DOE/EA-1216

Environmental Assessment

for the

Parallex Project Fuel Manufacture and Shipment

Los Alamos National Laboratory
Los Alamos, New Mexico

Predecisional Draft

Date Prepared: August 18, 1997
Prepared by: US Department of Energy
Los Alamos Area Office

5513

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ACRONYMS AND TERMS

AECL	Atomic Energy of Canada Limited
ALARA	as low as reasonably achievable
ARF	airborne release fraction
ARIES	Advanced Recovery and Integrated Extraction System
CANDU	Canadian Deuterium Uranium
CED	committed effective dose
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
the County	Los Alamos County
CRL	Chalk River Laboratories
DOE	Department of Energy
DOT	Department of Transportation
DR	damage ratio
EA	Environmental Assessment
EDE	effective dose equivalent
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FSAR	Final Safety Analysis Report
g	gram
gal.	gallon
HEPA	high-efficiency particulate air
HRCQ	Highway Route Controlled Quantity
in.	inch
kg	kilogram
km	kilometer
L	liter
LANL	Los Alamos National Laboratory
lb	pound
LCFs	latent cancer fatalities
LLW	low-level waste
LPF	leak path factor
m	meter
m^2	square meter
m^3	cubic meter
MACCS	MELCOR Accident Consequence Code System
MAR	material at risk
MEI	maximum exposed individual
mi	mile
mi^2	square mile
mm	millimeter
MOX	mixed oxide
mrem	millirem
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
NRU	National Research Universal
O_2	dioxide
oz	ounce
Park	Royal Crest Trailer Park
PC	polychloroprene
PF-4	plutonium facility
Pu	plutonium
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man; dose equivalent
RF	respirable fraction
ROD	Record of Decision

S&D PEIS	Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement
SOPs	Safe Operating Procedures
SST	safe secure transport
SWEIS	Site-Wide Environmental Impact Statement
TA-54	Technical Area 54
TA-55	Technical Area 55
TRANSCOM	Transportation Command
TRU	transuranic
U	uranium
UNH	uranyl nitrate hexahydrate
WIPP	Waste Isolation Pilot Plant

EXPONENTIAL NOTATION: Many values in the text and tables of the Environmental Assessment are expressed in exponential notation. An exponent is the power to which the expression, or number, is raised. This form of notation is used to conserve space and to focus attention on comparisons of the order of magnitude of the numbers (see examples):

1×10^4	=	10,000
1×10^2	=	100
1×10^0	=	1
1×10^{-2}	=	0.01
1×10^{-4}	=	0.0001

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GLOSSARY

burning	To consume in a reactor through fission.
depleted uranium	Uranium whose content of the isotope U-235 is less than 0.7 percent, which is the U-235 content of naturally occurring uranium.
downblend	The addition of uranium dioxide to a *master blend* to achieve a lower plutonium concentration.
fission	The splitting of a heavy atomic nucleus into at least two nuclei of lighter elements, accompanied by the release of energy and generally one or more neutrons.
fissile	The ability of a material to be fissioned by slow (thermal) neutrons. Fissile materials include U-235, U-233, Pu-239, and Pu-241.
homogeneity	The extent to which mixing of two powders has occurred.
irradiation	The bombarding of atoms with nuclear particles to change the structure of the nucleus and produce radioactive atoms. Fuel which has been in a reactor is often called "irradiated" because it has been bombarded with neutrons and has become more radioactive.
master blend	A mixture of 10 percent plutonium oxide and 90 percent uranium dioxide. Typically the first step in a MOX fuel fabrication process.
mixed oxide (MOX)	A mixture of plutonium dioxide and depleted or natural uranium dioxide.
natural uranium	Uranium with a U-235 concentration of approximately 0.7 percent, the average concentration of U-235 in uranium in the natural state.
pit	The core element of a nuclear weapon's primary component.
rem	The special unit of any of the quantities of absorbed radiation expressed as dose equivalent.
rod	A sealed tube of zircaloy designed to contain MOX fuel pellets.
weapons-grade	(also weapons-usable) The characteristic of a material (plutonium) that has been removed from (or originally intended for) weapons. Typically, weapons-grade refers to a certain level of the Pu-239 isotope (approximately 96 percent) occurring in the plutonium.
sinter	The process to form a homogeneous mass by heating without melting.
zircaloy	Any member of a group of alloys containing mainly zirconium that possess resistance to corrosion and stability over a wide range of temperatures and types of radiation.

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EXECUTIVE SUMMARY

In order to safeguard and manage the 41.9 tons (38 metric tons) of weapons-usable plutonium declared surplus to the United States' defense needs, the Department of Energy (DOE) has decided to implement a program to provide for safe and secure storage of the material, and a strategy for the dispositioning of weapons-usable plutonium obtained from decommissioned nuclear weapons, as specified in the Record of Decision for the *Storage and Disposition of Weapons-Usable Materials Final Programmatic Environmental Impact Statement* (S&D PEIS). The S&D PEIS examines an alternative for the dispositioning of weapons-usable plutonium as a mixed oxide (MOX) fuel in a reengineered heavy-water-moderated reactor, such as a Canadian Deuterium Uranium (CANDU) reactor. MOX reactor fuel would be made by mixing weapons-usable plutonium in oxide form with uranium dioxide and pressed into dry fuel pellets. These pellets are then loaded into fuel rods. DOE must test and demonstrate the feasibility of burning MOX fuel in CANDU reactors as part of its ongoing mission to evaluate the disposition of surplus weapons-grade fissile materials. The ability to successfully reengineer and operate heavy-water-moderated CANDU reactors with MOX fuel cycles has never been demonstrated on any industrial scale.

The Proposed Action is for DOE to fabricate and transport a limited amount of MOX fuel as part of the Parallex Project. This test and demonstration project has been named Parallex (parallel experiment) because of the roles the United States, Russia, and Canada would have in this project—the U.S. and Russia supplying test material to Canada as a neutral third country. The U.S. MOX fuel would be fabricated at Los Alamos National Laboratory (LANL), New Mexico and transported in one, two, or three shipments in a Department of Transportation approved package container(s) to a Canadian port(s) of entry on one of three approved routes. At the Canadian border, the Atomic Energy of Canada Limited (AECL) would take possession of the fuel and complete its shipment to the test reactor at Chalk River Laboratories in Chalk River, Ontario. The AECL would be responsible for conducting all subsequent fuel performance tests in their National Research Universal (NRU) reactor. The NRU test reactor is the only available reactor specifically redesigned to test MOX fuel performance as related to CANDU reactors. All spent fuel resulting from the tests would be disposed of in Canada under the Canadian spent fuel program.

A "sliding-scale" approach is the basis for the analysis of effects in this Environmental Assessment (EA). That is, certain aspects of the Proposed Action have a greater potential for creating adverse environmental effects than others; therefore, they are discussed in greater detail in this EA than those aspects of the action that have little potential for effect.

The Proposed Action would result in the fabrication of MOX test fuel at LANL and its delivery to the AECL NRU test reactor in Canada. A successful MOX fuel test could lead to the disposition of surplus weapons-grade plutonium from the U.S. and Russia by irradiation in CANDU reactors in Canada. The parallel disposition of weapons-grade plutonium would support the American and Russian goals of nuclear materials nonproliferation. The fabrication of the MOX fuel at LANL would generate small amounts of low-level and transuranic radioactive waste, and very small radioactive air emissions. The MOX fuel fabrication would not result in adverse health effects in the involved workers or public. The shipment(s) of MOX fuel would not adversely affect the environment at LANL or along the transportation routes. During the shipment(s), the truck crew and public would not be adversely affected by the low amount of penetrating radiation from the MOX fuel in the package container(s).

Under the No Action Alternative, no MOX fuel would be fabricated at LANL and no MOX fuel would be shipped to Canada. The existing MOX fuel already made would continue to be stored at LANL until a decision on its use or disposition is made. The AECL would have no source of U.S. MOX fuel and, therefore, would have to delay its testing program at the NRU reactor in parallel with Russian MOX fuel, or if Russian fuel were available, operate the testing program in the absence of U.S. supplied MOX fuel.

Two hypothetical MOX fuel fabrication and transportation accident scenarios were analyzed that evaluated a potential radiation release to the involved workers and public. Another transportation accident scenario not involving a radioactive release was also analyzed. The three accident scenarios did not result in potentially serious health effects to the involved workers or public during MOX fuel fabrication and transportation.

It is expected that activities associated with the Proposed Action would not amplify cumulative effects, because the contributions to adverse effects from the Proposed Action would be extremely small.

1.0 PURPOSE AND NEED

1.1 Introduction

The National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 et seq.), requires all federal agencies, including the Department of Energy (DOE), to consider the environmental consequences of proposed actions before decisions are made. In complying with NEPA, DOE follows the Council on Environmental Quality regulations (40 CFR 1500-1508) and DOE's own NEPA implementing regulations (10 CFR 1021). This Environmental Assessment (EA) has been prepared to provide sufficient information so that DOE may determine whether a Finding of No Significant Impact is warranted for the Proposed Action or whether an Environmental Impact Statement (EIS) must be prepared. The assessments of environmental effects presented in this EA are based on reasonable maximum assumptions that tend to overestimate effects. Thus, the actual environmental consequences of the Proposed Action are expected to be less than those presented here.

1.2 Background

The end of the Cold War has created a legacy of surplus weapons-usable fissile materials both in the United States and the former Soviet Union. Further agreements on disarmament may increase the surplus quantities of these materials. The global stockpiles of weapons-usable fissile materials pose a danger to national and international security in the form of potential proliferation of nuclear weapons and the potential for environmental, safety, and health consequences if the materials are not properly safeguarded and managed. In September 1993, President Clinton issued a *Nonproliferation and Export Control Policy* in response to the growing threat of nuclear proliferation. Further, in January 1994, President Clinton and Russia's President Yeltsin issued a *Joint Statement Between the United States and Russia on Nonproliferation of Weapons of Mass Destruction and the Means for Their Delivery.* To demonstrate the United States' commitment to these policies, President Clinton announced on March 1, 1995 that about 224 tons (203 metric tons) of U.S.-origin weapons-usable fissile materials, of which 165 metric tons are highly enriched uranium and 41.9 tons (38 metric tons) are weapons-usable plutonium, had been declared surplus to the United States' defense needs.

To safeguard and manage this material, DOE has decided to implement a program to provide for safe and secure storage of weapons-usable fissile materials and a strategy for the disposition of surplus weapons-usable plutonium, as specified in the Record of Decision (ROD) for the *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement* (S&D PEIS) (DOE 1996a). The fundamental purpose of the program is to maintain a high standard of security and accounting for these fissile materials while in storage, and to ensure the plutonium produced for nuclear weapons and declared excess to national security needs (now or in the future) is never again used for nuclear weapons.

The S&D PEIS examines various alternatives to implement the DOE strategy for disposition of surplus plutonium; the final approach decided upon would allow for immobilization of surplus plutonium in glass or ceramic formulations and the burning of surplus plutonium as mixed oxide fuel (MOX) in existing reactors. The reactors used for burning and irradiation could be both existing domestic commercial light-water reactors and reengineered heavy-water-moderated reactors, such as Canadian Deuterium Uranium (CANDU) reactors (in the event of an appropriate agreement among Russia, Canada, and the United States for the use of Canada as a politically neutral site for burning both Russian and U.S. MOX fuels). The extent of utilization of either or both of these potential disposition alternatives is dependent upon the results of additional technological development and demonstrations, costs, site-specific environmental reviews, nonproliferation considerations, and negotiations with Russia and Canada.

The exact locations for disposition facilities will be determined pursuant to a follow-on site-specific disposition EIS (a Notice of Intent for the Surplus Plutonium Disposition EIS was published in the Federal Register on May 22, 1997), as well as cost analysis and technical and nonproliferation studies. DOE candidate sites will be studied for possible facility construction under the EIS. The glass immobilization (vitrification) facility will be located at either the Hanford Site (Hanford) in Washington or the Savannah River Site in South Carolina (only one site). A potential MOX fuel fabrication facility will be located at either Hanford, the Savannah River Site, the Pantex Plant in Texas, or the Idaho National Engineering and Environmental Laboratory in Idaho. A weapons "pit" disassembly and conversion facility will be located at Hanford, the Idaho National Engineering and Environmental Laboratory, the Pantex Plant, or the Savannah River Site (only one site). The specific reactors, and their locations, that may be used to burn the MOX fuel would depend on contract negotiations, licensing, and environmental reviews. As determined in the S&D PEIS ROD, DOE will engage in a test and demonstration program for CANDU MOX fuel consistent with ongoing and potential future cooperative efforts with Russia and Canada. The test and demonstration activities could occur at Los Alamos National Laboratory (LANL), New Mexico, and at Chalk River Laboratories (CRL), Ontario, Canada, potentially beginning in 1997.

Through these efforts, the President will be provided the basis and flexibility to begin disposition, either unilaterally as an example to Russia, or multilaterally or bilaterally with other nations. Proceeding in this way will serve as a strong statement of the United States' commitment to nonproliferation and disarmament, will encourage similar actions by Russia and other nations, and will foster multilateral or bilateral disposition efforts and agreements.

1.3 Purpose and Need for Agency Action

DOE must test and demonstrate the feasibility of burning MOX fuel in CANDU reactors as part of its ongoing mission to evaluate the disposition of surplus weapons-grade fissile materials. The final S&D PEIS ROD issued January 14, 1997, established the dual-track strategy to irreversibly dispose of the Nation's surplus plutonium and to reduce from seven to three the number of sites that store nuclear weapons material. The strategy allows for immobilizing plutonium in glass or ceramic formulations and burning plutonium as MOX fuel in existing reactors. The ability to successfully re-engineer and operate heavy-water-moderated CANDU reactors with MOX fuel cycles has never been demonstrated on any industrial scale. The use of MOX fuel in CANDU reactors needs to be successfully demonstrated to adequately meet the disposition requirements in the event that use of these facilities is ultimately agreed upon by the various governments. Therefore, DOE now needs to fabricate and provide a limited amount of MOX fuel to facilitate the testing and demonstration of MOX fuel in CANDU reactors. This testing will verify equipment design and resolve related performance issues for full-scale operation, as well as the process for rendering plutonium oxide from weapons components.

1.4 Scope of this EA

A "sliding-scale" approach, following the DOE Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements (DOE 1993a), is the basis for effects analysis in this EA. That is, certain aspects of the Proposed Action have a greater potential for creating adverse environmental effects than others; therefore, they are discussed in greater detail in this EA than those aspects of the action that have little potential for effect. For example, implementation of the Proposed Action could slightly increase the accident risk to the motorists along the route from the commercial carrier's truck during transportation of the MOX fuel. The accident risk increase would be negligible when taken as a whole with the many other vehicles on the highway. With regard to this example, the EA, therefore, would present descriptive information on highway transportation only to the extent necessary for effects analysis, and not for every vehicle and motorist along the transportation route.

When details about a Proposed Action are incomplete a "bounding" analysis is often used to assess potential effects. When this approach is used, reasonable maximum assumptions are made regarding the input parameters needed for the modeling of the Proposed Action scenario. Such an analysis usually provides an overestimation of potential effects. In addition, any future actions that exceed the assumptions ("bounds") of the effects analysis would not be allowed until an additional NEPA review could be performed and a decision to proceed with that action(s) is then made.

1.5 Public Involvement

DOE has provided written notification of this project's NEPA review to the State of New Mexico, all of the states and federally recognized Indian reservations along the proposed shipment routes, the LANL area's four Accord[1] Pueblos (San Ildefonso, Santa Clara, Jemez, and Cochiti Pueblos), the Mescalero Apache Tribe, and to over 30 known stakeholders in the Los Alamos County (the County) area. The Predecisional Draft EA is provided to all of the states and federally recognized Indian reservations along the proposed shipment routes, the four Accord Pueblos, the Mescalero Apache Tribe, and to known stakeholders for their review and comment. During this same time, the Predecisional Draft EA is also made available to the public for review through placement in the DOE Public Reading Rooms in Los Alamos and Albuquerque, New Mexico. Upon request, the Predecisional Draft EA will be provided to all interested parties for their review. The Predecisional Draft EA will also be available for public review through the World Wide Web on the Internet (http://www.laao.doe.gov/LAAO/).

[1] Accord refers to the written agreements signed by DOE and the four Pueblos on December 8, 1992, stating the basic understanding and commitments of the parties and describing the general framework for working together. Subsequently, cooperative agreements between each Pueblo and DOE, and between each Pueblo and the University of California have been signed, which specify further details related to the accord agreements.

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2.0 PROPOSED ACTION AND ALTERNATIVES

This section describes the Proposed Action and discusses alternatives considered for enabling DOE to meet its purpose and need for agency action. The No Action alternative is analyzed as a baseline to compare with the consequences of implementing the Proposed Action. Alternatives that were considered but were not analyzed further in this EA are discussed in Section 2.3.

2.1 Description of the Proposed Action

To meet the purpose and need for Agency action, DOE proposes to fabricate and transport up to 59.2 lb (26.8 kg) of MOX fuel as part of the Parallex Project. This test and demonstration project has been named Parallex (parallel experiment) because of the roles of the United States and Russia in supplying test material. As originally envisioned, the Parallex Project would be a joint agreement between Russia, Canada, and the U.S. to demonstrate the irradiation[2] of U.S. and Russian MOX fuel in parallel in the Atomic Energy of Canada, Limited (AECL)-owned National Research Universal (NRU) reactor. This international project would use MOX fuel made in the U.S. (specifically LANL [Figure 1]) and Russia (specifically from Bochvar) from excess weapons-grade plutonium out of both countries' nuclear stockpile. The U.S. could unilaterally participate in the Parallex Project in the event that Russia is unable to participate in the proposed test and demonstration project, but it is hoped that Russia would engage in the early stages of this undertaking.

Research and development of MOX fuels has already been conducted at LANL as part of its ongoing mission relating to the development of energy sources for experiments and research reactors. However, these various MOX fuel forms were not made with weapons-grade plutonium. In contrast, the MOX fuel fabrication process involved in the Parallex Project would use weapons-grade plutonium (in unclassified form) obtained from decommissioned nuclear weapons. The U.S. would provide up to four types of MOX fuel in varying plutonium percentages for the Parallex Project.

The environmental review presented herein is limited to the fabrication and transportation of MOX fuel from LANL to the Canadian border. Environmental consequence assessment for activities conducted in Canada would be the responsibility of the Canadian government. The U.S. MOX fuel would be fabricated at LANL and transported to a Canadian port(s) of entry. At the Canadian border the AECL, per prior agreement, would then take possession of the fuel. The fuel would remain on the same truck and the AECL would complete the shipment to the reactor site. At Chalk River, Ontario, the MOX fuel would be delivered to CRL for testing in the NRU reactor. Figure 2 shows the general location of the CRL within Ontario, Canada, and North America. The AECL would be responsible for conducting all subsequent tests of the fuel's performance and the function of the reactor during the process. Fueling the NRU reactor with MOX fuel would be part of a feasibility test to determine MOX fuel performance in a converted CANDU reactor setup. The NRU test reactor is the only available reactor specifically redesigned to test MOX fuel performance. Positive test results could support subsequent decisions on the dispositioning of surplus weapons-grade plutonium in CANDU reactors. All spent fuel resulting from the tests would be disposed of in Canada under the Canadian spent fuel program.

2.1.1 Manufacture of MOX Fuel and Rods

For the Parallex Project, a Test Plan (Copeland 1996) was developed that provides the basis for DOE to fabricate (and transport to CRL in Ontario, Canada) four types of MOX fuel. Under this Test Plan, MOX

[2] The irradiation of MOX fuel would reduce the proliferation risk of the plutonium material. The plutonium in MOX fuel is also fissioned (burned) to produce energy.

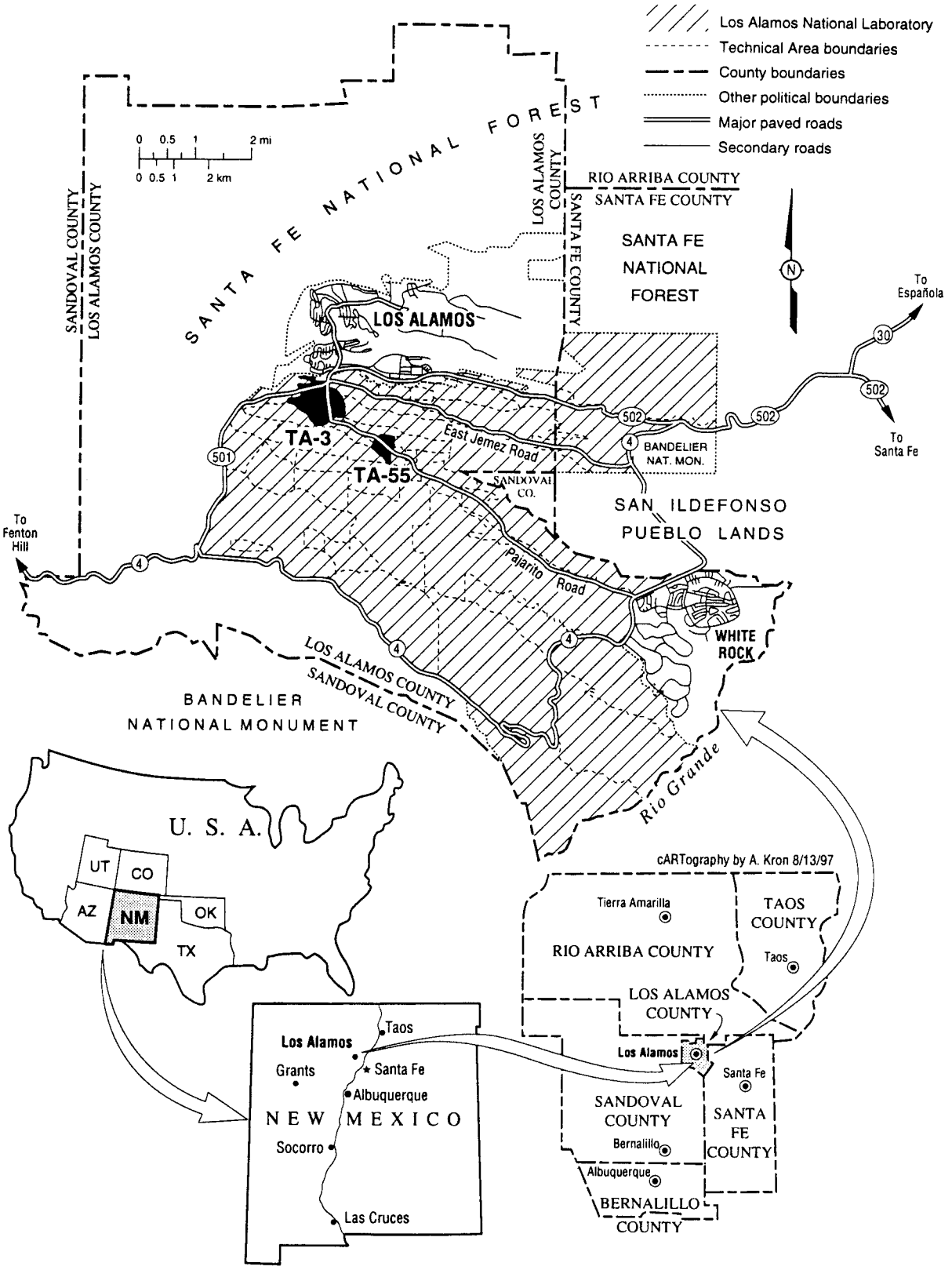

Figure 1. Location of Los Alamos National Laboratory.

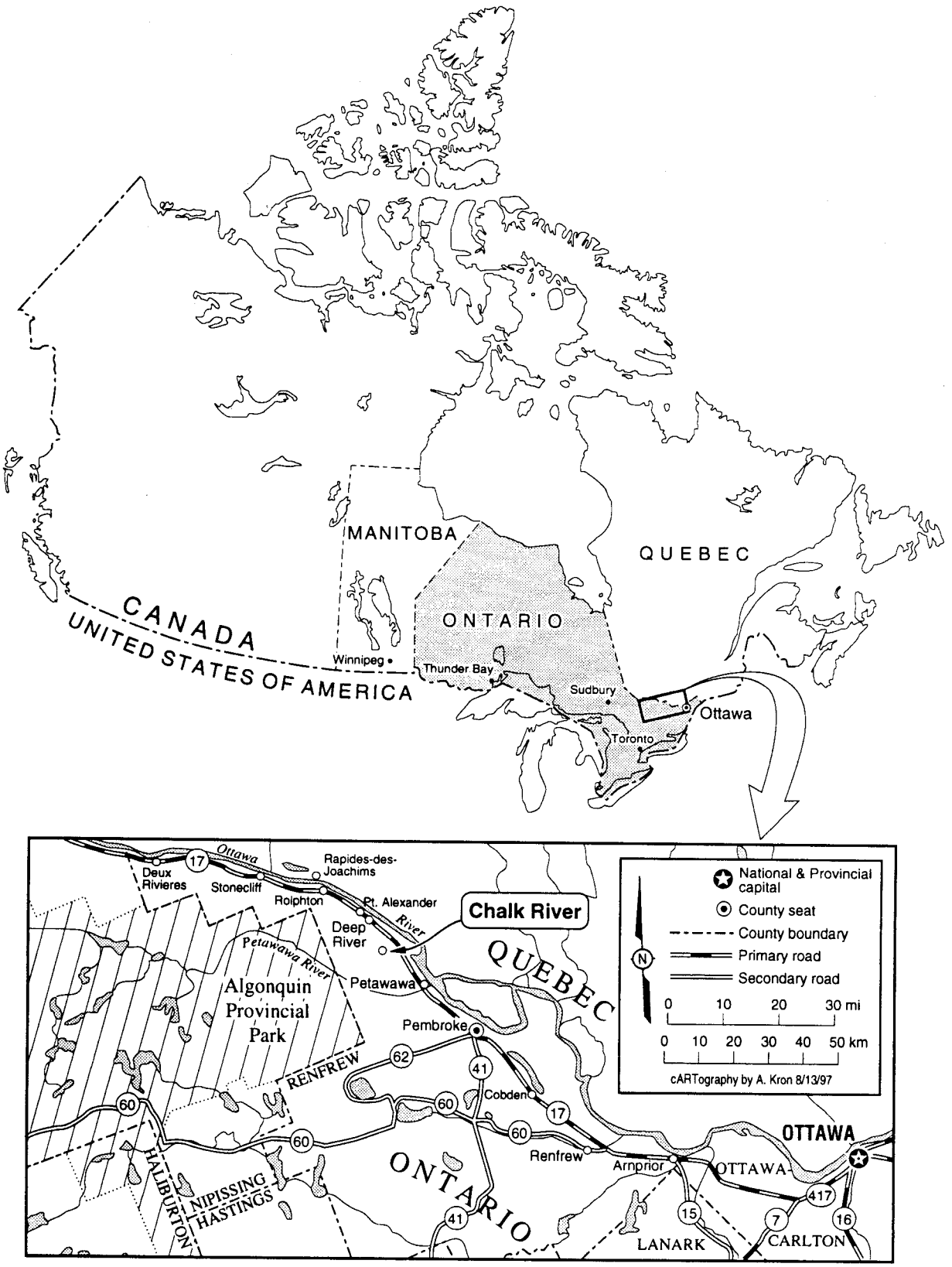

Figure 2. Location of Chalk River in relation to Ontario, Canada.

fuel with two different plutonium concentrations (1.6 percent and 3.1 percent) would be fabricated, and for each plutonium concentration, two different levels of homogeneity (intermediate and high) would be fabricated. Intermediate homogeneity is defined, for this project, as the homogeneity achieved from the mixing step in the standard fabrication process, whereas high homogeneity would be achieved through the inclusion of an additional mixing step. The amount of fuel to be fabricated for each combination of plutonium concentration and homogeneity level for the U.S. portion of the Parallex Project is shown in Table 2-1.

Table 2-1. Required Material to Complete the LANL Portion of the Parallex Test Plan

Type	Number of Rods	MOX Fuel lb (kg)	Plutonium lb (kg)	Uranium lb (kg)	Oxygen lb (kg)
1.6% Pu Intermediate Homogeneity	14	18.1 (8.2)	0.2 (0.1)	15.7 (7.1)	2.2 (1.0)
1.6% Pu High Homogeneity	14	18.1 (8.2)	0.2 (0.1)	15.7 (7.1)	2.2 (1.0)
3.1% Pu Intermediate Homogeneity	9	11.5 (5.2)	0.2 (0.1)	10.0 (4.5)	1.3 (0.6)
3.1% Pu High Homogeneity	9	11.5 (5.2)	0.2 (0.1)	10.0 (4.5)	1.3 (0.6)
Total	46	59.2 (26.8)	0.84 (0.4)	51.4 (23.2)	7.0 (3.2)

As part of DOE's initial bench-scale fabrication feasibility research and development efforts supporting the proposed Parallex Project, a MOX fuel fabrication process was studied and developed at LANL's plutonium facility (PF-4) located within Technical Area 55 (TA-55). A simplified version of the process is shown in Figure 3. This process was selected for use in the fabrication of the Parallex Project MOX fuel. The first step in the process is the receipt of plutonium dioxide powder, arising from the dismantlement of nuclear weapons at the DOE Pantex Plant near Amarillo, Texas. The plutonium dioxide is put though a thermal treatment process to remove impurities, such as gallium. The treated plutonium dioxide is then combined with uranium dioxide, which in this case was obtained from AECL, to make a master blend. The master blend is defined as having 10 percent plutonium.

After the master blend is made, additional uranium dioxide can be added (in predetermined amounts) in order to achieve the proper plutonium concentrations of 3.1 percent or 1.6 percent as needed in the final blends. The addition of more uranium dioxide is called downblending. These final blends are each then put through a standard mixing procedure, and the result is a powder of intermediate homogeneity. For each plutonium concentration, half of the intermediate homogeneity powder is then put through an additional mixing step to achieve the high homogeneity portion of the test matrix.

Once the proper plutonium concentrations and homogeneities of the powder blends have been achieved, the remainder of the fabrication process is as follows: pressing of the MOX fuel into the proper pellet shape, sintering of the pellets (heating by flame would not be used in this process), grinding of the pellets into the proper final dimensions, and cleaning of the pellets. For this project, process parameters for each of these steps were provided by AECL to meet the specifications of their reactor.

As part of the bench-scale research and development work already conducted at LANL, three batches of test MOX fuel were produced. From these batches, about 9.2 lb (4.2 kg) of 3.1 percent plutonium fuel

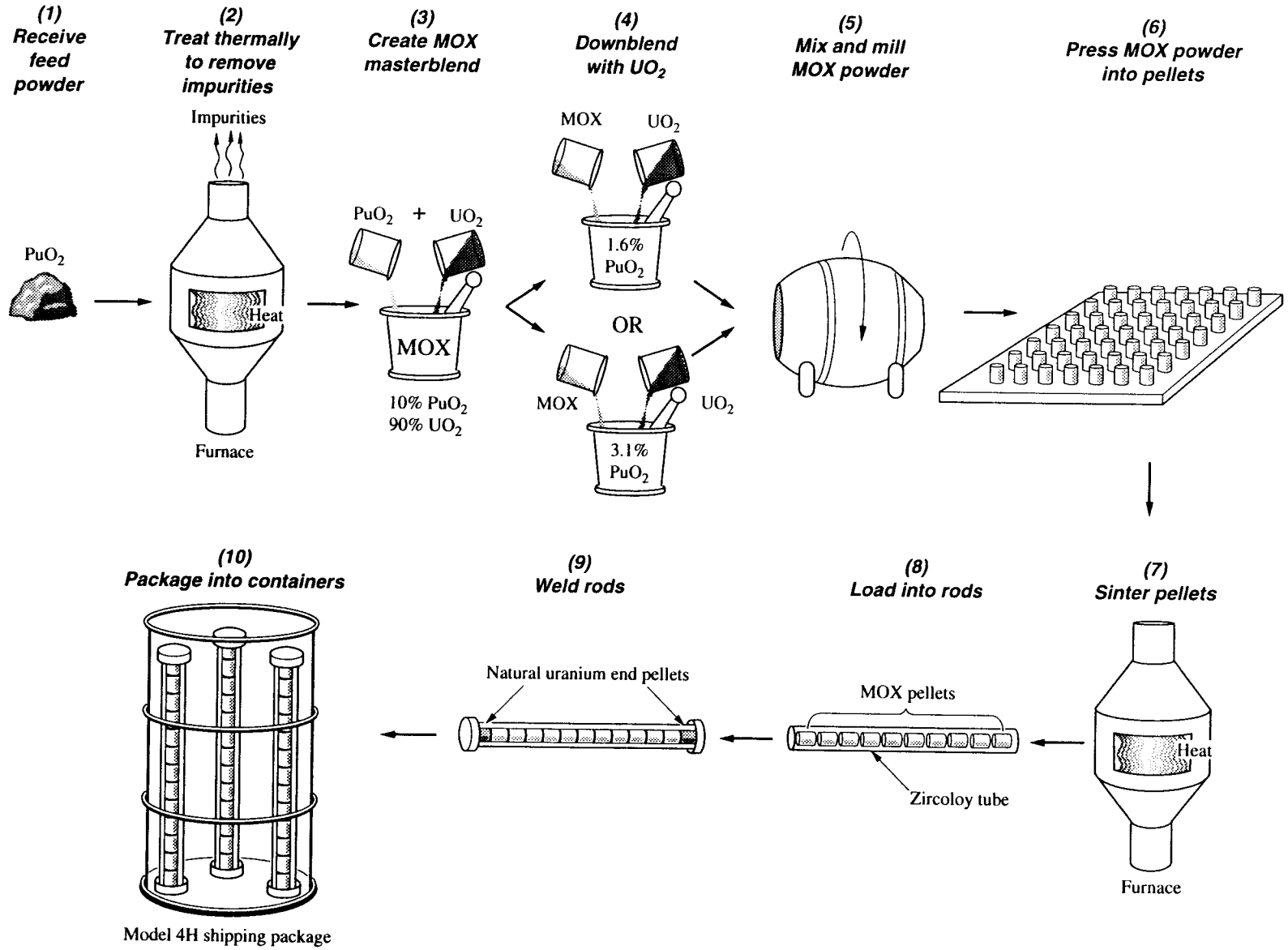

Figure 3. MOX fabrication and packaging.

was identified as acceptable and meeting the criteria for use in the Parallex Project. A master blend of 11.0 lb (5.0 kg) of MOX powder with 10 percent plutonium and 90 percent depleted uranium was also made that could be used to make most of the remaining amount of fuel needed to complete the test matrix. (Full completion of the test matrix fuel would most likely require an additional batch of master blend to be created.) The existing fabricated MOX fuel pellets and master blend powder are stored in PF-4 awaiting its use in the Parallex Project or another disposition method. For fabrication of the Parallex fuel, this already-created master blend of MOX powder (plus any newly created master blends) would go through the same processing steps as described above so that the resulting fuel powders contain the correct percentages of plutonium and correct homogeneity levels; in turn, these final powder blends would then be pressed into pellets.

After inspection, acceptable pellets would be loaded into zircaloy tubes (also known as rods), and natural uranium dioxide end pellets would be added, as necessary, to obtain the proper stack length. Endcaps would then be welded onto the loaded rods to create sealed, complete fuel rods. Rod loading and welding capabilities are being developed at LANL specifically for the materials used in this project. These fuel rods would then be leak checked, surveyed for possible contamination, and then stored in PF-4 prior to shipment to CRL.

The MOX fuel fabrication would be conducted by about a 12-person staff within PF-4. All of the handling and work with the plutonium and uranium would be done inside a series of gloveboxes. A typical glovebox is illustrated in Figure 4. The gloveboxes are sealed and have a self-contained negative pressure ventilation system that is high-efficiency particulate air (HEPA) filtered. Radiological monitors are located in the gloveboxes. The estimated 12-person staff involved in the process would be trained in health and safety requirements and required to follow the written operating procedures for MOX fuel fabrication. The workers would be dressed in personal protective clothing consisting of gloves, overalls, and shoe covers. In addition to the glovebox built-in safety measures, PF-4 is sealed to the outside and is also maintained with a negative air pressure to prevent the escape of airborne contamination. The PF-4 area has its own air ventilation system equipped with radiation monitors, alarms, and HEPA filtration to prevent the escape of contamination into the atmosphere.

On average, the 12 workers directly involved with the plutonium and uranium handling would receive a dose of approximately 355 mrem per year, assuming a year-round routine operation. The anticipated time required to complete the fabrication of any necessary fuel rods would be about six months. A limited amount (approximately 170 ft^3 [4.8 m^3]) of low-level radioactive solid waste[3], such as rags and gloves, would be produced from the fabrication process. A small amount, 22 ft^3 (0.62 m^3), of solid transuranic (TRU) waste such as gloves and plastic bags would be produced inside the gloveboxes. Ethanol would be used in the glovebox to clean the MOX fuel pellets before loading into the rods. The ethanol would be applied with a small cloth. No ethanol liquid waste would be produced because the ethanol would evaporate.

2.1.2 Shipping Package Description and Rod Packaging

Approved packaging refers to a container and all accompanying components or materials necessary to perform its containment function. Packages used by DOE for radioactive and hazardous materials shipments are either certified to meet specific performance requirements or built to specifications described in the Department of Transportation (DOT) hazardous materials regulations (49 CFR 100-199). For

[3] Solid waste in this context refers to dry radiological waste and not Resource Conservation and Recovery Act (RCRA) waste.

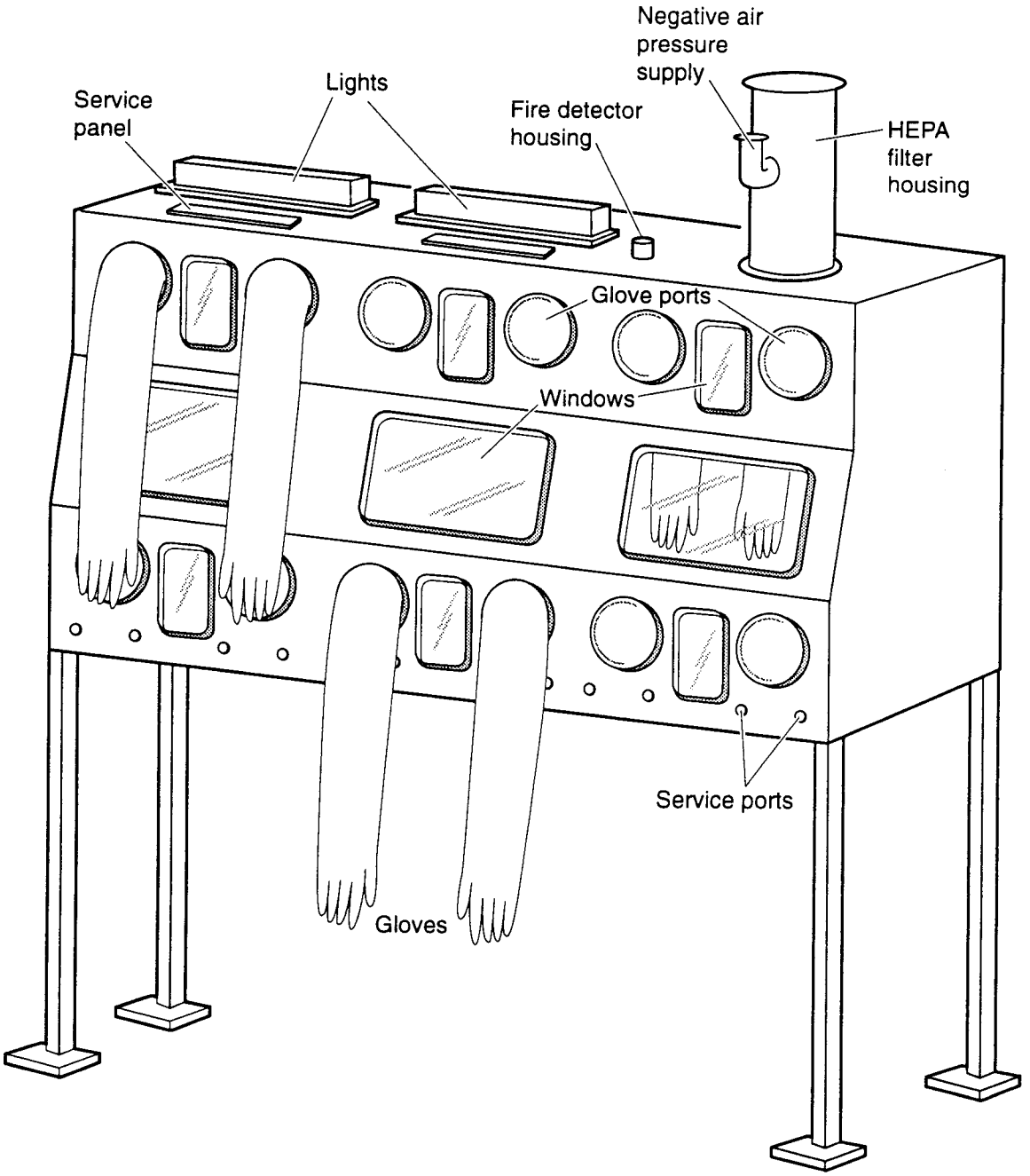

Figure 4. Schematic glovebox design.

relatively low-level radioactive materials, DOT Specification Type A packages are used. These packages are designed to retain their contents under normal transportation conditions. For the Parallex Project, a Type A shipping package on a commercial truck would be used to transport the LANL MOX fuel to Canada.

The Type A package used in the shipment(s) would be certified by both the U.S. and Canadian Transportation authorities. The Type A shipping package proposed for use was designed and manufactured by Canada. It is known as the Model 4H Enriched Fuel Bundle Shipping Package. This package meets DOT Type A specifications. The Model 4H Package can be generally described as a 55-gal. (208-L) metal drum with a sealable lid. Individual storage spaces surrounded by packing material are located in the drum. The Model 4H Package is illustrated in Figure 5. Additional technical information of the Model 4H Package is presented in Appendix A along with a copy of the Canadian shipping package certificate. The U.S. DOT shipping package certificate is also presented in Appendix B.

2.1.3 Transportation of MOX Fuel

When the MOX fuel is identified for shipment, the rods would first be placed inside a Model 4H Package. The rod packaging would be done at the TA-55 facility by workers in personal protection clothing and under the supervision of radiation control technicians. Engineering controls, such as HEPA filtration, and continuous air monitors would be used to protect personnel and the environment. Administrative controls, such as radiation work permits and radiological postings, would also be in place for safety and health protection during the rod packaging. The work area and workers would be monitored for radiation during and after the packaging procedure. At TA-55, the Model 4H Package would be loaded by forklift into a LANL vehicle designed to transport radioactive materials. Such a vehicle is designed to prevent security breaches and loss of material content during transport. Following standard procedure, the LANL vehicle would transport the MOX fuel in the Model 4H Package approximately 2 mi (3.2 km) to the LANL shipping warehouse at TA-3. Because of the low radioactivity per shipping package, no roads along the route would be closed to public access during the MOX fuel transfer to the warehouse.

After arriving at the LANL shipping warehouse, the manifest documents would be processed. Up to two Model 4H Packages would then be loaded with a forklift into a commercial truck. The loading and shipping of radioactive materials would be carried out in accordance with DOT regulations and existing LANL Safe Operating Procedures (SOPs). Once loaded, the truck would then be ready to leave for Canada.

The amount of LANL MOX fuel needed to test in the Parallex Project has been calculated and all of the fuel described in Table 2-1 could be fabricated simultaneously and transported as one shipment. However, this scenario is unlikely due to evolving programmatic decisions, developments, and schedules. For example, from the initial research and development for the Parallex Project, it was determined that approximately 9.2 lb (4.2 kg) of MOX pellets (at 3.1 percent plutonium) was acceptable as fuel for the test irradiation. A programmatic decision was then made to leave open the option that this fuel could be shipped and tested as the first test fuel bundle. The fabrication of the complete test matrix (including the full amount of originally planned 3.1 percent plutonium fuel) would follow. This first test fuel could also include additional fuel pellets (up to 2.4 lb [1.1 kg]) to serve as spares, archives, or samples, for a total initial shipment amount of 11.7 lb (5.3 kg). The timing of further project developments could then affect whether the remainder of the fuel could be shipped as a complete package or divided into multiple smaller shipments.

For purposes of analysis here, three possible shipment scenarios were developed based on the above uncertainties. In Scenario 1, all of the MOX material would be transported in a single shipment. This

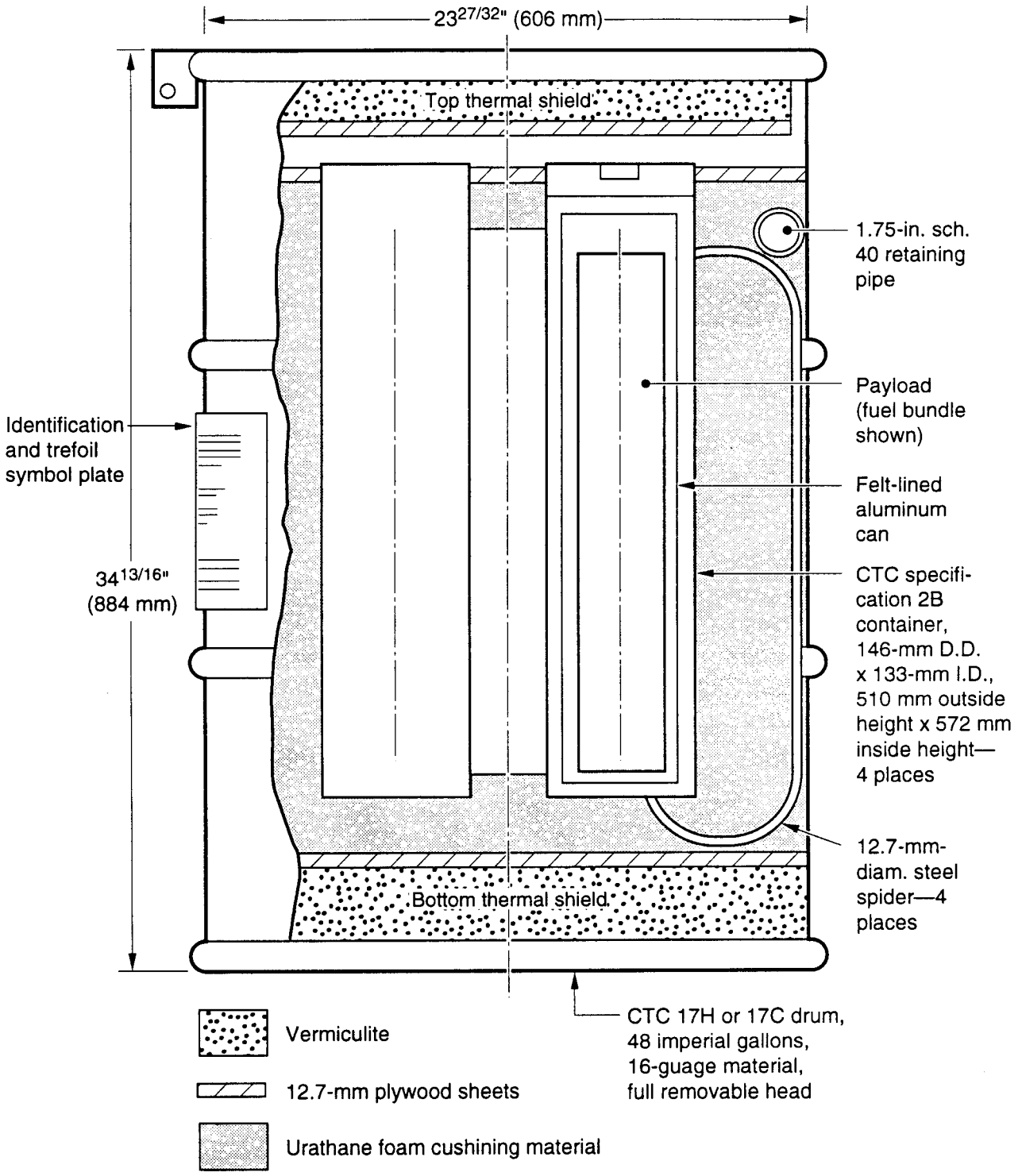

Figure 5. AECL Model 4H shipping package.

would include the 11.7 lb (5.3 kg) of lead test fuel, plus the entire test matrix quantities. In Scenario 2, the lead test fuel [11.7 lb (5.3 kg)] would be shipped separately, followed by a different shipment of the complete test matrix amounts. Scenario 3 is similar in that the lead test fuel is shipped first, but the test matrix quantities would be further divided into two shipments (one for each plutonium concentration). The specific quantities for each shipment scenario are described in Table 2-2. In all cases, the 6.6 lb (3.0 kg) of shim pellets were divided proportionally between the shipments.

Table 2-2. Material Quantities to be Shipped for Various Shipment Scenarios

Shipment Scenario	Mass of Shim Pellets lb (kg)	Mass of MOX fuel Pellets lb (kg)	Total 3.1% MOX fuel lb (kg)	Total 1.6% MOX fuel lb (kg)	Total Plutonium lb (kg)	Total Uranium lb (kg)	Total Oxygen lb (kg)
1	6.6 (3.0)	71.2 (32.3)	35.1 (15.9)	36.1 (16.4)	1.5 (0.666)	67.1 (30.45)	9.2 (4.18)
2	1.1 (0.5)	11.7 (5.3)	11.7 (5.3)	0 (0)	0.32 (0.145)	11.0 (4.97)	1.5 (0.69)
	5.5 (2.5)	59.5 (27.0)	23.4 (10.6)	36.1 (16.4)	1.2 (0.521)	56.2 (25.48)	7.7 (3.50)
3	1.1 (0.5)	11.7 (5.3)	11.7 (5.3)	0 (0)	0.3 (0.145)	11.0 (4.97)	1.5 (0.69)
	2.2 (1.0)	23.4 (10.6)	23.4 (10.6)	0 (0)	0.6 (0.290)	22.0 (9.94)	3.0 (1.37)
	3.3 (1.5)	36.1 (16.4)	0 (0)	36.1 (16.4)	0.5 (0.231)	34.2 (15.55)	4.7 (2.12)

The above three scenarios were developed in order to provide bounding cases for transportation effect analyses. The single shipment (Scenario 1) provides a bound by having the largest quantity of material to be shipped, and hence the largest possible effects from the actual materials. The three shipments (Scenario 3) provide a different type of bound in that they represent the largest number of shipments, hence the greatest possible effect from the actual transportation.

2.1.4 Transportation Routes

Pursuant to DOT and Nuclear Regulatory Commission (NRC) requirements, the transportation route would principally use interstate highways, minimize bridge crossings, not pass through tunnels, bypass high population areas (where possible), minimize distance and time, minimize public effects, and generally be safe. A commercial truck would be used to transport the MOX fuel because of the Model 4H Package safety features and low radioactivity levels per shipment. The shipment(s) would be transported along interstate highways, whenever possible. Shipment over specific routes, i.e., using interstate bypasses around cities and using the most direct interstate highways, is required for shipments identified by the DOT as Highway Route Control Quantity (HRCQ). A HRCQ designation is given to radioactive materials (within a single package) that have a radioactivity level (curie) specified in 49 CFR 173.403. More than 7 ounces (200 g) of plutonium per shipment would be required for a Parallex Project shipment to be declared HRCQ. As currently envisioned, not all Parallex Project MOX fuel shipments would be categorized as HRCQ. HRCQ shipments are regulated under the DOT transportation regulations (49 CFR 397.101). As an added safety measure, all of the LANL MOX fuel shipments to Canada would follow routes meeting HRCQ requirements. In addition to using interstate highways and bypasses, routing regulations require that the quickest routes must be selected in order to reduce the time the radioactive material is in transit. DOT routing regulations permit appropriate state agencies to designate routes for HRCQ shipments through their state. States granted approval of state-designated alternative route may request advance notification of the shipment. DOE would also identify the MOX fuel shipments as High Visibility Shipments. A High Visibility Shipment requires, in addition to DOT transportation regulations, a Transportation Plan and a satellite communications relay to a central command center (TRANSCOM).

The TRANSCOM system would know the exact location of a truck in real time during a shipment from LANL to the Canadian border.

Three routes from LANL to the Canadian border that meet DOT routing requirements were analyzed to present a bounding case for transportation effects. These routes are illustrated in Figure 6. The three routes each have a separate port of entry into Canada. A computer routing program named HIGHWAY (ORNL 1993) was used to determine the three best routes. The HIGHWAY model, developed by Oak Ridge National Laboratory, predicts highway routes for transporting radioactive materials in the United States. The database of the HIGHWAY model calculates routes which maximize the use of the Interstate highway system. The computer model is designed to circumvent urban areas by use of available highway bypasses. These features allow the HIGHWAY code to conform to the DOT transportation routing regulations.

The three analyzed routes are listed in Table 2-3 and are identified by the name of the city closest to the actual international border crossing. All three routes meet the DOT transportation routing regulations and, therefore, are all acceptable for transporting the MOX fuel to the Canadian border from Los Alamos. The three routes vary in distance. Within the U.S., the Pembina, North Dakota route is the shortest to reach the Canadian border, whereas the Watertown, New York route is the longest within the U.S. to reach the border. In comparison, the Port Huron, Michigan route is the shortest route overall between Los Alamos and Chalk River. Despite these differences, all three routes are acceptable for transporting MOX fuel. In the Proposed Action, the MOX fuel would be transported to Canada in up to three shipments. For each shipment, one of the three routes must be used and the exact route would be chosen by the freight company. A detailed description of each of the three routes is presented in Section 3.2.2.

Table 2-3. Transportation Routes

Origin	Port of Entry	Destination	Distance to Canadian Border, mi (km)	Total Distance mi (km)
Los Alamos, NM	Pembina, ND	Chalk River, ON	1,530 (2,462)	2,822 (4,542)
Los Alamos, NM	Port Huron, MI	Chalk River, ON	1,755 (2,824)	2,252 (3,624)
Los Alamos, NM	Watertown, NY	Chalk River, ON	2,126 (3,422)	2,325 (3,742)

2.2 No Action Alternative

The No Action alternative provides an environmental baseline to compare to the potential effects of the Proposed Action. It must be considered even if DOE is under a court order or legislative command to act [10 CFR 1021.321(c)]. Under this alternative, LANL would continue to store the existing MOX fuel at TA-55. No additional fuel pellets or additional fuel rods would be made for the Parallex Project. The AECL would have no source of U.S. MOX fuel rods and, therefore, would have to delay its testing program at the NRU reactor in parallel with Russian MOX fuel, or if Russian fuel were made available, operate the testing program in the absence of U.S. supplied MOX fuel.

2.3 Alternatives Considered but Dismissed from Further Consideration

Alternatives for producing the MOX fuel at other DOE facilities and using other fabrication technologies were also considered. Additionally three alternatives for transporting the MOX fuel were considered as well: 1) transport by air, 2) transport by rail, and 3) ground shipment by safe secure transport (SST). For the reasons stated below, these alternatives were dismissed from further consideration in this EA.

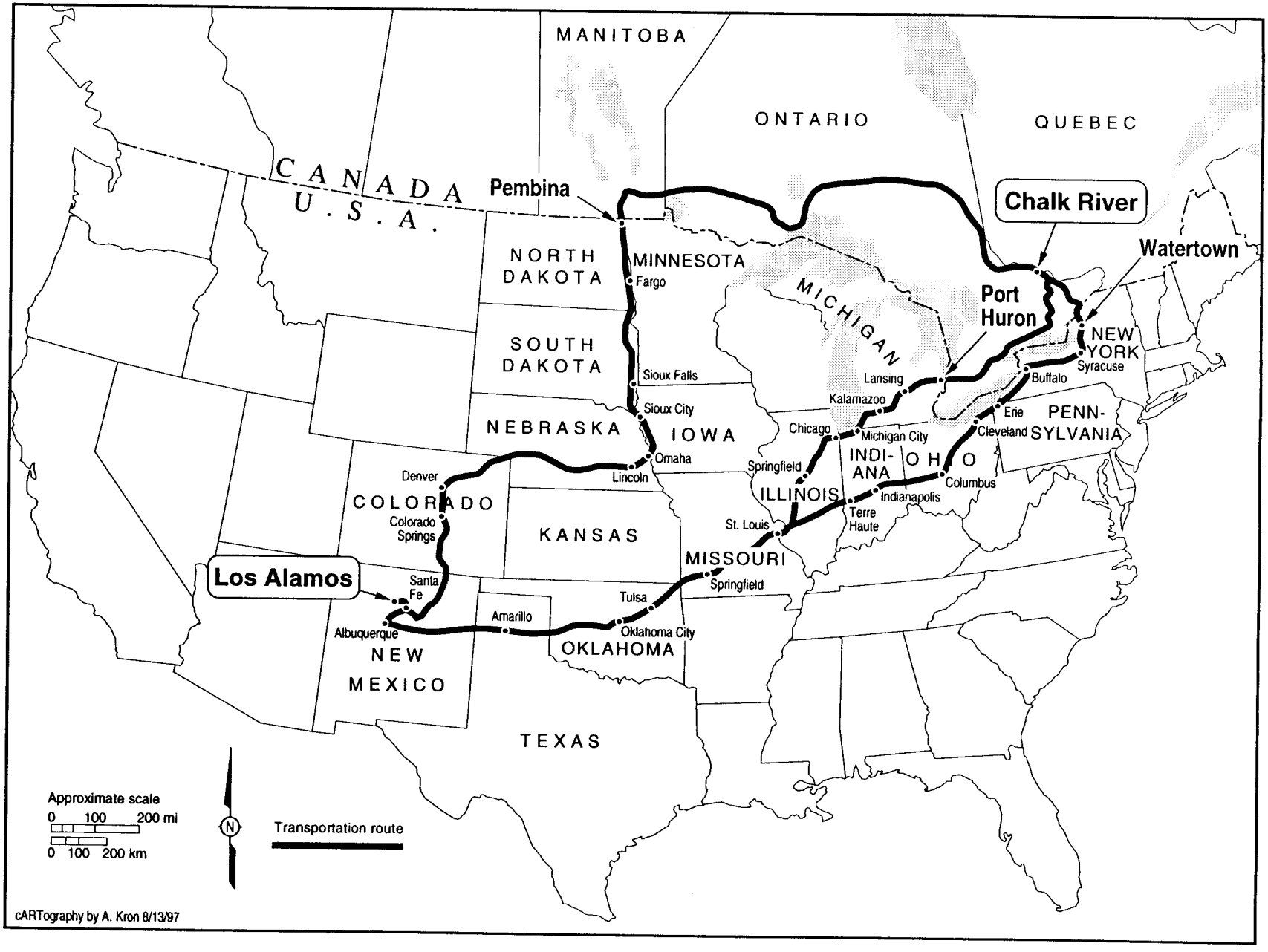

Figure 6. Transportation routes from Los Alamos to Chalk River.

2.3.1 MOX Fabrication at Other DOE Facilities

Under this alternative, MOX fuel would be fabricated at other DOE facilities and then shipped to CRL. No DOE site other than LANL presently has the technological ability or facilities to process plutonium and uranium and fabricate MOX fuel. The costs of upgrading another DOE facility to fabricate MOX fuel would be high. In addition, the time required for the upgrade would delay the fabrication and shipment of MOX fuel such that the Parallex Project schedule would not be met. The U.S. MOX fuel would not be tested in the NRU reactor in a timely manner. Therefore, this alternative was dismissed from further analysis.

2.3.2 Other Technologies for MOX Fabrication

This alternative would use other methods such as computer simulation or surrogate fuels to evaluate the fabrication of MOX fuel. The use of computer simulation is not developed to the point where it can be applied to MOX fuel fabrication. The use of surrogate fuels in the Parallex Project would not produce the irradiation data required for verifying reactor performance. The technology and fabrication process developed at LANL from research and development is currently the only reasonable way of fabricating MOX fuel for the Parallex Project. Therefore, this alternative was dismissed from farther analysis because it does not meet the purpose and need for MOX fuel fabrication in support of the Parallex Project.

2.3.3 Transport of MOX Fuel by Air

Federal regulations under 10 CFR 71.88 (Air Transport of Plutonium) explicitly prohibit the transportation of plutonium by air or the delivery to a carrier for air transport unless the plutonium is 1) in a medical device, 2) in a form with a specific activity no greater than 0.002 μCi/g, 3) shipped in a single package with no more than a specified quantity, and 4) shipped in a specifically authorized NRC-package with a Certificate of Compliance. Plutonium is a component of MOX fuel. The restrictions imposed for transportation of plutonium by air prohibits this alternative for shipment of the MOX fuel quantities needed for the Parallex Project. In addition, air transport is considered to be more hazardous than ground transport due to the potential for greater distribution of radioactive materials in the event of a major air accident. This alternative was dismissed from further analysis.

2.3.4 Transport of MOX Fuel by Rail

Rail shipment is an allowable mode for the transport of radioactive materials and is regulated by DOT under 49 CFR 174.700. However, there is no direct rail service from Los Alamos, New Mexico. A rail shipment of MOX fuel would be designated as high visibility. This mode of transport would not be feasible because of the high visibility, lack of a TRANSCOM system, lack of dedicated rail routes, and long layovers for railcar transfers. Cumulatively, all the complications of rail transport negates use of this transport mode. Therefore, this alternative does not support the purpose and need for agency action and was dismissed from further analysis.

2.3.5 Shipment of MOX Fuel by SST

DOE and DOT require high security in the transportation of special nuclear material, for example, plutonium in the form of metal. Shipments of plutonium and uranium in certain forms are required to be transported by the SST system. Plutonium and uranium oxides in greater than 13.2-lb (6-kg) and 44-lb (20-kg) quantities, respectively, require shipment by SST. The SST fleet is a DOE owned and operated transportation system and consists of armored tractor-trailers and special escort vehicles. The vehicles are continuously monitored and the couriers operating the escort vehicles and trucks are heavily-armed Federal agents (SNL 1996). The SST system is primarily designed for use in the continental U.S.

The MOX fuel rods do not meet the DOE criteria required for SST use, such as material form and radioactivity level. The added security and expense of the SST system is not needed because the MOX fuel would be in small quantities, would have a negligible radioactive dose to the public, and could not easily be converted into weapons-usable form. The shipment of small MOX fuel quantities does not justify the use of SSTs. However, for the disposition of MOX fuel as discussed in the S&D PEIS, it is anticipated that SSTs would be required because of the larger quantities of fuel. This alternative was dismissed from further analysis for this EA.

2.4 Foreseeable Related and Future Actions

The LANL Site-Wide Environmental Impact Statement (SWEIS), currently being prepared, will address cumulative effects for all LANL operations including those that could result from a decision made regarding the subject of this EA. A ROD for the LANL SWEIS is expected in 1998. Delaying the proposed project until the LANL SWEIS is completed could result in unacceptable program risks. The DOE Advisory Council for the LANL SWEIS has determined that this EA is an interim action and would not affect or be affected by the LANL SWEIS and would not prejudice the ultimate decision on the SWEIS. DOE has therefore determined that the NEPA analysis of the Proposed Action should continue in parallel with the LANL SWEIS process.

In the recent Notice of Intent on the preparation of an EIS on Surplus Plutonium Disposition, DOE proposes to establish a MOX fuel fabrication facility under one alternative. The MOX fuel would be used in existing commercial light water reactors in the U.S. Some of the MOX fuel could also be used in CANDU reactors in Canada depending upon negotiation of a future international agreement between Canada, Russia, and the United States. The ROD for this EIS is anticipated to be issued in late 1998. The production and shipment of a limited amount of MOX fuel to conduct the Parallex Project is needed before that time frame and would neither affect nor be affected by the analysis, not would it prejudice the ultimate decision on the EIS. DOE has therefore determined that the NEPA analysis of the Proposed Action should continue in parallel with the Surplus Plutonium Disposition EIS.

3.0 AFFECTED ENVIRONMENT

Section 3.0 describes the natural and human environment that could be affected by either the Proposed Action or No Action alternative and provides the context for understanding the environmental consequences described in Section 4.0. Environmental issues not likely to be affected are addressed in less detail.

3.1 Potential Environmental Issues

Based on the proposed project description, potential environmental resources that may be affected as a result of implementing the Proposed Action have been considered. Environmental issues were identified and either addressed or not analyzed, depending upon their individual applicability to the Proposed Action. Table 3-1 identifies the subsection where potential environmental issues are discussed or notes why they are not addressed further for this project. Only negligible effects are anticipated from MOX fuel fabrication and transportation.

Table 3-1. Potential Environmental Issues

Potential Issue	Applicability	Described in Section
Human Health	Yes	Section 3.3
Air Quality	Yes	Section 3.4
Waste Management	Yes	Section 3.5
Environmental Justice	No	Section 3.6
Socioeconomics	NA-no change in socioeconomic conditions.	NA
Ecological Resources/Wetlands/Floodplains	NA-due to use of established interstates. No new transportation routes.	NA
Environmental Restoration/Waste Management	NA-no clean up required.	NA
Aesthetics	NA-no change in aesthetics.	NA
Noise Levels	NA-no noise above normal highway traffic.	NA
Cultural Resources	NA-no construction activities.	NA
Parks, forests, conservation areas, or areas of importance for public recreation	No effects.	NA
Seismology and Geology	NA-route, buildings meet codes.	NA
Wild Horses and Burros	NA-none present.	NA
Prime Farmland	NA-none present.	NA
Coral Reefs and Tundra	NA-none present.	NA
Water Quality	NA-none affected.	NA

3.2 Regional Settings

3.2.1 LANL

Four roads convey traffic to and from LANL (see Figure 1). State Road 502 is heavily used by commuter traffic from Santa Fe and Española. State Roads 4 and 502 provide access to LANL for small communities to the west of LANL. East Jemez Road and Pajarito Road are DOE-owned and provide public access to many technical areas at LANL. In addition to private vehicles, DOE and LANL employee and government vehicles contribute extensively to the volume of traffic on each of these roadways.

In 1995, the County had an estimated population of approximately 18,180 (based on the 1990 US census adjusted to July 1, 1995). Two residential and related commercial areas exist in the County. The Los Alamos townsite has an estimated population of 11,400. The White Rock area, including the residential areas of White Rock and Pajarito Acres, has about 6,800 residents.

PF-4 at TA-55 is centrally located within the LANL core operations complex. It is the only facility of DOE designed to simultaneously handle plutonium and uranium. Active and diverse research and development on the chemical and physical properties of plutonium are conducted at the facility. For protection of the worker, environment, and public, the facility is compartmentalized into laboratories. All plutonium and uranium is handled within a glovebox line that prohibits unprotected contact by the workers. The closed gloveboxes have an air filtration system consisting of HEPA filters and radiation monitors. In addition, the laboratory in which the gloveboxes are stationed has negative air pressure and a secondary air filtration and radiological monitoring system. The facility's air emission stacks are routinely monitored and sampled for control of radiological emissions. The facility is equipped with other engineering controls to contain the plutonium during routine operations and possible accidents.

Detailed descriptions of LANL's physical and socioeconomic environment, its climate, meteorology, hydrology, cultural resources, waste management, floodplains, wetlands, and threatened and endangered species are presented in the 1979 Final Environmental Impact Statement for Los Alamos Scientific Laboratory Site (DOE 1979) and the most recent Environmental Surveillance Report (LANL 1996).

3.2.2 Three Analyzed Routes: General Overview

As discussed in Section 2.1.4, three routes from LANL to the Canadian border were analyzed. The following routes meet DOT routing requirements; all three use available interstate highways and city bypasses, where available, to go around high-population areas.

3.2.2.1 Los Alamos, New Mexico to North Dakota - Canada Border

The Canadian border crossing for this route would be near Pembina, North Dakota (population 642) (Rand McNally 1995) as shown in Figure 6. The proposed MOX fuel shipment(s) would be transported by commercial truck (enclosed trailer) from LANL to Santa Fe, New Mexico (population 55,859). The shipment(s) would then be routed north along Interstate Highway 25, past Colorado Springs (population 281,140) toward Denver, Colorado. Denver is the largest city along the LANL-to-Pembina route, with a 1990 population of almost 468,000 people. This portion of the route from Santa Fe to Denver is located in the high plains, just east of the Rocky Mountains.

The shipment(s) would then continue northeast along Interstate Highways 76 and 80 toward the Nebraska cities of Lincoln (population 191,972) and Omaha (population 335,795). This portion of the route in northeastern Colorado and Nebraska is characterized by fairly flat terrain with much lower elevations. This part of the proposed route also parallels sections of the South Platte River and the Platte River.

Once in the Omaha area, the shipment(s) would be routed north along Interstate Highway 29, through western Iowa and eastern South and North Dakota. Between Omaha, Nebraska and Sioux City, Iowa (population 80,505), the route would parallel the course of the Missouri River, located nearby to the west. The route would then continue north, past Sioux Falls, South Dakota (population 100,814), and Fargo, North Dakota (population 74,111). This route essentially follows the high plains northward to the Canadian border.

3.2.2.2 Los Alamos, New Mexico to Michigan - Canada Border

The Canadian border crossing for this route would be near Port Huron, Michigan (population 34,400) (Rand McNally 1995) as shown in Figure 6. As in the route described above, the proposed MOX fuel shipment(s) would be transported by commercial truck from LANL to Santa Fe, New Mexico (population 55,859). The shipment(s) would then continue southwest along Interstate Highway 25 to Albuquerque, New Mexico (population 384,736). At Albuquerque, the route would continue east into Texas along Interstate Highway 40. Amarillo (population 157,615) is the largest Texas city along this section of the route. Continuing east along Interstate Highway 40 into Oklahoma, the shipment(s) would be routed to Oklahoma City (population 444,719). The shipment(s) would then continue northeast along Interstate Highway 44 through fairly flat terrain, toward Tulsa, Oklahoma (population 367,302) and on to Missouri.

Once in Missouri, the shipment(s) would continue northeast along Interstate Highway 44, past the cities of Springfield (population 140,494) and St. Louis (population 396,685). From St. Louis, the shipments would again be routed northeast, this time along Interstate Highway 55, toward Springfield, Illinois (population 105,227) and Chicago (population 2,783,726).

At Chicago, the largest city along the LANL-to-Port Huron route, the shipment(s) would enter the Great Lakes region of the U.S. From Illinois, the shipment(s) would continue northeast along Interstate Highway 94 past Michigan City, Indiana (population 33,822) and into south-central Michigan past Kalamazoo (population 223,000). The route would then proceed northward along Interstate Highway 69 toward Lansing (population 128,100) and Flint (population 140,100), ending at the border crossing near Port Huron, Michigan.

3.2.2.3 Los Alamos, New Mexico to New York - Canada Border

The Canadian border crossing for this route would be near Watertown, New York (population 29,429) (Rand McNally 1995) as shown in Figure 6. The route from LANL to Watertown follows the Port Huron route until St. Louis, Missouri (population 396,685). At St. Louis, the shipment(s) would be routed along Interstate Highway 70 toward Terre Haute, Indiana (population 57,483) and Indianapolis, Indiana. Indianapolis, with a 1990 population of 731,327, is the largest city along the LANL-to-Watertown route.

Continuing along Interstate Highway 70, the shipment(s) would be routed east into central Ohio to Columbus (population 632,910). At Columbus, the route would proceed north along Interstate Highway 71 to Cleveland, Ohio (population 505,616). The shipment(s) would then continue northeast on Interstate 90 along the edge of Lake Erie past Erie, Pennsylvania (population 108,718) and Buffalo, New York (population 328,123). Continuing along Interstate Highway 90, the shipment(s) would be routed east to Syracuse, New York (population 163,860) and then, following Interstate Highway 81, north past Watertown, New York (population 29,429) to the crossing.

3.3 Human Health

The basic approach used in assessing human health concerns from exposure to radiation is to first identify the affected environments and establish a baseline that represents the effects from current conditions. Changes in this baseline resulting from the fabrication and transportation of MOX fuel are then examined for both normal operations and potential accidents. These changes are discussed in Section 4.1.1.

The normal background radiation that exists day-to-day in the human environment, with little variability, is used as a radiation exposure baseline. A background radiation dose is the exposure received by the public from radiation present in the environment from either natural or manmade sources (e.g., radon and medical X-rays, respectively). Background doses are unrelated to MOX fuel fabrication and transportation activities and are expected to remain constant over time. The four major sources of naturally occurring

radiation are cosmic radiation; sources in the earth's crust, known as terrestrial radiation; sources in the human body, known as internal sources; and radon (LANL 1995a) (Table 3-2). The four major sources of manmade radiation are medical radiation procedures, nuclear medicine, consumer products, and other miscellaneous sources (LANL 1995b) (Table 3-2). The average annual radiation dose equivalent to a member of the general population from both natural and manmade background sources is about 360 mrem. In Los Alamos, naturally occurring background dose averages less than 350 mrem per year because of higher altitude and radon levels (LANL 1995a). Manmade background radiation averages about 65 mrem per year.

Table 3-2. Average Annual Background Dose

Source - Naturally Occurring	mrem per year
Cosmic	28
Terrestrial	28
Internal	40
Radon	200
Source - Manmade	**mrem per year**
Medical X-Rays	39
Nuclear Medicine	14
Consumer Products	10
Other	2

3.3.1 MOX Fuel Fabrication

A comprehensive explanation of exposures, doses and dose calculation methods, health effects due to radiation, and LANL's radiological program can be found in the annual environmental surveillance report (LANL 1996). Although most plutonium and uranium isotopes are alpha-particle emitters, the nature of the working environment, i.e. hot cells, gloveboxes, other protective enclosures, ventilation systems, and personnel protective measures, prevents internal (or "inside the body") exposure to the alpha particles. These protective measures would be in place for the MOX fuel fabrication workers. The predominant source of personnel radiation exposure in these facilities is external radiation exposure, such as X-rays, gamma rays, or neutrons that accompany the alpha or beta particles emitted by the plutonium and uranium isotopes. External radiation exposure is also "penetrating radiation" because, unlike alpha or beta particles, this radiation penetrates clothing and skin and reaches the internal organs. Shielding barriers between penetrating radiation sources and MOX fuel fabrication workers is used to reduce the dose.

Exposure to penetrating radiation, routinely measured by personal dosimetry badges, is reported as the effective dose equivalent (EDE) in units of rems for the period during which the dosimeter was worn. Penetrating exposure is used in this EA as the unit of comparison for human effects of routine and accident events for the Proposed Action.

Exposure to radiation may increase the MOX fuel worker's chance of developing fatal cancer. DOE has adopted the NRC's recommended risk conversion factors that express radiation doses in terms of risk of excess cancer fatalities. These risk factors are 400 cancer fatalities per million person-roentgen equivalent man (person-rem) for workers and 500 cancer fatalities per million person-rem for the general population (NRC 1991a). The EDE to individuals in the general public, also referred to as doses, from natural

background sources has been estimated in order to provide a basis of comparison with doses resulting from LANL operations.

Members of the public living near LANL can potentially receive doses due to radioactive emissions from LANL. The Environmental Protection Agency (EPA) limits doses received by members of the public through airborne releases to 10 mrem annually (EPA 1992). The DOE limits doses received by members of the public, taking all exposure pathways into consideration, to 100 mrem annually (DOE 1993b).

LANL personnel, such as the MOX fuel fabrication workers, who may be exposed to radiation are included in the health physics monitoring program. Whole-body doses to all individuals working in DOE facilities are limited according to the as low as reasonably achievable (ALARA) concept and are kept within the 2,000 mrem per year administrative control level specified by DOE (DOE 1994a). Additionally, the laboratory standards supplement the LANL Radiological Control Manual by encouraging further reduction of the administrative control levels for personnel exposures during operations at LANL. For example, processes at TA-55 have ALARA levels set below the DOE level. MOX fuel workers wear appropriate anticontamination clothing, including smocks, shoe covers, and rubber gloves as needed when working with radioactive material.

A small quantity of MOX fuel has been fabricated in PF-4 at TA-55 that can be used for the Parallex Project. During the production of the fuel, the involved workers were protected from direct plutonium and uranium contact by gloveboxes and personal protective clothing. SOPs developed for the fabrication and worker health and safety were followed. Six months were required to train the MOX fuel fabrication technicians, set up the equipment, start up the process, and fabricate the 11.7 lb (5.3 kg) of MOX fuel. The average involved worker dose for the MOX fuel made for research and development purposes was 355 mrem per year. This is well below the DOE ALARA guidelines for LANL workers of 2,000 mrem (2 rem) per year.

3.3.2 MOX Fuel Transportation

Commercial carriers are required to transport radioactive materials in accordance with DOT regulations (49 CFR 179), NRC regulations (10 CFR 71), and all applicable DOE Orders. For shipments that require real-time tracking for security purposes, a TRANSCOM (transportation computerized satellite tracking system) linked truck is used that involves a tamper-proof satellite relay system located within the vehicle. A transportation plan detailing the shipment material(s) and associated requirements is developed and written by DOE. The commercial carrier contracted for radioactive TRANSCOM shipments is required to follow the DOE transportation plan. For overland transport, in conformity with DOT routing regulations for HRCQ shipments of radioactive material, interstate highways and interstate bypasses are the required method of travel whenever possible (49 CFR 397.101). Responsibility for each shipment would transfer from the U.S. to the Canadian Government at the border.

In the U.S., more than 42,700 miles of interstate highways are open to traffic. The network of interstate highways serves virtually all of the nation's large urban areas and all states but Alaska. Fatality and injury rates are much lower for interstate travel than for travel on other highways or by rail as shown in Table 3-3. In 1993, a nation-wide fleet of 10,636 freight trucks traveled a total of 593,262,000 mi (954,770,000 km) on existing U.S. highways (NSC 1994).

Most commercial transportation routes between major cities are along interstate highways within the U.S. with the use of local access routes being required for pick-up and delivery point transportation. For transportation analysis, the routes are divided by the transportation computer model known as RADTRAN into route-segments according to population density. In general, three population density zones are defined by the computer model. The zones correspond to mean population densities for rural, suburban, and urban

areas and are expressed as persons per square mile or square kilometer (ORNL 1993). Rural is defined as 0 to 66 people per square kilometer, suburban is defined as 67 to 1,670 people per square kilometer, and urban is defined as greater than 1,670 people per square kilometer. In Tables 3-4, 3-5, and 3-6, the actual population for each proposed potential route-segment is expressed using a weighted population number.

Table 3-3. Urban Fatality and Injury Rates per 100 Million Person Miles* in 1994

Type of Transport	Fatalities	Injuries
Interstates	0.39	38.1
Other Highways	0.81	134.7
Urban Rail	1.11	80.7

(from: Cox and Love 1996)
* A person mile is one person traveling one mile in a vehicle, whether passenger or driver.

Table 3-4. Travel Summary: Los Alamos to North Dakota - Canada Border

	Rural	Suburban	Urban
People per mi^2 (km^2)	12.3 (4.8)	1,009.9 (389.9)	5,398.9 (2,084.5)
Distance - mi (km)	1,406.5 (2,263.5)	107.9 (173.6)	15.5 (25)

Source: RADTRAN code used for transportation analysis
Total Distance to the Canadian Border - 1,530 mi (2,462 km)

Table 3-5. Travel Summary: Los Alamos to Michigan - Canada Border

	Rural	Suburban	Urban
People per mi^2 (km^2)	25.3 (9.8)	799.5 (308.7)	5,602.9 (2,163.3)
Distance - mi (km)	1,361.5 (2,191.1)	360.9 (580.8)	32.1 (51.7)

Source: RADTRAN code used for transportation analysis
Total Distance to the Canadian Border - 1,755 mi (2,824 km)

Table 3-6. Travel Summary: Los Alamos to New York - Canada Border

	Rural	Suburban	Urban
People per mi^2 (km^2)	29.4 (11.3)	772.6 (298.3)	5,451.8 (2,105)
Distance - mi (km)	1,615.8 (2,600.3)	473.1 (761.3)	37.4 (60.3)

Source: RADTRAN code used for transportation analysis
Total Distance to the Canadian Border - 2,126 mi (3,422 km)

DOE's hazardous material (radioactive and nonradioactive) shipments are small compared to the large shipment volume from non-DOE hazardous material transport activities. DOT estimates that approximately 4 billion tons of regulated hazardous materials are transported each year and that approximately 500,000 movements of hazardous materials occur each day. There are also approximately 2 million annual shipments of radioactive materials involving about 2.8 million packages, which represents about two percent of the annual hazardous materials shipments (DOE 1995a).

In comparison, DOE ships about 6,200 radioactive packages (commercial and classified) annually among its sites. DOE's annual shipments of radioactive packages represent less than 0.3 percent of all radioactive shipments in the United States, and less than 0.006 percent of all hazardous material shipments. DOE's unclassified radioactive and other hazardous materials are transported by commercial carrier (truck, rail, or air carriers) while abiding by all applicable DOE and federal transportation regulations (DOE 1995a).

In addition, there are nonradiological risks of highway travel. These risks are caused by air pollution or by highway accidents and do not involve a radiological release. Millions of miles are driven by cars and trucks on the U.S. highways every year. The risk of a highway accident increases with the number of highway miles traveled by a vehicle. In 1993, for example, 10,636 freight trucks traveled 593,262,000 mi (954,770,000 km). For the same year, there were 4.64 truck accidents per 1,000,000 vehicle miles (NSC 1994).

3.4 Air Quality

LANL and the County are remote from major metropolitan areas and major sources of industrial pollution. In 1994, air quality at LANL was much better than ambient air quality standards set by the EPA and the New Mexico Environment Department (LANL 1996). Information on nonradioactive air emissions is summarized in the LANL annual Environmental Surveillance Report (LANL 1996). Radioactive and nonradioactive air emissions from LANL operations are in compliance with the Clean Air Act and the New Mexico Air Quality Control Act.

3.5 Waste Management

LANL personnel operate an on-site radioactive management and disposal site (Area G) at Technical Area 54 (TA-54) for low-level radioactive waste (LLW). In 1996, LANL operations generated 162,790 ft^3 (4,609.8 m^3) of solid LLW. LLW may be disposed of on-site or shipped off-site to commercial disposal facilities.

Some LANL operations generate TRU wastes. Personnel place these materials in containers such as specially designed 55-gallon drums. The containers are sealed and certified to Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (DOE 1991). Containers are then transported to TA-54, Area G, where they are currently placed on asphalt pads in air-supported structures. The stacking array allows drums to be individually inspected and the storage areas are monitored. TRU wastes are being stored pending DOE decision to dispose at WIPP or another location. In 1996, LANL operations generated 3,291.3 ft^3 (93.2 m^3) of solid TRU waste. This amounted to a substantial decrease from the 7,080 ft^3 (200 m^3) generated in 1990.

3.6 Environmental Justice

Under Presidential Executive Order 12898 of February 11, 1994:

"1-101. *Agency Responsibilities.* To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions, the District of Columbia, the Commonwealth of Puerto Rico, and the Commonwealth of the Mariana Islands" (EO 1994).

DOE is in the process of finalizing procedures for implementing the Executive Order. The manner in which environmental issues should be addressed in an EA is expected to be addressed in the procedures. The analysis of environmental justice in this EA is not intended to establish the direction of DOE's future procedures implementing the Executive Order.

Minority populations, as categorized by the U.S. Bureau of the Census, are considered to be all people of color, exclusive of white non-Hispanics. Minorities include individuals classified as Black (African-American); American Indian, Eskimo, or Aleut; Asian or Pacific Islander; persons of Hispanic origin; and

other non-white persons. Within a 10-mi (16-km) radius of LANL, only 14 percent of the 18,115 persons are of minority status including Hispanics and Native Americans. The principal population centers located within a 50-mi (80-km) radius of LANL are Santa Fe, Española, and the Pojoaque Valley. These areas have an approximate total population of 214,727 people. Fourteen pueblos and Native American reservations are located within a 50-mi (80-km) radius of LANL. The populations of the four Accord Pueblos are as follows: San Ildefonso Pueblo has a population of 1,499; Santa Clara Pueblo has a population of about 3,000; Cochiti Pueblo has 1,342 people; and Jemez Pueblo has a population of about 1,750 (Commerce 1991). Minority individuals account for 65 percent of the general population of 133,028 living 10 to 30 mi (16 to 48 km) from LANL. Within a 50-mi (80-km) radius of LANL, minority individuals account for 54 percent of the population of 214,727.

Low-income is defined as an annual household income of less than 15,000 dollars in 1989[4]. As reported in the 1990 Census, only 581 households (about 2 percent) within 10 mi (16 km) of LANL were classified as low-income households. However, the number of low-income households increases sharply beyond the 10-mi (16-km) radius. In the 10- to 30-mi (16- to 48-km) radius of LANL, 12,995 households (23 percent) were low-income. Within a 50-mi (80-km) radius of LANL, 18,519 households (24 percent) were categorized as low-income households (DOE 1995b).

No disproportionally high and adverse human health or environmental effects on minority and low-income populations adjacent to LANL would be expected if the Proposed Action to fabricate MOX fuel rods for use in the Parallex Project is implemented since there would be no anticipated measurable effects to the public from this action. Both minority and low-income populations are likely to be present along portions of the three analyzed transportation routes. Tables 3-7, 3-8, and 3-9 were generated using state-level data from a recent study of poverty in the U.S. and from the 1990 census (Baugher and Lamison-White 1996; U.S. Census Data 1990).

Transportation accidents are random occurrences that could potentially affect the population around the accident site. However, the random nature of these accidents precludes any intentional disproportionate effect to minority or low-income populations. Although populations that are subject to environmental justice considerations are likely to be present along the three transportation routes, there would be no disproportionally high and adverse health or environmental effects to any population expected from the transportation events as part of the Proposed Action.

In addition, no disproportionate adverse effects on low-income, minority, or Native American populations are known to occur with the storage of MOX fuel at LANL. Therefore, no disproportionally high adverse human health or environmental effects to populations subject to environmental justice concerns are anticipated under the No Action alternative.

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[4] Poverty thresholds vary by size of family and number of related children under 18 years of age. In 1989, 14,990 dollars was the official poverty threshold for a family of five persons. Poverty thresholds in 1989 dollars range from 8,076 dollars per year for a family of two to 25,480 dollars for a family of nine persons or more (Census 1997).

Table 3-7. Environmental Justice Population Summary: Los Alamos to North Dakota - Canada Border

State	% of Population Living in Poverty in 1995†	% Minority Population (Non-whites and Persons of Hispanic origin‡)
New Mexico (NM)	25.3	62.3
Colorado (CO)	8.8	24.4
Nebraska (NE)	9.6	8.9
Iowa (IA)	12.2	4.4
South Dakota (SD)	14.5	9.2
North Dakota (ND)	12	6.0

† As used in Baugher and Lamison-White (1996) "Poverty status is defined by a set of money income thresholds that vary by family size and composition. Families or individuals with income below their appropriate poverty thresholds are classified as poor".

‡ Minority population figures, as defined for this chart, are taken from the following 1990 US Census Tables: Black; American Indian, Eskimo, or Aleut; Asian or Pacific Islander; Other Races; and Persons of Hispanic Origin.

Table 3-8. Environmental Justice Population Summary: Los Alamos to Michigan - Canada Border

State	% of Population Living in Poverty in 1995†	% Minority Population (Non-whites and persons of Hispanic origin‡)
New Mexico (NM)	25.3	62.3
Texas (TX)	17.4	50.0
Oklahoma (OK)	17.1	20.4
Missouri (MO)	9.4	13.5
Illinois (IL)	12.4	29.3
Indiana (IN)	9.6	11.1
Michigan (MI)	12.2	18.6

† As used in Baugher and Lamison-White (1996) "Poverty status is defined by a set of money income thresholds that vary by family size and composition. Families or individuals with income below their appropriate poverty thresholds are classified as poor".

‡ Minority population figures, as defined for this chart, are taken from the following 1990 US Census Tables: Black; American Indian, Eskimo, or Aleut; Asian or Pacific Islander; Other Races; and Persons of Hispanic Origin.

Table 3-9. Environmental Justice Population Summary: Los Alamos to New York - Canada Border

State	% of Population Living in Poverty in 1995†	% Minority Population (Non-whites and persons of Hispanic origin‡)
New Mexico (NM)	25.3	62.3
Texas (TX)	17.4	50.0
Oklahoma (OK)	17.1	20.4
Missouri (MO)	9.4	13.5
Illinois (IL)	12.4	29.3
Indiana (IN)	9.6	11.1
Ohio (OH)	11.5	13.4
Pennsylvania (PA)	12.2	13.3
New York (NY)	16.5	37.5

† As used in Baugher and Lamison-White (1996) "Poverty status is defined by a set of money income thresholds that vary by family size and composition. Families or individuals with income below their appropriate poverty thresholds are classified as poor".

‡ Minority population figures, as defined for this chart, are taken from the following 1990 US Census Tables: Black; American Indian, Eskimo, or Aleut; Asian or Pacific Islander; Other Races; and Persons of Hispanic Origin.

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

This section evaluates the environmental effects of the Proposed Action. Each resource identified and not dismissed in Section 3.0 is evaluated in Section 4.0 for probable environmental consequences.

4.1.1 Human Health

The effect on human health from MOX fuel fabrication would come from the penetrating radiation environment within PF-4. Noninvolved workers, those performing other jobs as well as the usual PF-4 building personnel, would not be expected to receive a dose from the proposed operation. MOX fuel fabrication is not expected to measurably increase the airborne radioactive material emissions from PF-4 associated with routine operations, therefore, no effects to the public are expected. The shipment(s) of MOX fuel to the Canadian border in specially designed and shielded package containers in a commercial truck is not expected to increase the penetrating radiation dose to the public above background levels. No effects to the public are expected from the transportation.

4.1.1.1 MOX Fuel Fabrication

Estimates of long-term or chronic human health risk from the radiation environment are made based upon currently accepted radiation risk models (ICRP 1991). These risk estimates show the ultimate effects of radiation on humans, namely, an estimate of the added cancer fatalities in the exposed population. Human health risk is determined by converting the estimated dose into the probability of contracting a fatal cancer. The dose-to-risk conversion factor used for estimating cancer deaths was four latent cancer fatalities (LCFs) per 10,000 person-rem dose (4.0×10^{-4} cancer deaths per person-rem) for exposed workers (NRC 1991a, DOE 1993a). The health risk to an exposed individual is best expressed as the added probability of that individual developing a fatal cancer. As the probability approaches 1.0, the chances of development of a fatal cancer increase. As probability decreases, the chances of development of a fatal cancer similarly decrease. For exposed populations, the probability is more meaningful when it is considered as the number of additional cancer deaths. If the probability is less than 1.0, no additional cancer deaths are expected. If it exceeds 1.0, then additional cancer deaths are likely to occur.

No excess fatal cancers would be expected from penetrating radiation exposures associated with MOX fuel production used in the Parallex Project at LANL. The 12 involved workers exposed to penetrating radiation during total MOX fuel fabrication for the Parallex Project (including both that for the fuel that already exists and for the additional amounts of fuel pins yet to be manufactured) are estimated to receive a maximum dose of 661 mrem (0.661 rem) per year at work. The assumed dose used in this analysis, 661 mrem, is a "conservative" estimate meaning that it leads to an overestimate of ultimate health risk. The MOX fuel fabrication required to complete the test matrix would not be a year-long process, and the assumed total dose was derived as 95 percent of the maximum dose average for two workers in operations that are known to be similar to the Proposed Action. The 95 percent dose is defined here as a dose which is expected to be exceeded no more than 5 percent of the time as based on real data from similar operations. The 95 percent maximum dose is multiplied by the dose-to-risk conversion factor of 4×10^{-4} cancer deaths per person-rem resulting in a risk estimate of 2.6 in 10,000 (2.6×10^{-4}) per worker, which means that the probability of an individual worker developing a fatal cancer from MOX fuel fabrication is slightly above one chance in ten thousand. For comparison, the 661 mrem estimated dose is well below the DOE ALARA guideline for LANL workers of 2,000 mrem (2 rem) per year. The DOE regulatory annual dose limit for workers if 5,000 mrem (5 rem) per year (DOE 1996b), which corresponds to an individual annual risk of LCF of 2 in 1,000 (2.0×10^{-3}).

If all 12 Parallex Project workers were exposed to 661 mrem, it would result in a collective dose of 7.9 person-rem per year. Using the dose-to-risk conversion factor (4×10^{-4} cancer deaths per person-rem), the calculated risk of annual excess fatalities for the worker population is 3.2×10^{-3} (Table 4-1). This is less than the probability of 1.0 defined earlier in this section as the criteria above which no additional cancer deaths are expected. Therefore, no excess cancer deaths of workers are expected from radiation exposures associated with routine operations of MOX fuel fabrication at LANL at a full-production rate.

Table 4-1. Summary of Estimated Radiation Dose and Risk of Cancer Deaths to Worker Populations

Activity	rem Dose (mrem)	Worker Population	Person-rem (annual)	Risk of Excess Cancer Fatalities
MOX fuel fabrication (full-production rate)	0.661 (661)	12	7.9	3.2×10^{-3} per year

Operations would be analyzed, planned, and managed to ensure that worker exposures are kept as low as reasonably achievable. Based upon this information and the calculated risk, no excess cancer fatalities are expected and workers engaged in this proposed project are not expected to incur any harmful health effects from radiation exposures they receive during normal operations.

4.1.1.2 MOX Fuel Transportation

No changes to the existing highway infrastructure would be required to allow passage of the MOX fuel shipment(s), nor would the roads need to be closed. The normal traffic flow along the three analyzed MOX fuel transportation routes would not be expected to change with the added presence of one to three commercial truck(s).

A transportation analysis of the proposed shipment(s) of MOX fuel was performed using the RADTRAN 4 computer model developed and maintained by Sandia National Laboratories in Albuquerque, New Mexico. The analysis considered the following elements: mode of transportation, curies of material, proximity dose rates (transport index), type of packaging, accident severity category, and potentially affected populations. Transportation health risks were estimated for accident radiological dose rates, normal (incident-free) transportation radiological dose rates, and nonradiological accident effects (i.e., highway collision fatalities). The RADTRAN 4 computer model is discussed in detail in Appendix C.

The shipment(s) of MOX fuel by commercial truck from LANL to the Canadian border would not be expected to adversely affect the health of the public along the proposed routes. The incident-free dose is the radiological exposure received by the public while the shipment(s) are transported along the routes. Assuming, as an upper bound, all of the MOX fuel is transported in a single shipment, the incident-free doses to the public from each proposed route would be 4.1×10^{-9} person-rem for the Pembina route, 4.7×10^{-9} person-rem for the Port Huron route, and 5.7×10^{-9} person-rem for the Watertown route. These doses are summarized in Table 4-2. The shipment(s) of the MOX fuel along the three routes would result in a negligible radiological dose to the public.

Similarly, the shipment(s) of MOX fuel by commercial truck from LANL to the Canadian border along the proposed routes would not be expected to adversely affect the health of the truck crew. The incident-free dose is the radiological exposure received by the truck crew, if all the MOX fuel is transported in a single shipment, would be 6.3×10^{-10} person-rem for the Pembina route, 7.3×10^{-10} person-rem for the Port Huron route, and 8.8×10^{-10} person-rem for the Watertown route. These doses are also summarized in

Table 4-2. The truck crew would receive a negligible radiological dose from the shipment(s) of the MOX fuel along the three routes. More information on these doses is provided in Appendix C.

Table 4-2. Radiological Incident-Free Doses to the Public and Truck Crew during Single Shipment

Routes	Dose to the Public (person-rem)	Dose to the Truck Crew (person-rem)
Pembina, ND	4.1×10^{-9}	6.3×10^{-10}
Port Huron, MI	4.7×10^{-9}	7.3×10^{-10}
Watertown, NY	5.7×10^{-9}	8.8×10^{-10}

By using the single MOX fuel shipment as an upper bound, the risk of excess LCFs can be estimated for the total combined radiological dose to the public and truck crew for each proposed transportation route. As shown in Table 4-3, the estimated number of LCFs would be very small (much less than 1.0). Therefore, no adverse health effects to the public and truck crew would be expected from any scenario involving the shipment of MOX fuel across the U.S.

Table 4-3. Risk of Cancer Fatalities for Single Shipment for All Routes

Routes	Total Dose (person-rem)	Exposed Population LCFs
Pembina, ND	4.7×10^{-9}	2.3×10^{-12}
Port Huron, MI	5.4×10^{-9}	2.7×10^{-12}
Watertown, NY	6.6×10^{-9}	3.3×10^{-12}

4.1.2 Air Quality

Air emission from the fabrication of MOX fuel pellets and rods for the Parallex Project would be a very small percentage of the overall LANL annual air emissions. The MOX fuel pellets and rods would be made inside sealed gloveboxes that have negative pressure and a primary air system fitted with HEPA filtration. PF-4 laboratories are also equipped with a separate HEPA filtered air system. The rooms of PF-4 also have negative air pressure to prevent the escape of radioactive contaminants. Plutonium dioxide and uranium dioxide powders that become airborne inside a glovebox would be captured by the HEPA filtration system. In the event of a glovebox failure or accident, any airborne particles would also be captured by the PF-4 HEPA filters. The filters would prevent any measurable release of particles into the atmosphere. HEPA filters are regularly replaced and the used ones are treated and disposed of as radioactive waste. Any release of radioactive particles outside of gloveboxes would trigger alarms. Radiological control technicians would respond to the alarms and contain the situation. No MOX fuel powder particles would be expected to be released from PF-4 into the environment. In addition to continuous radiation monitoring in the facility, the air emission stacks are continuously monitored and sampled for radioactivity. No change to the air quality along the route(s) to Canada would be expected since the MOX fuel would be sealed in rods and package container(s) during transportation. No measurable radioactive particles would be released into the air. A commercial truck carrying MOX fuel would be one out of thousands of trucks on the road at any one time. The overall contribution of nonradiological air pollutants from a single vehicle to the air quality within a given airshed would be small to the point of being immeasurable.

4.1.3 Waste Management

LANL has established processes to manage radioactive liquid and solid wastes. Only solid waste would be generated from the Parallex Project MOX fuel fabrication. The LLW and TRU waste produced from the MOX fuel process would be within the LANL normal values of waste production. The estimated small quantities of solid LLW (169.9 ft^3/4.8 m^3) and TRU waste (21.95 ft^3/0.62 m^3) are well below the LANL yearly (1996) generation of LLW (162,790 ft^3/4,609.8 m^3) and TRU waste (3,291.3 ft^3/93.2 m^3). The LLW and TRU waste would be characterized by the generators before packaging. The wastes would be packaged following the LLW Acceptance Criteria and the WIPP Waste Acceptance Criteria before being transported to TA-54 for disposal (LLW) or storage (TRU waste). LLW would be packaged in specially designed cardboard boxes. The TRU waste would be stored in special 55-gal. drums. The LLW and TRU waste would consist of gloves, tape, plastic bags, booties, metal pieces, and rags. The LLW would be buried at the TA-54 disposal site. The TRU waste would be stored awaiting shipment to WIPP. No liquid waste, mixed waste, hazardous waste, or nonhazardous waste would be generated from MOX fuel fabrication. The sanitary wastewater production for PF-4 from the MOX fuel fabrication would not measurably increase. No radioactive waste would be generated during the shipment of MOX fuel to the Canadian border.

4.2 No Action Alternative

This section evaluates the environmental effects of the No Action alternative. Each resource identified and not dismissed in Section 3.0 is discussed in this section.

4.2.1 Human Health

Under this alternative, no additional MOX fuel would be fabricated at LANL for the Parallex Project. However, TA-55 workers would be involved with work on other plutonium processes. There would be no change to human health effects compared to normal TA-55 operations. No MOX fuel rods would be shipped to CRL. No shipment activities would mean that there would be no risk to the transport crew and members of the public along the route from routine radiological and accident exposures. There would be no change in the potential radioactive, chemical, biological, physical, or environmental hazards that could affect human health at LANL or along the proposed shipment routes under this alternative. MOX fuel pellets and master blend of plutonium dioxide would continue to be stored at LANL until some other use or disposition was determined. Storage of these materials would result in minor human health effects to workers involved in LANL material handling and management requirements.

4.2.2 Air Quality

There would be no further fabrication of MOX fuel at LANL for the Parallex Project. No change to the air emissions from the routine operations in PF-4 at TA-55 would be expected. Therefore, the air quality at TA-55 and the surrounding areas would not change from the routine operation baseline.

4.2.3 Waste Management

No additional fabrication of MOX fuel and rods would take place at LANL for the Parallex Project. Therefore, no additional solid wastes would be generated and managed at LANL under this alternative. There would be no change to the normal waste operations of LANL.

4.3 Comparison of Alternatives

The following summary table (Table 4-4) compares the two alternatives presented in this EA and the expected consequences under each alternative. The Proposed Action would fabricate MOX fuel and result in the shipment(s) of MOX fuel to CRL, Canada from LANL, New Mexico without any negative effects to

the transportation environment and negative effects to the human health. The No Action alternative would result in no MOX fuel fabrication or shipment(s) to Canada.

Table 4-4. Summary of the Potential Effects of the Proposed Action and the No Action Alternative

Factor	Proposed Action	No Action
Human Health	No anticipated excess fatal cancers would be expected from MOX fuel fabrication or transportation.	No change
Transportation	Transport of radioactive materials from LANL to the Canadian border would have negligible environmental consequences.	No change
Air Quality	Negligible emissions from MOX fuel fabrication.	No change
Waste Management	Negligible amounts of LLW and TRU waste.	No change

4.4 Cumulative Effects

Cumulative effects on the environment result from the incremental effect of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions. Cumulative effects can result from individually minor, but collectively significant, actions taking place over a period of time (40 CFR 1508.7). MOX fuel and rod fabrication at LANL would contribute a negligible increase to the air emissions and waste generation from routine LANL operations. Potential radiation exposures to workers would be maintained below ALARA guidelines. The small solid waste and air emission volumes generated from the fabrication of MOX fuel and rods would not be expected to affect the life expectancy of the waste disposal facility at LANL or WIPP; nor would it affect the air emission management programs at LANL. The shipment(s) of MOX fuel to CRL would be very small in size and numbers. The required number of highway road miles to CRL for the shipment(s) is very small compared to the millions of miles traveled yearly by commercial trucks. DOE is not aware of any projects along the proposed routes that would contribute to any cumulative effects from MOX fuel shipments. Because the contributions to adverse effects from the Proposed Action would be extremely small, it is expected that activities associated with the Proposed Action would not exacerbate cumulative effects.

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5.0 ACCIDENT ANALYSIS

Abnormal events or accidents are hypothetical incidents that are not a planned part of routine operations. This EA evaluates three hypothetical accident scenarios (see Appendix C) that have a reasonable probability of occurrence and are provided as the bounding cases that could be associated with the fabrication and transportation of MOX fuel and rods under the Proposed Action and that could affect workers, the public, and the environment. One accident scenario occurs during MOX fuel and rod fabrication and the other two accident scenarios examined occur during fuel shipment(s). The potential accident scenarios for the transportation of the MOX fuel from LANL to the Canadian border were developed using the RADTRAN 4 computer model.

The three accident scenarios developed are expected to be credible and bounding. The scenarios are credible in that their estimated likelihood of occurrence range from "anticipated" to "extremely unlikely" (i.e., from once every ten years to once every million years [10^{-1} to 10^{-6} per year]). Table 5-1 shows the qualitative classification of likelihood. The scenarios also represent the upper bounds, which means that other credible accidents would pose less serious risks. The analysis of the three accidents resulted in low consequences for each accident. The involved worker and public radiation exposure was low, as was the calculated LCFs.

Table 5-1. Qualitative Likelihood Classification

Descriptive Word	Estimated Annual Likelihood of Occurrence	Description
Anticipated	$10^{-1} \geq p > 10^{-2}$	Incidents that may occur several times.
Unlikely	$10^{-2} \geq p > 10^{-4}$	Accidents that are not anticipated to occur.
Extremely Unlikely	$10^{-4} \geq p > 10^{-6}$	Accidents that would probably not occur.
Beyond Extremely Unlikely	$10^{-6} \geq p$	All other accidents.

Source: DOE 1994b

5.1 MOX Fuel Fabrication Fire Accident

This accident scenario is assumed to occur during a MOX fuel and rod fabrication shift in the PF-4 plutonium processing laboratory of TA-55. The fire is assumed to occur adjacent to a granulation glovebox where the pellets are screened through a sieve. Nearby LLW boxes filled with combustible materials are ignited by generation of internal heat or a spilled flammable liquid. The laboratory is unattended, at first, and the fire spreads to the rubber gloves of the adjacent glovebox. Workers then enter the laboratory unaware of the fire and are exposed to plutonium dioxide by breathing airborne particulates produced by the fire. Depending on the particle size, the inhaled plutonium dioxide would settle in different parts of the respiratory tract. The inhalation of a large amount of plutonium dioxide in a short time period would be characterized as an acute exposure. The health effect from an acute exposure would be radio pneumonitis, which is the inflammation of the lungs with pneumonia-like symptoms. A large amount (1.0 μCi or greater) of plutonium dioxide would have to be inhaled to give the large dose required to cause radio pneumonitis. Radio pneumonitis has been observed in experimental animals but never in a human. The inhalation of a small amount (much less than 1.0 μCi) of plutonium dioxide would be characterized as a chronic exposure. The health effect from a chronic exposure would be development of respiratory cancer decades after the exposure. A chronic exposure is analyzed in this accident scenario. Under this scenario the material at risk is the plutonium oxide in the glovebox. The likelihood of this accident occurring was calculated to be between one in 100 and one in 10,000 years (10^{-2} to 10^{-4}) and categorized as "unlikely." "Unlikely" is defined in Table 5-1. An accident consequence computer code was used to estimate the radiological dose to involved workers at 1.8×10^{3} mrem. A radiation dose of 3.14×10^{-5} mrem was estimated for the maximally exposed public located at the Royal Crest Trailer Park

(Park), which is a privately owned mobile home park situated about 2,953 ft (900 m) north of PF-4. The low level of released material within PF-4 and mitigation of the release by the two-stage HEPA filtration system result in a negligible dose to residents at the Park and no LCFs within that population. Analytical details regarding this accident are provided in Appendix C.

5.2 MOX Fuel Transportation Accidents

Two credible transportation accident scenarios were analyzed for the shipment of MOX fuel to the Canadian border. One accident involved the release of radioactive materials and the other did not release radioactive materials.

The first accident relates to an event that leads to the MOX fuel package container breaking open, igniting, and releasing plutonium dioxide particles into the air. As an upper bound, this accident scenario assumes the MOX fuel is transported in a one-shipment configuration. The public is assumed to be near enough to the accident to breathe air contaminated with plutonium dioxide. The largest radiological risk to the public is through the inhalation pathway which includes resuspended particles under this scenario. Table 5-2 lists the public radiological dose-risks from inhalation of a single shipment accident on each of the proposed routes. Long-term doses are reported as population doses.

Table 5-2. Radiological Dose-Risks for a Single-Shipment Accident on all Routes

Route	Inhalation (person-rem)	Resuspension (person-rem)
Pembina	4.9×10^{-9}	2.2×10^{-9}
Port Huron	1.1×10^{-9}	4.9×10^{-9}
Watertown	1.5×10^{-9}	6.8×10^{-9}

No early fatalities are expected for any shipment configuration by any route. The maximum potential accident consequence (50-year population dose) for the single-shipment configuration is 1.2×10^{3} person-rem committed effective dose (CED) for an urban link of a proposed route. The probability of this accident consequence occurring is very low (8.1×10^{-13}). The expected number of excess LCFs from breathing plutonium dioxide particles is less than one in a million (6.0×10^{-7}) for the maximum estimated population dose. For this accident scenario, an individual public member standing outdoors and within a few meters of the accident would receive a maximum first-year dose of 5.8×10^{-2} mrem from breathing plutonium dioxide. The population and individual doses and LCFs are low. The probability of such a severe accident occurring and adversely affecting the public is extremely unlikely. No fatalities from an accident radiation exposure would be expected from the shipment(s) of MOX fuel by any of the proposed routes. Appendix C provides more information on transportation risk and consequence analysis.

Under the second accident scenario for the MOX fuel transportation to the Canadian border, no radioactive material is released by the vehicular collision. This scenario analyzed fatalities expected to occur from the MOX fuel commercial truck crashing. The accident analysis estimated no expected driver or public fatalities. The calculated fatality number is much less than 1.0 which considers up to three round trips for each proposed route. This accident scenario takes into account the empty truck's return trip from the Canadian border (Appendix C).

6.0 AGENCIES CONSULTED

The following U.S. and Canadian agencies were contacted during the preparation of this analysis regarding the MOX fuel and rod shipment(s) to Canada for the Parallex Project:

- U.S. Nuclear Regulatory Commission, Washington, D.C. 20555
- U.S. Department of Transportation, Washington, D.C. 20590
- Atomic Energy of Canada Limited, Mississauga, Ontario, Canada L5K1B2
- Canadian Atomic Energy Control Board, Ottawa, Canada K1P5S9

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APPENDIX A. CANADIAN SHIPPING PACKAGE CERTIFICATE

Description of Model 4H Shipping Package

Certification

Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

RADIOACTIVE MATERIAL TYPE B(U) PACKAGE DESIGN APPROVAL CERTIFICATE
No. CDN/4212/B(U)F, (REV. 6)

30-A1-153-0 September 16, 1994

The Atomic Energy Control Board hereby certifies that the package, as described below, has been demonstrated to meet the regulatory requirements prescribed for Type B(U) Fissile packages as described in the Canadian Transport Packaging of Radioactive Materials Regulations and in the IAEA Regulations*, subject to the following limitations, terms and conditions.

All users of this authorization shall register their identity in writing with the Atomic Energy Control Board prior to the first use of this authorization and shall certify that they possess the necessary instructions for preparation of the package for shipment.

This certificate does not relieve the shipper from any requirement of the government of any country through or into which the package will be transported.

PACKAGE IDENTIFICATION

Atomic Energy of Canada Limited Model 4H Enriched Fuel Bundle Shipping Package, serial nos. 1 to 8.

PACKAGING DESCRIPTION

The Atomic Energy of Canada Limited (AECL) Model 4H Enriched Fuel Bundle Shipping Package, as shown on AECL Drawings A-5580-A12, E-5580-A2, E-5580-2, E-5580-3 and E-5580-SA1, consists of a reinforced 208 litre drum filled with foam, vermiculite and plywood. The matching lid is attached by a 2.66 mm (12 gauge) closure ring with drop forged lugs and a 15.9 mm diameter bolt. A 2.4 mm diameter hole is provided for a security seal. The drum contains a weldment of spacers and plates attached to four Specification 2R containers on 216 mm centres. The 2R containers are closed by luted (Teflon tape) and threaded steel plates. The plates are colour-coded and numbered to match the 2R containers. The 2R containers enclose felt-lined aluminum carriers, packing materials as restricted below, and the authorized radioactive contents.

Containment for Type A and LSA quantities is provided by the closed drum and Specification 2R containers and additional containment for Type B quantities is provided by the leak tight fuel cladding on the elements and bundles. The maximum gross weight of the package is 250 kg.

The package shall bear the competent authority identification mark "CDN/4212/B(U)F".

AUTHORIZED RADIOACTIVE CONTENTS

The contents are described for individual Specification 2R compartments. When the contents of the four compartments are common, the package mass limit is four times (4x) the compartment mass limits. Paragraphs a) through e) below list the appropriate Transport Indices and Allowable Numbers for a package. When the contents of the four compartments are not common, the package mass limit is the total of each of the appropriate compartment mass limits but the Transport Index and Allowable Number for the package shall be based on the most restrictive contents of any one compartment.

As prepared for shipment, each of the Specification 2R compartments may contain up to 100 grams hydrogen, and

(a) not more than 22.6 kg of unirradiated uranium oxide containing up to 20 kg uranium enriched in the isotope U-235 to a maximum of 10 weight percent (wt.%) in the form of pellets, powder or scrap with Allowable Number and Transport Index as set out in Table 1;

TABLE 1: UO_2 Limits on Transport Indices and Allowable Numbers

Max. wt. % U-235 in U	Transport Index (per package)	Allowable Number
2.75	1.3	38
3.00	1.7	29
3.50	2.7	18
5.00	4.2	11
10.00	50.0*	1

* Transport as Exclusive Use

or

(b) not more than 20 kg of unirradiated uranium enriched in the isotope U-235 up to 5 wt.% as metal in the form of slugs, powder, pellets or scrap or as carbide (UC) in the form of pellets, elements or bundles sealed in fuel cladding with Allowable Numbers and Transport Indices as set out in Table 2;

TABLE 2: U and UC Limits on Transport Indices and Allowable Numbers

Max. wt.% U-235 in U	Transport Index (per package)	Allowable Number
2.00	1.3	38
2.25	1.4	35
2.50	2.0	25
2.75	3.0	16
3.00	4.2	11
3.50	8.4	5
5.00	12.5*	4

* Transport as Exclusive Use

or

(c) not more than 0.35 kg of unirradiated uranium enriched in the isotope U-235 up to a nominal level of 93 wt.% (maximum of 0.33 kg U-235) as slugs, powder, pellets or scrap shipped exclusive use with an Allowable Number of 2 and Transport Index of 25;

or

(d) mixed oxides of unirradiated uranium and thorium, $(U,Th)O_2$, containing not more than 5 wt.% UO_2 with uranium enriched in the isotope U-235, up to 93 wt.% in quantities not exceeding:

1) 7 kg total uranium plus thorium when the UO_2 content is equal to or exceeds 1.75 wt.% $(U+Th)O_2$ in the form of powder, pellets or scrap not in sealed fuel cladding; or

2) 20 kg total uranium plus thorium when the UO_2 content is less than 1.75 wt.% $(U+Th)O_2$ in the form of powder, pellets or scrap not in sealed fuel cladding; or

3) 20 kg total uranium and thorium in the form of pellets, elements or bundles sealed in zirconium alloy fuel cladding, with Allowable Numbers and Transport Indices as set out in Table 3;

TABLE 3: $(U,Th)O_2$ Limits on Transport Indices and Allowable Numbers

Max. wt.% UO2 in (U,Th)O2	Transport Index (per package)	Allowable Number
4.25	1.3	38
4.50	1.4	35
4.75	1.6	31
5.00	1.8	27

or

(e) not more than 22.6 kg of oxides of unirradiated uranium (natural or depleted) and plutonium (separated and further described in reference **), $(U,Pu)O_2$, containing a maximum of 20 kg total of uranium and plutonium with up to 4 wt.% PuO_2 in $(U+Pu)O_2$ sealed in zirconium alloy fuel cladding with Allowable Numbers and Transport Indices as set out in Table 4;

TABLE 4: $(U,Pu)O_2$ Limits on Transport Indices and Allowable Numbers

Max. wt.% PUO2 in (U,P7)O2	Transport Index (per package)	Allowable Number
1.25	1.3	38
1.50	1.5	33
1.75	2.0	25
2.00	2.8	17
2.25	3.8	13
2.50	5.0	10
2.75	6.3	7
3.00	8.4	5
3.50	10.0	5
4.00	12.5*	4

* Transport as Exclusive Use

SHIPMENT

This package shall be prepared for shipment in accordance with AECL Procedure No. A-12052-PR-1, the Canadian Transport Packaging of Radioactive Materials Regulations, and the IAEA Regulations*.

Calculation of Allowable Numbers for nuclear safety include conservative evaluations of spacing of normal packages and damaged packages, as determined by testing, and worst combination of moderation by water of any density within the packaging and in the interstitial space of arrays of packages fully reflected by water.

Shipment is authorized as Fissile Class II, with a minimum Transport Index as specified under Authorized Radioactive Contents, or the highest radiation dose rate, in microsieverts per hour divided by 10, measured at one meter from any accessible external surface of the package, whichever is larger.

EXPIRY DATE

This certificate expires September 30, 1998.

W.R. Brown
Director
Radioisotopes and Transportation
Division

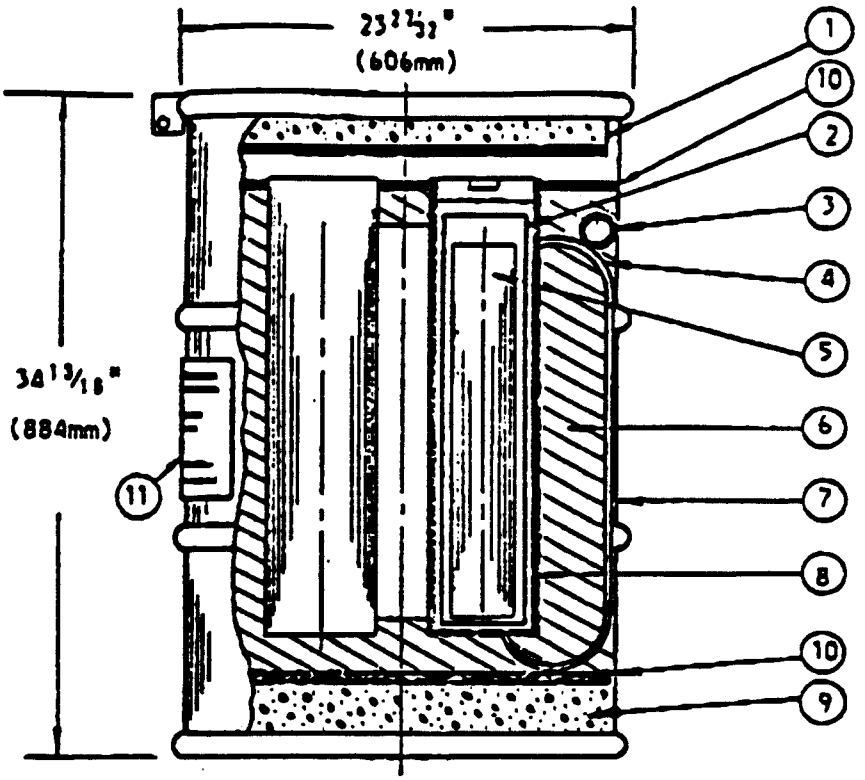
REFERENCE

* International Atomic Energy Agency Safety Series N° 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition (as amended).

** Fissile Material Packaging 4H Compliance with Canadian Transport Regulations, Report No. CRNL 1698, W.R. Taylor.

NOTES

1. AECL Drawing A-5580-A12 attached.
2. Revision 0: August 2, 1978. Original certificate.
3. Revision 1: August 4, 1981. Certificate renewed.
4. Revision 2: September 15, 1983. Certificate renewed.
5. Revision 3: June 3, 1987. Certificate renewed.
6. Revision 4: August 31, 1990. Registered user requirement added.
7. Revision 5: September 27, 1991. Certificate renewed.
8. Revision 6: September 16, 1994. Certificate renewed.



1. TOP THERMAL SHIELD (VERMICULITE)
2. FELT LINED ALUMINUM CAN
3. 1½ INCH SCH.40 RETAINING PIPE
4. 12.7mm DIAMETER STEEL SPIDER - 4 PLACES
5. PAYLOAD (FUEL BUNDLE SHOWN)
6. CUSHIONING MATERIAL (URETHANE FOAM)
7. CTC 17H OR 17C DRUM, 40 IMPERIAL GALLONS, 16 GAUGE MATERIAL, FULL REMOVABLE HEAD
8. CTC SPECIFICATION 2R CONTAINER, 146mm O.D. x 133mm I.D., 610mm OUTSIDE HEIGHT x 572mm INSIDE HEIGHT - 4 PLACES
9. BOTTOM THERMAL SHIELD (VERMICULITE)
10. 12.7mm PLYWOOD SHEET
11. IDENTIFICATION AND TREFOIL SYMBOL PLATE

NOTES:

1. AUTHORIZED RADIOACTIVE CONTENTS - SEE AECB CERTIFICATE NO. CDN/4212/B(U)FT
2. CONFORMS TO IAEA TYPE B(U) AND FISSILE PACKAGING REQUIREMENTS AS SPECIFIED IN "REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE MATERIALS" SAFETY SERIES NO. 6
3. GROSS WEIGHT 250 kg (550 lb.) MAXIMUM
   TARE WEIGHT 150 kg (350 lb.)
4. RADIOACTIVE CONTENTS TO BE PACKAGED AS PER DRAWINGS A-12052-PR1 AND E-5580-SA1
5. PACKAGING DESIGN DRAWINGS

E-5580-A2	ASSEMBLY
E-5580-2	SUB-ASSEMBLY AND DETAILS
D-5580-3	DRUMHEAD DETAILS
E-5580-SA1	PACKING SUBASSEMBLIES
A-12052-PR1	OPERATING PROCEDURES

FIGURE 1 MODEL 4H PACKAGING CDN/4212/B(U)F

ATOMIC ENERGY OF CANADA LIMITED	APPROVED	A-5580-A12	SHEET 1 OF 1

OPERATING PROCEDURES

1. SCOPE

These procedures specify authorized radioactive contents and instructions for inspecting, loading, shipping and maintaining the packagings.

These procedures are mandatory and comply with Canadian transport regulations. Detailed handling and operating procedures at specific sites shall follow appropriate site practices.

Sections 3 through 5 of these procedures should be used as a Check List for consignors.

2. APPLICABLE DRAWINGS AND DOCUMENTS

2.1 CRNL Drawings, Latest Revision

E-5580-A2	Fissile Class II Packaging	- Assembly
E-5580-2	Fissile Class II Packaging	- Sub-assembly and Details
D-5580-3	Fissile Class II Packaging	- Drumhead Details
E-5580-SA1	Fissile Class II Packaging	- Packing Sub-assemblies

2.2 Atomic Energy Control Board Certificate, CDN/4212/B(U)FT

2.3 International Atomic Energy Agency, Safety Series No. 6 "Regulations for the Safe Transport of Radioactive Materials" 1973 Edition.

2.4 International Atomic Energy Agency, "The Physical Protection of Nuclear Materials", INFCIRC/225, September 1975.

3. RADIOACTIVE CONTENTS

The radioactive contents listed below must be packaged according to the methods described on drawing E-5580-SA1. Special attention shall be directed to the restriction that the hydrogen content in each of the four Specification 2R compartments

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SUBMITTED WRT	DATE 6/10/77	DR'N.	DATE	
APP'D.	DATE 9-11 77	CHK'D.	DATE	
CHALK RIVER NUCLEAR LABORATORIES		BLDG. No	CODE	CLASS
ATOMIC ENERGY OF CANADA		A		

OPERATING PROCEDURES FOR ENRICHED FUEL BUNDLE PACKAGE IDENTIFICATION CDN/4212/B(U)F

is limited to [illegible] g, as prepared for ship[illegible]nt.

The contents are described for individual Specification 2R compartments. When the contents of the four compartments are common, the package mass limit is four times (4X) compartment mass limits. Paragraphs a) through e) below list the appropriate Transport Indices and Allowable Numbers. When the contents of the four compartments are not common, the package mass limit is the total of each of the appropriate compartment mass limits. In this case, the Transport Index and the Allowable Number for the package shall be based on the most restrictive contents of any one compartment.

As prepared for shipment, each of the Specification 2R compartments may contain:

a) not more than 22.6 kg of unirradiated uranium oxide containing up to 20 kg uranium enriched in the isotope U-235 to a maximum of 10 weight percent in the form of pellets, powder or scrap. Table 1 lists pertinent shipping relationships.

TABLE 1 UO_2 SHIPPING RELATIONSHIPS

Max. wt.% U-235 in U	Transport Index	Allowable Number of Packages/shipment
2.75	1.3	38
3.00	1.7	29
3.50	2.7	18
5.00	4.2	11
10.00	50.0*	1

* Transported as Full Load

b) not more than 20 kg of unirradiated uranium enriched in the isotope U-235 up to 5 wt.% as metal in the form of slugs, powder or scrap <u>or</u> as carbide (UC) in the form of pellets, elements <u>or</u> bundles sealed in fuel cladding.

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SUBMITTED WRT	DATE 79.07.04	DR'N.	DATE
APP'D.	DATE	CHK'D.	DATE
		BLDG. No.	CODE / CLASS

OPERATING PROCEDURES FOR ENRICHED FUEL BUNDLE PACKAGE IDENTIFICATION CDN/4212/B(U)F

ATOMIC ENERGY OF CANADA LIMITED

A-12052-PR-1

Table 2 lists pertinent shipping relationships

TABLE 2 U and UC SHIPPING RELATIONSHIPS

Max. wt.% U-235 in U	Transport Index	Allowable Number of Packages/Shipment
2.00	1.3	38
2.25	1.4	35
2.50	2.0	25
2.75	3.0	16
3.00	4.2	11
3.50	8.4	5
5.00	12.5*	4

* Transported as Full Load

c) not more than 0.35 kg of unirradiated uranium enriched in the isotope U-235 up to a nominal level of 93 weight percent (maximum of 0.33 kg U-235) in the form of slugs, powder, pellets or scrap. The Transport Index is 25, the Allowable Number is 2, and the packages must be transported as Full Load.

d) mixed oxides of unirradiated uranium and thorium, $(U,Th)O_2$, containing not more than 5 weight percent UO_2 with uranium enriched in the isotope U-235 up to 93 weight percent, in quantities not exceeding

1. 7 kg total uranium plus thorium when the UO_2 content exceeds 1.75 weight percent $(U,Th)O_2$ in the form of powder, pellets or scrap not sealed in fuel cladding; or,

2. 20 kg total uranium plus thorium when the UO_2 content is less than 1.75 weight percent $(U,Th)O_2$ in the form of powder, pellets or scrap not sealed in fuel cladding; or,

3. 20 kg total uranium and thorium in the form of pellets, elements or bundles sealed in zirconium alloy fuel cladding.

Table 3 lists pertinent shipping relationships.

TABLE 3 $(U(93)Th)O_2$ SHIPPING RELATIONSHIPS

Max. wt.% UO in $(U(93),Th)O_2$	Transport Index	Allowable Number of Packages/Shipment
4.25	1.3	38
4.50	1.4	35
4.75	1.6	31
5.00	1.8	27

e) not more than 22.6 kg of mixed oxides of unirradiated uranium (natural or depleted) and plutonium (separated), $(U,Pu)O_2$, containing a maximum of 20 kg uranium plus plutonium with up to 4 weight percent PuO_2 in $(U,Pu)O_2$ sealed in zirconium alloy fuel cladding. Table 4 lists pertinent shipping relationships and Table 5 lists isotopic composition.

TABLE 4 $(U(nat),Pu)O_2$ SHIPPING RELATIONSHIPS

Max. wt.% PuO_2 in $(U,Pu)O_2$	Transport Index	Allowable Number of Packages/Shipment
1.25	1.3	38
1.50	1.5	33
1.75	2.0	25
2.00	2.8	17
2.25	3.8	13
2.50	5.0	10
2.75	6.3	7
3.00	8.4	5
3.50	10.0	5
4.00	12.5*	4

*Transported as Full Load

IGN AND PRINT IS THE PROPERTY OF ATOMIC ENERGY ... ITED IT MUST BE RETURNED WITH QUOTATION ... ERY OF MATERIAL AND EQUIPMENT AND MUST ... IN MANUFACTURING FOR OTHERS EXCEPT BY ... ON OF OWNERS.

SUBMITTED WRT	DATE 6/10/77	DR'N.	DATE	
APP'D.	DATE	CHK'D.	DATE	
CHALK RIVER NUCLEAR LABORATORIES		BLDG. No.	CODE	CLASS
ATOMIC ENERGY OF CANADA		A	12052-DR-1	

OPERATING PROCEDURE FOR ENRICHED FUEL BUNDLE PACKAGE IDENTIFICATION CDN/4212/B(u)F

TABLE PLUTONIUM ISOTOPIC COMPOSITION

Isotope	Composition, kg/kg Pu	
	Reference	Maximum
Pu-238	0.002	0.006
Pu-239	0.580	1.00
Pu-240	0.320	0.350
Pu-241	0.070	0.100
Pu-242	0.030	0.250

4. LOADING INSTRUCTIONS

4.1 Pre-Shipment Inspections

Inspect the outer packaging for obvious damage. Ensure that the drum cover fits properly and that the closure ring and bolt are serviceable. Ensure that the felt lined aluminum can is in good condition.

2 Radioactive Contents Packing

Load the radioactive contents into the felt lined aluminum cans according to drawing E-5580-SA1.

Place the loaded aluminum cans into the Specification 2R steel tubes.

Apply a layer of Teflon tape to the Specification 2R closure plug threads.

Match the colour-coded plugs to the Specification 2R steel tubes.

Turn down the plugs. Apply a firm torque, about 40 N m (30 ft.lb.), until the slots in the Specification 2R tube wall and the plug are aligned. Additional Teflon tape may be applied to the plug threads in order to make a proper fit.

Install and secure the locking plate, detail 8 of drawing E-5580-2.

Install the drum cover, its closure ring, bolt and security seal wire.

5. SHIPPING INSTRUCTIONS

Shipments must comply with Section V of the IAEA Regulations as follows.

5.1 Non-fixed Radioactive Contamination

Check the external surface of the package for contamination by wiping areas with clean absorbent paper. Surface contamination shall not exceed 10^{-7} µCi/mm^2 (3.7 mBq/mm^2) for beta-gamma nor 10^{-8} µCi/mm^2 (0.37 mBq/mm^2) for alpha emitting radioactive materials when averaged over any 30,000 mm^2 area. The efficiency of the counting instrument must be taken into account when the activities are calculated.

Upon receipt of radioactive materials which contain plutonium check the inside and outside of the aluminum cans and the inside of the Specification 2R containers for contamination and decontaminate or replace packaging components as required.

Prior to each use and upon receipt of a shipment, visually inspect the interiors of each aluminum can for traces of foreign materials. If such traces exist, check for contamination and decontaminate or replace packaging components as required.

5.2 Radiation Dose Rates

Check external package radiation dose rates. Radiation levels shall not exceed either 200 mrem/h on contact with the external surface of the package or 10 mrem/h at one metre from any external surface of the package.

5.3 Labelling

Package labelling must conform to the most recent appropriate transport regulations.

Specifically, each package requires two Radioactive Yellow III labels. Apply the labels to two opposite sides of the package. The following information must be placed on each label.

Principal Radioactive Content	- as appropriate
Activity of Contents	- as appropriate
Transport Index	- see Section 3

When Low Specific Activity materials are being shipped, i.e. the materials listed in Section 3 a) and b) overstamp the words "Radioactive LSA" on the labels.

In the case of Full Load shipments, see Tables 1,2 and 4, overstamp the words "Full Load" on the labels.

In the case of empty packages, the Radioactive Yellow III labels shall be removed and replaced with "EMPTY" labels. Also, the words "TYPE B(U)", "FISSILE CLASS II", "MATIÈRE RADIOACTIVE MATERIAL" and the trefoil symbol, all of which are on the package nameplate, shall be masked.

If a package contains two different materials or if the package has one or more empty compartments, for example, 1 fuel bundle with 2 weight percent PuO_2 in $(U,Pu)O_2$, 2 fuel bundles with 1 weight percent PuO_2 in $(U,Pu)O_2$ and one empty compartment, the higher Transport Index number shall be applied to the label, in this case 2.8, see Table 4.

5.4 Vehicle Placarding

Placarding must conform to the most recent appropriate transport regulations.

Specifically, for road or rail shipments, the vehicle requires 3 placards with the words "MATIÈRE RADIOACTIVE MATÈRIAL" at least 75 mm high. Apply placards to the rear and two sides of the vehicle.

When the vehicle is used to transport empty packages only, the words "MATIÈRE RADIOACTIVE MATERIAL" shall be masked.

5.5 Notification

Provide advance notification of each shipment to the consignee and obtain his approval of any shipment containing 100 g or more of Plutonium or Uranium isotope U-235 alone or combined.

For export shipments provide the followig information to the competent authority of any country into or through which the package will be transported.

a) Before the first shipment, provide copies of the applicable package design and shipment certificates, i.e. CDN/4212/B(U)FT, latest revision.

b) Before each shipment, notify the competent authorities of the expected shipment and arrival dates and the proposed routing. Also, include sufficient information so that the package may be identified.

5.6 Shipping Documents

Complete the consignor's certification for the package contents and that the package has been properly prepared for shipment.

Complete the appropriate site release forms.

5.7 Other Requirements

Shipments must conform to the requirements of the transport mode, i.e. road, rail, marine or air as appropriate.

Shipments must comply with appropriate security requirements, see IAEA Publication INFCIR/225.

6. MAINTENANCE

Packages require little maintenance and do not require periodic leakage tests. Pre-shipment inspection constitutes the extent of maintenance requirements. If any of the packaging components shows signs of obvious damage it must be replaced or repaired. Obvious damage means such things as tears in the drum wall or cover, ill-fitting drum covers, unserviceable closure rings, bolts and locking plates, ill-fitting pipe plugs, poor quality felt lined aluminum cans or movement of the Specification 2R steel tubes within the drum.

DESIGN AND PRINT IS THE PROPERTY OF ATOMIC ENERGY OF CANADA LIMITED IT MUST BE RETURNED WITH QUOTATION OR DELIVERY OF MATERIAL AND EQUIPMENT AND MUST NOT BE USED IN MANUFACTURING FOR OTHERS EXCEPT BY PERMISSION OF OWNERS.

SUBMITTED WRT	DATE 79.07.04	SR'N.	DATE	
APP'D.	DATE	CHK'D.	DATE	
OPERATING PROCEDURES FOR ENRICHED FUEL BUNDLE PACKAGE IDENTIFICATION CDN/4212/B(U)F	CHALK RIVER NUCLEAR LABORATORIES	BLDG. No.	CODE	CLASS
	ATOMIC ENERGY OF CANADA	A		

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APPENDIX B. USA SHIPPING PACKAGE CERTIFICATE

U.S. Department of Transportation

Research and Special Programs Administration

400 Seventh Street S.W.
Washington D.C. 20590

**COMPETENT AUTHORITY CERTIFICATION
FOR A TYPE B(U)F FISSILE
RADIOACTIVE MATERIALS PACKAGE DESIGN
CERTIFICATE USA/0485/B(U)F, REVISION 0**

REVALIDATION OF CANADIAN COMPETENT AUTHORITY CERTIFICATE CDN/4212/B(U)F

This certifies that the radioactive materials package design described below is hereby approved for use within the United States for import and export shipments only. Shipments must be made in accordance with the applicable regulations of the International Atomic Energy Agency[1] and the United States of America[2].

1. Package Identification - AECL Model 4H Enriched Fuel Bundle Shipping Package, Serial Nos. 1 through 8.

2. Packaging Description and Authorized Radioactive Contents - as described in Canadian Certificate of Competent Authority CDN/4212/B(U)F, Revision 6 (attached).

   Shipment is authorized as Fissile Class II with a minimum transport index as specified in Canadian Certificate of Competent Authority CDN/4212/B(U)F, Revision 6, or the highest radiation dose rate, in microsieverts per hour divided by 10, measured at one meter from any accessible external surface of the package, whichever is larger.

3. General Conditions

   a. Each user of this certificate must have in his possession a copy of this certificate and all documents necessary to properly prepare the package for transportation in accordance with the endorsed certificate.

   b. Each user of this certificate, other than the original petitioner, shall register his identity in writing to the Office of Hazardous Materials Technology (DHM-23), Research and Special Programs Administration, U.S. Department of Transportation, Washington D.C. 20590.

   c. This certificate does not relieve any consignor or carrier from compliance with any requirement of the Government of any country through or into which the package is to be transported.

   d. This certificate provides no relief from the limitations for transportation of plutonium by air in the United States as cited in the regulations of the U.S. Nuclear Regulatory Commission 10 CFR 71.88.

---

1 "Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition, as amended," published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

2 Title 49, Code of Federal Regulations, Parts 100 - 199, United States of America

(- 2 -)

CERTIFICATE USA/0485/B(U)F, REVISION 0

4. Marking and Labeling - The package shall bear the marking USA/0485/B(U)F in addition to other required markings and labeling.

5. Expiration Date - This certificate expires on September 30, 1998.

This certificate is issued in accordance with paragraph 806 and 814 of the IAEA Regulations and Section 173.473 of Title 49 of the Code of Federal Regulations, in response to the petition and information dated August 4, 1994 submitted by Edlow International Company, Washington, DC, and in consideration of other information on file in this Office.

Certified by:

James K O'Steen

OCT 20 1994

James K. O'Steen, Director
Office of Hazardous Materials
Technology

(DATE)

Revision 0 - Issued to revalidate Canadian Certificate of Competent Authority No. CDN/4212/B(U)F, Revision 6, which authorizes the use of the AECL Model 4H package.

APPENDIX C. RISK ASSESSMENT

1.0 Potential Effects on Human Health from MOX Fuel Fabrication Accident

Potential accidents associated with MOX fuel fabrication at LANL are reported in the document *Process Hazard Analysis (PrHA) for Fuel Pellet Fabrication and Pin Assembly Operations* (LANL/NMT-8 1997). The construction and engineering features of the TA-55 building structure and HEPA filtration system are such that essentially no off-site radiological consequences would result from accidents involving MOX fuel fabrication. The procedures, training, and equipment in use at TA-55 result primarily in low-level risk scenarios for TA-55 personnel and personnel on the Laboratory site. Because of this, the involved worker was found to be the primary receptor for most of the identified hazards.

The single credible (reasonable probability of occurrence) accident with the potential highest consequence was selected for description in this EA (DOE 1993a). This accident is termed "bounding," meaning that other potential credible accidents related to MOX fuel fabrication operations at LANL would pose less serious risks. The bounding accident described below is "Fire External to the Glovebox." In addition to this accident being bounding, the assumptions made to evaluate the accident tend to lead to an overestimate of risk. This is done in order to be protective of human health.

The fire is assumed to occur adjacent to a granulation glovebox where the pellets are screened through a sieve. The basic elements for the localized fire scenario are that low-level waste boxes filled with combustible room waste are stacked in front of the glovebox and ignited resulting from internal heat generation or a spill of flammable liquid. The laboratory room is unattended at the start of the fire, and the initiating fire ignites the gloves of the glovebox. Workers are assumed to enter the room after the gloves have been ignited, exposing themselves to finely divided plutonium oxides that have been suspended in the air by the fire, thus obtaining an internally deposited dose through respiration.

An assessment of risk considers the chance or likelihood that an accident would occur and the consequences that result from the accident. The likelihood that an accident would occur is generally a function of multiple events occurring in succession. Some of the events necessary for this accident to proceed to the point of worker exposure include ignition of the waste boxes, spread of the fire, failure of sprinkler systems, ignition of gloves, and breaching of gloves. The likelihood of occurrence of this accident was estimated at between once in 100 and one in 10,000 years (10^{-2} to 10^{-4} per year), or "unlikely" (LANL/NMT-8 1997). This qualitative estimate of likelihood is conservative, i.e., the accident can be realistically expected to occur at a lower frequency than 10^{-2} to 10^{-4} per year.

Determining the potential exposure to radiological material resulting from an accident begins with estimating the amount of material at risk (MAR). For this accident scenario, the MAR was estimated in LANL/NMT-8 (1997) and is detailed in Section 2.0 of this appendix. The MAR is then used to estimate the "source term," which is the amount of material made airborne that is of a size that can enter the human breathing system. The MAR was estimated to be 10.2 g and the source term was estimated as 0.10 g of aerosol (LANL/NMT-8 1997).

The exposure portion of the consequence analysis is for the maximum exposed individual (MEI) located at the Park, which is 2,953 ft (900 m) north of TA-55. The radiation dose to the MEI was calculated using the standard Gaussian model parameters of source term development, dispersion, intake and dose conversion factor. The Gaussian modeling was performed with the MELCOR Accident Consequence Code System (MACCS) (LANL/NMT-8 1997) using meteorological data described by Haskin (1995). The estimated dose to the MEI from this accident is 3.14×10^{-5} mrem. Combining the accident's estimated consequence and likelihood of occurrence, the risk to the MEI is minimal as explained in the following sections of this appendix.

2.0 Summary of Supporting Calculations for the Bounding Accident: Fire External to the Glovebox

Process Description

For fuel pellet production activities, approximately 24 gloveboxes (atmosphere controlled), powder preparation equipment, four automatic pellet presses, three synthesis furnaces, and three sintering furnaces are available for use. The fuel is a ceramic pellet of mixed plutonium oxide and uranium oxide. Fuel is normally processed in 7-lb (3-kg) or less batches. Typical process steps followed for this operation are

- receipt of oxide powders,
- removal of gallium in high-temperature furnace,
- ball milling,
- blending the powder in tubular blender,
- compacting in hydraulic press,
- granulation – push through screen,
- pressing the granules into pellets,
- binder removal through heating,
- pellet sintering,
- centerless grinding of pellet to achieve final dimensions,
- vibratory milling,
- batch characterization (measurement and analysis),
- heat in tube furnace to adjust oxygen content,
- fuel pin assembly and welding, and
- characterization of the welds and helium leak testing.

The fire is assumed to occur adjacent to a granulation glovebox where the pellets are screened through a sieve. The source term is finely divided plutonium in oxide form. The basic elements for the localized fire scenario are that LLW boxes filled with combustible room waste are stacked in front of the glovebox and ignited resulting from internal heat generation. The laboratory room is unattended at the start of the fire, and the initiating fire ignited the gloves of the glovebox. Workers are assumed to enter the room after the gloves have been ignited to obtain a worker dose.

Accident Estimated Likelihood of Occurrence

Expert judgement was used to qualitatively estimate that the likelihood of occurrence of this accident is "unlikely," or between one in 100 and one in 10,000 years (10^{-2} to 10^{-4} per year) (LANL/NMT-8 1997). The likelihood that an accident would occur is generally a function of multiple events occurring in succession. Some of the events necessary for this accident to occur include chance or frequency of fire in similar facilities, failure of sprinkler systems, ignition of the gloves, and breaching of the gloves. Table 5-1 shows that unlikely accidents are not anticipated to occur in the lifetime of a facility or operation. Two of the events mentioned above, chance or frequency of fire in similar facilities and failure of sprinkler systems are quantified here to confirm that the qualitative estimate of unlikely is conservative (over-estimates the likelihood of occurrence).

In 1982 a report was issued by the DOE Office of the Assistant Secretary of Environment Protection, Safety, and Emergency Preparedness; Office of Operation Safety on the performance and reliability of automatic sprinkler systems (DOE 1982). Over 30,000 automatic sprinkler system experiences of DOE and its predecessor agencies were analyzed in detail for the time period 1952–1980 from the standpoint of effectiveness and reliability. From 1952 to 1980, 115 fires large enough to activate sprinkler systems occurred in DOE facilities, and the accumulated sprinkler system operating experience for DOE facilities nationwide during this period is greater than 30,000 sprinkler system-years (DOE 1982). Therefore, the average frequency of fires was estimated as follows:

$$F(\textit{fire}) = \frac{115\ \textit{fires}}{30{,}000\ \textit{sprinkler system-years}} = 0.0038\ \textit{fires per sprinkler system-year}$$

Of the 115 fires involving sprinkler systems in DOE facilities since 1952, the sprinklers were successful in controlling or extinguishing the fire in 113 of the incidents. Therefore, the probability of sprinkler failure on demand is $2 \div 115 = 0.017$. The combined frequency of fire in similar facilities and failure of sprinkler systems is then $0.0038 \times 0.017 = 6.5 \times 10^{-5}$. Thus, the frequency of damaging fires based on real operational experience is slightly less than one chance in 10,000 years (or 6.5×10^{-5} per year). This adequately supports that the qualitative estimate of occurrence of unlikely for this accident scenario is conservative, i.e., the accident can be expected to occur at a frequency of no more than once in one hundred years.

2.1 Accident Scenario Release Source Term

For material released in the form of particulate matter or aerosols, the "source term" or amount of material made airborne and that is of respirable size can be estimated by the following expression:

$$\text{Source Term (ST)} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF (DOE 1994c)},$$

where

MAR = amount of material at risk (the amount available to be acted on),

DR = damage ratio (the fraction of the MAR affected by the accident conditions),

ARF = airborne release fraction (fraction of the affected material that is made airborne),

RF = respirable fraction (fraction of the airborne particles that are respirable), and

LPF = leak path factor (the fraction of material transported through some type of confinement).

The total source term would be a linear combination of the source terms from all mechanisms by which respirable Pu powder is driven airborne. The DR is the fraction of the MAR that can actually be acted upon by the stresses caused by the accident conditions.

The product of the first four factors in the source term formula gives the respirable initial source term to the workers. The initial source term multiplied by the LPF determines the final source term released to the environment. Calculation of the source term is summarized in Table C-1 and details of the source term calculation are discussed below.

Table C-1. Source Term Development

Scenario/Source	MAR	DR	ARF × RF	LPF	Source Term
Fire External to Glovebox	0.36 oz (10.2 g)	1.0	0.01	1.0	3.5×10^{-3} oz (0.1 g)

Source: Preliminary estimates from DOE and LANL Risk Assessment Team.

Because this operation is similar to operations for producing heat source pellets, information on the MAR from heat source production in the TA-55 Final Safety Analysis Report (FSAR) was used.

The MAR for the source term from combustion of the gloves is estimated to be 0.36 oz (10.2 g). This is derived from the following conservative assumptions:

- 2.5 oz (70 g) of fine Pu powder is lost during a 7-lb (3-kg) campaign.
- All of the lost powder has been distributed evenly as depositions on the glovebox internal walls and on the inside surfaces of the 12 gloves (normal airflow would draw most of the powder into the glovebox HEPA filter and routine internal glovebox surface cleaning would also decrease surface loading).
- Each glove has 5.9×10^{-2} oz (1.7 g) of powder deposited on it (normally the gloves are replaced approximately every two weeks).
- 6 gloves on one side of the glovebox are ignited and burn completely.

The loss of 2.5 oz (70 g) during a campaign is based on operational experience. However, the exact amount of powder lost is not as relevant as the degree of glove contamination for the present source term analysis. The value of 5.9×10^{-2} oz (1.7 g) per glove represents the maximum expected contamination level on the gloves.

The gloves are made of a rubber derivative called Hypalon (chlorosulphonated polyethylene). Airborne release fractions and respirable fractions for rubber and elastomers based on the experimental data are published by DOE (DOE 1994c). The ARF values range from 2.0×10^{-4} (plutonium nitrate solution on pieces of rubber glove) to 3.5×10^{-2} (uranyl nitrate hexahydrate [UNH] on polychloroprene [PC]). The extreme values are both for liquid solutions on combustible rubber/elastomer but represent a difference in heat input. For balled-milled depleted uranium dioxide and air-dried UNH salt on PC, the ARFs range from 3.7×10^{-3} to 1.0×10^{-2} with an RF of 0.16. Therefore, a reasonably conservative bound for ARF and RF for the accident conditions is 0.01 and 1.0, respectively. If the ARF and RF values of 0.01 and 1.0, respectively are applied to the MAR of 0.36 oz (10.2 g), the initial source term is 3.5 × 10-3 oz (0.10 g).

2.2 Accident Consequences

Worker Dose

The dose to workers in the room is calculated as follows:

$$CEDE = ST \times SA \times BR \times ET \times DCF/RV,$$

where

CEDE = cumulative effective dose equivalent (rem),

ST = source term (g),

SA = specific activity (Ci/g),

BR = breathing rate (m^3/s),

ET = evacuation time(s),

DCF = dose conversion factor (rem/Ci), and

RV = room volume (m^3).

Using a BR of 3.33×10^{-4} m^3/s, an ET of 30 seconds, an RV of 850 m^3, and SAs and DCFs (Clow et al. 1994), the 50-year CEDE is a maximum of 1,800 mrem (1.8 rem) as shown in Table C-2. The short-term effects from this initial dose would be minor but should not cause lost time or disability (NRC 1995).

Table C-2. Intake Calculations

ST	SA	BR	ET	DCF	RV	CEDE (rem)
5.0×10^{-3}	6.133×10^{-2}	3.33×10^{-4}	30	5.1×10^{6}	850	1.8

Public Dose

The dose to the public was calculated using the Gaussian dispersion model MACCS2, as described by Haskin (1995) and in the TA-55 FSAR. MACCS2 performs probabilistic calculations of the potential off-site consequences of atmospheric releases of radioactive material resulting from accidents. MACCS was extensively verified (checked and tested) during its development. The standard Gaussian model parameters of source term development, dispersion, intake, and dose conversion factor were used. Weather information used in the Gaussian modeling was based on the 95th percentile weather information. The 95th percentile weather is stability class F and a wind speed of 1.9 m/s. About 5 percent of the time TA-55 weather would be more stable, i.e., less favorable for atmospheric dispersion of releases. The MEI is located 2,953 ft (900 m) from PF-4 at the Royal Crest Trailer Court. The CEDE for the fire scenario is 3.14×10^{-5} mrem. This assumes a LPF of 2×10^{-6} which is based on two-stage HEPA filtration. (Note: The MEI dose is not used in cancer fatality estimates, but rather, an integrated dose is used as described in a later section.)

The estimated dose, 3.14×10^{-5} mrem, to the MEI received in a relatively short period of time, is expected to cause no immediate long-term health effects as based on guidance by DOE (DOE 1990).

2.3 Risk Assessment

Maximum Exposed Individual

Risk estimates consider the estimated likelihood of occurrence of an accident and the dose consequence of the accident so that the magnitude of potential effect from the accident can be estimated. With an estimated likelihood of occurrence of "unlikely" and a dose consequence of 3×10^{-5} mrem, the risk to the MEI at the Park is minimal. No LCFs would be expected among the surrounding population from this dose.

3.0 Potential Effects on Human Health from MOX Fuel Transportation and Accidents

3.1 RADTRAN 4 Computer Code for Transportation Risk Assessment

RADTRAN 4 (Neuhauser and Kanipe 1992) produces estimates of incident-free population dose, accident doses, and individual doses. Doses may be converted to health effects. RADTRAN 4 calculates incident-free population dose for subgroups of members of the public [persons adjacent to the route (on-link), persons at stops] and for persons who may be occupationally exposed [mainly crew members and inspectors]. Incident-free dose is defined as that dose which may be incurred by persons on or near a transportation route that results from exposure to external radiation emitted by the intact package in the course of normal transportation. The external radiation emitted by packages containing radioactive material is limited by regulation, but for certain types of shipments (e.g., spent nuclear fuel) measurable doses may be incurred by individuals within short distances of the shipment. In the present analysis, however, the package dose rates are well below regulatory limits.

The most important input parameters for these calculations are (1) route characteristics and (2) package characteristics. A highway route is normally divided into *route-segments* or *links* according to population density and road type. All travel in the U.S. for all three routes considered in this analysis is on highways except for the access route from LANL to the nearest interstate highway (Interstate Highway 25). Population densities and road type information are among the outputs of routing codes such as HIGHWAY (ORNL 1992), which was used in this analysis. Population-density data are also used to assign a rural, suburban, or urban designation to each route-segment. This designation influences other input parameters such as vehicle speed. The two most important package characteristics for incident-free dose estimation are external dose rate and package dimension. These values are used to model the package as a point source. Both moving point-source [e.g., for off-link population] and stationary point-source [e.g., for stops] calculations are performed by RADTRAN 4 to conservatively estimate dose to persons within 2,625 ft (800 m) of the lane centerline and at truck stops. Dose to crew members is estimated with a stationary point-source calculation in which the distance from source to the crew cab is a parameter and time of exposure is estimated by multiplying the velocity by the distance term. In the present analysis the package dose rates are quite low.

Accident doses are estimated for a series of separate *accident-severity categories* that represent the full spectrum of accidents from minor (a "fender bender") to extremely severe (total containment failure). For each severity category, a probability is calculated based on state-level accident-rate data and condition probabilities, given that an accident has occurred, that it would be of a particular severity. In this analysis, an eight-category severity scheme is used (NRC 1977), and package response is based on test data, including tests to failure, for the 6M package type (McWhirter et al. 1975; Bonzon 1977).

Radiological consequences (50-year cumulative effective doses or CEDs) are calculated by RADTRAN 4. The code uses test data or model predictions of the amount of material that might be released in a given severity of accident, expressed as a fraction of the total or *release fraction* (RADTRAN variable RFRAC).

The release fraction is modified by properties of the material being shipped that determine how much of it might be released in aerosol and respirable aerosol form under various accident conditions, since aerosolization represents two dominant means by which any released radioactive material might be transported away from the immediate accident site. This transport is conservatively modeled as a ground-level dispersion from a small-diameter plume, regardless of the type of accident, which maximizes both downwind ground deposition and inhalation values. In reality, in a very severe accident involving a major fire, the thermal effects would be far more likely to loft any released material higher in the atmosphere, which results in considerable downwind dilution and, hence, lower individual doses. The exposure pathways considered in this analysis are inhalation, resuspension (delayed inhalation from particles originally deposited on the ground and subsequently resuspended), groundshine (exposure to external radiation from deposited particulates), and cloudshine (exposure to external radiation from particulates in the passing plume). Since little penetrating radiation is emitted by the MOX payload in this analysis, doses from inhalation and resuspension dominate the consequence calculation. The output is a calculation of population dose for each accident severity. The potentially exposed population consists of all persons located under the plume footprint out to a downwind distance of 50 mi (80 km). Since exact locations cannot be predicted in the transportation analysis, the potentially exposed population is estimated for each route segment based on the same population density used for incident-free dose calculations, which is assumed to be uniformly distributed. The population estimate for each route is also given in the RADTRAN 4 output.

The probability and consequence values are combined to generate dose estimates, which are the primary output of RADTRAN 4. Probability and consequence values are also shown separately, however, to reveal the magnitudes of the two components. As an estimate of the maximum individual inhalation dose to a person located near the hypothetical accident site for each severity is also generated by RADTRAN 4. This value is useful in that it puts the population dose estimates in perspective.

Dose estimates may be multiplied by a health-effects factor to estimate the expected number of cancer fatalities in the exposed population. That factor is 5.0×10^{-4} health-effects per rem (ICRP 1991). In addition, RADTRAN also examines the individual dose estimates for varying distance from the hypothetical accident site to determine whether early fatality (i.e., death within one year) would be expected. The dose threshold for early fatality is quite large and was not expected to be exceeded in this analysis.

The RADTRAN 4 computer model was used to estimate human health effects from the proposed MOX fuel shipments. Health effects were estimated on a per shipment basis for the material transported from Los Alamos, New Mexico to the Canadian border. The total radiological dose and LCF estimates were calculated for each shipment along the three routes up to the Canadian border. The human health risk analysis was an integral component of the overall transportation analysis performed by RADTRAN 4. Therefore, there was overlap in the input parameters used by the code. For human health, the normal (incident-free) transportation radiological exposure and the nonradiological emissions effects were estimated. The RADTRAN 4 identified the potential recipients of radiological and nonradiological effects as the crew (occupational exposure) of the transport and the public (nonoccupational exposure) along the route, respectively.

The RADTRAN 4 input parameters were developed for each route for this analysis with the HIGHWAY computer routing code (ORNL 1993). One parameter, known as a link, represents rural, suburban, or rural travel within a state. Urban, suburban, and rural population data are used by the HIGHWAY code to develop route-specific population densities. In addition, the code uses state-level accident rate data to uniquely describe each link. The HIGHWAY code also maximizes the use of interstate highways along the selected routes. These and other parameters were used in RADTRAN 4 to determine radiological and nonradiological risks.

For this project, three separate shipment configurations were analyzed. They are

- Single shipment - All the MOX fuel is shipped in a single shipment.
- Double shipment - All the MOX fuel is shipped in a total of two shipments.
- Triple shipment - All the MOX fuel is shipped in a total of three shipments.

The radioisotope inventory of plutonium and uranium per shipment is largest for the single-shipment configuration, but the total distance traveled is minimized. Conversely, the radioisotope inventory per shipment is reduced for the triple-shipment option, but the total distance traveled is also three times that of the single-shipment configuration. The double-shipment case is intermediate; inventories are the same as or less than in the triple-shipment configuration, but only two shipments are made. These two offsetting parameters tend to even out the risk estimates, yielding only minor differences between the three routes. The radioisotope inventories for the single-shipment configuration is shown in Table C-3.

Table C-3. Isotope Inventory (in curies) of Single-Shipment Configuration

Isotope	Single Shipment
Plutonium-239	38.80
Plutonium-240	8.90
Plutonium-238	1.41
Plutonium-241	96.30
Plutonium-242	0.0016
Total Uranium	0.0102

The shipment packaging itself is modeled by RADTRAN 4 as an accident-resistant 6M package (Bonzon 1977). A 6M package can be illustrated as a 55-gal. steel drum with inner containers and a welded top. The 6M shipping package design is used by the computer model to represent 55-gal. drum-like shipping containers with sealed tops. This design is similar and comparable to the AECL Model 4H shipping package (Figure 5), which is proposed for use in this project. RADTRAN also has eight Accident-Severity Categories developed from continuous frequency curves representing increasing effect force and fire duration at a fixed reference temperature of 800 degrees C. The Accident-Severity Category Classification Scheme is shown in Figure C-1. The release fractions for the eight Accident-Severity Categories are based on physical test data (McWhirter et al. 1975). For this transportation analysis, the release fractions for Accident-Severity Categories 5 through 8 were the same (5.0×10^{-8}). No effects are expected in Categories 1 through 4 because the release fractions for these categories are zero. The release fractions are zero due to the highly accident-resistant design of the shipping package. The failure of the shipping package would occur in Category 5 and up. For the RADTRAN 4 modeling, a total containment failure was presumed for Categories 5 through 8. The Characteristic Package Dimension, another RADTRAN input variable, was set at the package's maximum dimension of 3.3 ft (1.0 m). The Package Dose Rate (at 1 m from the package surface) does not exceed 5.0×10^{-7} mrem per hour. This low external dose rate is reflective of the very low activity of the package contents.

3.2 Potential Transportation Incident-Free Radiological Dose

The incident-free dose is defined as the radiological exposure received by the crew and public from the MOX fuel as the fuel is being transported along a route. The total incident-free doses (4.7×10^{-9}, $5.4 \times$

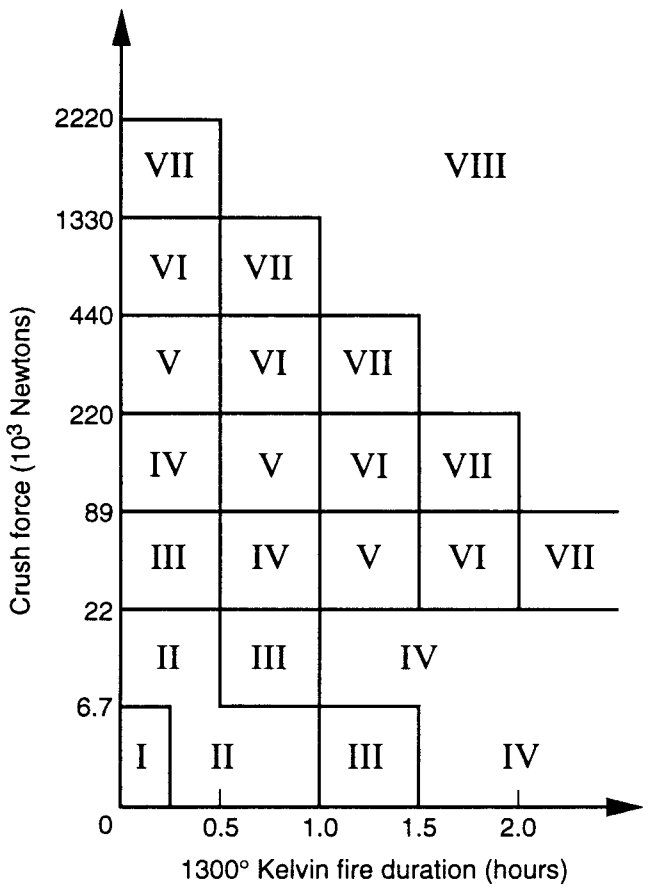

Figure C-1. Accident severity category classification scheme—motor trucks.

10^{-9}, 6.6×10^{-9} person-rem), for all three shipment configurations were extremely low and of the same order of magnitude as would be expected from the low external dose rates of the packages. Table C-4 gives values for the Los Alamos, New Mexico to Pembina, North Dakota route. The total exposed population within 2,625 ft (800 m) of the route is estimated at 209,000. This number is estimated by the RADTRAN model using the latest census data.

Table C-4. Total Incident-Free Doses (in person-rem) for All Shipment Configurations to Pembina, ND

Shipment Configuration	Dose to Crew	Dose to Public	Total
Single	6.3×10^{-10}	4.1×10^{-9}	4.7×10^{-9}
Double	6.1×10^{-10}	3.9×10^{-9}	4.5×10^{-9}
Triple	6.1×10^{-10}	3.6×10^{-9}	4.4×10^{-9}

Total doses for the Port Huron and Watertown routes (Tables C-5 and C-6) show a slight upward trend over the shorter Pembina, North Dakota route, but all of the doses are within less than one order of magnitude of each other. When the conservatism of the dose estimations is considered, these dose estimates are not sufficiently different from each other or from the Pembina route to serve as a basis for route selection.

Table C-5. Total Incident-Free Doses (in person-rem) for All Shipment Configurations to Port Huron, MI

Shipment Configuration	Dose to Crew	Dose to Public	Total
Single	7.3×10^{-10}	4.7×10^{-9}	5.4×10^{-9}
Double	7.0×10^{-10}	1.2×10^{-9}	1.3×10^{-8}
Triple	6.8×10^{-10}	4.4×10^{-9}	5.1×10^{-9}

Table C-6. Total Incident-Free Doses (in person-rem) for All Shipment Configurations to Watertown, NY

Shipment Configuration	Dose to Crew	Dose to Public	Total
Single	8.8×10^{-10}	5.7×10^{-9}	6.6×10^{-9}
Double	8.5×10^{-10}	5.5×10^{-8}	6.3×10^{-8}
Triple	8.3×10^{-10}	5.4×10^{-9}	6.2×10^{-9}

The three routes overall have very low radiological doses to the crew and public. By using the single shipment total radiation dose value for each MOX fuel shipment, the LCFs can be estimated. As shown in Table C-7, the estimated fatalities would be very small and well below the U.S. EPA guideline of one fatality for one million persons (1.0×10^{-6}).

No adverse effects would be expected to the crew and public during the shipments of the MOX fuel from the low radiological doses.

Table C-7. Latent Cancer Fatalities from Incident-Free Doses for all Routes

Routes	Total (public and crew) Dose (person-rem)	Exposed Population LCFs
Pembina, ND	4.7×10^{-9}	2.3×10^{-12}
Port Huron, MI	5.4×10^{-9}	2.7×10^{-12}
Watertown, NY	6.6×10^{-9}	3.3×10^{-12}

3.3 Radiological Vehicular Accident

The doses calculated by RADTRAN 4 for the accident scenario involving a fire and release of plutonium dioxide particles into the air are listed in Table C-8. The total doses are the same for a given route, regardless of shipment and configuration, because the sum of the risks for two or more shipments is always the equivalent of the same total amount of material being transported along the identical route with identical population densities and accident probabilities. Individual shipment doses are distinct. For example, the doses in the Total column for each of the two shipments in the Pembina - Double category would be 2.1×10^{-9} person-rem and 5.9×10^{-10} person-rem (not listed in table), respectively, which sum to 2.7×10^{-9} (rounded to two significant digits), which is the same as the single-shipment value.

Table C-8. Public Radiological Dose-Risks (in person-rem) for all Routes and Shipment Configurations

Route-Configuration	Groundshine	Inhalation	Resuspension	Cloudshine	Total
Pembina-Single	7.3×10^{-13}	4.9×10^{-10}	2.2×10^{-9}	6.7×10^{-19}	2.7×10^{-9}
Pembina-Double	7.3×10^{-13}	4.9×10^{-10}	2.2×10^{-9}	6.7×10^{-19}	2.7×10^{-9}
Pembina-Triple	7.3×10^{-13}	4.9×10^{-10}	2.2×10^{-9}	6.7×10^{-19}	2.7×10^{-9}
Port Huron-Single	1.6×10^{-12}	1.1×10^{-09}	4.9×10^{-9}	1.5×10^{-18}	6.0×10^{-9}
Port Huron-Double	1.6×10^{-12}	1.1×10^{-09}	4.9×10^{-9}	1.5×10^{-18}	6.0×10^{-9}
Port Huron-Triple	1.6×10^{-12}	1.1×10^{-09}	4.9×10^{-9}	1.5×10^{-18}	6.0×10^{-9}
Watertown-Single	2.2×10^{-12}	1.5×10^{-09}	6.8×10^{-9}	2.0×10^{-18}	8.3×10^{-9}
Watertown-Double	2.2×10^{-12}	1.5×10^{-09}	6.8×10^{-9}	2.0×10^{-18}	8.3×10^{-9}
Watertown-Triple	2.2×10^{-12}	1.5×10^{-09}	6.8×10^{-9}	2.0×10^{-18}	8.3×10^{-9}

The associated total health-effects risks from the estimated public dose from the accident scenario are 1.4×10^{-8} cancer fatalities for the Pembina route, 3.0×10^{-8} for the Port Huron route, and 4.2×10^{-8} for the Watertown route. All are lower than the EPA guideline of 1.0×10^{-6}.

No radiological consequences are expected for accidents in Severity Categories 1 through 4. Consequences for Categories 5 through 8 are similar. No early fatalities are expected for any shipment configurations by any route. Because long-term doses are reported as population doses and do not consider the probability of an accident occurring, the total exposed population under a conservatively modeled plume footprint (extending to 50 mi [80 km] from the hypothetical accident site) for each population density traversed by each route was also calculated.

The potential accident consequences (50-year population dose) vary by route segment. The maximum for the single-shipment configuration is 1.2×10^{-3} person-rem CED for an urban link with a total potentially exposed population of approximately 3 million persons. The probability of occurrence of an accident with

consequences of this magnitude in an urban area is between 6.0×10^{-10} per shipment for a Category 5 accident and 8.1×10^{-13} per shipment for a Category 8 accident. A minimum dose of 4.4×10^{-5} person-rem CED was for a rural link with a total potentially exposed population of about 6,500 persons was calculated. The probability of the latter increases in comparison to the maximum because the majority of the route traverses low population-density areas. It had a probability of occurrence of between 3.7×10^{-6} per shipment (Category 5) and 3.6×10^{-8} (Category 8). The expected number of health effects (cancer fatalities) is considerably less than one (6×10^{-7}) for the maximum estimated population dose. All maximum accident doses for the double- and triple-shipment configurations are lower than the maximum for the single shipment by all routes because of their reduced isotope inventories.

3.4 Nonradiological Vehicular Accidents

It is possible that vehicular accidents could occur from transporting MOX fuel from LANL to the Canadian border without involving the release of radioactive materials. Based upon the results of the RADTRAN 4 analysis provided in Tables C-9 and C-10, no worker fatalities or fatalities to members of the public would be expected (i.e. number is much less than 1.0). This analysis included an evaluation of up to three round trips on any one of the three potential transportation routes.

Table C-9. Total Fatalities to Truck Crew Resulting from Nonradiological Accident

Route-Configuration	Rural	Suburban	Urban	Total
Pembina-Single	6.8×10^{-5}	1.3×10^{-6}	1.1×10^{-7}	6.9×10^{-5}
Pembina-Double	1.4×10^{-4}	3.6×10^{-6}	2.1×10^{-7}	1.4×10^{-4}
Pembina-Triple	2.0×10^{-4}	3.8×10^{-6}	3.2×10^{-7}	2.1×10^{-4}
Port Huron-Single	6.6×10^{-5}	4.3×10^{-6}	2.2×10^{-7}	7.0×10^{-5}
Port Huron-Double	1.3×10^{-4}	8.6×10^{-6}	4.3×10^{-7}	1.4×10^{-4}
Port Huron-Triple	2.0×10^{-4}	1.3×10^{-5}	6.5×10^{-7}	2.1×10^{-4}
Watertown-Single	7.8×10^{-5}	5.6×10^{-6}	2.5×10^{-7}	8.4×10^{-5}
Watertown-Double	1.6×10^{-4}	1.1×10^{-5}	5.1×10^{-7}	1.7×10^{-4}
Watertown-Triple	2.3×10^{-4}	1.7×10^{-5}	7.6×10^{-7}	2.5×10^{-4}

Table C-10. Total Fatalities to the Public Resulting from Nonradiological Accidents

Route-Configuration	Rural	Suburban	Urban	Total
Pembina-Single	2.4×10^{-4}	4.5×10^{-6}	3.8×10^{-7}	2.5×10^{-4}
Pembina-Double	4.8×10^{-4}	9.0×10^{-6}	7.6×10^{-07}	4.9×10^{-4}
Pembina-Triple	7.2×10^{-4}	1.4×10^{-5}	1.1×10^{-6}	7.4×10^{-4}
Port Huron-Single	2.3×10^{-4}	1.5×10^{-5}	7.8×10^{-7}	2.5×10^{-4}
Port Huron-Double	4.6×10^{-4}	3.0×10^{-5}	1.6×10^{-6}	4.9×10^{-4}
Port Huron-Triple	6.9×10^{-4}	4.5×10^{-5}	2.3×10^{-6}	7.4×10^{-4}
Watertown-Single	2.8×10^{-4}	2.0×10^{-5}	9.0×10^{-7}	3.0×10^{-4}
Watertown-Double	5.6×10^{-4}	4.0×10^{-5}	1.8×10^{-6}	6.1×10^{-4}
Watertown-Triple	8.4×10^{-4}	6.0×10^{-5}	2.7×10^{-6}	9.0×10^{-4}