energy storage component of the accelerator.

- **Solvents** - Includes ethyl alcohol, which is used to clean various components between test shots.

- **Dilute Copper Sulfate Solution** - Used to fabricate high-power resistors for use in the Marx generators.

- **Sulphur Hexafluoride (SF_6)** - Used as the insulator gas in switching components. Pure SF_6, although chemically and physiologically inert, does not support respiration in enclosed areas. When subjected to high-voltage discharge, some breakdown occurs, and the byproducts formed are corrosive and somewhat toxic. Used SF_6 is passed through a reclaimer where the breakdown products are filtered out so that the SF_6 can be recycled.

- **A Class 4 Nd:YAG Laser Trigger System** - Used to trigger the gas-insulated switch in the pulse-forming section. This laser, which has a completely enclosed beam path, presents a potential electrical as well as optical hazard to personnel.

- **Confined Spaces** - The Advanced Pulsed Power Research Module's oil tank is a confined space and requires a confined space permit for entry.

11.5.4 Hazard Controls

Hazard controls at the Advanced Pulsed Power Research Module facility include:

- **Radiation Shielding** - Consists of concrete block walls surrounding the experiment cell and a lead “dog house” to shield against the bremsstrahlung from the beam stop (carbon anode).

- **Access Control** - All areas of the Advanced Pulsed Power Research Module facility have access control maintained by gates with locking mechanisms. Before a shot, hazardous areas are searched to ensure that personnel are out of those areas. During the critical period of charging and firing, the accelerator systems are interlocked with access control so that any breach automatically disables all systems and places the accelerator in a safe condition.

- **Electrical Safety** - Electrical safety has been enhanced for work on the Marx generators through an electronic discharge system and a manually operated, mechanical shorting system.

- **Secondary Oil Containment** - Building 963 is constructed with secondary containment in the form of concrete trenching that will contain a catastrophic oil leak. The trenching has alarms located approximately 2 in. from the bottom of the trench that provide warning when any appreciable quantity of liquid accumulates in the trenches. The oil storage tank and pumping system, located in Building 966, are constructed with secondary containment. The oil transfer lines, which are made of double-walled piping, slope to the concrete catch basin in the basement of Building 966.

- **Confined Space Safety** - The oxygen content of the drained Advanced Pulsed Power Research Module oil tank atmosphere is continuously monitored during activities conducted inside the tank.

SF_6 is chemically and physiologically inert but does not support respiration. SF_6 leaked in an enclosed area could act as a simple asphyxiate, but is not toxic. When subjected to high-voltage discharge, some breakdown occurs and the fluorides formed are corrosive and somewhat toxic. Thus, used SF_6 that has not been passed through a purifying reclaimer is an inhalation hazard to personnel and could damage sensitive equipment. A reclaimer will remove these breakdown products. The supply of SF_6 is stored after purification. Leakage of SF_6 gas as a fugitive emission from the closed system is possible, but the building ventilation system immediately removes this gas to the outside and effectively dilutes it from extremely small concentrations to negligible amounts in outside air.

(Sullivan *et al.*, 1996)

11.6 Accident Analysis Summary

11.6.1 Selection of Accidents Analyzed in Safety Documents

The analysis of hazards and potential accidents that could occur at the Advanced Pulsed Power Research Module facility considers natural phenomena events, external events, and internal (or operational) events. The analyses of natural phenomena events and the aircraft crash event are generic to all SNL facilities.

11.6.2 Analysis Methods and Assumptions

A hazard mode and effect analysis was performed to evaluate operational events at the Advanced Pulsed Power Research Module. The hazard mode and effect analysis is a systematic engineering procedure that identifies the specific ways (modes) in which a piece of equipment might fail or a desirable action, task, or effort might fail to occur. For each mode, the analysis determines the key causative factors, effects, mitigative measures, and the expected risk that such a hazard mode might impose. For each hazard mode identified, the consequences of failure are rated in terms of relative severity, and an estimate of the relative probability of occurrence is assigned. Consequence severity and accident probability were assigned using the criteria provided in AL 5481.1B.

11.6.3 Summary of Accident Analysis Results

For some of the Tech Area IV accelerator facilities, a scenario evaluation methodology was used to perform the facility accident analysis. For these facilities, a set of “generic” events to be evaluated was established by examining sources of energy, radiation, and hazardous materials in the facility. These selected events represent the major contributors to overall facility accident risk. The residual risk results of the Advanced Pulsed Power Research Module accident assessment are summarized in Table 12-131 in terms of these generic events.

Table 12-131. Summary of Advanced Pulsed Power Research Module Accident Assessment Results

Event	Severity	Probability
Electric shock	Catastrophic (I)	Extremely unlikely (C)
Radiation exposure	Negligible (IV)	Extremely unlikely (C)
Fire	Catastrophic (I)	Extremely unlikely (C)
Asphyxiation	Catastrophic (I)	Extremely unlikely (C)
Earthquake	Negligible (IV)	Unlikely (B)
Tornado	Catastrophic (I)	Unlikely (B)
High winds	Negligible (IV)	Likely (A)
Flood	Negligible (IV)	Unlikely (B)
Aircraft crash	Catastrophic (I)	Unlikely (B)

There are two accident scenarios (electric shock and aircraft crash) in which the severity of an accident could be catastrophic, however, the probability is extremely unlikely or unlikely.

(Sullivan *et al.*, 1996)

11.7 Reportable Events

The Advanced Pulsed Power Research Module has had no occurrences over the past five years.

11.8 Scenarios for Impact Analysis

In all of the scenarios for impact analysis in this section, base year values are for FY1996 unless otherwise noted.

11.8.1 Activity Scenario for Test Activities: Accelerator Shots

11.8.1.1 Alternatives for Test Activities: Accelerator Shots

Table 12-132 shows the alternatives for accelerator shots for the Advanced Pulsed Power Research Module.

Table 12-132. Alternatives for Test Activities: Accelerator Shots

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
40 shots	500 shots	1,000 shots	1,000 shots	2,000 shots

11.8.1.2 Assumptions and Actions for the “Reduced” Values

The “reduced” value assumes one shot per week. This level of activity represents the minimum possible to maintain operational capability.

11.8.1.3 Assumptions and Rationale for the “No Action” Values

For the base year, CY1997 is used instead of FY1996 because the facility only became operational in May of 1996. In future years, the number of shots could double based on five shots per day, five days per week, and 40 operational weeks. This number of shots also assumes increased budget. This is a good possibility because Advanced Pulsed Power Research Module technology could be the chosen design basis for the X-1.

11.8.1.4 Assumptions and Actions for the “Expanded” Values

The “expanded” value assumes an increased level of activity of up to ten shots per day instead of five. This scenario would likely unfold given the interest in the Advanced Pulsed Power Research Module technology as a design prototype for the X-1. The expanded number for shots would support proof-of-concept objectives.

11.8.2 Material Inventories

11.8.2.1 Nuclear Material Inventory Scenarios

The Advanced Pulsed Power Research Module has no nuclear material inventories.

11.8.2.2 Radioactive Material Inventory Scenarios

The Advanced Pulsed Power Research Module has no radioactive material inventories.

11.8.2.3 Sealed Source Inventory Scenarios

The Advanced Pulsed Power Research Module has no sealed source inventories.

11.8.2.4 Spent Fuel Inventory Scenarios

The Advanced Pulsed Power Research Module has no spent fuel inventories.

11.8.2.5 Chemical Inventory Scenarios

The Advanced Pulsed Power Research Module has no inventories of chemicals of concern.

11.8.2.6 Explosives Inventory Scenarios

The Advanced Pulsed Power Research Module has no explosives inventories.

11.8.2.7 Other Hazardous Material Inventory Scenario for Insulator Oil

11.8.2.7.1 Alternatives for Insulator Oil Inventory

Table 12-133 shows the alternatives for insulator oil at the Advanced Pulsed Power Research Module.

Table 12-133. Alternatives for Insulator Oil Inventory

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
130,000 gal	130,000 gal	130,000 gal	130,000 gal	130,000 gal

11.8.2.7.2 Operations That Require Insulator Oil

The insulator oil is ANSI/ASTM D 3487 Type II Shell 69701 DIALA AX transformer oil (PCB levels, if any, are below the 50 parts per million regulatory limit). The oil is a high-voltage, dielectric material that prevents electrical breakdown when the accelerator is charged. The oil tank holds approximately 130,000 gal of oil.

11.8.2.7.3 Basis for Projecting the “Reduced” and “Expanded” Values

The 130,000 gal is the machine-required operational amount. The Advanced Pulsed Power Research Module requires this amount (130,000 gal) regardless of the alternative.

11.8.3 Material Consumption

11.8.3.1 Nuclear Material Consumption Scenarios

Nuclear material is not consumed at the Advanced Pulsed Power Research Module.

11.8.3.2 Radioactive Material Consumption Scenarios

Radioactive material is not consumed at the Advanced Pulsed Power Research Module.

11.8.3.3 Chemical Consumption Scenarios

Information initially provided for this section resides in the Facility Information Manager database and will be made available to the analysts responsible for preparing the sitewide environmental impact statement.

11.8.3.4 Explosives Consumption Scenarios

Explosives are not consumed at the Advanced Pulsed Power Research Module.

11.8.4 Waste

11.8.4.1 Low-Level Radioactive Waste Scenario

Low-level radioactive waste is not produced at the Advanced Pulsed Power Research Module.

11.8.4.2 Transuranic Waste Scenario

Transuranic waste is not produced at the Advanced Pulsed Power Research Module.

11.8.4.3 Mixed Waste

11.8.4.3.1 Low-Level Mixed Waste Scenario

Low-level mixed waste is not produced at the Advanced Pulsed Power Research Module.

11.8.4.3.2 Transuranic Mixed Waste Scenario

Transuranic mixed waste is not produced at the Advanced Pulsed Power Research Module.

11.8.4.4 Hazardous Waste Scenario

11.8.4.4.1 Alternatives for Hazardous Waste at the Advanced Pulsed Power Research Module

Table 12-134 shows the alternatives for hazardous waste at the Advanced Pulsed Power Research Module.

Table 12-134. Alternatives for Hazardous Waste

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
5 kg	50 kg	100 kg	100 kg	200 kg

11.8.4.4.2 Operations That Generate Hazardous Waste

The Advanced Pulsed Power Research Module generates hazardous waste as part of ongoing operations.

11.8.4.4.3 General Nature of Waste

The waste is comprised of copper sulfate liquid, contaminated oils and oily rags, waste capacitors, and nonhalogenated, solvent-contaminated rags.

Some SF_6 breaks down when subjected to high-voltage discharges during accelerator shots, and the fluorides formed are corrosive and somewhat toxic. Used SF_6 that has not been passed through a purifying reclaimer is an inhalation hazard to personnel and could damage sensitive equipment. If a reclaimer removes these toxins, they are disposed of with other hazardous waste generated at the facility.

11.8.4.4.4 Waste Reduction Measures

No waste reduction measures exist.

11.8.4.4.5 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value and “expanded” value are proportional to the number of shots discussed in “11.8.1 Activity Scenario for Test Activities: Accelerator Shots” (as are those for the FY2003 and FY2008 timeframes). A multiplier of 0.1 kg per shot has been used to project the waste scenario (number of shots x 0.1 = the estimated mass of hazardous waste generated).

11.8.5 Emissions

11.8.5.1 Radioactive Air Emissions Scenarios

Radioactive air emissions are not produced at the Advanced Pulsed Power Research Module.

11.8.5.2 Chemical Air Emissions

Information on an extensive list of chemicals was obtained from the SNL/NM Chemical Inventory System (CIS). For the air emissions analysis, the entire annual inventory of these chemicals was assumed to have been released over a year of operations for each specific facility (i.e., the annual inventory was divided by facility operating hours). The emissions from this release were then subjected, on a chemical-by-chemical basis, to a progressive series of screening steps for potential exceedances of both regulatory and human health thresholds. For those chemicals found to exceed this screening, process knowledge was used to derive emission factors. The emission factors for these chemicals were then modeled using the U.S. Environmental Protection Agency’s *Industrial Source Complex Air Quality Dispersion Model,* *Version 3*. The results of this modeling are discussed as part of the analysis in support of the SNL/NM site-wide environmental impact statement.

11.8.5.3 Open Burning Scenarios

The Advanced Pulsed Power Research Module does not have outdoor burning operations.

11.8.5.4 Process Wastewater Effluent Scenario

The Advanced Pulsed Power Research Module does not generate process wastewater.

11.8.6 Resource Consumption

11.8.6.1 Process Water Consumption Scenario

The Advanced Pulsed Power Research Module does not consume process water.

11.8.6.2 Process Electricity Consumption Scenario

The Advanced Pulsed Power Research Module does not consume process electricity.

11.8.6.3 Boiler Energy Consumption Scenario

The Advanced Pulsed Power Research Module does not consume energy for boilers.

11.8.6.4 Facility Personnel Scenario

11.8.6.4.1 Alternatives for Facility Staffing at the Advanced Pulsed Power Research Module

Table 12-135 shows the alternatives for facility staffing at the Advanced Pulsed Power Research Module.

Table 12-135. Alternatives for Facility Staffing

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
5 FTEs	5 FTEs	7 FTEs	7 FTEs	7 FTEs

11.8.6.4.2 Operations That Require Facility Personnel

Operations at the Advanced Pulsed Power Research Module facility require personnel to operate the facility and research scientists to support the evaluations and diagnostics of test results.

11.8.6.4.3 Staffing Reduction Measures

No staffing reduction measures exist.

11.8.6.4.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value assumes the level of FTEs to maintain the facility at minimum operational capability. The “expanded” value assumes additional staff to achieve the expanded number of shots described in “11.8.1 Activity Scenario for Test Activities: Accelerator Shots.” While additional operational staff may or may not be required, additional staff in support of evaluations and diagnostics would be required to support the projected level of activity.

11.8.6.5 Expenditures Scenario

11.8.6.5.1 Alternatives for Expenditures at the Advanced Pulsed Power Research Module

Table 12-136 shows the alternatives for expenditures at the Advanced Pulsed Power Research Module.

Table 12-136. Alternatives for Expenditures

Reduced Alternative	No Action Alternative			Expanded Alternative
	Base Year	FY2003	FY2008	
$1.5 million	$3.5 million	$5 million	$5 million	$5.5 million

11.8.6.5.2 Operations That Require Expenditures

Advanced Pulsed Power Research Module operations reflect both staffing costs ($250,000 per FTE) and operational expenses (consumables and other costs).

11.8.6.5.3 Expenditure Reduction Measures

Some cost-saving measures may be available in the out years.

11.8.6.5.4 Basis for Projecting the “Reduced” and “Expanded” Values

The “reduced” value assumes the minimum operating budget required to maintain operational capability. The “expanded” value assumes the total amount required to achieve the staffing level and level of activity required of the projected number of shots identified in “11.8.1 Activity Scenario for Test Activities: Accelerator Shots.”

12.0 REFERENCES

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40 CFR 61, Subpart H, *National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities*.

20 NMAC 3, *Radiation Protection*.

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