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APPENDIX N: INTEGRATED TECHNOLOGY PROJECT

N.1 PURPOSE AND NEED FOR AGENCY ACTION

The U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA) is the Federal Agency responsible for providing the U.S. with nuclear weapons and ensuring that those weapons remain safe and reliable. The Stockpile Stewardship Program comprises the activities associated with research, design, development, and testing of nuclear weapons, as well as the assessment and certification of their safety and reliability.

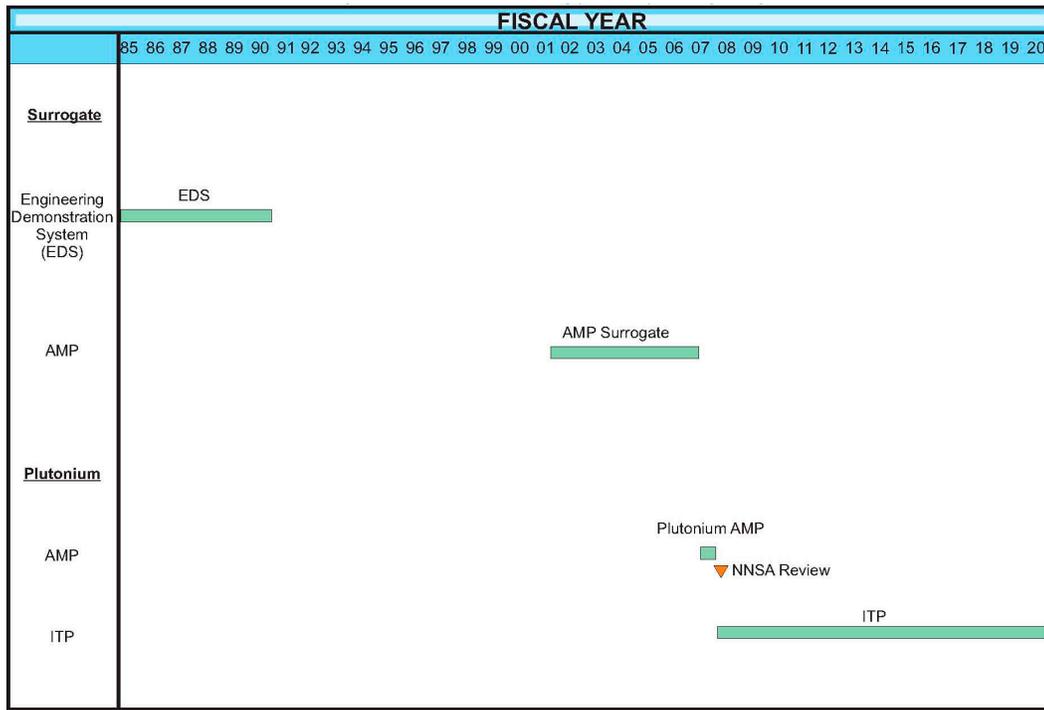
NNSA expects existing weapons to remain in the stockpile for decades. Accordingly, the effect of the aging process on weapon reliability is a critical area of research. In the past, weapons certification and reliability were demonstrated through underground nuclear tests of nuclear weapons. With this option no longer available, alternatives to underground weapons testing have been developed to verify the safety and reliability of the aging weapons. The Science-Based Stockpile Stewardship and Management Program (SBSSMP) includes both analytical and experimental components. The goal of the Accelerated Strategic Computing Initiative (ASCI), for example, is to model weapons and weapons physics analytically. The experimental effort consists of a wide range of tests, including small-scale constitutive experiments, subcritical experiments, and dynamic experiments. The goal of these experiments is to better understand both the physics of nuclear weapons as well as their ability to meet specified military requirements.

SBSSMP experiments are needed to increase the understanding of the complex physics and behavior of materials during a nuclear explosion and ultimately to certify the efficacy of the Nation's aging stockpile. Accurate, theoretical, scientific, and experimental data are required to validate the computer models of the weapon performance. SBSSMP experiments involve the use of both surrogate and actual materials that would be used in the weapon system.

In 2000, the Office of Defense Programs (DP) determined that there was a need for augmentation of the current inventory of special nuclear materials (e.g., plutonium, enriched uranium) to support the Stockpile Stewardship certification activities. DP directed that the Atomic Vapor Laser Isotope Separation¹ (AVLIS) capabilities be made available for use and the AVLIS facilities be maintained in a state of readiness. Lawrence Livermore National Laboratory (LLNL) responded with a proposal for the development of a low-level AVLIS effort to foster the technology and ensure that critical skills were not lost (LLNL 2000v). This effort, known as the Advanced Material Program (AMP), was designed to develop and retain the necessary AVLIS equipment and skill set through a series of enrichment demonstrations of the technology.

¹ A laser isotope separation technique based on small atomic spectroscopic differences to selectively ionize one isotope over another.

The purpose of the Integrated Technology Project (ITP) is to apply AMP-demonstrated technology to support augmentation of special nuclear materials for SBSSMP experiments. The mission need is discussed in an NNSA classified reference to this appendix (NNSA 2003c). NNSA would minimize development of new infrastructure by using existing facilities, inventories of plutonium, and existing technologies of sufficient flexibility to accommodate different plutonium feed stocks. The proposed timeline for the AMP and ITP is shown in Figure N.1–1.



Source: Original.

Note: EDS, the Engineering Demonstration System, is discussed in Section N.2.2.

FIGURE N.1–1.—Proposed Advanced Material Program Integrated Technology Project Timeline

N.2 PROJECT OVERVIEW

This chapter discusses the basic science, AVLIS technology background and process of laser isotope separation. This discussion is intended to provide the reader and decisionmaker with enough information and perspective to evaluate the alternatives presented in Chapter 3 of the LLNL SW/SPEIS.

N.2.1 Isotopes and Isotope Separation

Separated isotopes of different elements are needed for many purposes, including nuclear reactors, weapons, power supplies for space probes, medicine, and research. While different isotopes of an element have different weights and different nuclear properties, they have nearly identical chemical properties. They react to chemicals in the same manner, and melt and boil at essentially the same temperature. Therefore, except for the lightest elements, it is difficult to separate the isotopes from one another using normal industrial means. Instead, isotope separation techniques have been developed that isolate the different isotopes based on their slight mass-dependent differences.

The AVLIS technology is based on the small atomic spectroscopic differences to selectively ionize, or remove electrons, from one isotope over another. The electron energy states of any atom are very precisely defined and depend slightly on its atomic weight. Therefore, the electron energy states of one isotope will differ slightly from that of another isotope of the same element. These different electron energy states of each isotope correspond to unique laser light absorption characteristics. When the correct frequency (or frequencies) of precisely tuned laser light hits an atom of the desired isotope, the atom absorbs the energy and loses an electron. The loss of the negatively charged electron leaves the atom, now an ion, with a positive charge. The isotopically selected positive ions can be separated from the rest of the uncharged or neutral isotopes by the application of an electrical field. In summary, the AVLIS technology involves the separation of isotopes by selectively ionizing the isotopes of choice, then separating the ions with an electromagnetic field.

N.2.2 AVLIS Technology Background

During World War II, the U.S. developed large-scale isotope separation capabilities to produce enriched uranium. The legacies of this effort are the gaseous diffusion plants at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. In the 1970s, the U.S. initiated a program to develop the advanced gaseous centrifuge technology as the next step in uranium isotope enrichment. The U.S. also supported the development of other approaches to uranium isotope separation. After intensive review and competition between these programs in the 1980s, the AVLIS technology developed at LLNL was chosen as the only advanced uranium enrichment technology program in the U.S.

Research on the AVLIS technology began at LLNL in the early 1970s and has been ongoing ever since. The practical development of the AVLIS technology at LLNL has required a major engineering effort over two decades. The original goal of the work on the AVLIS technology at LLNL was to develop a safe, environmentally acceptable, and cost-effective means of separating isotopes of uranium.

As the scientific and technical feasibility of using the AVLIS technology to separate uranium isotopes became clear in the 1970s, scientists at LLNL successfully demonstrated the scientific approach to separating isotopes of plutonium. In a peer review competition in 1983, the AVLIS technique was selected as the Nation's technology for plutonium isotope enrichment to convert DOE's fuel-grade plutonium to weapon-grade. A scientific and engineering development program for the AVLIS technology, the Special Isotope Separation (SIS) Program, was carried out at LLNL during the 1980s. This program was directed toward the proposed construction and operation of an AVLIS plutonium separation plant at one of the DOE nuclear materials sites.

As part of the LLNL program, the Engineering Demonstration System (EDS) was designed and built in the Building 332 Plutonium Facility within the Superblock to perform demonstration experiments using the AVLIS technology for providing design process data for the future plant process lines for SIS. Control equipment, optical equipment, equipment frameworks, gloveboxes, utilities, and beamtubes were installed in Building 332 as part of the EDS (Figure N.2.2-1). Successful experiments were conducted in EDS using selected lanthanides as surrogate materials in a series of demonstration experiments.

An Environmental Assessment (EA) was issued in 1990 (DOE/EA-0421) (DOE 1990d) on the Proposed Action to assess resuming the use of the AVLIS technique with nonradioactive, nonhazardous surrogate metals in anticipation of any additional demonstration activities that might have been needed to verify the SIS facility design.

In 1990, the Secretary of Energy announced a decision to indefinitely postpone construction of the SIS plutonium production plant being proposed for construction. The SIS Program at LLNL was closed out and the equipment was placed in standby, with the glovebox de-inventoried and the EDS cleaned of surrogate materials.

The basic equipment associated EDS (e.g., glovebox racks, ventilation equipment, power leads) are still mostly intact. A large fraction of the skilled personnel who worked on the EDS project are still employed at LLNL, although many have retired or would soon be eligible for retirement.

The Finding of No Significant Impact (FONSI) for the EDS EA (DOE 1990b) stated that the resumption of EDS tests using surrogate materials simulating plutonium characteristics would allow minimizing the scope of, and defining the manner in which EDS tests for SIS using plutonium would proceed, if DOE were to pursue such operations in the future. In the FONSI, DOE committed that any proposed plutonium operations associated with the EDS would require preparation of an Environmental Impact Statement (EIS) and issuance of a Record of Decision. Experiments were run using nonradioactive surrogate materials only.

In 2002, NNSA determined that the AMP is included within the bounds of the scope and impacts of the *Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories* (LLNL 1992a) and the *Supplemental Analysis for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories* (DOE 1999a). AMP would use the LLNL AVLIS technology to conduct a series of limited laser isotope separation experiments on plutonium (and nonradioactive surrogates of plutonium), utilizing the newly built solid state laser systems (DOE 2002o).

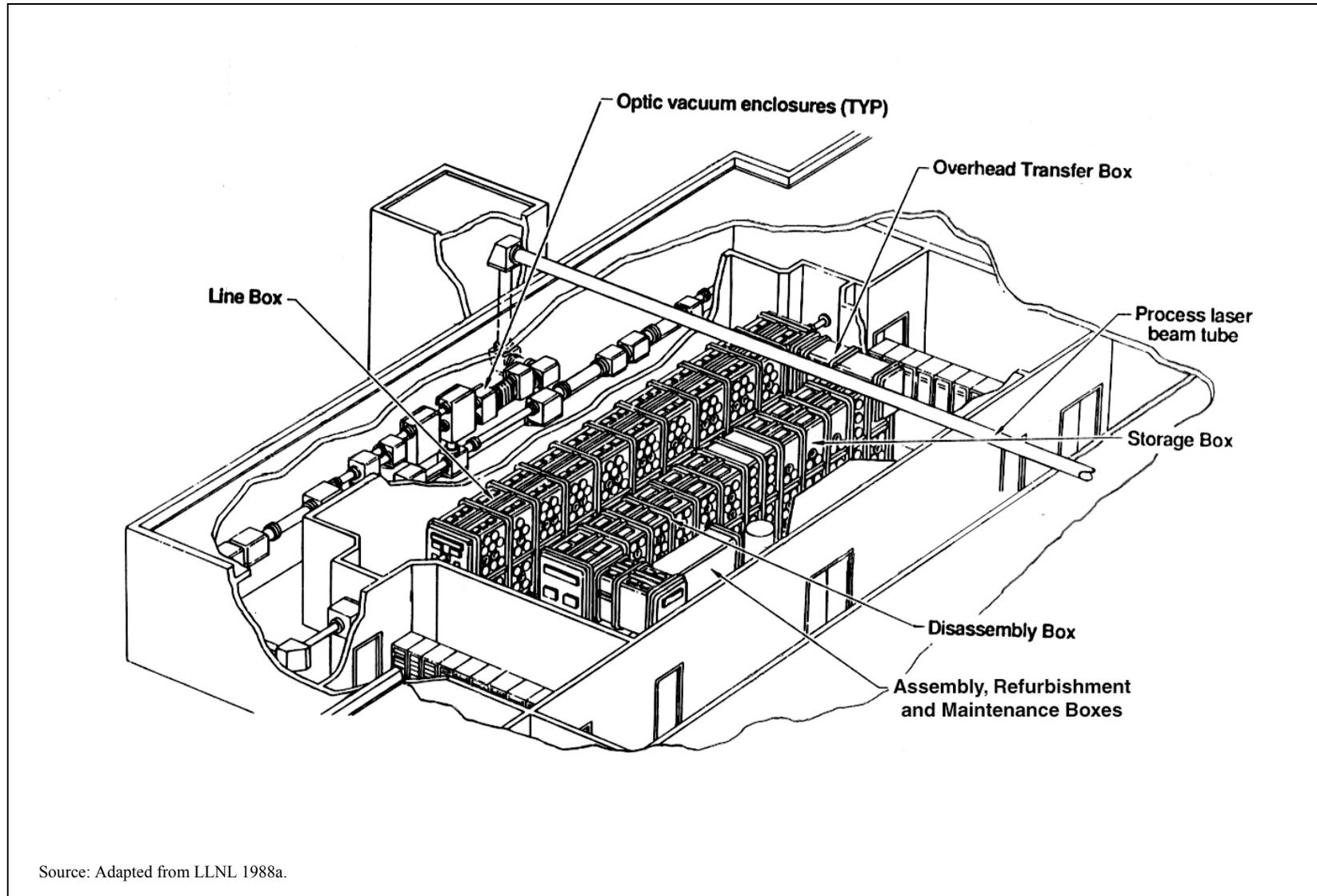


FIGURE N.2.2-1.—Engineering Demonstration System Equipment Layout

N.2.3 Process Description

The AVLIS process uses precisely tuned laser light to ionize a specific isotope or isotopes within a vapor of mixed isotopes. Once ionized, the desired isotope is separated from the other isotopes by attracting it to an electrically charged plate. The process can also be operated so that the unwanted isotopes are ionized and extracted, leaving the desired isotope. The choice between the two methods depends on the desired isotope and the mixture of the isotopes in the feedstock, but usually the minor species are ionized.

The mass balance aspects of separating isotopes using the AVLIS technology involve several steps. These steps include preparation of the feed material, separation of the isotopes, and processing of the separated isotopes.

N.2.3.1 Preparation of Feed Material

The isotope separation process discussed in this document requires feed material in the form of metal spheres that each weigh about 300 grams. The preparation of the feed material is dependent upon the chemical form of the feedstock. If the feedstock has other elements present or is not in the metallic form, it must undergo chemical purification and/or conversion to metal. Once produced, the metal feed material is fashioned into the spheres required for use in the separator unit.

N.2.3.2 AVLIS Technology

The separation of isotopes using lasers relies on the differences in the light absorption characteristics of the individual isotopes. The isotope separation process consists of two basic systems: the laser system and the separator system (Figure N.2.3.2–1).

N.2.3.2.1 Laser System

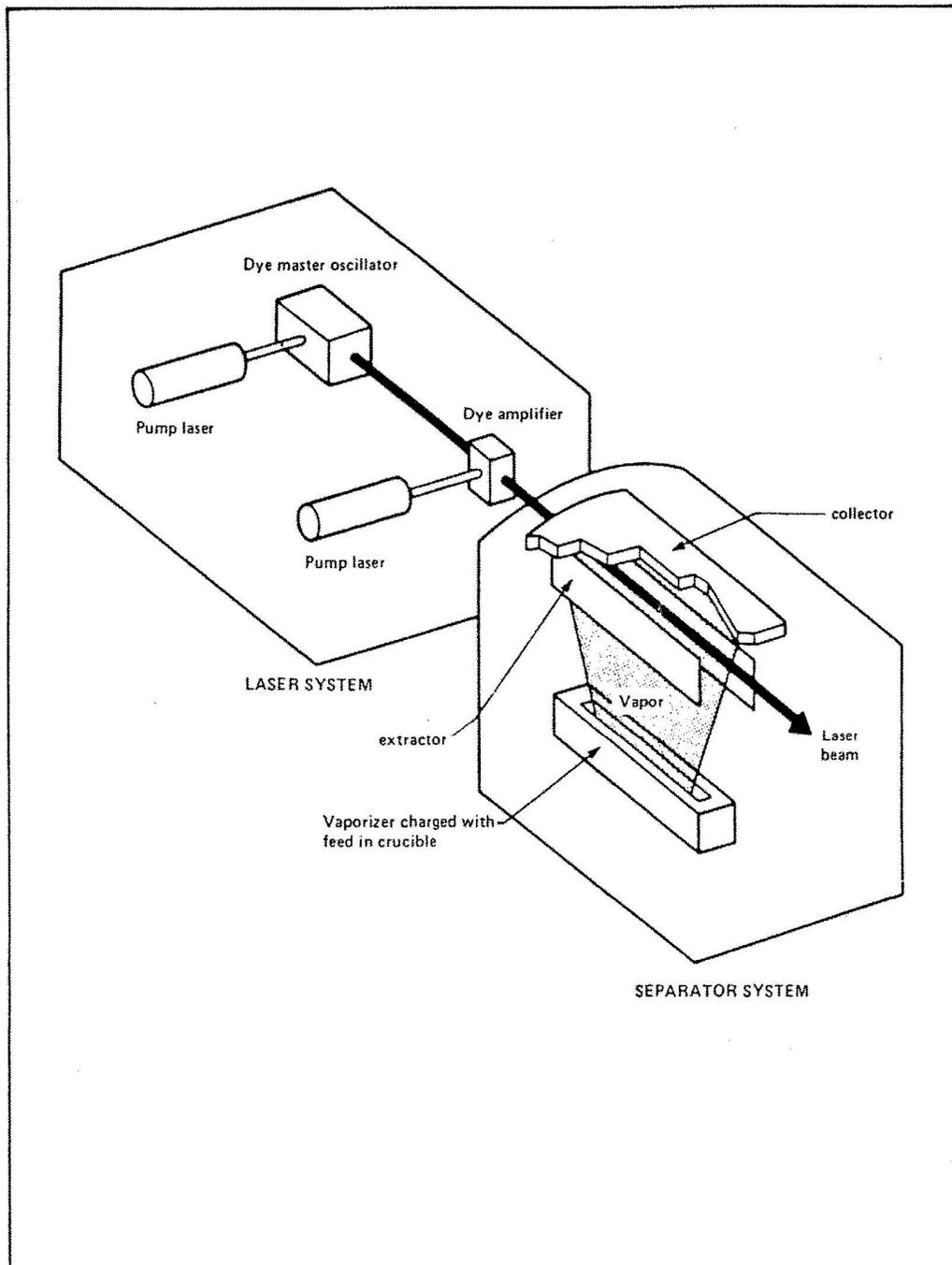
The laser system uses pumped dye lasers to produce the precisely tuned light at the frequencies required to ionize the desired isotopes in the separator vapor stream. The construction of the laser system is described in Section N.3.1.1.

Laser Instrumentation and Control Subsystem

The laser instrumentation and control subsystem measures all parameters and directly controls all laser functions. Local control is usually provided at the workstation level, while integrated remote control systems allow for supervisory control during operations.

N.2.3.2.2 Separator System

In the separator unit, the metal feed is vaporized from a crucible by an electron beam heat source. The stream of atomic vapor moves upward from the crucible where it is illuminated by the precisely tuned laser beams. The lasers supply light at the exact frequencies to ionize the desired isotope(s) in the vapor stream. The ionized isotope(s) is attracted to the electrically charged plates (extractor plates) at the sides of the separator (Figure N.2.3.2–1). The remaining neutral isotopes in the vapor stream continue upward between the charged plates and condense on an uncharged plate (collector plate) at the top of the separator unit.



Source: Adapted from LLNL 1988a.

FIGURE N.2.3.2-1.—Schematic of AVLIS System

Usually, the minor isotope(s) is ionized and collected at the charged plates. The non-ionized vapor stream, depleted of the minor ionized isotope, deposits on the uncharged plate overhead. The minor isotope is often the desired isotope and is called the product, whereas the neutral vapor collected on the overhead plate is called the byproduct.

In other cases, the minor isotope is an impurity. In these cases the extracted material is the byproduct and the collected material is the product. The same laser system could be tuned to ionize either. The process parameters and the logistics of the particular separation run are tailored to the specific feed material and mission requirements.

Separator Equipment

A separator unit, in which the laser light and vapor interact to provide the separation of isotopes, consists of a feeder mechanism, vaporizer assembly, charged extractor plates, and an uncharged collector plate. The separator unit is placed within a vacuum chamber. Associated utilities include cooling systems, power supplies, vacuum pumps, and Instrumentation and Control equipment.

N.2.3.3 Processing of Separated Isotopes

After the material has undergone isotope separation, the collector and extractor plates undergo chemical processing to remove the separated isotopes that are in the metallic form. As discussed above, the desired isotope (product) may be on either the extractor plates or the collector plate with the other plate(s) containing the remaining isotopes (byproduct).

N.3 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

Since the closeout of the SIS, laser technology in general has continued to advance. The AMP at LLNL is a research and development project that began in 2001 to conduct a series of laser isotope separation demonstrations on surrogate materials and, on a limited basis, plutonium utilizing modern laser hardware. Under the No Action Alternative, the AMP would continue through completion. As part of the AMP, new lasers would be built and deployed and a separator unit would be installed in the Superblock. At the conclusion of the AMP, the equipment would be placed in cold standby.

Under the Proposed Action, the AMP would continue through completion. However, instead of placing the equipment in cold standby the equipment developed under the No Action Alternative would be used to process sufficient amounts of material as required by the broader SBSSMP objectives. This proposed project is called the ITP.

Under the Reduced Operation Alternative, the AMP would be discontinued and would not be completed.

The ITP alternatives evaluated in this document make the following bounding assumptions:

- An annual feedstock throughput of 100 kilograms of plutonium over the life of the system (20 years) for the Proposed Action, with a representative isotopic assay, was chosen to both define and bound the human health and environmental impacts for this analysis. Alternate feedstocks and throughput would be bounded by these quantities.
- The AMP and ITP separation operations would be located in the room within Building 332, where the EDS operations took place, using some of the existing legacy equipment and

installed utilities. Alternative rooms and equipment could also be used; however, the analysis here is based on the present EDS location and bounds the environmental impacts of the separation operations. Alternative rooms and equipment arrangements would be designed to remain within the bounds of the environmental impact of the present EDS location.

N.3.1 No Action Alternative

Under the No Action Alternative, the AMP would be completed with the following three phases: (1) construction and installation of modern laser technology capable of separating isotopes, (2) the separation of isotopes of surrogate materials, and (3) separation of limited plutonium quantities with the newly built hardware. The AMP would utilize existing laboratories, facilities, and capabilities primarily in Buildings 161, 332, and 335.

N.3.1.1 Construction of Laser System

The pump lasers used for the SIS Program employed copper vapor. Since the closeout of SIS, laser technology has continued to advance. Today's pump lasers are much more efficient and involve lesser use of hazardous chemicals. The first phase of the AMP involves the construction of modern solid state (Class 4) laser systems that pump the precisely tuned dye lasers used to separate isotopes.

The construction and testing of the new solid state lasers would take place in Building 161. The expected efficiency of the new solid-state pump lasers would be greater than the copper vapor laser technology. Therefore, less electrical power, equipment, space, and material usage would be required. The solid state lasers would not use hazardous chemicals.

Once built and tested, the pump lasers would be used to excite the tunable recirculating organic dye lasers. The dye solutions for the dye lasers would be prepared from a variety of dyes dissolved in alcohol in specific concentrations. The dyes are chemically distinct but have similar physical properties.

The dyes are stored in powder form in glass or plastic containers until needed. The dyes would vary, but all are likely carcinogenic or mutagenic. Rhodamine 6G (R6G), is a commercially available dye within this family chemically similar dyes and has a material safety data sheet specifying its hazards. The dyes would be mixed with an alcohol, such as ethyl, isopropyl, and methyl alcohols. A dye laser would use, at most, 15 liters of organic dye solution. The mixed dye would be stored in glass or plastic containers labeled as to the contents, concentrations, and appropriate warnings. The powders and mixed laser dyes would be stored in designated chemical storage cabinets. Total estimated use for the AMP is 60 liters of dye mixture. Disposal of the spent dyes would be in accordance with LLNL hazardous waste disposal requirements.

N.3.1.2 Separation of Isotopes of Surrogate Materials

In the second phase of the AMP, the complete laser system would be used to demonstrate the separation of isotopes of surrogate materials. The surrogate materials are nonradioactive rare-earth elements in the lanthanide series. This phase would allow for the certification of fieldable hardware and for validation of the process physics models. The separation experiments and the chemical processing of the surrogate feed material and processed isotopes would take place in Building 161 and would not involve radioactive materials.

Initially, several runs of 10 to 20 hours would be conducted to calibrate and test the separator hardware and laser systems. Subsequently, up to six experimental runs separating isotopes of the surrogate materials would be performed. Each run would last up to 200 hours. After the experimental runs, the separated material would be processed for recovery. The surrogate materials would be chemically recovered in nonnuclear facilities at LLNL through dissolution in a hydrochloric acid bath.

N.3.1.3 *Separation of Plutonium Isotopes*

After the experiments using surrogate materials are complete, the third phase of the AMP would begin. In the third phase, the equipment and work would be relocated to Building 332 and Building 335. The process lasers would be relocated from Building 161 to Building 335, which has existing space, utilities, and laser system support structures still in place from the SIS Program. Building 335 is separate from Building 332 where plutonium is handled and stored. The process light beams would be combined for transport through an evacuated beam tube to Building 332, where the separators would be installed.

The experiments in Building 332 would initially use surrogate material, in the same manner as the experiments performed in Building 161, to recalibrate the equipment and establish baseline operating parameters. Subsequently, several small runs of 10 to 20 hours with plutonium feed material would be conducted to calibrate and test the separator hardware and laser systems for the parameters to separate isotopes of plutonium. Once the equipment has been recalibrated, two to four plutonium isotope separation demonstration runs would be performed processing up to 4 kilograms. Each run would last up to 200 hours. The chemical processing of the feed material, handling of the isotope separation process, and the chemical processing of the separated isotopes would be different for experiments using plutonium than those for surrogate materials. Certain existing techniques, procedures, and equipment in Building 332 would be used for plutonium. The preparation of the plutonium feed material, separation of the isotopes, and processing of the product and byproduct that are associated with the AMP are discussed below.

N.3.1.3.1 *Preparation of Feed Material*

Plutonium already stored at LLNL would be used as the feed material for the third phase of the AMP. There would be no offsite transportation of plutonium associated with the AMP (Figure N.3.1.3.1–1). The plutonium feedstock would be chemically purified and cast into the proper feed form in the Materials Processing Laboratory of Building 332. The chemical processing of the plutonium would use the existing gloveboxes, equipment, and personnel in the Materials Processing Laboratory. Similar work with plutonium is currently performed in this room for other projects. For the separation of plutonium isotopes, the feedstock is often in powdered oxide form and contains varying amounts of americium as a result of radioactive decay. Therefore, the feedstock must be converted to plutonium metal, the americium removed, and the purified plutonium cast into the appropriate feed form.

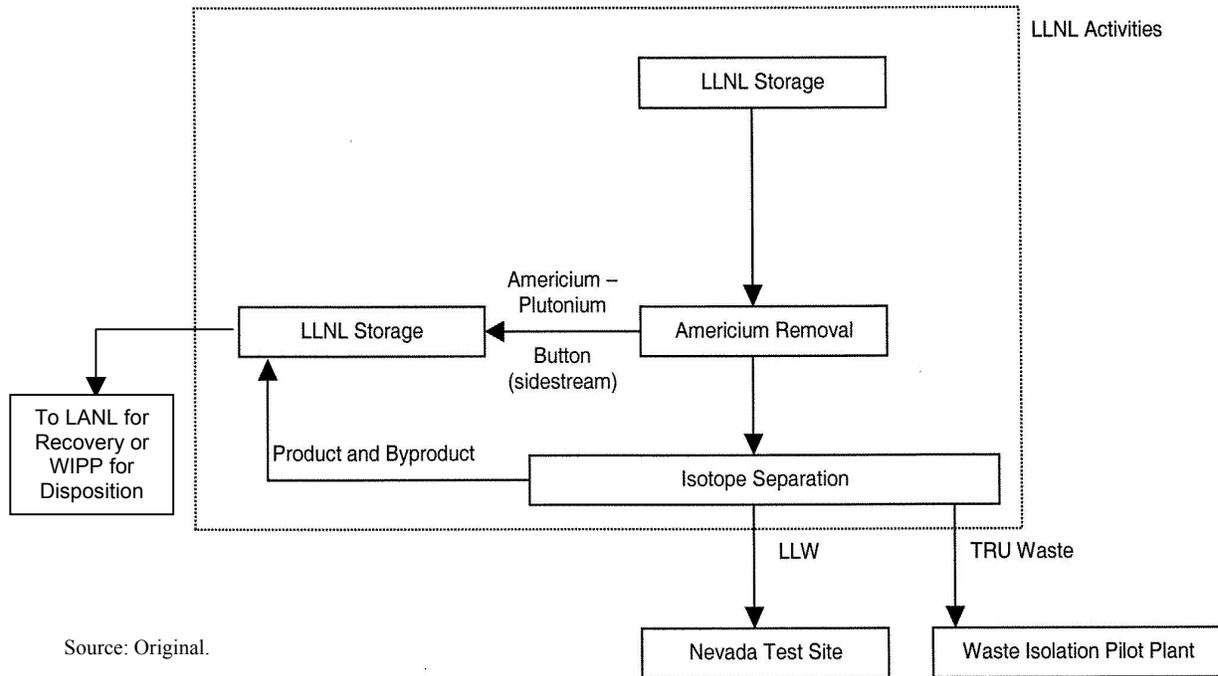


FIGURE N.3.1.3.1–1.—Material Flowchart for the Advanced Materials Program

Metal Conversion (Direct Oxide Reduction)

First the plutonium oxide feedstock (containing a small amount of americium oxide) is converted to metal. In metal conversion, the oxide powder is heated, or calcined, to remove any residual absorbed water and other volatile materials. Then the oxide is reduced to metal through direct oxide reduction. This is a one-step conversion process in which the oxide reacts with calcium metal to produce metal. A molten-salt mixture dissolves the reaction byproduct, calcium oxide, allowing the plutonium (and americium) metal to coalesce. The reaction takes place in a glovebox furnace designed for pyrochemical operations. The salt is then physically separated from the plutonium metal. If required, the metal is transferred to the next process step of americium removal. The salt resulting from the direct oxide reduction step contains a small amount of plutonium. The residue salt containing this plutonium is regenerated by bubbling hydrogen chloride or chlorine through the dissolved salt. The dissolved calcium oxide is converted to calcium chloride with oxygen released to the glovebox exhaust. The residual plutonium is converted to plutonium chloride or Cs_2PuCl_6 that is reduced back to metal during the next direct oxide reduction.

Americium Removal (Molten-Salt Extraction)

A molten-salt extraction process is used to remove the americium from the feedstock. In the molten-salt extraction process, plutonium metal is put in contact with a molten salt mixture containing a small amount of plutonium chloride or Cs_2PuCl_6 , which is supplied from a sidestream. The plutonium chloride or Cs_2PuCl_6 selectively converts the americium to americium chloride, and after cooling, the americium chloride containing salt is separated from the plutonium metal. The plutonium metal is then sent to feed casting.

Residual americium chloride and plutonium chloride in the residue salt are reduced to a metal alloy during a salt scrub process. In the salt scrub process, the residue salt is heated to a molten state and then similar to direct oxide reduction, calcium metal is used to reduce the actinide chlorides to americium and plutonium alloyed metals and producing a calcium chloride salt (reaction byproduct). Because of the differences in density, the alloy and salt are easily separated once cooled. The calcium chloride salt can be discarded as transuranic waste or recycled after being regenerated. The americium/plutonium metal button (americium/plutonium button) would be stored for future transport to a facility for further plutonium recovery and disposition of the americium, or sent to the Waste Isolation Pilot Plant (WIPP) in New Mexico.

Feed Material Casting

After the americium has been removed from the plutonium metal, the plutonium metal is melted and cast into the spheres needed for the separators. These so-called feedballs would be loaded into a carousel that would be placed into the separator unit.

Some plutonium metal would be left over in the casting melt crucible called a skull. The plutonium skull from casting would be recycled by hydriding the plutonium, chlorinating the plutonium hydride, and using the resulting plutonium chloride as the sidestream input to the molten-salt extraction process described under americium removal.

N.3.1.3.2 *Separator System*

Installation of Equipment

The separators and support equipment would be installed in Building 332 in the room where the EDS is located. The legacy EDS mechanical structures, glovebox frames, utilities, and beam tubes are still in place. The EDS was comprised of the Line Box, a large glovebox with eight separator stations in line with the laser beam with the storage capacity for an additional eight separators. The upper part of the Line Box also contained the various vacuum, cooling system, power conditioning, and instrument support equipment. The lower portion of the Line Box housed a transport system used to move the separator units between stations and the other gloveboxes. A separator refurbishment station; a separator disassembly station; and two assembly, re-supply, and maintenance boxes (Box A and B) comprised the remainder of the EDS (Figure N.2.2–1).

The AMP may convert the assembly, resupply, and maintenance boxes at the east end of the legacy EDS equipment, to a separator station and one separator refurbishment station (Figure N.2.2–1). The central part of maintenance Box A contains a test chamber in the upper half of the box that is nearly identical to the vacuum chambers in the EDS Line Box. The test chamber would be replaced with a separator chamber. Laser beam ports and vapor control ports would be added. Assembly, resupply, and maintenance Boxes A and B would be radiologically isolated

from the rest of the EDS line. Assembly, resupply, and maintenance Box B would undergo minor changes to serve as the refurbishment glovebox, where the separated isotopes would be removed from the separator and new feed material added. One separator unit left over from the EDS would be used in these experiments. The remainder of the EDS equipment would remain inactive.

Separation of Isotopes

The carousel loaded with plutonium metal feedballs from the Materials Processing Laboratory would be attached to the separator unit. In the separator unit, the plutonium metal feedballs would be fed, as needed, from the carousel into a heated side arm where they melt and the molten plutonium pours into a crucible. In the crucible, the molten plutonium would be further heated by an electron beam causing it to vaporize and move rapidly upward through the laser beam(s). The laser light selectively ionizes different plutonium isotopes. The ionized plutonium isotopes are separated from the remaining isotopes by their attraction to electrically charged plates.

N.3.1.3.3 *Processing of Separated Isotopes*

After the plutonium has undergone isotope separation, the collector and extractor plates would be processed in the Materials Processing Laboratory to remove the separated isotopes. The separator plates and other components would be processed for plutonium recovery, hydriding the plutonium and collecting the resultant powder. The process depends on the composition and size of the plates. The plutonium hydride from the product and byproduct would be either converted back to plutonium metal or oxide powder for storage.

The separator plates and other components containing the product and byproduct metal would be processed in existing gloveboxes and equipment in Building 332. The chemical processing of the amounts of feed material and separated isotopes to be used in AMP fall within the current levels of chemical processing capacity of Building 332 at LLNL. No major changes in existing gloveboxes would be required to provide this support.

N.3.1.3.4 *Transportation*

There would be no offsite transportation of plutonium feed material, byproduct, or product associated with the AMP.

N.3.2 **Proposed Action**

The Proposed Action for ITP is to utilize the separation system (composed of the separator and laser subsystems) described under the No Action Alternative in Section N.3.1, to process different feedstocks of plutonium for use in Stockpile Stewardship Program experiments (see Chapter 1 of the LLNL SW/SPEIS). Any decision to proceed with the Proposed Action is subject to the successful performance of the AMP demonstration and a determination of Program need. Under the Proposed Action, the amount of material that would be processed, up to 100 kilograms of plutonium per year, would be considerably greater than the 4 kilograms per year processed under the AMP (No Action Alternative). The changes to the AMP equipment and the Materials Processing Laboratory operations are described below. Some changes to existing Material Processing Laboratory operations, some reactivation of old equipment, and a greater amount of material use, storage, and transportation must be implemented.

N.3.2.1 *Development of Laser Systems*

The lasers installed in Building 335 as part of the AMP would not be put in cold standby as under the No Action Alternative. Instead they would be used to provide laser energy for the separation of plutonium isotopes under the Proposed Action. No additional changes to the laser system are anticipated.

N.3.2.2 *Separation of Plutonium Isotopes*

The separation of plutonium isotopes would proceed as described for the AMP under the No Action Alternative. Under the Proposed Action, there would be more extensive operations, both in terms of equipment use and material throughput. On an annual basis, processing of up to 100 kilograms of plutonium would be conducted.

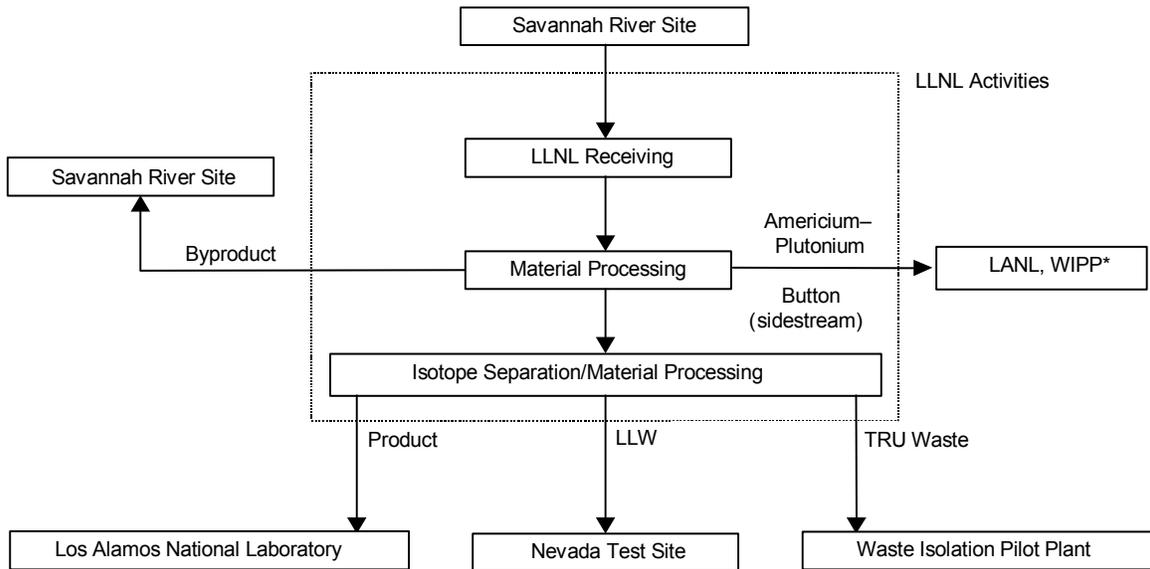
This change in throughput would require some changes in equipment and procedures from those described for the AMP. These changes would mostly involve the automation of some process steps to reduce doses to personnel.

In addition, the feed materials would vary under the Proposed Action and would include the shipment of products and byproducts to Los Alamos National Laboratory (LANL). The impacts of the isotope separation would differ somewhat according to the amount and type of feed material and the desired product, but are bounded by the choice of feed material assumed in the analysis.

To assess the impacts and wastes associated with the overall operations, those missions that could be foreseen as needing particular plutonium isotopes were used to develop realistic and bounding feed materials and other conditions for potential separation work. These conditions were used to evaluate the potential impacts to human health and the environment.

Various feedstock materials were identified for potential use. An Evaluation Feedstock (Section N.3.2.2.1) shipped from the Savannah River Site (SRS) was postulated for purposes of analysis that would bound the impacts of the potential feedstocks for most environmental resource areas and potential accidents. However, feedstock from Hanford was also evaluated in regard to transportation to assess the impacts from different routes. Figures N.3.2.2–1 and N.3.2.2–2 show the general material flow for the Evaluation Feedstock and the Hanford feedstock, respectively.

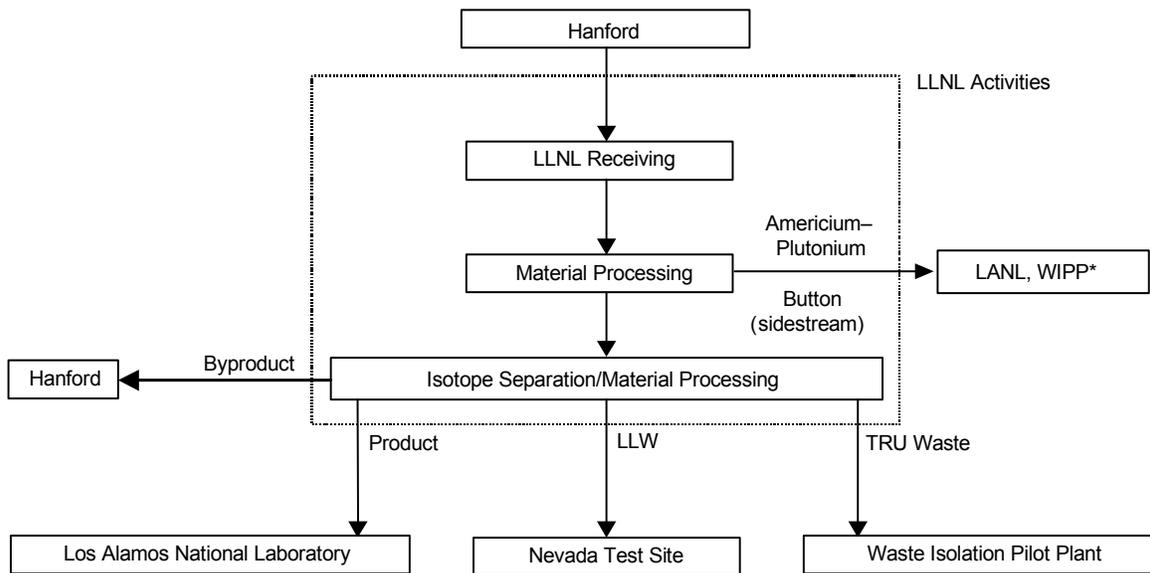
An annual process throughput of plutonium oxide, equivalent to 100 kilograms of plutonium metal with the Evaluation Feedstock isotopic composition, was used to bound the analyses of process rates, material amounts, radiation exposure, emissions, wastes, accidents, and transportation, unless otherwise stated.



Source: Original.

* The byproduct of the MSE step, an americium/plutonium button would be either sent to WIPP or sent to LANL to recover and recycle the plutonium.

FIGURE N.3.2.2-1.—Material Flowchart for the Evaluation Feedstock



Source: Original.

* The byproduct of the MSE step, an americium/plutonium button would be either sent to WIPP or sent to LANL to recover and recycle the plutonium.

FIGURE N.3.2.2-2.—Material Flowchart for the Hanford Feedstock

N.3.2.2.1 *Preparation of Feed Material*

The Evaluation Feedstock is an average of the isotopic characteristics of potential feedstock materials. The americium would be completely removed from the plutonium feed material prior to receipt at LLNL. However, it was assumed that 2 years of interim storage of the feedstock would occur before it would be used. During this time, there would be substantial ingrowth of americium-241 in the Evaluation Feedstock. Table N.3.2.2.1–1 presents the parameters of the Evaluation Feedstock at the time it is postulated that processing would begin. The feedstock would arrive at LLNL in the powdered oxide form.

TABLE N.3.2.2.1–1.—Evaluation Feedstock Parameters

Element	Weight Percentage
Plutonium (all isotopes)	99.22
Americium	0.64
Uranium	0.14

Source: NNSA 2003c.

The Evaluation Feedstock would be processed through direct oxide reduction, molten-salt extraction, and feed material casting prior to isotope separation. The processes are described in Section N.3.1.2.

A substantial amount of americium would be extracted from the feed material in the molten-salt extraction step. The americium/plutonium chloride salt would be reduced to an americium/plutonium metal button. Instead of storage at LLNL as under the No Action Alternative, the americium/plutonium metal button would be sent to WIPP for disposal or LANL for plutonium recovery. The annual bounding throughput of 100 kilograms of Evaluation Feedstock metal would result in approximately 10 kilograms of americium/plutonium metal annually.

N.3.2.2.2 *Separator System*

Installation of Equipment

In addition to the equipment used for the AMP, a second separator unit may be installed alongside the first.

Separation of Isotopes

The separation of the plutonium isotopes would proceed as described for the AMP in Section N.3.1.3. However, under the Proposed Action, the separator(s) would run a large part of the year to produce plutonium with the required isotopic composition. The bounding scenario assumes an annual process throughput of 100 kilograms of plutonium metal with the Evaluation Feedstock isotopic composition.

N.3.2.2.3 *Processing of Separated Isotopes*

After the plutonium has undergone isotope separation, the collector and extractor plates would be processed to obtain the product and byproduct as described for the No Action Alternative in Section N.3.1.3. The plutonium byproduct would be converted to oxide powder for packaging and shipment back to the site where the feed material originated. The product would be dehydrided to the metal or converted to oxide for packaging and shipment to LANL.

N.3.2.2.4 *Material at Risk Increase*

To accommodate the full throughput of 100 kilograms per year of plutonium processed and to permit plutonium processing for other NNSA programs, the material-at-risk (MAR) would be increased from 20 kilograms of fuel-grade plutonium equivalent to 60 kilograms of fuel-grade plutonium equivalent. Without this increase in MAR, the Proposed Action throughput levels could not be achieved. All environmental evaluations (e.g., accidents, worker population dose) have been performed with 60 kilograms MAR for the Proposed Action.

N.3.2.2.5 *Transportation*

In order to evaluate transportation, several cases were considered. In all cases, the product would be either dehydrated to metal or converted to the oxide for packaging and shipping to LANL. It is assumed to be a single shipment per year, though most likely the shipment would be combined with other material shipments to LANL.

One scenario involves the transportation of feed material from SRS and the return of the byproduct to SRS. In this case, the americium/plutonium button from the molten-salt extraction process would be shipped to WIPP, or sent to LANL for recovery and recycle of plutonium.

Another case involves the transportation of the feed material from Hanford to LLNL and the return of the byproduct to Hanford. The americium/plutonium button from the molten-salt extraction process would be shipped to WIPP, or sent to LANL for recovery and recycle of plutonium.

N.3.3 **Reduced Operation Alternative**

Under the Reduced Operation Alternative, the AMP activities would be discontinued. The No Action Alternative or the Proposed Action would not be implemented. No laser separation of isotopes of surrogate material or plutonium would take place. The Building 332 EDS equipment would remain in its current status of cold standby.

N.3.4 **Comparison of Alternatives and Environmental Consequences**

Impacts

Table N.3.4–1 compares the potential environmental consequences of the No Action Alternative, Proposed Action, and Reduced Operation Alternative. Section N.5 provides detailed assessments of the alternatives and environmental consequences. The evaluations of the consequences summarized in Table N.3.4–1 are based on mitigation measures that would be implemented.

As indicated in the Table N.3.4–1, changes in the Proposed Action impacts as compared to the No Action and Reduced Operation Alternatives occur in several areas. The primary impacts include increase in transuranic and low-level waste. These range from 10.42 cubic meters per year of transuranic waste in the Proposed Action to 0.42 cubic meters per year in the No Action Alternative and none in the Reduced Operation Alternative. Low-level waste generation would range from 10.42 cubic meters per year during the Proposed Action to 0.63 cubic meters during the No Action Alternative, and none for the Reduced Operation Alternative.

TABLE N.3.4–1.—Comparison of Potential Impacts of No Action Alternative, Proposed Action, and Reduced Operation Alternative

	No Action		Proposed Action		Reduced Operation
Socioeconomics					
Long-Term Employees	10		27		0
New Hires	0		14		0
Local Housing	No Impacts		No Impacts		No Impacts
Environmental Justice	No Disproportionately High and Adverse Impacts		No Disproportionately High and Adverse Impacts		No Impacts
Community Services					
Fire/Police	No Impacts		No Impacts		No Impacts
School	No Impacts		No Impacts		No Impacts
Nonhazardous waste	Minimal Impacts		Minimal Impacts		No Impacts
Air Quality					
Hazardous toxic air pollution	No Impacts		No Impacts		No Impacts
Radiological Air Pollutants	Pu 3.0×10^{-4} μ Ci/yr Am 3.4×10^{-7} μ Ci/yr U 3.8×10^{-10} μ Ci/yr		Pu 7.4×10^{-3} μ Ci/yr Am 8.6×10^{-6} μ Ci/yr U 9.4×10^{-9} μ Ci/yr		No Impacts
	<u>Annual Dose</u>	<u>LCF/yr</u>	<u>Annual Dose</u>	<u>LCF/yr</u>	
MEI	2.5×10^{-9} mrem	1.5×10^{-15}	6.2×10^{-8} mrem	3.7×10^{-14}	No Impacts
Offsite Population	1.3×10^{-7} person-rem	7.7×10^{-11}	3.3×10^{-6} person-rem	2.0×10^{-9}	
Noise					
	No Impacts		No Impacts		No Impacts

TABLE N.3.4–1.—Comparison of Potential Consequences of No Action Alternative, Proposed Action, and Reduced Operation Alternative (continued)

	No Action				Proposed Action					Reduced Operation
Traffic and Transportation										
Traffic	No Impacts				No Impacts					No Impacts
Transportation	No Impacts				Up to 0.55 person-rem (3.3×10^{-4} LCFs) for incident free transportation.					No Impacts
Utilities and Energy										
Electricity	100 MWh per year				2.8 GWh per year (less than 1% of LLNL usage)					No Impacts
Materials and Waste Management										
Materials Management	Would involve use of radioactive and hazardous materials, plutonium, americium, laser dyes, and cleaning fluids				Would involve use of radioactive and hazardous materials, plutonium, americium, laser dyes, and cleaning fluids. Plutonium use would be 25 times that of No Action.					No Impacts
Waste Management (quantities in m ³ per year)	Hazardous Solid 0.42	LLW Solid 0.63	TRU solid 0.42	Hazardous Solid 0.21	Hazardous Liquid 0.21	LLW Solid 10.42	TRU Solid 10.42	Mixed Solid 0.42	No Impacts	
Occupational Protection										
	Annual Dose				Annual Dose					No Impacts
	MEI		Population		MEI		Population			
Radiological Dose	Dose mrem	LCF	Dose Person-rem	LCF	Dose mrem	LCF	Dose person-rem	LCF		
Public	2.5×10^{-9}	1.5×10^{-15}	1.3×10^{-7}	7.7×10^{-11}	6.2×10^{-8}	3.7×10^{-14}	3.3×10^{-6}	2.0×10^{-9}		
Workers	6.8×10^{-2}	4.1×10^{-5}	1.4	8.6×10^{-4}	1.2	7.0×10^{-4}	32.2	1.9×10^{-2}		

TABLE N.3.4–1.—Comparison of Potential Consequences of No Action Alternative, Proposed Action and Reduced Operation Alternative (continued)

Bounding Radiological Accidents		
No Action	Proposed Action	Reduced Action
Aircraft Crash	Room Fire Unfiltered	
For the bounding radiological accident: <u>Median Meteorology</u> - 0.2 LCFs to the noninvolved worker population - 0.06 LCFs in the offsite population <u>Unfavorable Meteorology</u> - 1.5 LCFs to the noninvolved worker population - 0.72 LCFs in the offsite population	For the bounding radiological accident: <u>Median Meteorology</u> - 0.56 LCFs to the noninvolved worker population - 0.17 LCFs in the offsite population <u>Unfavorable Meteorology</u> - 4.7 LCFs to the noninvolved worker population - 2.0 LCFs to the offsite population	No Impact

Source: Original.

Am = americium; LCF = latent cancer fatality; LLW = low-level waste; MEI = maximally exposed individual; MWH = megawatt hour; m³ = meters cubed; μCi/yr = microcuries per year; TRU = transuranic; Pu = plutonium; U = uranium.

The worker population dose is estimated to be 32.2 person-rem per year for the Proposed Action, 1.43 person-rem per year for the No Action Alternative, and none for the Reduced Operation Alternative.

Facility accidents for the Proposed Action are predicted to result in less than one latent cancer fatality (LCF) to the public based on the median meteorology. Using unfavorable meteorological conditions, two LCFs to the public and five additional LCFs for the noninvolved worker population are expected. The bounding radiological accident for the noninvolved worker population for No Action is the aircraft crash into Building 332. This is based on a MAR of 20 kilograms plutonium and results in a person-rem dose of 3.2×10^2 and less than one (0.2) LCF.

For the Proposed Action, the bounding radiological accident for the noninvolved worker population would be the unfiltered room fire in Building 332. This is based on a MAR of 60 kilograms plutonium and results in a person rem dose of 9.3×10^2 and less than one (0.6) LCF. The bounding transportation accident involves shipment of ITP transuranic waste to WIPP. Although the probability of its occurrence is only 8.4×10^{-10} per year, the accident yields 4.6×10^4 person-rem and 28 LCFs. This is the bounding transportation accident for the entire LLNL.

N.3.5 Alternatives Eliminated from Detailed Review

Separation in Calutrons at Oak Ridge

A calutron uses the electromagnetic deflection of ionized atoms to separate isotopes. The calutrons at Oak Ridge were used to separate isotopes of uranium for the development of the first atomic bomb. During the Cold War they were replaced as the main process for the separation of uranium isotopes by other technologies such as gaseous diffusion. Since then, the calutrons have been used to produce a number of nonradioactive isotopes. The calutrons are currently being decommissioned. Therefore, the calutrons are unavailable for processing the materials for the SBSSMP testing program.

Chemical Separation at Savannah River Site

Plutonium production and recovery activities were carried out in the past at the SRS. This chemical separation activity involved the processing of materials that had been irradiated in the production reactors to produce new plutonium for the weapons program. These facilities have been placed in cold standby. While the chemical processing of the feed materials for the SBSSMP does not qualify as processing for production purposes, the facilities at SRS are considered plutonium production facilities and are being shut down per NNSA and U.S. policies and programmatic decisions. Therefore, the SRS facilities are not considered available for supplying the materials needed for the SBSSMP testing program. Also the SRS facilities are large-scale facilities unsuited for production of small amounts of this research material.

N.4 DESCRIPTION OF THE AFFECTED ENVIRONMENT

Chapter 4 of the LLNL SW/SPEIS describes the environmental setting and existing conditions associated with the current operations at LLNL pertinent to the issues evaluated in this appendix.

N.5 ENVIRONMENTAL CONSEQUENCES

The environmental consequences resulting from the No Action Alternative, Proposed Action, and Reduced Operation Alternative as well as bounding accident scenarios are presented in the following sections.

N.5.1 No Action Alternative

The No Action Alternative is a brief, one-time demonstration project. It would take place in existing rooms in existing buildings. No excavation would be needed. Therefore, there would be no impacts to Land Use and Applicable Plans, Prehistoric and Historic Cultural Resources, Aesthetics and Scenic Resources, Geologic Resources (geologic hazards are considered as part of the accident screening), Ecology, and Water Resources (water use and wastewater treatment).

While the AMP would only fully operate with plutonium for about a month in Building 332, the impacts are given in annual terms to allow comparison with the Proposed Action. In addition, the AMP would not use the same feedstock material as the Proposed Action. Material already at LLNL would be used. However, to bound the material that might be used and provide easy comparison to the Proposed Action, 4 kilograms of Evaluation Feedstock is assumed to be processed in the AMP.

The quantities of materials to be used in AMP fall within the current working limits of Building 332 and LLNL. The chemical processing of the feed material and separated isotopes would be minor and within the current levels of chemical processing capacity of the Materials Processing Laboratory in Building 332 at LLNL. The chemical processing associated with the 1984 laser separation of plutonium isotopes was performed in Building 332.

N.5.1.1 *Socioeconomic Characteristics and Environmental Justice*

Implementation of AMP, would not employ any new personnel. The personnel that would perform the work are already employed at LLNL. There would be no impacts to employment, population, housing, or economic factors. There would be no disproportionately high and adverse impacts to minority or low-income populations.

N.5.1.2 *Community Services*

The No Action Alternative would not be a special generator of nonhazardous solid waste. The generation of nonhazardous waste is proportional to the number of employees. Since existing LLNL employees would perform the work associated with AMP, there would be no increase in the generation of nonhazardous waste.

N.5.1.3 *Air Quality*

The laser, separator and chemical processing activities would generate air emissions. Some gaseous effluents would be generated in the glovebox operations. These effluents would be exhausted through the Building 332 stack. Radioactive atmospheric releases during normal operations are shown in Table N.5.1.3–1. The release pathway is through the glovebox filter and two stages of facility high-efficiency particulate air (HEPA) filtration prior to discharge to the building stack. A HEPA filter efficiency of 99.97 percent was assumed.

**TABLE N.5.1.3–1.—Estimated Annual Radioactive Release for Normal Operations
(No Action Alternative)**

Element	Feed Composition Weight Percentage	Release ($\mu\text{Ci}/\text{year}$)
Plutonium	99.22	3.0×10^{-4}
Americium	0.64	3.4×10^{-7}
Uranium	0.14	3.8×10^{-10}
Total Atmospheric Release		3.0×10^{-4}

Source: NNSA 2003c.

$\mu\text{Ci}/\text{yr}$ = microcuries per year.

N.5.1.4 *Noise*

The activities in the Materials Processing Laboratory under the No Action Alternative would be the same as current activities. The noise level would be the same as current levels. The lasers, separators, and chemical processing systems are not a large source of noise. The No Action Alternative would not increase noise in Building 332.

N.5.1.5 *Traffic and Transportation*

The No Action Alternative would not involve new hires that would affect traffic counts in the LLNL area and therefore would not require the rerouting of any traffic. There would be no offsite transportation of feed material, byproduct, or product associated with AMP.

N.5.1.6 *Utilities and Energy*

The estimated electrical usage for the No Action Alternative including lasers is 100 megawatt hours per year. This usage is within the capacity of the LLNL electricity supply.

The main cooling of the laser system is supplied by a dual channel closed loop cooling system containing a water-cooled condenser section. The LLNL Low Pressure Cooling Water system would be used to supply cooling water. The cooling water would be recirculated back into the LLNL system. Any primary loop cooling water that was accidentally fouled by the laser chemicals would be disposed of per LLNL hazardous waste disposal guidelines. The separators would use cooling water from the Building 332 cooling water system. The supply of this cooling water is within the normal operations of Building 332.

The AMP would need clean, dry compressed air at 75 to 100 pounds per square inch on a routine basis, and on occasion, limited amounts of argon. The supply of these gases is within the normal operations of Building 332.

N.5.1.7 *Materials and Waste Management*

The laser system would be solid-state lasers optically pumping recirculating organic dye lasers. The organic dyes (R6G is bounding) are stored in either powder or liquid form. The dyes would be mixed with ethyl, isopropyl, or methyl alcohol, depending on the dye requirements. About 50 liters of the mix would be used per year. Total alcohol use and storage is bounded by one 55-gallon drum.

The organic dyes are mutagenic and carcinogenic chemicals. Handling and storage of these chemicals is routine for the laser program. Proper environment and safety procedures for handling and storage would be implemented.

It is estimated that the AMP experiments and recovery operations would generate a one-time inventory of two 55-gallon drums of hazardous waste, three drums of low-level waste (discarded gloves, booties, wipes, etc.), and two drums of transuranic waste.

N.5.1.8 *Decontamination and Decommissioning*

Decontamination and decommissioning (D&D) for the AMP demonstration involve the separator related equipment including gloveboxes and the process lasers. The Material Processing Laboratory systems provide general support to multiple Plutonium Facility programs and would not be decontaminated and decommissioned at the end of the AMP activities.

The D&D of the separator and laser equipment would take approximately 18 months and would result in a one-time generation of 4 cubic meters of transuranic waste, 12 cubic meters of low level waste, and 0.5 cubic meters of hazardous waste.

N.5.1.9 *Occupational Protection*

Impacts from Normal Operations

Public Health Impacts

NNSA expects minimal public health impacts from the radiological consequences of AMP operations. Public radiation doses would likely occur from airborne releases only. Table N.5.1.9–1 lists the projected normal radionuclide emission rates for the AMP process, the incremental radiation doses estimated for the public (offsite maximally exposed individual [MEI] and collective population dose), and the corresponding incremental LCFs, which represent the impacts of the airborne radioactive releases.

TABLE N.5.1.9–1.—Annual Radiological Impacts on the Public from Advanced Materials Program Operations

Radionuclide	Emission Rate (Ci/yr)	Offsite MEI Offsite Population ^a			
		Dose (mrem/yr)	LCF Probabilities ^{b, c}	Dose (person- rem)	LCFs ^c
Plutonium	3.0×10^{-10}	2.4×10^{-9}	1.4×10^{-15}	1.3×10^{-7}	7.6×10^{-11}
Americium	3.4×10^{-13}	1.3×10^{-10}	7.6×10^{-17}	3.2×10^{-9}	1.9×10^{-12}
Uranium	3.8×10^{-16}	3.4×10^{-14}	2.0×10^{-20}	8.4×10^{-13}	5.1×10^{-16}
Total:		2.5×10^{-9}	1.5×10^{-15}	1.3×10^{-7}	7.7×10^{-11}

Source: NNSA 2003c.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^b Indicates the increased probability of a LCF to this individual receptor.

^c Based on a cancer risk estimator of 0.0006 LCFs per person-rem.

Ci/yr = curies per year; LCF = latent cancer fatality; MEI = maximally exposed individual; mrem/yr = millirem per year.

As shown in the table, the expected annual radiation dose to the offsite MEI would be much smaller than the limit of 10 millirem per year set by both the U.S. Environmental Protection Agency (EPA) (40 CFR Part 61) and DOE (DOE O 5400.5) for airborne releases of radioactivity. The risk of a LCF to this individual from operations would be approximately 1.50×10^{-15} per year (i.e., about 1 chance in 667 trillion per year of a LCF). The projected number of fatal cancers to the population within 50 miles would be 7.7×10^{-11} per year (i.e., about 1 LCF in 129 billion years).

Impacts to Advanced Materials Program Workers

Estimates of annual radiological doses to workers involved with AMP facility operations are a function of (1) the number of radiological workers, as determined in the development of the AMP staffing estimate for each process; (2) the average working dose rate at the process location (e.g., glovebox surface) for each unit operation or workstation; and (3) the amount of time spent by workers in the area.

This last factor was determined from a time-motion study previously performed for the SIS project of direct “hands-in-gloves” labor required to perform each individual operation. Dose rate reduction and efficiency scaling factors were applied for operations that were assumed to be automated.

As indicated above, the collective annual doses (millirem per year) received by an individual is calculated based on the number of workers required for the various processes, the time spent in each process area, and the associated dose rates for each operation. The average individual dose is calculated as the collective exposure divided by the estimated number of radiological workers. The estimates of annual radiological doses and health effects to workers are provided in Table N.5.1.9–2 based on the flow process of Figure N.3.1.3.1–1. As shown in the table, the annual doses to individual workers for all levels of production would be below DOE limit of 5 rem (10 CFR Part §835.202), and would not exceed DOE recommended control level of 1 rem (10 CFR Part §835.1002). The projected number of fatal cancers in the workforce from annual operations would be 0.00086 (or 1 chance in 1,162 that the worker population would experience a fatal cancer per year of operations).

TABLE N.5.1.9–2.—Annual Radiological Impacts on Advanced Materials Program Workers

Number of Radiological Workers (FTEs)	21
Individual Workers^a	
Average individual whole body dose (rem/year)	6.8×10^{-2}
Average worker LCF probability ^b	4.1×10^{-5}
Worker Population	
Collective dose (person-rem/year)	1.4
LCFs ^b	8.6×10^{-4}

Source: Original.

^a The regulatory dose limit for an individual worker is 5,000 millirem per year (10 CFR Part §835). However, 10 CFR Part 835.1002 establishes a Control Level of 1,000 millirem per year. To reduce doses to levels that are as low as is reasonably achievable, an effective dose reduction plan would be enforced.

^b Based on a cancer risk estimator of 6.0×10^{-4} LCFs per person-rem.

FTEs = Full Time Equivalent workers; LCF = latent cancer fatality.

N.5.2 Proposed Action

The Proposed Action would take place in existing rooms in existing buildings. Therefore, there would be no impacts to land use and applicable plans, prehistoric and historic cultural resources, aesthetics and scenic resources, geologic resources (geologic hazards are considered as part of the accident screening), ecology, water resources (water use and wastewater treatment are discussed in utilities and energy), and noise.

N.5.2.1 Socioeconomic Characteristics and Environmental Justice

The Proposed Action would employ 27 people with an annual payroll of \$2.1 million to \$2.3 million. Some of these personnel are already employed at LLNL. However, it is assumed that up to 14 people may be new hires. The annual cost of equipment and supplies is approximately \$3 million. The addition of new workers would be within the 5 to 8 percent turnover/new hire

rate at LLNL, or through internal transfers to other projects. There would be no impacts to employment, population, housing, economic factors, or environmental justice.

N.5.2.2 Community Services

The Proposed Action would not be a special generator of nonhazardous solid waste. The amount of waste would be proportional to the number of employees. Since approximately 14 employees could be new hires, a 0.1 percent increase in the workforce, the increase in nonhazardous solid waste would be a 0.1 percent increase, or 6.1 cubic meters per year.

N.5.2.3 Air Quality

The laser, separator and chemical processing activities would generate air emissions. Gaseous effluents would be generated in the glovebox operations. These effluents would be exhausted through the Building 332 stack. Radioactive atmospheric releases during normal operations are shown in Table N.5.2.3–1. The release pathway is through the glovebox filter and two stages of facility HEPA filtration prior to discharge to the building stack. A HEPA filter efficiency of 99.97 percent was assumed.

**TABLE N.5.2.3–1.—Estimated Annual Radioactive Release for Normal Operations
(Proposed Action)**

Element	Feed Composition Weight		Release ($\mu\text{Ci}/\text{year}$)
		Percentage	
Plutonium		99.22	7.4×10^{-3}
Americium		0.64	8.6×10^{-6}
Uranium		0.14	9.4×10^{-9}
Total Atmospheric Release			7.4×10^{-3}

Source: Original.

$\mu\text{Ci}/\text{yr}$ = microcuries per year.

N.5.2.4 Noise

The activities in the Materials Processing Laboratory under the Proposed Action would be the same as current activities. The noise level would be the same as current levels. The laser and separators are not a large source of noise. The Proposed Action would not increase noise in Building 332.

N.5.2.5 Traffic and Transportation

The ITP would not employ enough new hires to affect traffic counts in the LLNL area. The ITP would not require the rerouting of any traffic.

Under the Proposed Action, the radioactive feed materials would be transported to LLNL for processing into materials useful for SBSSMP. The resulting product, byproducts, and transuranic waste would be shipped to locations offsite. The feed, product, and byproduct from the Isotope Separation step (see Figure 3.2.2–1 and 3.2.2–2) would be shipped in Safe Secure Transport (SST) vehicles in model 9975 containers. If the plutonium from the molten-salt extraction step was to be recovered and recycled, this byproduct from the molten-salt extraction step americium/plutonium button (see Figures 3.2.2–1 and 3.2.2–2) would be shipped to LANL in SST's in 9975 containers. If the plutonium in the molten-salt extraction process was not recycled, the byproduct would be shipped to WIPP as transuranic waste in Transuranic Package

Transporter-II (TRUPACT-II) containers on trucks. All other transuranic waste would also be shipped to WIPP in TRUPACT-II containers on trucks.

Using limitations on mass, heat, and fissile gram equivalents specified by the container certifications, the number of containers per shipment campaign was calculated. Based on the number of containers that can be transported on the specified trucks, the number of shipments was calculated. For purposes of analysis, it was assumed that Safe Secure transporters carry 25 Model 9975 containers. Trucks for transuranic waste carry up to three TRUPACT-II. Table N.5.2.5–1 describes the shipment campaigns under the ITP Proposed Action. The shipment campaign list contains two options for shipment of the americium/plutonium button. Only one option would be selected.

The methodology for calculating radiological consequences from this transportation is described in Section 5.1.11 and Appendix J of this LLNL SW/SPEIS. For incident-free transport (no accidents), the consequence would be the radiation dose received by the truck drivers and members of the public driving on the highways, living near the highways, and present at rest stops. Because of the small amount of radioactive material being transported and the shielding of the containers and truck, the actual radiation dose rate near the truck is expected to be immeasurably small. For analysis purposes, a small dose rate of one millirem per hour was assumed near the trucks. Table N.5.2.5–2 presents the collective dose and number of LCFs from transportation under the ITP Proposed Action.

TABLE N.5.2.5–1.— Integrated Technology Project Shipment Campaigns Under the Proposed Action

Material	Origin	Destination	Packaging	Number of Containers	Number of Shipments/Year
SRS-Origin Material					
Feed	SRS	LLNL	9975	79	4
Product	LLNL	LANL	9975	1	1
Byproduct	LLNL	SRS	9975	66	3
Am/Pu Button (LANL case)	LLNL	LANL	9975	14	1
Am/Pu Button (WIPP case)	LLNL	WIPP	TRUPACT-II	19	7
TRU Waste	LLNL	WIPP	TRUPACT-II	2	1
Hanford-Origin Material					
Feed	Hanford	LLNL	9975	49	2
Product	LLNL	LANL	9975	1	1
Byproduct	LLNL	Hanford	9975	24	1
Am/Pu Button (LANL case)	LLNL	LANL	9975	23	1
Am/Pu Button (WIPP case)	LLNL	WIPP	TRUPACT-II	32	11
TRU Waste	LLNL	WIPP	TRUPACT-II	3	1

Source: Original.

Am/Pu = americium/plutonium; LANL = Los Alamos National Laboratory; SRS = Savannah River Site; TRU = transuranic; TRUPACT-II = transuranic package transporter-II; WIPP = Waste Isolation Pilot Plant.

TABLE N.5.2.5–2.—Annual Impacts from Incident Free Radiological Transportation

Material	Occupation (drivers)		Public	
	Collective Dose (person-rem)	Number of LCFs	Collective Dose (person-rem)	Number of LCFs
SRS-Origin Material				
Feed	9.4×10^{-2}	5.6×10^{-5}	1.9×10^{-1}	1.1×10^{-4}
Product	1.1×10^{-2}	6.4×10^{-6}	1.7×10^{-3}	1.0×10^{-6}
Byproduct	7.1×10^{-2}	4.2×10^{-5}	1.4×10^{-1}	8.4×10^{-5}
Am/Pu Button (LANL case)	9.3×10^{-3}	5.6×10^{-6}	6.9×10^{-3}	4.1×10^{-6}
Am/Pu Button (WIPP case)	6.1×10^{-2}	3.6×10^{-5}	1.3×10^{-1}	7.7×10^{-5}
TRU Waste	8.7×10^{-3}	5.2×10^{-6}	1.8×10^{-2}	1.1×10^{-5}
Hanford-Origin Material				
Feed	1.6×10^{-2}	9.7×10^{-6}	4.4×10^{-2}	2.7×10^{-5}
Product	1.1×10^{-2}	6.4×10^{-6}	1.7×10^{-3}	1.0×10^{-6}
Byproduct	8.1×10^{-3}	4.8×10^{-6}	2.1×10^{-2}	1.3×10^{-5}
Am/Pu Button (LANL case)	9.3×10^{-3}	5.6×10^{-6}	2.0×10^{-2}	1.2×10^{-5}
Am/Pu Button (WIPP case)	9.5×10^{-2}	5.7×10^{-5}	2.0×10^{-1}	1.2×10^{-4}
TRU Waste	8.7×10^{-3}	5.2×10^{-6}	1.8×10^{-2}	1.1×10^{-5}

Source: Original.

Am/Pu = americium/plutonium; LANL = Los Alamos National Laboratory; LCF = latent cancer fatality; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Should a shipment undergo a high-impact accident with fire, radioactive materials could be released and expose members of the public. Table N.5.2.5–3 presents the highest consequences of an accident for each shipment campaign and the estimated probability of that accident occurring. Although lesser impact accidents with higher probability could occur, they would release a lesser amount or no radioactivity. Also the same high-impact accident could occur in a lesser-populated area with lesser impacts but somewhat greater probability.

To determine consequences of complete scenarios that can be implemented, the shipment campaigns must be combined into a scenario involving five parts: feed, product, byproduct, americium/plutonium button, and transuranic waste. Table N.5.2.5–4 presents the complete scenario consequences for both the SRS- and Hanford-origin feed. For incident-free consequences, the reported values are sums from Table N.5.2.5–2 based on the assumption that the americium/plutonium button is shipped to WIPP as transuranic waste. Because accident consequences do not sum, the accidents with the highest consequences from Table N.5.2.5–3 are provided.

The total probability (sum of probabilities for all accidents with releases) of any accident occurring that releases radioactive material is 4.0×10^{-6} per year for SRS-origin material, with consequences ranging from 6.5×10^{-3} to 3.5×10^4 person-rem (3.9×10^{-6} to 21 LCFs). For Hanford-origin material, the total probability of any accident that releases radioactive material is also 4.0×10^{-6} per year with consequences ranging from 6.5×10^{-3} to 4.6×10^4 person-rem (3.9×10^{-6} to 28 LCFs).

TABLE N.5.2.5–3.—Annual Accident Consequences and Probabilities from Radiological Transportation

Material	Collective Dose (person-rem)	Number of LCFs	Probability
SRS-Origin Material			
Feed	2.6×10^4	16	2.8×10^{-11}
Product	7.9×10^3	4.8	3.5×10^{-12}
Byproduct	2.7×10^4	16	2.1×10^{-11}
Am/Pu Button (LANL case)	7.2×10^3	4.3	3.5×10^{-12}
Am/Pu Button (WIPP case)	3.5×10^4	21	5.9×10^{-9}
TRU Waste	1.3×10^4	7.9	8.4×10^{-10}
Hanford-Origin Material			
Feed	2.4×10^4	14	8.0×10^{-12}
Product	2.0×10^3	1.2	3.5×10^{-12}
Byproduct	2.4×10^4	14	4.0×10^{-12}
Am/Pu Button (LANL case)	2.8×10^3	1.7	3.5×10^{-12}
Am/Pu Button (WIPP case)	3.2×10^4	19	9.2×10^{-9}
TRU Waste	4.6×10^4	28	8.4×10^{-10}

Source: Original.

Am/Pu = americium/plutonium; LCF = latent cancer fatality; LANL = Los Alamos National Laboratory; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

Table N.5.2.5–4.—Complete Scenario Impacts

	Incident Free Impacts		Highest Consequence Accident Impacts		
	Collective Dose (person-rem)	Number of LCFs	Collective Dose (person-rem)	Number of LCFs	Probability per Year
SRS-origin Material	5.5×10^{-1}	3.3×10^{-4}	3.5×10^4	21	5.9×10^{-9}
Hanford-origin Material	1.6×10^{-1}	9.5×10^{-5}	4.6×10^4	28	8.4×10^{-10}

Source: Original.

LCF = latent cancer fatality; SRS=Savannah River Site.

N.5.2.6 Utilities and Energy

The estimated electrical usage for the ITP including powering the lasers is 2.8 gigawatt hours per year. This usage is less than 1 percent of the LLNL usage in the year 2001 and well within the capacity of the LLNL electricity supply.

The main cooling of the laser system is supplied by a dual channel closed loop cooling system containing a water-cooled condenser section. The LLNL Low Pressure Cooling Water system would be used to supply cooling water. The cooling water would be recirculated back into the LLNL system. Any primary loop cooling water that was accidentally fouled by the laser chemicals would be disposed of per LLNL hazardous waste disposal guidelines. The separators would use cooling water from the Building 332 cooling water system.

The ITP would need clean dry compressed air at 75 to 100 pounds per square inch on a routine basis, and on occasion, limited amounts of argon. The supply of these gases is within the normal operations of Building 332.

N.5.2.7 *Materials and Waste Management*

Materials Management

The laser system would be solid state lasers optically pumping recirculating organic dye lasers. The organic dyes (e.g., R6G) are stored in either powder or liquid form. The dyes would be mixed with ethyl, isopropyl, or methyl alcohol depending on the dye requirements. About 50 liters of the mixed would be used initially and about 15 liters per year replenishment would be required. Total alcohol use and storage is bounded by one 55-gallon drum.

The organic dyes are mutagenic and carcinogenic chemicals. Handling and storage of these chemicals is routine for the laser program. Proper environment and safety procedures as described in the LLNL Health and Safety Manual for handling and storage would be implemented.

Waste Management

It is estimated that the ITP operations would generate hazardous, radioactive, and mixed waste. Table N.5.2.7–1 presents the amounts for each type of waste generated annually from the ITP. This generation is slightly above the average waste generation for the Materials Processing Laboratory, but within the rate generated during historical surges in operations. Under the Proposed Action, transuranic waste generated at Superblock would be shipped directly to WIPP following a certification process (LLNL 2003x).

TABLE N.5.2.7–1.—Annual Waste Generation from the Proposed Action

Waste Type	Form	Annual Amount (55 gallon drums)
Hazardous	Solid	1
	Liquid	1
LLW	Solid	50
TRU Waste ^a	Solid	50
Mixed Waste	Solid	2

Source: LLNL 2003bj.

^a Includes Am/Pu button shipments to WIPP.

LLW = low-level waste; TRU = transuranic.

N.5.2.8 *Decontamination and Decommissioning*

D&D for the ITP involves the separator related equipment including gloveboxes and process cases. The Material Processing Laboratory systems provide general support to multiple Plutonium Facility programs and would not be D&D at the end of the ITP activities.

The D&D of the separator and laser equipment would take approximately 20 months and would result in the one-time generation of 4 cubic meters of transuranic waste, 12 cubic meters of low level waste, and 0.5 cubic meters of hazardous waste.

N.5.2.9 Occupational Protection

Impacts from Normal Operations

Public Health Impacts

NNSA expects minimal public health impacts from the radiological consequences of ITP operations. Public radiation doses would likely occur from airborne releases only. Table N.5.2.9–1 lists the projected normal radionuclide emission rates for the ITP process, the incremental radiation doses estimated for the public (offsite MEI and collective population dose), and the corresponding incremental LCFs which represent the impacts of the airborne radioactive releases.

TABLE N.5.2.9–1.—Annual Radiological Impacts on the Public from Proposed Action

Radionuclide	Offsite MEI			Offsite Population ^a	
	Emission Rate (Ci/yr)	Dose (mrem/yr)	LCFs ^{b,c}	Dose (person-rem)	LCFs ^c
Plutonium	7.4×10^{-9}	5.9×10^{-8}	3.6×10^{-14}	3.3×10^{-6}	2.0×10^{-9}
Americium	8.6×10^{-12}	3.2×10^{-9}	1.9×10^{-15}	7.9×10^{-8}	4.7×10^{-11}
Uranium	9.4×10^{-15}	8.5×10^{-13}	5.1×10^{-19}	2.1×10^{-11}	1.3×10^{-14}
Total		6.2×10^{-8}	3.7×10^{-14}	3.3×10^{-6}	2.0×10^{-9}

Source: Original.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^b Indicates the increased probability of a LCF to this individual receptor.

^c Based on a cancer risk estimator of 0.0006 LCFs per person-rem.

Ci/yr = curies per year; LCF = latent cancer fatality; MEI = maximally exposed individual.

As shown in the table, the expected annual radiation dose to the offsite MEI would be much smaller than the limit of 10 millirem per year set by both the EPA (40 CFR Part 61) and DOE (DOE O 5400.5) for airborne releases of radioactivity. The risk of a LCF to this individual from operations would be approximately 3.7×10^{-14} per year (i.e., about 1 chance in 27 trillion per year of a LCF). The projected number of fatal cancers to the population within 50 miles would be 2.0×10^{-9} per year (i.e., about 1 LCF in 500 million years).

Impacts to ITP Workers

Estimates of annual radiological doses to workers involved with ITP facility operations are a function of (1) the number of radiological workers, as determined in the development of the ITP staffing estimate for each process; (2) the average working dose rate at the process location (e.g., glovebox surface) for each unit operation or workstation; and (3) the amount of time spent by workers in the area. This last factor was determined from a time-motion study previously performed for the SIS project of direct “hands-in-gloves” labor required to perform each individual operation. Dose rate reduction and efficiency scaling factors were applied for operations that were assumed to be automated. Automation, local shielding, and administrative measures have been utilized to achieve minimum worker doses.

The average individual dose is calculated as the collective exposure divided by the estimated number of radiological workers. Exposure to individual workers would be monitored to ensure that no individual worker would exceed the LLNL limit for worker dose. Some work may be rotated among workers to ensure individual worker dose remains within the LLNL limit.

The estimates of annual radiological doses and health effects to workers are provided in Table N.5.2.9–2. As shown in the table, the annual doses to individual workers for all levels of production would be below DOE limit of 5 rem (10 CFR Part §835.202), but could exceed DOE recommended Control Level of 1 rem (10 CFR Part §835.1002). There are no projected fatal cancers in the workforce from annual operations. The collective dose to all workers of 32.2 person-rem per year would result in no LCFs (calculated value of 1.9×10^{-2} or 1 chance in 50 that the worker population would experience a fatal cancer per year of operations).

TABLE N.5.2.9–2.—Annual Radiological Impacts for Proposed Action

Materials and Storage Retrieval (MSR) Workers	
Number of Workers	10
Average individual whole body dose (rem/year)	1.0
Average worker LCF probability ^b	6.0×10^{-4}
Collective dose (person-rem/year)	10
LCFs ^b	6.0×10^{-2}
Radiological Workers other than MSR (FTEs)	
Number of Workers	19
Average individual whole body dose (rem/year) ^a	1.17
Average worker LCF probability ^b	7.0×10^{-4}
Worker Population	
Collective dose (person-rem/year)	22.2
LCFs ^b	1.3×10^{-2}
All Workers	
Collective dose (person-rem/year)	32.2
LCFs ^b	1.9×10^{-2}

Source: Original.

^a The regulatory dose limit for an individual worker is 5,000 millirem per year (10 CFR Part 835). However, 10 CFR Part §835.1002 establishes a Control Level of 1,000 millirem per year. To reduce doses to levels that are as low as is reasonably achievable, an effective dose reduction plan would be enforced.

^b Based on a cancer risk estimator of 6.0×10^{-3} LCFs per person-rem.
FTEs = Full Time Equivalent workers; LCF = latent cancer fatality.

N.5.3 Reduced Operation Alternative

Under the Reduced Operation Alternative, neither the No Action Alternative, AMP, nor the Proposed Action, ITP, would be implemented. There would be no impacts to any of the environmental resource aspects discussed in Chapter 4 of this LLNL SW/SPEIS. The purpose and need discussed in Section N.1 would not be fulfilled. The ongoing loss of experienced personnel would continue without replacement. This technology would not be developed further and knowledgeable personnel would eventually be lost to other employment or retirement.

N.5.4 Bounding Accident Scenarios

Impacts from Facility Accidents

This section presents the potential impacts on workers (both involved and noninvolved) and the public due to potential accidents associated with operation of the AMP and ITP. An accident is a sequence of one or more unplanned events with potential outcomes that endanger the health and safety of workers and the public. An accident can involve a combined release of energy and hazardous materials (radiological or chemical) that might cause prompt or latent health effects. The sequence usually begins with an initiating event, such as a human error, equipment failure, or earthquake, followed by a succession of other events that could be dependent or independent of the initial event, which dictate the accident's progression and the extent of materials released. Initiating events fall into three categories:

- *Internal initiators* normally originate in and around the facility, but are always a result of facility operations. Examples include equipment or structural failures and human errors.
- *External initiators* are independent of facility operations and normally originate from outside the facility. Some external initiators affect the ability of the facility to maintain its confinement of hazardous materials because of potential structural damage. Examples include aircraft crashes, vehicle crashes, nearby explosions, and toxic chemical releases at nearby facilities that affect worker performance.
- *Natural phenomena initiators* are natural occurrences that are independent of facility operations and occurrences at nearby facilities or operations. Examples include earthquakes, high winds, floods, and lightning. Although natural phenomena initiators are independent of external facilities, their occurrence can involve those facilities and compound the progression of the accident.

If an accident were to occur involving the release of radioactive or chemical materials, workers, members of the public, and the environment would be at risk. Workers in the facility where the accident occurs would be particularly vulnerable to the effects of the accident because of their location. The offsite public and noninvolved workers would also be at risk of exposure to the extent that meteorological conditions exist for the atmospheric dispersion of released hazardous materials. Using approved computer models, the atmospheric dispersion of released hazardous materials and their effects were predicted. However, prediction of latent potential health effects becomes increasingly difficult to quantify for facility workers as the distance between the accident location and the worker decreases. This is because the individual worker exposure cannot be precisely defined with respect to the presence of shielding and other protective features. The worker also may be injured or killed by physical effects of the accident itself.

Radiological Accidents

The radiological impacts to three receptors were estimated: (1) the MEI at the LLNL boundary, (2) the offsite population within 50 miles of the Livermore Site, (3) a noninvolved worker 100 meters from the release point, and (4) the population of noninvolved workers. Each of the analyzed scenarios could result in the fatality or serious injury of one or more involved workers depending on the number present.

Tables N.5.4–1 and N.5.4–2 show the frequencies and consequences of the postulated set of accidents for the No Action Alternative for the public (offsite MEI and the general population living within 50 miles of the facility), a hypothetical noninvolved worker, and the population of noninvolved workers for both median and unfavorable meteorological conditions. No accidents were postulated for the Reduced Operation Alternative as AMP activities would be discontinued and the Proposed Action would not be implemented. Tables 5.4–3 and 5.4–4 show this same information for the Proposed Action. The accidents listed in these tables were selected from the accident scenarios associated with current plutonium operations in Building 332 as described in the Building 332 Safety Analysis Report (LLNL 2003t) and accident scenarios associated with separator operations described in previous analyses prepared to support the EDS (LLNL 1989).

The selection process and screening criteria, used in Appendix D, ensure that the accidents chosen for evaluation in this LLNL SW/SPEIS bound the impacts of all reasonably foreseeable accidents that could occur at the ITP and AMP.

The bounding accident for the Proposed Action is a room fire (unfiltered) because of the potential for fatalities and offsite exposure. This scenario would also apply to ITP operations. This accident scenario has a frequency of 3.9×10^{-7} . The material at risk is assumed to be the entire maximum potential inventory of 60 kilograms (fuel-grade equivalent plutonium) for all programs. Applying release fractions that are consistent with those in the Building 332 Safety Analysis Report, this event leads to a release into the environment of 0.75 grams of fuel-grade equivalent plutonium.

Another accident associated with current plutonium operations in Building 332 is a radioactive material spill (unfiltered). This scenario would also apply to ITP operations. This accident scenario has a frequency of 1.0×10^{-6} per year, and leads to a release into the environment of 0.11 grams of fuel-grade equivalent plutonium.

An inadvertent plutonium criticality for a powder in a workstation is also a credible accident scenario for current plutonium operations in Building 332. This scenario would also apply to ITP operations. This scenario has a frequency of 3.2×10^{-5} per year and is assumed to involve 1×10^{-5} fissions and an associated release of radioactive noble gases (i.e., isotopes of krypton and xenon) and volatile substances (i.e., isotopes of iodine). The release rates are shown in Appendix D of this LLNL SW/SPEIS.

Potential accident scenarios associated with the separation process include the Design-Basis Fire and a radioactive materials spill. The Design-Basis Fire has a frequency of 2.0×10^{-4} per year (LLNL 1989) and would result in a release to the environment of 0.003 grams of fuel-grade equivalent plutonium.

The radioactive materials spill scenario associated with the separation process has a frequency of 10^{-6} to 10^{-4} per year (LLNL 1989) and would result in a release to the environment of 0.0037 grams of fuel-grade equivalent plutonium.

Consequences of accidental radiological releases were determined using the MELCOR Accident Consequence Code System, Version 2 (MACCS2) computer code (Chanin and Young 1997). MACCS2 is a DOE/Nuclear Regulatory Commission-sponsored computer code that has been widely used in support of probabilistic risk assessments for the nuclear power industry and in support of safety and the *National Environmental Policy Act* documentation for facilities throughout DOE complex. The MACCS2 code is further described in Appendix D.

The accident with the highest consequence to the offsite population (Table N.5.4–3) is the room fire (unfiltered). The increased number of LCFs in the offsite population would be 0.17 per year (i.e., about 1 chance in 6 of a LCF). The risk of a LCF to the offsite MEI would be 2.6×10^{-4} (i.e., about 1 chance in 3,790 of a LCF). The risk of a LCF to a noninvolved worker located at a distance of 100 meters from the accident would be 3.1×10^{-3} (i.e., about 1 chance in 320 per year of a LCF). The increased number of LCFs in the population of noninvolved workers would be 0.56 (or 1 chance in 1.8 of a LCF).

Table N.5.4–1.—Accident Frequency and Consequences for the No Action Alternative (Median Meteorology)

Accident	MEI			Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
	Frequency (per year)	Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c	Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c
Room Fire, Unfiltered	3.9×10^{-7}	1.5×10^{-1}	8.8×10^{-5}	9.3×10^1	5.6×10^{-2}	1.7	9.9×10^{-4}	3.1×10^2	1.9×10^{-1}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	7.4×10^{-2}	4.4×10^{-5}	4.1×10^1	2.4×10^{-2}	8.5×10^{-1}	5.1×10^{-4}	1.4×10^2	8.5×10^{-2}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	1.4×10^{-2}	8.7×10^{-6}	3.3×10^{-1}	2.0×10^{-4}	6.6×10^{-2}	4.0×10^{-5}	1.6×10^1	9.4×10^{-3}
Design Basis Fire (Separation Process)	2.0×10^{-4}	1.8×10^{-3}	1.1×10^{-6}	1.1	6.7×10^{-4}	2.0×10^{-2}	1.2×10^{-5}	3.7	2.2×10^{-3}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	2.5×10^{-3}	1.5×10^{-6}	1.4	8.2×10^{-4}	8.0×10^{-4}	4.8×10^{-7}	4.8	2.9×10^{-3}
Aircraft Accident	1.5×10^{-6}	1.5×10^{-1}	8.9×10^{-5}	9.7×10^1	5.8×10^{-2}	1.8	1.1×10^{-3}	3.2×10^2	2.0×10^{-1}

Source: Original.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.^b Increased likelihood of latent cancer fatalities.^c Increased number of latent cancer fatalities.

LCF = latent cancer fatality; MEI = maximally exposed individual.

**N.5.4-2.—Accident Frequency and Consequences for the No Action Alternative
(Unfavorable Meteorological Conditions)**

Accident	Frequency (per year)	Offsite MEI		Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
		Dose (rem)	LCFs ^b	Dose (person- rem)	LCFs ^c	Dose (rem)	LCFs ^b	Dose (person- rem)	LCFs ^c
Room Fire, Unfiltered	3.9×10^{-7}	2.8	1.7×10^{-3}	1.1×10^3	6.5×10^{-1}	1.5×10^1	8.9×10^{-3}	2.6×10^3	1.6
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	1.4	8.4×10^{-4}	7.2×10^2	4.3×10^{-1}	9.6	5.8×10^{-3}	1.1×10^3	6.3×10^{-1}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	2.7×10^{-2}	1.6×10^{-5}	1.1×10^1	6.4×10^{-3}	3.8×10^{-1}	2.3×10^{-4}	2.2×10^1	1.4×10^{-2}
Design Basis Fire (Separation Process)	2.0×10^{-4}	3.4×10^{-2}	2.0×10^{-5}	1.3×10^1	7.8×10^{-3}	1.8×10^{-1}	1.1×10^{-4}	3.1×10^1	1.9×10^{-2}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	4.7×10^{-2}	2.8×10^{-5}	2.4×10^1	1.4×10^{-2}	3.2×10^{-1}	1.9×10^{-4}	3.6×10^1	2.2×10^{-2}
Aircraft Accident	1.5×10^{-6}	2.89	1.7×10^{-3}	1.2×10^3	7.2×10^{-1}	2.4×10^1	1.4×10^{-2}	2.5×10^3	1.5

Source: Original.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^b Increased likelihood of latent cancer fatalities.

^c Increased number of latent cancer fatalities.

LCF = latent cancer fatality.

**TABLE N.5.4-3.—Integrated Technology Project Accident Frequency and Consequences for the Proposed Action
(Median Meteorology)**

Accident	MEI			Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
	Frequency (per year)	Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c	Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c
Room Fire, Unfiltered	3.9×10^{-7}	4.4×10^{-1}	2.6×10^{-4}	2.8×10^2	1.7×10^{-1}	4.94	3.1×10^{-3}	9.3×10^2	5.6×10^{-1}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	7.4×10^{-2}	4.4×10^{-05}	4.1×10^1	2.4×10^{-2}	8.4×10^{-1}	5.1×10^{-4}	1.4×10^2	8.5×10^{-2}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	1.5×10^{-2}	8.7×10^{-6}	3.3×10^{-1}	2.0×10^{-4}	6.6×10^{-2}	4.0×10^{-5}	1.6×10^1	9.5×10^{-3}
Design Basis Fire (Separation Process)	2.0×10^{-4}	1.8×10^{-3}	1.1×10^{-6}	1.1	6.7×10^{-4}	2.0×10^{-2}	1.2×10^{-5}	3.7	2.2×10^{-3}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	2.5×10^{-3}	1.5×10^{-6}	1.4	8.2×10^{-4}	8.0×10^{-4}	4.8×10^{-7}	4.8	2.9×10^{-3}
Aircraft Accident	1.5×10^{-6}	1.5×10^{-1}	8.9×10^{-5}	9.7×10^1	5.8×10^{-2}	1.8×10^1	1.1×10^{-3}	3.2×10^2	2.0×10^{-1}

Source: Original.

^aBased on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^bIncreased likelihood of a LCF.

^cIncreased number of LCFs.

LCF = latent cancer fatality; MEI = maximally exposed individual.

**TABLE N.5.4–4.—Integrated Technology Project Accident Frequency and Consequences for the Proposed Action
(Unfavorable Meteorological Conditions)**

Accident	Frequency (per year)	Offsite MEI		Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
		Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c	Dose (rem)	LCFs ^b	Dose (person-rem)	LCFs ^c
Room Fire, Unfiltered	3.9×10^{-7}	8.4	5.0×10^{-3}	3.3×10^3	2.0	4.5×10^1	2.7×10^{-2}	7.8×10^3	4.7
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	1.4	8.4×10^{-4}	7.2×10^2	4.3×10^{-1}	9.9	5.8×10^{-3}	1.1×10^3	6.3×10^{-1}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	2.7×10^{-2}	1.6×10^{-5}	1.1×10^1	6.4×10^{-3}	3.8×10^{-1}	2.3×10^{-4}	2.2×10^1	1.4×10^{-1}
Design Basis Fire (Separation Process)	2.0×10^{-4}	3.4×10^{-2}	2.0×10^{-5}	1.3×10^1	7.8×10^{-3}	1.8×10^{-1}	1.1×10^{-4}	3.1×10^1	1.9×10^{-2}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	4.7×10^{-2}	2.8×10^{-5}	2.4×10^1	1.4×10^{-2}	3.2×10^{-1}	1.9×10^{-4}	3.6×10^1	2.1×10^{-2}
Aircraft Accident	1.5×10^{-6}	2.9	1.7×10^{-3}	1.2×10^3	7.1×10^{-1}	2.4×10^1	1.4×10^{-2}	2.5×10^3	1.5

Source: Original.

^aBased on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^bIncreased likelihood of a LCF.

^cIncreased number of LCFs.

LCF = latent cancer fatality.

Using data representing unfavorable meteorological conditions, the increased number of LCFs in the offsite population would be 2.0 per year. The risk of a LCF to the offsite MEI would be 5.0×10^{-3} (i.e., about 1 chance in 198 of a LCF). The risk of a LCF to a noninvolved worker located at a distance of 100 meters from the accident would be 2.7×10^{-2} (i.e., about 1 chance in 37 of a LCF). The increased number of LCFs in the population of noninvolved workers would be 4.7.

Tables N.5.4–5 and N.5.4–6 show the frequency and risk of the postulated set of accidents for the No Action Alternative for a noninvolved worker (assumed to be a worker located 100 meters from the release point), the population of noninvolved workers, and the public (offsite MEI and the general population living within 50 miles of LLNL) for both median and unfavorable meteorological conditions. The term “risk” means the consequence of the accident (radiation dose or LCFs) multiplied by the frequency for that accident (per year). Tables N.5.4–7 and N.5.4–8 show this same information for the Proposed Action.

Nonradiological Accidents

Accidents were evaluated for previous applications of the AVLIS technology where the amount of dye used was 10 to 100 times the amount to be used in the ITP (LLNL 1992b). For the previous system, spills, fires, and explosions were assessed involving hundreds of gallons of ethanol or dye solution. Table N.5.4–9 presents the maximum exposures associated with these accidents.

TABLE N.5.4–9.—Hazardous Chemical Exposures Due to Accidents Associated with Large-scale AVLIS Activities

Compound	Receptor	Distance	Exposure	Effect
Ethanol Vapor	Onsite	100 m	23 mg/m ³	Negligible
	Offsite	320 m	2.3 mg/m ³	Negligible
Dye Release	Onsite	100 m	1.3 mg/m ³	Negligible
	Offsite	320 m	0.075 mg/m ³	Negligible

Source: Original.

m = meters; mg/m³ = milligrams per cubic meter.

Given that the amounts dye and alcohol involved in the analyzed accidents is orders of magnitude above the entire inventory for the ITP, the impacts of accidents associated with the laser system would be limited to the physical affects of any fire and bounded by other nonradiological accidents.

TABLE N.5.4–5.—Accident Frequency and Risk for the No Action Alternative (Median Meteorology)

Accident	MEI			Offsite Population		Individual Noninvolved Worker		Noninvolved Worker Population	
	Frequency (per year)	Dose Risk (rem)	LCFs Risk	Dose Risk (person-rem)	LCFs Risk	Dose Risk (rem)	LCFs Risk	Dose Risk (person-rem)	LCFs Risk
Room Fire, Unfiltered	3.9×10^{-7}	5.7×10^{-8}	3.4×10^{-11}	3.6×10^{-5}	2.2×10^{-8}	6.4×10^{-7}	3.8×10^{-10}	1.2×10^{-4}	7.2×10^{-8}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	7.4×10^{-8}	4.4×10^{-11}	4.1×10^{-5}	2.4×10^{-8}	8.5×10^{-7}	5.1×10^{-10}	1.4×10^{-4}	8.5×10^{-8}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	4.6×10^{-7}	2.8×10^{-10}	1.0×10^{-5}	6.3×10^{-9}	2.1×10^{-6}	1.3×10^{-9}	5.0×10^{-4}	3.3×10^{-7}
Design Basis Fire (Separation Process)	2.0×10^{-4}	3.5×10^{-7}	2.1×10^{-10}	2.2×10^{-4}	1.3×10^{-7}	4.0×10^{-6}	2.4×10^{-9}	7.4×10^{-4}	4.5×10^{-7}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	2.5×10^{-7}	1.5×10^{-10}	1.4×10^{-4}	8.2×10^{-8}	8.0×10^{-8}	4.8×10^{-11}	4.8×10^{-4}	2.9×10^{-7}
Aircraft Accident	1.5×10^{-6}	2.2×10^{-7}	1.3×10^{-10}	1.4×10^{-4}	8.8×10^{-8}	2.8×10^{-6}	1.7×10^{-9}	4.8×10^{-4}	2.9×10^{-7}

Source: Original.

LCF = latent cancer fatality; MEI = maximally exposed individual.

**TABLE N.5.4–6.—Accident Frequency and Risk for the No Action Alternative
(Unfavorable Meteorological Conditions)**

Accident	MEI			Offsite Population		Individual Noninvolved Worker		Noninvolved Worker Population	
	Frequency (per year)	Dose Risk (rem)	LCFs Risk	Dose Risk (person-rem)	LCFs Risk	Dose Risk (rem)	LCFs Risk	Dose Risk (person-rem)	LCFs Risk
Room Fire, Unfiltered	3.9×10^{-7}	1.1×10^{-6}	6.6×10^{-10}	4.2×10^{-4}	2.5×10^{-7}	5.8×10^{-6}	3.5×10^{-9}	1.0×10^{-3}	6.1×10^{-7}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	1.4×10^{-6}	8.4×10^{-10}	7.2×10^{-4}	4.3×10^{-7}	9.6×10^{-6}	5.8×10^{-9}	1.1×10^{-3}	6.3×10^{-7}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	8.8×10^{-7}	5.3×10^{-10}	3.4×10^{-4}	2.0×10^{-7}	1.2×10^{-5}	7.3×10^{-9}	7.2×10^{-4}	4.3×10^{-7}
Design Basis Fire (Separation Process)	2.0×10^{-4}	6.7×10^{-6}	4.0×10^{-9}	2.6×10^{-3}	1.6×10^{-6}	3.6×10^{-5}	2.1×10^{-8}	6.2×10^{-3}	3.7×10^{-6}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	4.7×10^{-6}	2.8×10^{-9}	2.4×10^{-3}	1.4×10^{-6}	3.2×10^{-5}	1.9×10^{-8}	3.6×10^{-3}	2.1×10^{-6}
Aircraft Accident	1.5×10^{-6}	4.4×10^{-6}	2.6×10^{-9}	1.8×10^{-3}	1.1×10^{-6}	3.6×10^{-5}	2.1×10^{-8}	3.8×10^{-3}	2.3×10^{-6}

Source: Original.

LCF = latent cancer fatality; MEI = maximally exposed individual.

TABLE N.5.4.-7.—Integrated Technology Project Accident Frequency and Risk for the Proposed Action (Median Meteorology)

Accident	Frequency (per year)	MEI		Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
		Dose Risk (rem)	LCFs Risk ^b	Dose Risk (person-rem)	LCFs Risk ^c	Dose Risk (rem)	LCFs Risk ^b	Dose Risk (person-rem)	LCFs Risk ^c
Room Fire, Unfiltered	3.9×10^{-7}	1.7×10^{-7}	1.0×10^{-10}	1.1×10^{-4}	6.6×10^{-8}	1.9×10^{-6}	1.2×10^{-9}	3.6×10^{-4}	2.2×10^{-7}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	7.4×10^{-8}	4.4×10^{-11}	4.1×10^{-5}	2.4×10^{-8}	8.5×10^{-7}	5.1×10^{-10}	1.4×10^{-4}	8.6×10^{-8}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	4.6×10^{-7}	2.8×10^{-10}	1.0×10^{-5}	6.3×10^{-9}	2.1×10^{-6}	1.3×10^{-9}	5.0×10^{-4}	3.0×10^{-7}
Design Basis Fire (Separation Process)	2.0×10^{-4}	3.5×10^{-7}	2.1×10^{-10}	2.2×10^{-4}	1.3×10^{-7}	4.0×10^{-6}	2.4×10^{-9}	7.4×10^{-4}	4.5×10^{-7}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	2.5×10^{-7}	1.5×10^{-10}	1.4×10^{-4}	8.2×10^{-8}	8.0×10^{-8}	4.8×10^{-11}	4.8×10^{-4}	2.9×10^{-7}
Aircraft Accident	1.5×10^{-6}	2.2×10^{-7}	1.3×10^{-10}	1.5×10^{-4}	8.7×10^{-8}	2.7×10^{-6}	1.7×10^{-9}	4.8×10^{-4}	3.0×10^{-7}

Source: Original.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^b Increased likelihood of a LCF.

^c Increased number of LCFs.

LCF = latent cancer fatality; MEI = maximally exposed individual.

**TABLE N.5.4–8.—Integrated Technology Project Accident Frequency and Risk for the Proposed Action
(Unfavorable Meteorological Conditions)**

Accident	Frequency (per year)	MEI		Offsite Population ^a		Individual Noninvolved Worker		Noninvolved Worker Population	
		Dose Risk (rem)	LCFs Risk ^b	Dose Risk (person- rem)	LCFs Risk ^c	Dose Risk (rem)	LCFs Risk ^b	Dose Risk (person- rem)	LCFs Risk ^c
Room Fire, Unfiltered	3.9×10^{-7}	3.3×10^{-6}	2.0×10^{-9}	1.3×10^{-3}	7.6×10^{-7}	1.7×10^{-5}	1.0×10^{-8}	3.0×10^{-3}	1.8×10^{-6}
Radioactive Material Spill, Unfiltered	1.0×10^{-6}	1.4×10^{-6}	8.4×10^{-10}	7.2×10^{-4}	4.3×10^{-7}	9.6×10^{-6}	5.8×10^{-9}	1.1×10^{-3}	6.3×10^{-7}
Inadvertant Plutonium Criticality for a Powder	3.2×10^{-5}	8.8×10^{-7}	5.3×10^{-10}	3.4×10^{-4}	2.0×10^{-7}	1.2×10^{-5}	7.3×10^{-9}	7.2×10^{-4}	4.3×10^{-7}
Design Basis Fire (Separation Process)	2.0×10^{-4}	6.7×10^{-6}	4.0×10^{-9}	2.6×10^{-3}	1.6×10^{-6}	3.6×10^{-5}	2.1×10^{-8}	6.2×10^{-3}	3.7×10^{-6}
Radioactive Material Spill (Separation Process)	10^{-6} to 10^{-4}	4.7×10^{-6}	2.8×10^{-9}	2.4×10^{-3}	1.4×10^{-6}	3.2×10^{-5}	1.9×10^{-8}	3.6×10^{-3}	2.1×10^{-6}
Aircraft Accident	1.5×10^{-6}	4.4×10^{-6}	2.6×10^{-9}	1.8×10^{-9}	1.1×10^{-6}	3.6×10^{-5}	2.1×10^{-8}	3.8×10^{-3}	2.3×10^{-6}

Source: Original.

^a Based on the population of approximately 6,900,000 persons residing within 50 miles of LLNL.

^b Increased likelihood of a LCF.

^c Increased number of LCFs.

LCF = latent cancer fatality; MEI = maximally exposed individual.

N.6 MITIGATION MEASURES

The regulations promulgated by the Council on Environmental Quality to implement the procedural provisions of the *National Environmental policy Act* (42 USC §4321) require that an EIS include a discussion of appropriate mitigation measures (40 CFR Parts §1502.14[f] and 16[h]). Mitigation measures are discussed in Section 5.6 of this LLNL SW/SPEIS. The applicable mitigation areas for the Proposed Action are (1) waste management, where an active program of waste minimization and pollution prevention exists, (2) occupational protection (worker dose), where automation, local shielding, and administrative modules ensure that worker doses are as low as reasonably achievable, and (3) accidents where a formal program of HEPA filter maintenance and inspection is in place to ensure that no degraded HEPA operation contributes to the impact of a ITP radiological accident.

N.7 REFERENCES

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