SEC Petition Evaluation Report
Petition SEC-00051

Report Rev # 0 Report Submittal Date 2-01-2007

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Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00051	83.13	August 7, 2006	Los Alamos National Laboratory (LANL)

Petitioner Class Definition
All workers of LANL working in all Tech Areas from 1943 - 1975.

Proposed Class Definition
All employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working in operational Technical Areas with a history of radioactive material use at the Los Alamos National Laboratory for an aggregate of at least 250 work days during the period from March 15, 1943 through December 31, 1975, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. This definition excludes TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74.

Related Petition Summary Information			
SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
None			

Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report, SEC-00061	LANL

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Peer Review Completed By:	Signature on file ***Gregory V. Macievic***	2/6/07 *Date*
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Evaluation Report Summary: SEC-00051
Los Alamos National Laboratory (LANL)

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00051, qualified on August 7, 2006, requested that NIOSH consider the following class: *All workers of LANL working in all Tech Areas from 1943 - 1975.*

NIOSH-Proposed Class Definition

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working in operational Technical Areas with a history of radioactive material use at the Los Alamos National Laboratory for an aggregate of at least 250 work days during the period from March 15, 1943 through December 31, 1975, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. This definition excludes TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74. The class was modified (see Section 3.0 below) in order to: (1) specify the date when project staff began work at the site (March 15, 1943); (2) confine the class to those Technical Areas that had a history of radioactive material use and were also operational during the evaluation period; and (3) explicitly include all personnel who worked for the DOE, DOE contractors, or subcontractors (including all former MED/AEC workers) who were monitored or should have been monitored for radiological exposure.

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it does not have access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate radiation doses more precisely than a maximum dose estimate. Information available from the site profile and additional resources is not sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period. NIOSH will continue its evaluation to determine at what historical point (after the evaluation period addressed herein) that available information and data become adequate to: (1) estimate the maximum radiation dose incurred by any site worker; or (2) estimate radiation doses more precisely than a maximum dose.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate long-term doses for the members of the proposed class. Evidence indicates that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of radionuclides, combined with external exposures to gamma, beta, and neutron radiation. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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SEC Petition Evaluation Report for SEC-00051

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all job titles and/or job duties for all employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working in operational Technical Areas (TAs) with a history of radioactive material use at the Los Alamos National Laboratory for an aggregate of at least 250 work days during the period from March 15, 1943 through December 31, 1975, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report also does not contain the final determination as to whether the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Office of Compensation Analysis and Support's (OCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

42 C.F.R. § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also then determine whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

the health of members of a class when it has been established that it is not feasible to reconstruct (the incident) exposures for the class and that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the feasibility determination of the inability to reconstruct doses from an exceptionally high-level exposure has not been established, but NIOSH has determined that it is not feasible to reconstruct other (long-term) exposures, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

3.0 Petitioner-Requested Class/Basis & NIOSH-Proposed Class/Basis

Petition SEC-00051, qualified on August 7, 2006, requested that NIOSH consider the following class for addition to the SEC: *All workers of LANL working in all Tech Areas from 1943 - 1975.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the LANL workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00051 for evaluation:

> The petition contends that personal exposures in some job categories were unrecorded and that accurate data to perform precise dose reconstructions do not exist for some employees. The supporting information raises issues associated with unmonitored individuals, lack of environmental monitoring prior to 1965, lack of bioassay data, and lack of other relevant information needed to document or estimate maximum internal or external exposures, particularly during the early years of LANL operations.
>
> The petitioners provided affidavits from seven individuals who described contamination incidents, suspected overexposures, lack of monitoring, and unavailability of records.

[2] See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at http://www.cdc.gov/niosh/ocas.

The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working in operational Technical Areas with a history of radioactive material use at the Los Alamos National Laboratory for an aggregate of at least 250 work days during the period from March 15, 1943 through December 31, 1975, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. This definition excludes TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74. The class was modified in order to: (1) specify the date when project staff began work at the site (March 15, 1943); (2) confine the class to TAs with a history of radioactive material use; and (3) explicitly include all personnel who worked for the DOE, DOE contractors, or subcontractors (including all former MED/AEC workers) who were monitored or should have been monitored for radiological exposure.

Table 5-1 summarizes the LANL TAs, key processes, dates of operation, and primary radiation sources. Twelve of the listed TAs had no history of radioactive material use or were not operational during the evaluation period and were, therefore, excluded from further evaluation in this report: TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed numerous data sources to determine the availability of information relevant to determining the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed by NIOSH.

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. As part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into LANL operations or related topics/operations at other sites:

- *Technical Basis Document for Los Alamos National Laboratory – Introduction,* ORAUT-TKBS-0010-1 Rev. 00; January 25, 2005

- *Technical Basis Document for Los Alamos National Laboratory – Site Description,* ORAUT-TKBS-0010-2; Rev. 00; May 7, 2004

- *Technical Basis Document for Los Alamos National Laboratory – Occupational Medical Dose,* ORAUT-TKBS-0010-3; Rev. 00; December 29, 2004

- *Technical Basis Document for Los Alamos National Laboratory – Occupational Environmental Dose*, ORAUT-TKBS-0010-4; Rev. 00; October 8, 2004

- *Technical Basis Document for Los Alamos National Laboratory – Occupational Internal Dose,* ORAUT-TKBS-0010-5; Rev. 00; December 21, 2004

- *Technical Basis Document for Los Alamos National Laboratory – Occupational External Dose,* ORAUT-TKBS-0010-6; Rev. 00; May 10, 2005

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs and procedures as part of its evaluation:

- *OTIB: Maximum Internal Dose Estimates for Certain DOE Complex Claims,* ORAUT-OTIB-0002, Rev. 01 PC-2; May 7, 2004

- *OTIB: Internal Dose Overestimates for Facilities With Air Sampling Programs,* ORAUT-OTIB-0018, Rev. 01; August 9, 2005

- *OTIB: Analysis of Coworker Bioassay Data for Internal Dose Assignment,* ORAUT-OTIB-0019, Rev. 01; October 7, 2005

- *OTIB: Assignment of Missed Neutron Doses Based on Dosimeter Records,* ORAUT-OTIB-0023, Rev. 00; March 7, 2005

- *OTIB: Dose Reconstruction Considerations for Recycled Uranium Contaminants,* ORAUT-OTIB-0053 (draft)

- *OTIB: Internal Dosimetry Coworker Data for Los Alamos National Laboratory,* ORAUT-OTIB-0062 (draft)

- *OTIB: Los Alamos National Laboratory Bioassay Data Project,* ORAUT-OTIB-0063 (draft)

- *Generating Summary Statistics for Coworker Bioassay Data,* ORAUT-PROC-0095, Rev. 00; June 5, 2006

4.3 Facility Employees and Experts

NIOSH also reviewed information from the following three NIOSH Worker Outreach Meetings:

- Meeting with University Professional and Technical Employees Local 1663 at Northern New Mexico Community College; Espanola, New Mexico; June 18, 2005

- Meeting with International Guard Union of America Local 69; Los Alamos, New Mexico; August 16, 2005

- Meeting with New Mexico Building and Construction Trades Council; Albuquerque, New Mexico; June 20, 2006

To obtain additional information, NIOSH interviewed two primary former LANL employees and received historical information from a current member of the LANL Radiation Protection Division. These employees were principal members of the LANL health physics staff. NIOSH determined during the preparation of this report and evaluation of the available data and process information that further interviews would be unlikely to locate additional information of sufficient magnitude to alter the evaluation's outcome for the broad period of time and extensive number of Technical Areas included in this report.

- *Conversation with Jim Lawrence and John Voltin*; discussion of external badging practices; Interviewer: G. Calhoun; Interviewees: J. Lawrence and J. Voltin; August 20, 2002; SRDB Ref ID: 7897

- *Interviews and Personal Communications with J. N. P. Lawrence by T. E. Widner (2003)*; general interview conducted on August 20, 2003 plus follow-up comments on the 11-03-03 draft of the External Dosimetry TDB; Interviewer: T. Widner; Interviewee: Jim Lawrence; 2003; SRDB Ref ID: 27882

- *Personal Communications Between Tom Widner and James N. P. Lawrence (2004)*; follow-ups on the August 20, 2003 general interview; Interviewer: T. Widner; Interviewee: Jim Lawrence; 2004; SRDB Ref ID: 27884

- *Interpretation of LANL Personnel Radiation Dose Reports; Personal Communications with John Voltin, LANL Radiation Information Management Team Leader (February 2005)*; Interviewer: T. Widner; Interviewee: J. Voltin; February 2, 2005; SRDB Ref ID: 27886

- *E-mail from Paul Hoover to Jack Buddenbaum Dated November 17, 2006, Regarding Pre-1969 In Vivo Results at LANL*; Interviewer: T. Widner; Interviewee: Paul Hoover (LANL); 2006; SRDB RefID: 27881

Additional discussions were held with the ORAU Team TBD Team Lead for LANL to clarify information presented in the TBDs.

4.4 Previous Dose Reconstructions

NIOSH reviewed its NOCTS dose reconstruction database to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review for the period of March 15, 1943 through December 31, 1975. (NOCTS data available as of: December 19, 2006)

Table 4-1: No. of LANL Claims Submitted Under the Dose Reconstruction Rule
(March 15, 1943 through December 31, 1975)

Description	Totals
Total number of claims submitted for energy employees who meet the proposed class definition criteria	657
Number of dose reconstructions completed for energy employees who were employed during the years identified in the proposed class definition	300
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition	384
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	526

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. In a few cases, claimant interviews provided information that might be useful for dose reconstructions. Such information included specific TA or building work locations, work duties, types of monitoring, radioactive materials involved, and descriptions of incidents. Most of the remaining claimant interview reports did not include specific work location, source term, specific monitoring, or incident involvement information.

NIOSH was able to obtain internal and external monitoring records for partial time periods and for a partial list of the radionuclides of concern (ROCs) at the site. Similarly, some effluent release and work area air monitoring records were also available for portions of the site and some of the ROCs. The available information has allowed NIOSH to complete dose reconstructions for 300 workers using either an overestimating or an underestimating dose reconstruction methodology, as described in NIOSH internal procedure OCAS-PR-003, *Performing and Reporting Dose Reconstructions*. These methods make use of relatively limited and case-specific information that are not necessarily sufficient to demonstrate the feasibility of estimating radiation doses for a class of employees (which may include individuals for whom these methods are inappropriate).

More specifically, the overestimating methodology uses overestimates of radiation exposures to limit the need for additional research and analysis for cases that apparently did not involve a compensable level of radiation dose and, hence, for which a more precise determination of the doses received by the employees would delay, without any benefit to the claimants, the completion of the dose reconstructions and the resolution of the related claims. The underestimating methodology similarly uses underestimates of radiation exposures to limit the need for additional research and analysis, but in this case the dose reconstruction process is abbreviated at the point when it becomes apparent that the case involved a compensable level of radiation dose, allowing the claimants to be compensated more

expeditiously. Neither of these methods is useful when only a comprehensive and maximally-detailed dose reconstruction can establish whether or not the individual incurred a compensable level of radiation dose.

The review of completed and pending cases included a wide variety of job titles, including: carpenter, electrician, machinist, chemist, security guard, technician, physicist, custodian, animal caretaker, vehicle inspector, and research scientist. Years of service ranged from less than one year up to 42 years. Completed reconstructions used various approaches, both underestimates (partial reconstructions) and overestimates. Reconstructions that have been completed for monitored worker cases applied available external and internal monitoring data as well as missed dose. For cases with monitoring gaps, or where the worker did not have either internal or external monitoring data, the reconstructions relied on co-located worker data (e.g., when the worker was involved in an incident), technical information bulletins ORAUT-OTIB-0002 and ORAUT-OTIB-0018, ambient on-site doses from other DOE sites, internal co-worker data from across the DOE complex, radiological protection guide values, or TBD-tabulated values.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database to locate documents supporting the evaluation of the proposed class. Three hundred and thirty-one (331) documents in this database were identified as pertaining to LANL. These documents were evaluated for their relevance to this petition. The documents include historical background on external dosimetry programs and evaluations, internal monitoring, contamination monitoring, air monitoring, environmental monitoring, medical monitoring, process materials, and facility and process descriptions.

4.6 Other Technical Sources

NIOSH reviewed the following technical sources in support of the evaluation of the proposed class:

- *Overview of Los Alamos National Laboratory - 1997*, LA-UR-97-4765; LANL Environment, Safety, and Health Division; 1998; SRDB Ref ID: 27224

- *Internal Dosimetry and Dose Assessment at Los Alamos National Laboratory*, Inkret, W. C., LANL; 1993; SRDB Ref ID: 14522

- *Air Monitoring and Its Evolution at the LASL Plutonium Facility*, LA-4076; LASL; 1969; SRDB Ref ID: 27223

- *History of LANL's Bioassay Program from Inception to 1993*, LA-UR-05-1942; Clark, M. J.; LANL; 2005; SRDB Ref ID: 17157

- *Brief History of Biological Monitoring and Dose Assessment for Tritium at Los Alamos*, LANL, 1987; SRDB Ref ID: 14512

- *Compendium of Reports on Various Nuclides, Work Groups and Operations, Circa 1945*, LASL; 1946; SRDB Ref ID: 14878

- *Evaluation of Polonium-210 Exposure for Termination Reports*, LANL, 1979. SRDB Ref ID: 14519

- *Interim Report of the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project,* ChemRisk et. al.; Version 3B; July 27, 2004; SRDB RefID: 27260

- *Los Alamos National Laboratory (LANL) Female Cohort Mortality Study (lafema01)*, DOE Comprehensive Epidemiologic Data Resource (CEDR), 1987; CEDR site: http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lafema01

- *Los Alamos National Laboratory (LANL) Male Cohort Mortality Study (lamena03)*, DOE Comprehensive Epidemiologic Data Resource (CEDR), 1993; CEDR site: http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lamena03

- *Los Alamos National Laboratory (LANL) Female Suicide Analytic Study (lasuia02)*, DOE Comprehensive Epidemiologic Data Resource (CEDR), 1988; CEDR site: http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lasuia02

- *Follow-Up Study of Select Manhattan Project Plutonium Workers (laupua01))*, DOE Comprehensive Epidemiologic Data Resource (CEDR), 1987; CEDR site: http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=laupua01

- *Analytic Health Study of Los Alamos, Zia Company, and Manhattan Project Workers (lahswa04))*, DOE Comprehensive Epidemiologic Data Resource (CEDR), 1987; CEDR site: http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lahswa04

4.7 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners (received June 26, 2006):

Submittal No. 1 (SECIS 9457 and 9460):

- Initial Form B Submission
- Atomic Energy Commission Release No. B-30, *AEC Announces Completion of Investigation and Review of December 30 Radiation Accident at Los Alamos Scientific Laboratory*; March 2, 1959
- Attachment titled: Special Exposure Cohort Petition for Los Alamos National Laboratory
- Article: *U.S. to Pay Workers for Radiation Exposure*; April 12, 2000; http://www.navajoboy.com/artus.htm

Submittal No. 2 (SECIS 9638):

- Revised Form B Submission
- Attachment: In response to your request for additional information and corrections to the application
- Atomic Energy Commission Release No. B-30, *AEC Announce Completion of Investigation and Review of December 30 Radiation Accident at Los Alamos Scientific Laboratory*; March 2, 1959
- Attachment Titled: Special Exposure Cohort Petition for Los Alamos National Laboratory
- Article: *U.S. to Pay Workers for Radiation Exposure*; April 12, 2000; http://www.navajoboy.com/artus.htm
- Letter to Larry Elliott from Tom Udall; March 17, 2006
- Letter to C. Russell Shearer from Tom Udall; March 17, 2006
- Letter to H. Ruiz from L. Elliot, January 26, 2006
- Letter to H. Ruiz from L. Elliot; February 7, 2006
- Page from Presentation: Development of the Site Profile for the Los Alamos National Laboratory; August 16, 2005
- Environmental Health Perspectives, Volume 110, No. 7, July 2002, *Compensating for Cold War Cancers*
- Newspaper article: Sunday Journal, February 19, 2006, *Bingaman Says Budgets Unfair to Hispanics*

- Copy of web page from URL: http://www,abqjournal.com/north/_news02-04-04, *Budget Could Accelerate Lab Worker Claims*
- Unknown date and source: *DOL Rule for Atomic Workers' Compensation is Born Broken; Rule Defies Congressional Direction and Intent*
- Tiger Team Assessment of the Los Alamos National Laboratory; U. S. Department of Energy Environment, Safety, and Health; November 1991
- Letter to Mr. Milan Mikale; April 20, 1987
- Six pages from a medical record

Submittal No. 3 (SECIS 9822):

- Revised Cover sheet and Form B submission including F.2 as the submission basis
- Exhibit A: Affidavit from R. Chavez
- Exhibit B: Affidavit from R. Chavez
- Exhibit C: Dosimetry records for R. Ruiz
- Exhibit D: Powerpoint presentation, *Development of the Site Profile for LANL*
- Exhibit E: Affidavit from H. Ruiz
- Exhibit F: Affidavit from D. Cooper
- Exhibit G: Affidavit from D. Cooper
- Exhibit H: Affidavit from M. Martinez
- Exhibit I: Affidavit from L. Martinez
- Exhibit J: Affidavit from J. Garcia
- Exhibit K: Affidavit from A. Serrano

5.0 LANL Radiological Operations Relevant to the Proposed Class

The following subsections summarize both radiological operations at LANL from March 15, 1943 to December 31, 1975 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing both processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

NOTE: Throughout this evaluation report, the term "LANL" will be employed to refer to all historical phases of, and successive names for, the Los Alamos site.

5.1 LANL Plant and Process Descriptions

Security was the overriding consideration in the selection of the site originally known as Site Y, later the Los Alamos Scientific Laboratory, and finally the Los Alamos National Laboratory (in 1981). The basic selection criteria were that the site be in an isolated, relatively remote, and inaccessible

location. Accordingly, the search was first narrowed to the sparsely-populated areas of northern New Mexico and southern Nevada. The search then refined its focus on two sites - Jemez Springs and the Los Alamos Ranch School near Otawi (approximately 50 miles north of Albuquerque). After a November 1942 site visit, General Leslie Groves selected the Los Alamos site as the location for the new laboratory. Discussions with the owners of the school revealed a willingness to immediately sell their privately-held land and vacate. On November 25, 1942, Groves received authorization to acquire the site. By month's end, supervision of Site Y initial construction had been assigned to the Corps District Engineer in Albuquerque. By year's end, the University of California had assumed responsibility for procuring supplies and personnel (Hewlett and Anderson, pp. 229-230; Smyth 1945, p. 207).

The start date for the Los Alamos site can be reasonably considered March 15, 1943. Although the existing school buildings enabled some personnel to move to the site and immediately begin preliminary work, Laboratory Director J. Robert Oppenheimer and a few of his staff did not arrive until March 15, 1943. They were housed near the site in guest houses that were once part of the school. Other personnel were housed in nearby ranches or in Santa Fe. Work with radioactivity, specifically plutonium and enriched uranium, would not be carried out for some months (i.e., until these materials could be produced in sufficient quantity at Hanford and Oak Ridge). The first work with plutonium apparently took place in mid-1943. In May 1943, Site Y requested a 14-day loan of 200 micrograms of plutonium from the plutonium project in order to experimentally measure fission neutron production and yield (Kathren, Gough and Benefiel, pp. 277-8).

As the requested quantity was half the extant world supply of plutonium, great care was taken to avoid the loss of even a single atom of the material, which was personally brought to the site by Glenn T. Seaborg. Experimental work with this tiny quantity of plutonium was carried out in July 1943 in Technical Area (TA) 1 (Hewlett and Anderson, p. 212).

Early plutonium studies at Los Alamos had to be carried out on a micro-chemical basis because even milligram quantities of the material were unavailable. Not until the spring of 1944 were gram amounts of plutonium available from the Clinton Pile at Oak Ridge (Hewlett and Anderson, p. 243-245). In March 1944, the first shipment of enriched uranium was received: a portion of the 200 grams of 12 percent-enriched material that had been thus far produced in the Alpha 2 racetrack at Oak Ridge (Groves, p. 110; Hewlett and Anderson, p. 164). Shipments of plutonium from the Hanford production reactors to Los Alamos did not begin until early 1945; the first small sample of plutonium arrived on February 2, 1945.

The Los Alamos laboratory initially had a single mission: design and manufacture of the first nuclear weapons. This entailed a great deal of both experimental and theoretical research, particularly with regard to fission of U-235 and Pu-239 by neutrons and the production of fission products. Related work was also performed on the chemistry, metallurgy, preparation, and assembly of the weapons' nuclear components. Los Alamos was charged with fabricating the fissile components of the weapons, which included machining metallic plutonium and uranium to exacting tolerances. Neutronics studies required construction of two small test reactors and a number of critical facilities. In addition, a great deal of non-radiological work was carried out involving high explosives and other ancillary weapons components. By mid-1943, the organization to carry out this mission had been finalized as four divisions reporting to Director Oppenheimer: Theoretical, Experimental Physics, Chemistry and Metallurgy, and Ordnance. The efforts of these four divisions and the myriad other

sites working to provide component materials resulted in the deployment of two nuclear devices that brought an accelerated end to the war in the Pacific.

After World War II, many scientists (particularly those with greater prominence and seniority who had worked on the first nuclear weapons) left Los Alamos and the weapons development and testing program shrank and began to wind down. In 1946, responsibility for the lab was transferred from the military to the newly-created civilian Atomic Energy Commission (AEC).

By mid-1947, there was a resurgence of activity at the then-renamed Los Alamos Scientific Laboratory (LASL). Aided by a large construction budget the following year, the much more broadly-defined mission included development of fast neutron reactors and thermonuclear weapons research. These projects brought with them new radiological concerns, specifically doses from neutrons and tritium. Los Alamos remained the lead facility for the fabrication of nuclear components for weapons until 1949, when the Plutonium Finishing Plant at the Hanford site in Washington State began making the central cores for nuclear devices. However, LASL remained a back-up production facility. In addition, the lab designed, developed, and fabricated nuclear components for test devices, a function that has continued throughout its lifetime. Furthermore, its work broadened to include a wide spectrum of radiologically-related research and operational activities. Weapons development and testing remained central; however, the broadened mission also included fission product studies, isotope applications, reactors, and advanced accelerators, such as the Los Alamos Meson Physics Facility (LAMPF) and Project Sherwood, and the Kiwi reactor program assigned to the lab in 1957 (Hacker pp. 200-205). Many of the LASL programs, especially the weapons development and testing, were carried out in parallel with what is now the Lawrence Livermore National Laboratory, a second weapons laboratory started in 1952 (Hewlett and Duncan, pp. 583-4).

The diversity and breadth of research and other work involving ionizing radiation at the site is enormous, but over the years, nuclear weapons development, testing and related activities have been the dominant activities. Much of the weapons-testing work involving actual detonation of nuclear devices was conducted off site, generally at the Nevada Test Site (NTS) (which became operational in 1951) and the Pacific Proving Ground (PPG) (where the initial tests were conducted). In addition, research and other activities involving reactors and critical assemblies have been a significant part of the LANL mission. Most known radionuclides have at one time or another been present at the site.

The large scope and wide breadth of site activities involving radiation and radioactive materials also include early biomedical studies of tritium and plutonium, experimental application of mesons to medical therapy, fission product studies, dynamic testing of uranium, neutron cross-section measurements, source development, criticality studies, reactor developments, and controlled fusion. These are but a few of the more significant radiologically-related activities carried out over the years.

Another significant site activity during the period under evaluation was the implosion testing involving radioactive lanthanum (RaLa), conducted from September 21, 1944 through March 6, 1962. These activities are the subject of an SEC class that includes potentially-exposed workers from this program, as defined in the Evaluation Report for Petition SEC-00061 (covering the time period September 1, 1944 through July 18, 1963). Therefore, the report herein does not evaluate the feasibility of dose reconstruction for RaLa activities, with the exception of potential dose resulting from residual strontium-90 contamination after July 18, 1963.

5.2 LANL Functional Areas

To accomplish its mission, LANL was divided into a number of physically separate Technical Areas which spread in time over a relatively large area. No less than 75 numbered TAs have been identified along with several off-site locations. These TAs and locations, along with their significant radiation sources, are briefly described in Table 5-1. The tabulation of radiation sources is, of necessity, incomplete and only an overview; more detailed information is available in ORAUT-TKBS-0010-2. In addition to the potential intakes of the radiation sources specifically identified, personnel at the sites where radiation sources or radiation-generating machines were present also had the potential for exposure to external radiations from beta radiation, gamma rays, and neutrons.

Twelve of the TAs listed in Table 5-1 had no known history of radioactive material use or were not operational during the evaluation period and are, therefore, excluded from this evaluation. Other TAs listed with an unknown history are assumed to have had some exposure potential and are thus considered in the proposed class definition.

Historically, the diverse nature of LANL work, the large number of specific programs, and the numerous areas both on and off site where activities were carried out does not lend itself to a detailed evaluation of each specific functional or technical area. To some extent, this evaluation was accomplished in ORAUT-TKBS-0010-2, which also gives a detailed chronology of site facilities construction.

A more representative picture of the laboratory can be obtained by an overview of the site's main functional areas of activity:

- LANL Weapons Development and Testing (Section 5.2.1)
- LANL Critical Assemblies, Reactors, and Reactor Development (Section 5.2.2)
- LANL Accelerators, X-ray Equipment, and Radiography Sources (Section 5.2.3)
- LANL Biomedical Research (Section 5.2.4)
- LANL Project Sherwood and Fusion Research (Section 5.2.5)
- LANL Waste Treatment and Disposal (Section 5.2.6)

Additional information regarding LANL functional activities can also be found in ORAUT-TKBS-0010-2.

5.2.1 LANL Weapons Development and Testing

LANL's long-standing central mission, to which major portions of its efforts were devoted, was the development and testing of nuclear weapons. This work involved extensive studies with enriched and depleted uranium and plutonium. From the outset, it was recognized that uranium enriched in U-235, and subsequently Pu-239, could be made to produce an uncontrolled chain reaction of nuclear fissions. This reaction would involve an enormous release of energy, including a burst of gamma and neutron radiations, and the production of a wide range of fission products with atomic numbers ranging from 30 (zinc) to 65 (terbium), with 97 percent of the nuclei produced by U-235 thermal fission having mass numbers from about 85 to 104 and 130 to 140 (Glasstone p. 481-3). Most fission products are radioactive, with half-lives ranging from a fraction of a second to a few weeks or months; a few, such as Sr-90 and Cs-137, have much longer half-lives of approximately 30 years. In addition to the more

than 100 radioactive nuclear species produced by the fission process, there are other radioactive species produced by neutron activation of the casing and other components of the device, most notably the production of radioisotopes of the heavy elements, in particular plutonium.

Work at LANL centered around not only the neutronics of the fission process but also the chemistry and metallurgy of uranium and plutonium, the identification and characterization of fission products, and the development and characteristics of thermonuclear devices. Fission product studies required sampling, collection and transport of radioactive samples from the off-site nuclear testing locations to Los Alamos.

Examples of other significant LANL weapons-related activities involving radioactivity include a large number of experimental implosion diagnostics studies carried out between 1944 and 1961, with La-140 used as a surrogate for fission product activity and either natural or depleted uranium as a surrogate for the fissionable material. RaLa experiments took place at TA-10, which included several buildings and four outdoor firing sites. La-140 separations took place in the radiochemistry building, TA-10-1. In 1951, the La-140 separations operation was moved to TA-35, commonly referred to as the "Ten Site." This operation remained at TA-35 until the end of the project. Other RaLa-related activities took place on a much smaller scale in Buildings Sigma, H, and U, all located in Technical Area 1 (TA-1). These studies were significant not only for the large amount of radioactive lanthanum used (301,802 Ci) but also in that this activity, along with Sr-90, was directly released to the environment. The LANL Director notified the AEC in a letter dated July 18, 1963 that the TA-10 site clean-up was complete. The evaluation herein only addresses residual contamination from RaLa activities after July 18, 1963.

Research on high explosives was carried out in a number of TAs from 1949 to 1970, and used tens of tons of depleted uranium, much of which was directly released into the environment.

Weapons tests were carried out largely at PPG and NTS, although several tests were conducted at other locations within the United States. Testing at PPG ceased in 1962 with the signing of the Test Ban Treaty, but LANL still maintained a presence there, conducting (among other things) radio-ecological studies. The first nuclear weapon test was the Trinity tower shot at Alamagordo, New Mexico, in August 1945. Six other tests, primarily non-weapons-related, were conducted in the 1960s and 70s in Alaska, Colorado, and New Mexico. A few weapons-related tests were conducted at Tonopah, Nevada (adjacent to NTS), and some near Hattiesburg, Mississippi.

5.2.2 LANL Critical Assemblies, Reactors, and Reactor Development

From the outset, criticality experiments were conducted, often to determine the critical mass of U-235 and Pu-239 needed for weapons and to gather other neutronics data. These experiments were initially carried out at TA-2, Omega Site, which had been designated for this purpose as well as the site for research reactors in 1943. Subsequently, these experiments were conducted at TA-18, Pajarito Site, which was originally developed in mid-1943 for radioactivity studies. Some criticality studies were moved to TA-18 in April, 1946 following a fatal criticality accident; the entire critical experiments group was relocated there from TA-1 in February 1953. Initially, criticality experiments were done in the open and hand-controlled, but fatal criticality accidents led to the institution of safety measures, including a ban on hand operations. Critical assemblies were used to generate pulses or bursts to simulate weapons detonations. These included the various Godiva assemblies, Jezebel, and SHEBA,

which was assembled in the 1950s. The critical assembly cores were composed of uranium enriched in the U-235 isotope, Pu-239, or U-233.

The reactors at Omega Site were small test devices, essentially uncontained. The first of these, a zero-power water boiler fueled with 14 percent enriched uranium, achieved initial criticality in May 1944. The boiling water reactor operations continued. Subsequently, in 1945, the Plutonium Fast Reactor dubbed Clementine was approved and achieved initial criticality in August 1946, ultimately reaching its design power of 25 kW in March 1949. Technical problems with Clementine resulted in its shutdown in 1950; it was replaced by the Omega West Reactor, which had a design basis of 5 MW. Clementine was decommissioned in 1953; Omega West continued operations until 1992. After criticality operations were moved to TA-18 in 1946, reactor operations at TA-2 were largely concerned with neutron studies and isotope production.

A number of other reactors were constructed and operated by LANL. The Los Alamos Power Reactor Experiment (LAPRE) was carried out at TA-35 between 1955 and 1960. This was followed by the Los Alamos Molten Plutonium Experiment (LAMPRE), which operated through the 1960s.

TA-35, also known as Ten Site, housed a number of other non-reactor operations, including La-140 separation cell and fusion research.

Project Rover was a major reactor research project that attempted to develop a practical nuclear rocket. No less than 16 Project Rover reactors (which included the Kiwi reactors) were developed by the Critical Experiments Group at TA-18 (Pajarito Site) between 1959 and 1972. These reactors were made and assembled in TA-18 where they underwent initial testing prior to being shipped to NTS where they underwent additional rigorous (and sometimes destructive) testing. Project Rover was terminated in 1973. Another significant reactor program was the helium-cooled Ultra-High Temperature Reactor Experiment (UHTREX). The UHTREX was constructed at TA-52 during the late 1960s; it only operated for about a year before being terminated in 1970. The facility was decontaminated in the 1980s.

Evaluations of reactor fuel elements and spent fuels were also associated with reactor projects. These activities were performed within hot cells located in TA-3, -21, and -48.

5.2.3 LANL Accelerators, X-Ray Equipment, and Radiography Sources

Accelerators have been present at the Los Alamos site since its inception. Initially, accelerators were used to generate neutrons to determine the critical masses of U-235 and Pu-239, to study Pu-239 pre-detonation characteristics, and to perform cross-section studies. Four accelerators were obtained from various universities and used during the war years: two Van de Graaff generators, a Cockcroft-Walton Machine, and a cyclotron. After the war, the Long Tank van de Graaff generator was returned to the University of Wisconsin and was replaced with a more modern unit with a vertical configuration. The other three units remained at Los Alamos. Additional accelerators were soon added, including: a small betatron; linear electron accelerators; small accelerators that generated 14 MeV neutrons by the deuterium-tritium reaction; and a van de Graaff accelerator in W building in TA-1 used to generate viable energy neutrons by the (p,n) reaction for cross-section studies.

The largest, and perhaps, most significant and unique accelerator at LANL is the LAMPF, located in TA-53. The LAMPF is an 800 MeV, 1 mA proton linear accelerator and one of just three facilities worldwide created for production of mesons. Construction on LAMPF began in 1968, and the full energy beam was first achieved on June 12, 1972. LAMPF was designed to produce an intense beam of protons with energy just above the pion production threshold, thereby producing an intense beam of subatomic particles. Originally, the purpose was to produce mesons and other subatomic particles in quantities large enough to be more readily studied. Later, the LAMPF was used for neutron-scattering studies. By means of its Proton Storage Ring, the LAMPF can generate high-intensity neutron pulses by proton bombardment of high Z targets, including uranium.

Because of its large size and unique capabilities, LAMPF produces a wide variety of radiations and, since at least the late 1970s when monitoring for short-lived activation gases began, has been the foremost source of airborne radioactivity releases to the environment.

X-ray equipment and/or radiography sources were used for non-destructive testing in TA-8, -13, -15, -16, and -24. In the 1960s, the Pulsed High Energy Radiographic Machine Emitting X-Rays (PHERMEX) became operational in TA-15. To simulate a radiation pulse from a nuclear detonation, PHERMEX produced pulsed X-rays by impinging a beam of electrons onto a tungsten target. Other X-ray equipment with potentials of up to 1 MeV, some of which were portable, were used to examine explosive casings, materials, dies, and molds. Radiography sources used in similar non-destructive testing included Co-60, Cs-137, and Ir-192.

5.2.4 LANL Biomedical Research

The Biomedical Research group conducted numerous studies on radiological interactions and the medical use of radioactive materials. These studies involved the radiolabeling of various compounds. The radionuclides most commonly employed in these research efforts were C-14, H-3, P-32, S-35, and radioactive iodines.

5.2.5 LANL Project Sherwood and Fusion Research

Controlled nuclear fusion research began in 1951 and was carried out under the auspices of Project Sherwood, a nationwide part of the Atoms for Peace Program. The initial work was carried out in TA-1 using the betatron, which had been modified for this purpose to induce a toroidal current in a plasma, which in turn produced a magnetic field that pinched or constricted the plasma column. This process, known as the Z-pinch, was unsuccessful but encouraging, and led to construction of more advanced accelerators to obtain the extremely high temperatures needed for a fusion reaction.

Although Project Sherwood was discontinued in the 1970s, thermonuclear fusion research continued at LANL. Construction of laser fusion laboratories for fusion research began at TA-35 in 1974; HELIOS and ANTARES are large laser facilities for the study of plasma containment by laser inertial confinement.

5.2.6 LANL Waste Treatment and Disposal

The site's initial waste management consisted of direct discharge of untreated liquid wastes to Acid Canyon from the mid-1940s until 1951. An exception was waste solutions containing plutonium, which were collected in storage tanks in TA-21 for eventual plutonium recovery. From the early 1950s onward, various liquid waste treatment facilities were placed into operation in TA-21, -35, -45, and 50. These facilities treated waste using flocculation-sedimentation-filtration, absorption beds, hold-up tanks to allow for radioactive decay of short-lived radionuclides prior to discharge, de-ionization, and grouting followed by ground shaft injection. Treated liquids were then discharged to various canyons.

Solid wastes were disposed of primarily in material disposal areas. These disposal areas are located in TA-4, -21, -33, and TA-54 (the central waste disposal facility which began operations in 1957 for low-level radioactive waste). The remaining solid waste facilities were used in the mid-1940s and ceased operations at various timeframes between the 1950s and 1970s.

Incinerators were also used primarily for volume reduction and, in some cases, for material recovery (specifically U-235). These incinerators were located at TA-1, -3, -21, and -42.

5.2.7 Summary of Key LANL Facilities

Table 5-1 summarizes the LANL TAs, key processes, dates of operation, and primary radiation sources. Twelve of the listed TAs had no history of radioactive material use or were not operational during the period of this evaluation: TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74.

The following abbreviations apply:

- a.k.a. = Also known as
- All = Pu-239, Pu-240, Pu-238, Am-241, U-235, DU, H-3, Po-210, Ac-227, Ra-226, MAP, MFP, NU, VFP
- NA = Not applicable
- NCD = No confirmed date
- DU = Depleted uranium
- EU = Enriched uranium
- HT = Tritium gas
- HTO = Tritium oxide
- MAP = Mixed activation products (e.g, C-11, N-13, O-15, Ar-41, Be-7, Na-22, Na-24, Co-58, Co-57, Mn-54, Mn-52, V-48, and others)
- MFP = Mixed fission products (e.g. Cs-137, Sr-90, radioactive noble gases, and others)
- NU = Natural uranium
- TRU = Transuranic materials
- VFP = Volatile fission products

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-0: Los Alamos Town site: Leased space in Los Alamos and White Rock for training, support, unclassified research and development, community outreach, museum	NA	NA	None	Original town site
TA-1 (General): Original Main Technical Area (inactive): Active 1943-65; turned over to Los Alamos County or private interest in 1966; all contamination removed by 1975.	1943	1965 active 1975 decomm.	See TA-1 entries below.	
TA-1-C, Uranium machining	1943	1964	Uranium	
TA-1-D, Pu chemistry and metallurgy	1943	1954	Pu-239, Pu-238, U-238, DU Am-241 Po-210 Ba-140, La-140	 Absorption depends on matrix or pure May indicate Sr-90
TA-1-D-2, Contaminated laundry	1943	1953	Pu-239; Pu-240; Pu238; Am-241, EU, DU, Po-210, Ac-227, Ra-226	
TA-1-D-5, Sigma vault - storage	NCD	1965	Pu-239, U-238	
TA-1-G, Uranium and graphite sigma pile	NCD	1959	Uranium, Ra-226	
TA-1-H and Gamma.	1945	1957, 1959	Po-210 MFP	Initiators Cs-137 contamination incident occurred
TA-1-HT, Heat treatment and machining	1946	1965	NU, EU	
TA-1-HT, Barrel House, Storage	NCD	1964	Pu-239, U-238	
TA-1-M, Processing and recovery EU	NCD	NCD	EU	Processing, metallurgy and recovery
TA-1-M-1, Machining	NCD	NCD	U-238	
TA-1-ML, Medical Laboratory	NCD	NCD	Cm, Am	Processing
TA-1-O	1943	1956	Radon, Radium	Radon cooked off sources on a hot plate; Ra /RaBe Calibration Sources
TA-1-Q	1943	1959	Radium Radon	A spill occurred Ra Calibration Sources
TA-1, Sigma Bldg	1944	1965	NU, EU, Th	Casting, machining, powder metallurgy

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-1-TU, Machining Tuballoy	NCD	1964	NU	
TA-1-TU-1, Recovery of EU	NCD	1964	EU	Furnace for burning rags
TA-1-V, Machine Shop	1943	1959	uranium	Unusual assignments
TA-1-W, Van de Graaff accelerator	1943	NCD	uranium, Po-210, H-3 Th-228	 "Mesiothorium"
TA-1-X, Cyclotron	1943	NCD	Be, U, Li, H-3, Sr targets. Zn-65	Targets had induced beta activity.
TA-1-Y, Physics Laboratory	1943	NCD	H-3, Uranium	
TA-1-Z, Cockcroft-Walton accelerator	1943	NCD	None	
TA-2, Omega Site (General): Early critical assembly experiments. Reactors were used for critical experiments until 1946 when the experiments were moved to TA-18. After 1946, Omega Site reactor operations focused on neutron experiments and isotope production.	Early 1940s	Major decomm. activity in 1991	See TA-2 entries below.	
TA-2, Water Boilers	1944	1974	EU, I-131, I-125, Rb-88, Cs-137, Xe-131, Ar-41, H-3, Pu-239	Enriched U fuel Neutrons
TA-2, Pu Fast Reactor, a.k.a. Clementine (1946–1952)	1946	1953	NU, Pu, I-131, I-125, Rb-88, Cs-137, Xe-131, Ar-41	Ruptured Pu fuel rod, U reflectors Neutrons
TA-2, Omega West Reactor (OWR) (1956-1992)	1956	1995	U-235 I-131, I-125, Rb-88, Cs-137, Xe-131, Ar-41, Cr-51, Na-24, Tc-99m	Enriched U fuel I-125 production Loop Schedule – at times operated "around the clock" Neutrons
TA-3, Core Area a.k.a South Mesa Site (General): Detonator manufacturing, metallurgy burn pit, firing sites (1943-49).	1943	Still active	See TA-3 entries below.	
TA-3-34, Cryogenics Laboratory	NCD	NCD	H-3	3,000 Ci HTO released in 1979
TA-3-35, Press Building (part of Sigma Complex)	NCD	NCD	EU	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-3-66, Sigma Complex, metallurgy and fabrication	NCD	NCD	EU, DU powders, Pu, thorium	Pu processing
TA-3-102, Machine shops;	NCD	NCD	uranium, Pu, DU	
TA-3-141, Rolling Mill (part of Sigma Complex)	NCD	NCD	DU, Pu, EU, thorium	
TA-3-159, Thorium Storage (part of Sigma Complex)	NCD	NCD	thorium	
TA-3-184, Occupational Health	NCD	NCD	Pu	
TA-3-216, Weapons Test Support	NCD	NCD	Pu	
TA-3-1698, Materials Science Laboratory: Processing, mechanical research	NCD	NCD	DU	
TA-3-FE-19	NCD	NCD	Plutonium	
TA-3-SM-16, Ion Beam Facility (IBF); Van de Graaff – Accelerator and Tritium operations	NCD	NCD	I-125 H-3 P-32	Iodide, labeled organics Labeled DNA precursors(OBT), water (HTO), HT Labeled organics, phosphates Neutrons
TA-3-SM-29, Chemical and Metallurgical Research (CMR); actinide chemistry and metallurgy research (1952 to present)	1951	Still active	Pu-238, Pu-239,EU, U-238, DU	Small quantities of uranium and plutonium, mixed fission products including iodines, Pu-238
TA-3-SM-29, Chemistry and Metallurgy Bldg., Wings 3, 5, and 7	NCD	NCD	H-3	HTO, HT
TA-3-SM-29 Chemistry and Metallurgy Bldg., Wing 9; handling of irradiated U and Pu in hot cells.	1961	NCD	Cs-137 MFP including I-131, Pu-238, Pu-239, Pu-240 EU, U-238, DU	Potential for low-level chronic intake in hot cell work 0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common.
TA-3-SM-40, Physics	NCD	NCD	All	Incident contaminated large portion of building with Po-210 through ventilation (late 1950s or early 1960s)
TA-3-SM-40, Tritium Instrument Calibration Facility	NCD	NCD	H-3	HTO, HT
TA-3-SM-700, Acid Neutralization and Pump Bldg.	NCD	NCD	Pu	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-4, Alpha Site: Constructed in 1944 as a test firing site for small-to-medium explosives. Firing site until 1956; Material Disposal Area C. During the summer of 1985, a clean-up operation was initiated as part of the Los Alamos Site Characterization Program. All remaining structures and their utilities were removed.	1944	1956 1985	DU	Firing site until 1956, Materials disposal site C.
TA-5, Beta Site: Former firing site used extensively in 1945. Site was constructed in 1944 as a test-firing site. Environmental contaminants at this site may include natural or depleted uranium, metallic beryllium, and/or cadmium. Burial of debris of firing sites during the years prior to 1985.	1944	<1985	DU	
TA-6, Two-Mile Mesa South Site: In 1944 and 1945, several buildings were constructed for detonator work, including three firing chambers, laboratory, and explosives pressing shop. In 1946 and 1947, pits (now MDA F) were dug on the mesa to bury classified objects. About 100 lenses constructed at S-Site were defective and destroyed by detonation, probably in area known as MDA F. Test firing continued at TA-6 until 1952 when operations were moved to TA-40. Explosives development and laser, chemical laboratory continued at TA-6 until 1976. Several small operations (e.g., carpenter shop cable fabrication shop) continued until 1980s. Ten magazines and other buildings were removed or destroyed by burning. As of 1998, some structures were still in place, but no longer used.	1944	1998	DU, Cs-137, Sr-90, Co-60	Detonator manufacturing
TA-7: Gomez Ranch Site: Former firing site used from 1944-47 for small explosive experiments with short-lived radionuclides.	1944	1947	DU, unknown	
TA-8, GT Site a.k.a. Anchor Site West: Gun firing sites 1943-45. Occasional tests performed using small quantities of polonium and beryllium, although no indications that these materials escaped targets. Gun-Firing Site abandoned in 1946 and guns and other items buried in pit on site now know as Material Disposal Site Q. Explosives processing 1945-50. Wooden structures removed at various times between 1949 and 1968. In 1949 and 1950, modern TA-8 was established north and west of Gun-Firing Site and is presently used, primarily for non-destructive X-ray testing.	1943	Old: 1950 New: Active	Pu-239, Pu-238, EU, DU, Co-60, Ir-192, Cs-137	Gun firing site

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-9, Anchor Site East a.k.a. Anchor Ranch, Old Anchor East, Far (Detonation) Point, Nu Site. Nu Site was known as TA-23 before incorporation into TA-9 in 1950. Old Anchor East was established in 1943 to house explosives production, development, test experiments, and X-ray work. Old Anchor East returned to AEC in 1957; permission for site decommission given in 1959; buildings and substructures removed between 1960 and 1965. Buildings known to contain radioactive contamination removed and disposed at TA-54. Far (Detonation) Point established in 1944 to conduct explosives detonation experiments in the open. Abandoned in late 1940s and decommissioned in 1965. MDA M at Far (Detonation) Point was used from 1948 to 1985 as surface dump for construction debris, other solid wastes, chemicals, and high explosives. Construction of TA-9 (New Anchor East) began in 1950 and currently contains a laboratory and office buildings, six magazines, a shop, two laboratory buildings, process laboratories, a machining building, and an environmental test chamber where explosives research is conducted.	1957	1960-65	DU, H-3, Sr-90	
TA-10-CMR-10, Bayo Canyon Site: Radioactive lanthanum test shots 1944-61; radioactive lanthanum radiochemistry 1944-50; site removed in 1963. In 1944, Bayo Canyon began to be used for firing experiments. In 1945, additional permanent structures were completed for chemistry work and firing. Best estimates are that from 1944 until 1961 (when firing ceased), approximately 2,000 kg of natural uranium and 3,380 kg of depleted uranium were released. In 1963, all remaining buildings were removed.	1944	1963	Sr-90, DU, NU La-140, Ba-140	RaLa radiochemistry
TA-11, K Site: Implosion studies; later high explosives, drop and vibration tests. TA-11 was constructed in the winter of 1944-45. The eastern part of the site was constructed of a heavily-bunkered control/laboratory building, shop, laboratory, storage building, and smelter.	1947	Still active	Ra-226, DU, H-3	20-MeV betatron Neutrons

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-12, L Site: Explosives testing. Constructed in 1944 for the Explosives Division (X-Division). Original structures included a trim building, control chamber, magazine, and a below-ground, steel-lined firing pit which was used from 1946 to 1953, when it was abandoned. One test in the structure involved a 154-lb (70 kg) sphere of uranium; other materials used included U-238. The burn site was used once to dispose of 0.5 lb of explosives by burning. An open section of the site was used for several months as a firing site for explosive charges. This site was abandoned by X-Division in 1946. By 1951, the explosives testing group GMX-2 occupied TA-12. Shots using uranium, lead, and He were conducted at the firing site, which was abandoned in the 1950s. In 1950, the Biomedical Group (H-4) constructed a bermed radiation test bunker and conducted animal irradiation experiments using a 1000-Ci sealed radioactive source of La-140 in transient equilibrium with Ba-140. L-Site was abandoned in 1953. Most of the structures were decontaminated and decommissioned (D&D) in 1960.	1948	mid-1960s	DU, U-238, La-140, Ba-140, Sr-90	
TA-13, P Site: Constructed in early fall 1944 for X-ray work in connection with explosives experiments (LASL HD, 1947); later incorporated with TA-16, status unknown. By the 1950s, all buildings except TA-13-2, -3, and -4 had been removed. These buildings were absorbed into the S Site Complex, TA-16, and were re-numbered TA-16-476, -477, and -478, respectively.	1944	1950s	DU, Po-210	X-rays
TA-14, Q Site: Explosives testing 1944-present. Constructed in 1944 for close observation work on small explosive charges. In 1952, the site was completely renovated and several structures were removed. In the early 1950s, a new extensive firing complex was built and remains at the site today. During its long history, TA-14 has remained an active firing site.	1944	Still active	DU In late 1980s, EU, Cs-137, Co-60 detected in waste ash samples from incinerator; H-3 in storage building.	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-15, R Site: In 1944, a small control building and two firing sites were established. Additional firing sites were established and abandoned over the years. Firing Point C was established in 1945 and in use until 1948; it was decommissioned in 1967. Firing Points E-F were established in 1947 and used extensively through 1973. The site was last used in 1981. Firing Point R-44, used for larger explosive tests, was built in 1951 and used extensively from 1956 to 1978 for diagnostic tests of weapons components. Since the mid-1980s, this site was used only for small experiments, the last being conducted in 1992. Firing Point R-45, the least-used of the active firing sites at TA-15, was built in 1951 and only used for small quantities of explosives. As of July 1998, R-45 still retained active status. Ector Firing Site, used from the mid-1980s, was used for dynamic radiography of explosion-driven weapons components. The use of the site has not been extensive. Pulsed High-Energy Radiation Machine Emitting X-Rays (PHERMEX) 1962-present. PHERMEX is a multiple-cavity electron accelerator capable of producing a very large flux of X-rays for weapons development testing. DARHT is intended to replace PHERMEX. In 1949, firing sites J and I were in operation but were later transferred to Kappa Site (TA-36). Several structures were removed in 1967.	1944	Still active	Pu-239, DU, H-3 In late 1980s, Cs-137, EU, U-238, Co-56, U-234, Th-230 detected in firing site soil samples.	PHERMEX X-rays
TA-16, S Site, Weapons Engineering Tritium Facility (WETF): Former explosives casting/machining operations; burning ground; TA-16 is the WETF for tritium handled in glove boxes. Built in 1945 to make full-scale castings. The WETF facility at TA-16 replaced the tritium facility at TA-33. TA-16 as a whole was constructed in 1944 and consisted of six buildings including a steam plant. Multiple buildings at this site were demolished in the 1950s and 1960s.	1945	Still active	Pu-239, DU H-3 U-238 In late 1980s, Cs-137, Pu-239, Pu-240, Pu-238 were detected in samples from the sewage treatment plant; U-235 in samples of two discharge outfalls	Explosive casting and machining Labeled DNA precursors (OBT), water (HTO), HT X-rays
TA-17, X Site	canceled	NA	None	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-18, Pajarito Canyon Laboratory: First developed in August 1943 by Group P-5, the Radioactivity Group, to study rates of spontaneous fissions from samples of radioactive materials. In 1944, Group G-3 took over the site, enlarged it and used it as a proving ground to study implosions. At this time, three firing sites were constructed: the first to study small explosive charges of a few pounds; the second to study medium explosive charges; and the third (Far Point – not to be confused with the Far [Detonation] Point at TA-9) to test charges of up to two tons. Far Point at TA-18 was later incorporated into Gamma Site which was then re-designated TA-27. Late in 1945, explosives testing by G Division ended. This group moved to the East Gate Laboratory. In April 1946, the site was transferred to Group M-12, Critical Assemblies Group. This became the nation's first critical assembly facility. A heavily-bunkered laboratory was built at the junction of the two canyons, and a trimming building and magazine were constructed back along the road toward Anchor Ranch. In 1947, after a fatal hand-on criticality experiment accident, remotely-controlled criticality experiment structures called Kivas were constructed. Kiva 1 was built in 1947. In 1951, office building and a second Kiva were constructed. Additional buildings were constructed between 1949 and 1951 and a third remotely-controlled Kiva was added in 1960. From 1955 to 1972, fission reactor mock-up studies for the Rover Program were conducted at these Kivas. Hydro assembly was conducted in 1957. With the termination of the Rover Program in 1973, TA-18 was downsized and reorganized and work shifted to mock-ups of a plasma-core power reactor, which used fuel elements and beryllium, enriched uranium foils, and uranium hexafluoride gas. Criticality work involving reactor safety, and later, nuclear detection technologies continued under various other groups. During the 1970s and 1980s, additional buildings were added. Presently termed the LACEF, work continues in nuclear criticality research nuclear weapons safeguards and security, and treaty verification technology. In 1979, 20 grams of UF_6 were released from Building 23 at TA-18.	1943	Still active	EU, U-233, Pu-239; Pu-240 polonium MFP, I-131	0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common. Ruptured Po source, 1953 Neutrons Betatron used from 1951 to 1954; enriched uranium metal sphere 1952; Pu core added 1 year later. 1954 unreflected, delta phase Pu (Pu-240 = 4.5%; also used sphere of 20.1% Pu-240 and 98.1% U-233)
TA-19, East Gate Laboratory: Released to AEC in 1962.	Early 1940s	1962	None	None
TA-20, Sandia Canyon Site: Former World War II testing and firing area for weapon initiators. TA-20 was located within present-day TA-72. TA-20 was decontaminated, decommissioned, and abandoned in 1957.	Early 1940s	1957	DU	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-21, DP Site a.k.a. DP Mesa (General): Former plutonium operations (DP West); uranium/polonium operations (DP East); Material Disposal Areas A, B, T, U, V; Tritium Systems Test Assembly, Tritium Science and Fabrication Facility (1945 to 1978). TA-21 was conceived of, and built, during the spring and summer of 1945 for chemical and metallurgical work. The site, as it was developed and used over the years, can be divided into two main sections: DP East and DP West. DP East activities primarily consisted of tritium research. DP West activities primarily included inorganic and biochemistry research. In 1977, a transfer of work to the new plutonium facility (TA-55) began and much of the complex was vacated. TA-21 was partially decommissioned and decontaminated in 1977-1980. As of 1993, most of the contaminated buildings, exterior duct work, and underground structures still remained at the site	1945	1977-80	See TA-21 entries below. In late 1980s, Cs-137 and U-234 detected in sediments in inactive waste water treatment system outfall; MFP identified in 1979 stack emissions.	
TA-21, DP West, Plutonium facility	1945	NCD	WGPu	
TA-21 DP West	>1945	NCD	Pu-238, Pu-239, Pu-240, Am-241, Pu-241	0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common.
TA-21, CMR, Heat sources	>1945	NCD	Pu-238	Accident with glovebox breached 1971
TA-21-2 and TA-21-3, Wet Chemistry	>1945	1982	Pu	1958 accident, separated phases in Pu process tank, unshielded tank
TA-21-3, Oxalate precipitation operations	>1945	NCD	Pu-239, Pu-238, EU	
TA-21-4 and TA-21-5, Dry chemistry	>1945	1981	Pu	
TA-21-4	1945	1948	EU hydride	
TA-21-4	1960	NCD	Pu-239	Hot cell examine irradiated Pu and EU fuel elements
TA-21-5, Pu fabrication	>1945	Limited use in 1975	Pu-239, Pu-238	Fire contaminated exhaust filter, 1959
TA-21-12, Filter building	>1945	1975	Pu	Contaminated with Ac
TA-21-35 and TA-21-257, Liquid Waste Reprocessing	Late 1940s	1986	All	Pu and transuranic liquid wastes
TA-21-150, Pu fuels development, heat sources development	1963	NCD	Pu-238, Pu-239	Sealed capillary broke, 2800 x MPC Oct 1970
TA-21-151 and TA-21-152, Experimental program	1945	1984	Po-210, Ac-227	Initiator production

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-21-153	1945	In service until 1970-1973	Po-210, Ac-227	Initiator production
TA-21-155, Tritium Systems Test Assembly (TSTA), deuterium and tritium fuels.	1984	1990	HT, HTO	>10 billion Ci. Equipment failure -- H-3, 13.8 Ci released
TA-21-155	1949	NCD	Po-210, Ac-227	Initiator production
TA-21-155, DP East, TSTA Tritium Test Assembly Facility, and TA-21-209, Salt Laboratory	>1945	NCD	H-3	Labeled DNA precursors(OBT), water (HTO), HT
TA-21-210, Pu research	>1945	NCD	Plutonium	
TA-22, TD (Trap Door) Site: Late in 1944, four buildings were constructed to assemble the conventional explosives for the Fat Man weapon. In 1948, the buildings were remodeled into office, laboratory, and fabrication space to replace those activities at TA-6. New magazines were also built. In early 1980s, a new Detonation Systems Laboratory was constructed and occupied in 1985 when the older buildings were demolished or abandoned.	1944	NCD	DU	Detonator development
TA-23, NU Site: Nu Site was established for X-Division during 1943 and 1944 for explosives testing. TA-23 is described as primarily a firing site with two laboratories and a magazine. Post-war activities resulted in contamination with HE, beryllium, radionuclides (e.g., U-238). Nu Site was decommissioned during 1949 and 1950 in preparation for the construction of New Anchor East, at which time it was incorporated into TA-9 for administrative purposes.	1945	1950	U-238	Firing site
TA-24, T Site: X-ray studies of explosives; later incorporated with TA-16. T Site was constructed in the fall of 1944 as a service area for X-ray examination of high explosive charges. A year later, a large storage magazine was constructed. In 1946, a fire damaged the main laboratory building; it was rebuilt in the spring of 1947. Facilities at TA-16 are believed to have once been TA-24 facilities.	1944	Currently non-operational	DU	Facilities transfer to TA-16 X-rays
TA-25, V Site: Explosives assembly; later incorporated with TA-16. V Site, with its two main buildings, was constructed in 1944 for experimental work in connection with special assemblies. In 1945, the work was transferred to TD-Site (TA-22) and the site underwent extensive alterations permit S-Site process work on explosive charges. In July 1945, V-Site was taken over by S-Site.	1944	Currently non-operational	DU	Taken over by TA-16

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-26, D Site: Storage vault and guard building 1946-48; removed in 1966. D-Site was constructed in the summer of 1946 and consisted of a concrete storage vault and a small sentry building and guard tower.	1946	1966	EU, U-238, H-3, U-233	Storage Vault
TA-27, Gamma Site (Far Point): Plutonium gun assembly 1945-47. Site active from 1944 to late 1946/early 1947. This firing site was an extension of Pajarito Site (TA-18), and during that time (1944-1945), it was called Far Point (not to be confused with Far [Detonation] Point at TA-9). The entire site was abandoned and fenced off in early 1947. Gravel for road material was excavated from lower Pajarito Canyon between 1949 and 1962 along the length of Pajarito Canyon east of TA-18 and within TA-27. During the 1960s, all structure, foundations, and other debris were removed and the ground surface leveled. In March 1960, the area of Gamma Site was reopened to begin construction of a road to White Rock. The road was widened, paved, and opened to the public as Pajarito Road on July 11, 1962. The last major site activity occurred in 1969, when sanitary sewage lagoons and a sever line from TA-18 were built. The lagoons and sever line were the subject of VCA and EC activities in 1995. The former TA-27 is presently located within the fragment impact circle of Firing Site 12 and TA-36 and is potentially affected by operations there.	1945	1947	Pu-239 DU, thorium	Pu gun assembly
TA-28, Magazine A: Firing site 1979; explosives storage area.	1979	Still active	DU	Firing site
TA-29, Magazine B: Explosives storage area; abandoned in 1957.	Early 1940s	1957	DU	Explosives storage area
TA-30, Electronics Test Area: Electronics testing.	1945	1948	Unknown	
TA-31, East Receiving Yard: Warehouses west of airport.	1948	1954	Unknown	
TA-32, Medical Research Laboratory: Bio-research facility; 1943-54; removed in 1954; incinerator use included. TA-32, known as the Rat Lab, was a small area located behind the Zia Company's Supply Division Building. Most studies performed here were on internal metabolism of radionuclides, which would have required using low concentrations of radioactive materials.	1943	1954	Radio-labeling compounds, including I-131, C-14, S-35, H-3, N-15, P-32 Pu-238 (Wingfield, 1974)	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-33, HP (Hot Point) Site: Consists of five sites: Main Site, South Site, East Site, Area 6, and the National Radio Astronomy Observatory (NRAO) Site. Established in 1947 as a substitute test site for weapon components experiments being conducted at Trinity Site. Experiments involved testing of beryllium-containing initiators. Many experiments used uranium components. Polonium-210 was used as the radioactive source. Experiments performed in underground chambers (1948-56 shaft experiments), on surface firing pads, and firing sites. These activities cease in 1972. High Pressure Tritium Laboratory operated at Main Site from 1955 until late 1990. Research at TA-33 released the largest amount of airborne tritium from routine LASL operations. Releases in 1978 were considerably higher than previous years. From 1973 to 1977, the average routine release of tritium gas from TA-33 was 3050 Ci (range 615 to 5916 Ci). Material Disposal Areas (MDAs) D, E, K.	1947	1980s late	H-3 U-238, U-236, Po-210, Pu, EU, Pu-239/240 (drum storage stain)	HTO, HT
TA-34, New Laboratory Warehouse Area	canceled	NA	None	
TA-35, Ten Site (General): Radioactive lanthanum 1951-63; Los Alamos Power Reactor Experiment (LAPRE) I/II 1950s; Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) I 1960s; laser fusion research 1974. This site is divided into five facility management units. Work includes nuclear safeguards research and development concerned with techniques for nondestructive detection, identification, and analysis of fissionable isotopes. Research is also done on reactor safety, laser fusion, optical sciences, pulsed-power systems, high-energy physics, tritium fabrication, metallurgy, ceramic technology, and chemical plating. Major decommissioning activities were completed in 1981, including LAMPRE I, a titanium-contaminated laboratory, and removal of contaminated air scrubbers from TA-35-7 (DOE/EIS-0238).			See TA-35 entries below.	
TA-35, CMR-10	1950	1963	La-140, Ba-140 Po-210	Sr-90 contamination suspected (F,S)
TA-35, LAMPRE	1955	1967	MFP, Sr-90, Co-60, VFP, MAP, Np-237, Pu	Molten Pu fuel
TA-35, LAPRE I, LAPRE II test reactors	1955	1960	MFP, Sr-90, Co-60, VFP, MAP	Highly enriched U fuel
TA-35, Laser Fusion Research	1974	NCD	unknown	
TA-35, Target Fabrication Facility (TFF), TSL-213	NCD	NCD	H-3	Labeled DNA precursors(OBT), water (HTO),

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
				HT
TA-36, Kappa Site: Replaced TA-9, TA-23, and TA-12 in 1950; five active firing sites (Eenie, Meenie, Minie, Lower Slobovia, and IJ, and a storage magazine at Moe; non-nuclear ordnance and armor. In 1983, boundary of TA-36 changed to incorporate I-J Site (formerly part of TA-15) which was used for firing non-nuclear explosive shots up to 500 lb. TA-36 also includes former TA-27 and part of TA-54 (located north of TA-18). Lower Slobovia also contains a firing site debris pit.	1950	Still active	DU	
TA-37, Magazine Area C: Explosives storage area.	NCD	Still active	DU	
TA-38, Monterey Site (canceled)	NCD	NCD	None	
TA-39, Anchor Canyon Site: Operated by the Shockwave Physics Group; consists of five firing points, several gun sites, a waste disposal pit, Material Disposal Area Y; incinerator 1955-60; photographic study of the behavior of non-nuclear weapons. In the later 1980s, U-235 was detected in soil samples taken from the TA-39 landfill used to dispose of firing site debris.	NCD	NCD	NU, DU, thorium, EU, Pu	Firing points
TA-40, Detonator Firing (DF) Site: Built in 1950 to replace the detonator firing chambers at TA-6. Contains six firing points used since 1950 for explosives testing related to research and development of detonators and other small explosives assemblies. TA-40 includes an inert assembly building, six firing chambers, five shot preparations buildings, eight magazines. In the 1980s, one firing chamber was upgraded to house a two-stage gas gun. First contained test-firing site completed in 1992. Scrap Detonation Site (SDS) consists of detonation area, a burn pit, and three small burn areas operated as RCRA interim status hazardous waste thermal treatment unit for open burning and open detonation of explosive scrap until 1985.	1950	1985	H-3, U	
TA-41, W (Weapons Group WX) Site: Engineering of nuclear components; fabrication of test materials.	NCD	NCD	H-3, Pu, U, Am-241	Engineering of nuclear components Fabrication of test materials
TA-41-4, Ice House	NCD	NCD	H-3	HTO, HT
TA-42, Incinerator Site: Reduced low-level Pu-contaminated waste; abandoned in 1970; decommissioning began 1978.	NCD	1978	All	Reduced low-level Pu-contaminated waste

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-43, Health Research Laboratory (HRL): Biological research 1953-70; replaced TA-32.	1953	1970	I-125 H-3 C-14 P-32 All others possible	Iodide, labeled organics Labeled DNA precursors(OBT), water (HTO), HT Labeled DNA precursors Labeled organics, phosphates
TA-45, Radioactive Liquid Waste Treatment Plant, WD Site; removed majority of plutonium before discharge to Acid Canyon.	1951 1960	1964- operations ended 1966– decomm.	All MFP, Pu-238, Pu-239, EU, U-238	Removed Pu before discharging effluents
TA-46, WA Site: Rover batteries.	1950	1974	EU, U-238, Th	
TA-46, WA Site: U isotope separation; photochemistry research; lasers.	1976	1980s	EU, U-238, Th	
TA-48, Radiochemistry Site: Actinide chemistry and hot cell isotope production. The radiochemistry building, built to house radiochemistry and nuclear medicine research, was constructed in 1957 when stack emissions are believed to have begun. Initial activities involved study of nuclear bomb test samples and evolved to include other weapons testing studies, radioactive materials waste disposal studies, basic radiochemistry research, and production of radioisotopes for nuclear medicine.	1950s	Still active	All , MAP, MFP, U, TRU	
TA-48, Nuclear Chemistry	1950s	Still active	Se-75 H-3 Cd-109 I-131	Spallation product, seen in hot chemistry on targets HTO, HT CL/NO_3 mixture loaded in $SnPO_4$ resin. Cd phosphate is most probable material of intake, very soluble, 1μ AMAD Fission product chemistry

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-49, Frijoles Mesa Site: Underground hydro-nuclear experiments 1960-61. A small radiochemistry facility was built at the site to support the experiments. Most above-ground structures have been removed and the surface has been decommissioned and decontaminated. The site is now used for Hazardous Devices Team Training.	1960	1961	H-3, Pu, U, EU, Pu-238, Pu-239, Pu-240, Am-241, Cs-137	
TA-50, Waste Management Site: Treated liquid wastes before discharge to Mortandad Canyon; replaced TA-45, -35; controlled air incinerator 1976.	1963	NCD	Pu-238, Pu-239, Pu-240 All, including U, EU, Pu-238, Pu-239, Pu-240, Sr-90, Sr-88, Am-241, Cs-137, Mn-54, Co-56, Co-58, Co-60, Zn-65, Se-75, Y-88, La-140, Rb-83, Ba-133	0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common.
TA-51, Environmental Research Facility: Animal exposure facility 1962; now studies of impact of waste and waste storage on the environment.	1962	Still active	Co-60, Sr-90	Animal exposure facility Presently environmental impact research.
TA-52, Reactor Development Site: Ultra-High Temperature Reactor Experiment (UHTREX)	Late 1960s	1970	U-238, Pu-238, H-3, VFP, Kr, Xe, EU	High-temperature, gas-cooled, graphite reactor, UHTREX (Ultra-high Temperature Reactor Experiment)
TA-53, Los Alamos Neutron Science Center (LANSCE): Largest accelerator facility, LAMPF. In the late 1980s, a number of radionuclides were found in the sludge in the TA-53 Wastewater Treatment Lagoon that received discharges from the machine shop at TA-5.	1972	NCD	O-15, Ar-41 C-11 N-13 I-131 Induced activity in U targets, corrosion products H-3 Be-7	Short-lived air activation Short-lived air activation. By-product at LANSCE, seen in workers during beam cycle Short-lived air activation. 511 keV during beam cycle Medical isotope production 2A metal, metalloid behavior, very reactive, occurs in virtually massless quantities, typically seen when target cells are opened for maintenance, usually in oxide form

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-53, Currently active solid waste disposal area; Materials Disposal Areas G, H (inactive), J, and L. MDA G is the LLW disposal area for the Laboratory and has been in use since 1957. It has also been used to store low-level TRU mixed waste, as well as liquid hazardous and mixed wastes. Three fires occurred at MDA G between 1960 and 1976. On 09/16/60, most of the exposed waste in Pit 1 burned before the fire was discovered. A fire in Pit 3 on 11/21/64 burned boxes and resulted in detectable alpha activity in the smoke. On 04/14/76, a fire in Pit 24 burned for several seconds with no detectable contamination. MDA H was used from 1960 until 1986 to dispose of classified waste, including but not limited to: weapon components, DU scraps, graphite nuclear reactor fuel elements, radioactive sources, detonators, solid radioactive waste tritium, and plutonium-contaminated shapes and records. Eight of the nine shafts at MDA H are sealed and one shaft received waste as late as 1986. The original closing plan for Shaft Nine was submitted in November 1986. Tritium migrated from the shafts at MDA H in the 1960s and early 1970s. Air samples collected from shafts at MDA H had elevated tritium activity of "1.6 to 4.4 million times the DOE derived concentration guide of 1.0×10^{3}". Subsequent investigations show that tritium has been released from MDA H shafts to the surrounding turf where it may be released by evaporation or transpiration from plants. MDA J began receiving administratively-controlled waste in 1961. Other residual amounts of non-nuclear hazardous waste were also received in the early years. The non-destructive testing (NDT) program, which supports verification and certification of TRU wastes, is conducted at MDA L.	1957	Still active	All, including TRU, H-3, DU Pu-238, Pu-239, Pu-240,	 0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common.
TA-55, Plutonium Facility (PF-4): Established in 1973 for operation of the Plutonium Processing Facility. Operations include fabrication of plutonium metal components, plutonium processing, and basic research of TRU materials. Replaced TA-21; SNM storage 1978 to present.	1973	Still active	H-3 Pu-238, Pu-239, Pu-240	Labeled DNA precursors(OBT), water (HTO), HT 0.1-10μ AMAD, oxide, nitrate, fluoride and metal. Oxide is most common.
TA-56, Subterranean Basalt Site: Melting basalt with electrically-heated penetrator; abandoned in 1976.	NCD	1976	Unknown	
TA-57, Fenton Hill Site: Hot Dry Rock geothermal project.	1978	Inactive	Unknown	
TA-58, Two-Mile Mesa North Site: Undeveloped and reserved for multi-use experimental sciences for TA-3 programs.	NCD	1989	Unknown	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-59, Occupational Health Site: Office of Environment, Safety, and Health offices, emergency management. Over the years, groups at TA-59 included industrial hygiene, environmental surveillance, epidemiology, health, environmental chemistry, and meteorology. A septic system, container storage area, and sump were investigated for radionuclides and chemicals and recommended for NFA.	NCD	NCD	All sources	
TA-60, Sigma Mesa: Test Fabrication Facility and Rack Assembly; Alignment Complex.	NCD	NCD	Unknown	
TA-61, East Jemez Road: Physical support and sanitary landfill.	NCD	NCD	Unknown	
TA-62, Northwest Site: Reserved for experiments, research, buffer zones. Used for detonator development activities for most of the history of the Laboratory.	NCD	NCD	Unknown	
TA-63, Pajarito Service Area: Environmental and waste management functions.	NCD	NCD	Unknown	
TA-64, Central Guard Facility, Hazardous Materials Response Team.	NCD	NCD	None	
TA-65, This undeveloped TA was incorporated into TA-51 and no longer exists.	Undeveloped	NA	None	
TA-66, Central Technical Support Site: Industrial partnership activities.	NCD	NCD	U-238 identified in 1977 stack emissions.	
TA-67, Pajarito Mesa: A buffer zone, designated as a technical area in 1989. Includes the location of the former TA-12 (also known as L Site), which was used from the 1940s to the mid-1950s as a firing site and dynamic testing area; area contains significant archeological sites.	1989	Active buffer zone	DU	
TA-68, Water Canyon Site: Dynamic testing area with study areas.	NCD	NCD	DU	
TA-69, Anchor North Site: Created in 1989. Incorporates a number of small structures (i.e., guard station, trailers for office space, incinerator building). Before 1989, structures designated with either TA-0 or TA-6 numbers. Incinerator (TA-69-3) built in 1959 and used until late 1970s to destroy classified documents. Currently environmental buffer for the dynamic testing area.	1989	Active buffer zone	Unknown	

Table 5-1: LANL Technical Areas, Operational Dates, and Radionuclides				
Location	**Start**	**Demolished or Decomm.**	**Radionuclides**	**Comment**
TA-70, Rio Grande Site: Undeveloped; buffer for the high-explosives test area. Never used for any Laboratory operations	1989	Active buffer zone	Unknown	
TA-71, Southeast Site: Undeveloped; buffer for the high-explosives test area. TA-71 has never been used by the Laboratory to conduct any experiment.	NCD	Active buffer zone	Unknown	
TA-72, East Entry Site: Protective Forces Training Facility. Former site of TA-20	NCD	NCD	Unknown	
TA-73, Los Alamos Airport: On-site disposal area; incinerator 1950s.	NCD	NCD	All	
TA-74, Otowi Tract: Large undeveloped area. Contains Laboratory water wells and future well fields, significant number of archeological sites and an endangered species breeding area.	NCD	NCD	None	
Pacific Proving Grounds, Nuclear tests: Marshall Islands (1945-51).	1945	1951	All	
AK, Nuclear tests: Amchitka (Long Shot, Milrow, Cannikin) 1965, 1969, 1971.	1965	1971	All	
NV, Nuclear tests, non-NTS: Fallon (Shoal); Tonopah (Faultless) 1968.	NCD	NCD	All	
CO, Nuclear tests: Grand Valley (Rulison) 1970; Rifle (Rio Blanco) 1973.	1970	1973	All, esp. H-3, Kr-85	
NM, Nuclear tests: White Sands (Trinity) 1945; Carlsbad (Gnome) 1961; Farmington (Gasbuggy) 1967.	1945	1967	All, esp. I-131, I-133, I-135, Cs-137, Ba-140, La-140, heavy elements	
MS, Nuclear tests: Hattiesburg (Salmon and Sterling).	NCD	NCD	Unknown	

5.3 Radiological Exposure Sources from LANL Operations

This section discusses the sources of potential radiological exposure present at LANL during the period under evaluation. These sources include alpha and beta emissions, neutrons, and photons, as well as a variety of incidents and accidents.

5.3.1 Alpha Particle Emissions

Many of the primary radioactive source materials handled at LANL were alpha particle emitters. Although alpha particles do not present an external exposure hazard, prevention of internal exposures to alpha emitters was recognized from the onset of site operations as the most significant radiological hazard protection challenge. The primary alpha-emitting radionuclides of concern were: weapons-grade plutonium (i.e., Pu-239, Pu-240); Po-210; and uranium in varying isotopic abundances of U-234, U-235, and U-238. Lesser quantities of Pu-238, Am-241, Th-232 (plus decay progeny), Ra-226 (plus decay progeny), U-233, and Cm-244 were used in various projects or as sources. Table 5-2 provides a summary of the characteristic alpha emission energy for each of these radionuclides.

Table 5-2: Alpha Particle Energies For LANL Alpha-Emitting Radionuclides

Radionuclide	Alpha Energy (MeV)
Pu-239	5.16, 5.11
Pu-240	5.17, 5.12
Po-210	5.31
U-234	4.72, 4.77
U-235	4.37, 4.40, 4.58
U-238	4.15, 4.20
Pu-238	5.50, 5.46
Am-241	5.49, 5.44
Th-232/(progeny)	3.95, 4.01/(5.34 to 8.78)
Ra-226/(progeny)	4.60, 4.78/(3.72 to 7.69)
U-233	4.82, 4.78
Cm-244	5.90
Th-230	4.68, 4.62
Pa-231	4.95, 5.01, 5.02

5.3.2 Beta Particle Emissions

The diverse activities conducted within LANL facilities during the period under evaluation involved an extensive beta particle-emitting source term. Historically, beta radiation over a broad range of energies would have been encountered from: certain plutonium isotopes; uranium progeny; thorium progeny; tritium; radioactive lanthanum (residual Sr-90 after 1963 is the only RaLa program-related contaminant addressed in this evaluation); activation and fission products from reactor and accelerator operations; and other radionuclides used in biomedical research or as calibration sources. Whether a beta source is considered an internal hazard or both an internal and external hazard depends on the maximum energy of the beta emission continuum for a given radionuclide, the shielding employed, and the use of protective clothing. In many cases, beta-emitting radionuclides also emit characteristic photons, as discussed in Section 5.3.4.

The emissions from low-energy beta emitters such as tritium (0.0186 MeV β_{max}) do not penetrate the outer dead skin layer and are, therefore, not considered as external hazards; however, they may present an internal hazard. Higher-energy beta emitters present both an external hazard (to the skin) and an internal hazard. Table 5-3 is not an all-inclusive list, but it provides a summary of the more prevalent beta-emitting radionuclides over a range of energies and segregated by process.

Table 5-3: Beta Particle Energies For LANL Beta-Emitting Radionuclides

Radionuclide	Beta Maximum Energy (MeV)
Weapons-related radionuclides:	
H-3	0.019
Pu-241	0.021
U-238 Progeny (Th-234, Pa-234^{m})	0.193, 2.29
U-235 Progeny (Th-231)	0.305
Ac-227	0.046
Sr-90/Y-90	2.27
Reactor/Accelerator-related (Mixed Fission and Activation Products) radionuclides:	
Cs-137	0.514
Co-60	0.314
I-131	0.606
Chemistry/metallurgy/miscellaneous radionuclides:	
Th-232/progeny	0.055 to 2.26
Ra-226/progeny	0.016 to 3.26
S-35	0.167
C-14	0.156
P-32	1.710

5.3.3 Neutron Exposures

There were numerous potential neutron exposure sources associated with essentially all of the predominant LANL operations. Neutron exposures could have resulted from plutonium chemical and metallurgical operations, neutron-generating sources, criticality experiments, and operating reactors and accelerators. The source of the neutron emissions from these activities and potential worker exposure would have been associated with the following:

- Spontaneous fission of Pu-240 (as an impurity in the weapons-grade plutonium).
- Alpha-neutron (α,n) reactions with low-atomic-number elements associated with plutonium chemical processing (PuF_4 and PuO_2) and, to a lesser extent, plutonium in metallic form.
- Fission neutrons from operating reactors and from criticality assembly experiments using plutonium or enriched-uranium spheres.
- Accelerator-produced neutrons.
- Neutron-generating sources either via the α,n reaction (PuBe, RaBe, PoBe) or via spontaneous fission sources (Cf-252).

The broad scope of the LANL neutron-generating activities resulted in a correspondingly extensive neutron energy spectrum. The spectrum ranged from the thermal energy region of 0.025 eV through the fission spectrum of 0.1 to 6.0 MeV (predominant energy of 0.7 to 1.0 MeV), and included high-energy, accelerator-produced neutrons up to 20 MeV. Table 5-4 provides the default neutron energy spectrum associated with the multiple LANL operations.

Table 5-4: Default Neutron Dose Fractions for LANL Materials

Operation	Neutron Dose Fraction Percentages by Neutron Energy		
	<10 to 100 keV	0.1 to 2 MeV	2 to 20 MeV
Plutonium Production	11%	56%	33%
Operating Reactors	0%	100%	0%
Accelerators	60%	20%	20%
Criticality Experiments	3.2 %	59%	38%
Chemistry and Metallurgy	10%	50%	40%
Neutron Sources	0%	100%*	0%

* Note: This dose fraction is not included in ORAUT-TKBS-0010-6; it is the author's interpretation of neutron energy distribution from the spontaneous fission of Cf-252.

5.3.4 Photon Exposures

As with neutron exposures, many LANL radiological operations, including waste handling, also involved gamma and X-ray photon radiation fields. Potential photon exposure sources to workers would have been associated with the following:

- Gamma-emitting fission and activation products resulting from reactor operations or accelerator-produced air or target activation products.
- Uranium compounds and associated decay progeny.
- Bremsstrahlung radiation.
- X-ray-generating machines.
- Aged weapons-grade plutonium work.
- Work with, or calibration sources of, americium, thorium, radium, cobalt, and other miscellaneous radionuclides.

Table 5-5 summarizes default photon energies for LANL materials.

Table 5-5: Default Photon Energies for LANL Operations

Operation	Gamma Energy Distribution Percentage		
	< 30 keV	30 to 250 keV	> 250 keV
Plutonium Processing and Production	65%	35%	0%
Uranium Production	0%	100%	0%
Reactors	0%	25%	75%
Accelerators	0%	5%	95%
X-Ray Generating/Radiography	0%	50%*	50%*
Waste Handling	0%	50%	50%
Calibration Sources	0%	25%	75%

* Note: This energy distribution is not included in ORAUT-TKBS-0010-6; it is the author's interpretation of photon energy distribution from Co-60, Cs-137, Ir-192 radiography sources, and portable 150 and 220 keV portable X-ray machines located in TA-16.

5.3.5 Incidents and Accidents

Numerous documented major incidents and accidents occurred at LANL during the evaluated time period. The major recorded incidents and accidents are summarized in the *Technical Basis Document for Los Alamos National Laboratory – Site Description* (ORAUT-TKBS-0010-2). Of the 54 accidents/incidents described, 40 occurred between 1943 and 1975. Four of these were non-radiological accidents involving explosives or fires. The remaining radiological incidents/accidents included 14 unplanned criticalities; three resulted in fatalities and overexposures, three resulted in overexposures, and eight did not involve known personnel exposures. The following is a brief chronological description of documented LANL criticalities (LANL, 2000).

1. February 11, 1945: *Dragon assembly; UH-3 pressed in styrex; single excursion; insignificant exposures.* The Dragon assembly was the first fissile system designed to generate prompt power excursions and was probably the first reactor of any kind whose reactivity exceeded prompt criticality. The Dragon was made of enriched UH-3. During the final excursion of about 6E15 fissions, the UH-3 cubes became so hot that blistering and swelling occurred. The whole system expanded about 1/8-inch. In the final excursion, the core material was damaged, but no active material was lost; there was no contamination and no one received any radiation.

2. June 6, 1945: *Pseudosphere of uranium cubes; water-reflected; single excursion; three significant exposures.* This experiment, designed before the days of remote control, was intended to establish the critical mass of enriched uranium metal surrounded by hydrogenous material. The uranium mass of 35.4 kg (average enrichment 79.2%) was stacked in the form of a pseudosphere constructed of ½-inch cubes and ½-inch x ½-inch x 1-inch blocks. The whole assembly was placed in a large tank that was then partially filled with water. Unexpectedly, the assembly became critical before water had completely covered the polyethylene box. The situation was aggravated because no scram device was built into the system and the inlet and drain valves were 15 feet apart. Before the system was reduced to a safely-subcritical state five or ten seconds later, a total of 3 to 4E16 fissions occurred. In this excursion, three people received radiation doses in the amounts of 66, 66, and 7.4 rep.

3. August 21, 1945: *Plutonium core reflected with tungsten carbide; single excursion; one fatality, one significant exposure*. A critical assembly was being created by hand-stacking 4.4 kilogram (kg) of tungsten carbide bricks around the plutonium core. The lone experimenter was moving the final brick over the assembly for a total reflector of 236 kg when he noticed from the nearby neutron counters that the addition of this brick would make the assembly supercritical. As he withdrew his hand, the brick slipped and fell onto the center of the assembly, adding sufficient reflection to make the system superprompt critical. A power excursion occurred. He quickly pushed off the final brick and proceeded to unstack the assembly. His dose was estimated as 510 rem from a yield of 1E16 fissions. He died 28 days later. An Army guard assigned to the building, but not helping with the experiment, received a radiation dose of approximately 50 rem.

4. May 21, 1946: *Plutonium core reflected with beryllium; one fatality, seven significant exposures*. The techniques involved in creating a metal critical assembly were being demonstrated to several people. The system consisted of the same plutonium sphere discussed in Item 3 above, reflected in this case by beryllium. The top and final hemispherical beryllium shell was being slowly lowered into place; one edge was touching the lower beryllium hemisphere while the edge 180° away was resting on the tip of a screwdriver. The person conducting the demonstration was holding the top shell with his left thumb placed in an opening at the polar point. The yield of this excursion was 3E15 fissions. The eight people in the room received doses of about 2100, 360, 250, 160, 110, 65, 47, and 37 rem. The man who performed the experiment died nine days later.

5. December 1949: *Water boiler reactor; control rods removed by hand; single excursion; insignificant exposure.* This accident occurred when two new control rods (poisons) were being tested in the water boiler reactor. The water boiler was a 12-inch diameter stainless steel sphere containing 13.6 liters of uranyl nitrate reflected by thick graphite. The rods had been installed and the operator was manually checking their drop times. After several tests of each individual rod (a safe procedure since one rod was sufficient to maintain subcriticality), both rods were pulled, held for about five seconds, and then dropped simultaneously. A short time later, the rods were again pulled and dropped together. The removal of the two rods increased the reactivity over prompt criticality, corresponding to a period of 0.16 seconds. The power probably rose within this period to a very broad peak of 2 or 3E16 fissions/sec and remained close to this value for about 1.5 seconds. The excursion was not immediately detected because all the instruments were turned off except for a direct reading thermometer that showed a temperature rise of 25C, equivalent to a yield of 3 or 4E16 fissions. The operator received a 2.5 rad dose.

6 & 7. February 1, 1951: *Critical separation experiment; two large 235-U metal masses in water; multiple excursions; insignificant exposures.* A water-reflected system was set up in 1949 to obtain the neutron multiplication of a single unit of fissile metal in water. The system had two scram devices. The excursion was precipitated by an experiment that measured the critical separation distance of two enriched uranium masses (each of 93.5% U-235) in water: one a solid cylinder of 24.4 kg, and the other a hollow cylinder of 38.5 kg. At the completion of the critical separation experiment (at a multiplication of 65.5), the assembly was scrammed. The water started draining, the cadmium screen dropped, the solid cylinder was lifting, and an excursion (later determined to be 1E17 fissions) was made evident by the jamming of neutron counters and the appearance on television of a vapor cloud above the water. Later reconstruction of the accident showed that the pneumatic tangential scram was the first to be effective and led directly to two types of difficulty. First, the center of reactivity of the left-hand cylinder proved to be below that of the stationary cylinder; second, the rapid lift through the water created hydrodynamic forces that swung the cylinders closer together. The combination of the two effects was enough to drive the assembly prompt critical and to have maintained at least this much reactivity for 0.2 seconds if the power excursion had not occurred. The first power spike is estimated to have contained 6E15 fissions. It is possible that one or more excursions into the prompt region followed because boiling was the primary quenching mechanism. In the excursion of 1E17 fissions, no radiation doses were received, and no contamination was found in the experimental area.

8. April 18, 1952: *Jemima, cylindrical, unreflected 235-U metal assembly; excursion history unknown; insignificant exposures*. The system in which the excursion took place was an acylindrical, unreflected, enriched 93% U-235 metal assembly made up of a number of plates, each 267 mm in diameter and 8 mm thick. Complete assembly of the two components had been made previously with six plates in the lower component, but with at first three, and then four, plates in the upper component. A plot of the reciprocal multiplication versus number of plates, or total uranium, shows clearly that the system should not have been assembled with 11 plates. Nevertheless, such an assembly was attempted following a computational error made independently by two people. Contrary to operating regulations, a graph of the data had not been plotted. The burst yield was 1.5E16 fissions. The power dropped essentially to zero when the automatic scram system separated the two masses of metal. During the remotely-controlled operation, no damage was done to the system, even to the fissile material. None of the personnel received any radiation and the experimental area was not contaminated.

9. February 3, 1954: *Lady Godiva reactor; bare 235-U sphere; control rod incorrectly operated; single excursion; insignificant exposure.* The Lady Godiva assembly was an unreflected metal reactor fabricated in three principal sections that when assembled formed a sphere. The critical mass was about 54 kg of uranium enriched to 93.7% U-235. It was operated remotely from a distance of 1/4 mile. The first accidental excursion occurred during preparations for a scheduled prompt burst, part of a program to measure the parameters associated with excursions. This accidental excursion was apparently caused because additional reactivity was inserted by error. The excursion yield was 5.6E16 fissions, about six times the yield of the average burst. There was no radiation hazard, contamination, personnel exposure to radiation, or significant damage to the major uranium parts. One piece was slightly warped and required re-machining.

10. February 12, 1957: *Lady Godiva reactor; bare 235-U sphere; added reflection; single excursion; insignificant exposures.* This accidental excursion occurred during preparations for an experiment in which the Lady Godiva reactor (see Item 8 above) was to provide a pulse of fast neutrons. As in 1954, the burst occurred during assembly. The extra reactivity is thought to have been contributed by a large mass of graphite and polyethylene that was to be irradiated. This mass had just been moved close to Godiva, and either the change in reflection was underestimated or the material slumped further toward Godiva. The burst yield was 1.2E17 fissions, about 12 times the standard excursion. The uranium metal was severely oxidized, warped, and apparently had been plastic near the center. The central burst rod was nearly ruptured and, at its center, must have been within 100º C of the uranium melting temperature. External damage was limited to the supporting structure; radioactive contamination consisted of oxide scale; clean-up proceeded rapidly. Repair of Lady Godiva was not practical; therefore, construction of Godiva II (specifically designed for burst operation) was accelerated. Despite the severity of the excursion, operating personnel received no significant radiation exposures because of the large distance between the reactor and the control room.

11. July 3, 1956: *Honeycomb critical assembly; U(93) metal foils moderated with graphite; single excursion; insignificant exposures.* The machine in which this excursion occurred consisted of a large matrix of 576 square aluminum tubes split down the middle with one-half of the matrix moveable on tracks. Generally, the facility had been used to simulate design features of complicated reactors because of the versatility in arrangements of uranium foil and various moderating materials. The stacking consisted of 58 kg of enriched (93% U-235) uranium in the form of 2- and 5-mil foils arranged between slabs of graphite with some beryllium reflector surrounding the core. The total mass of graphite was 1,139 kg. At the time, some changes had been made in the reflector and graphite moderator, and criticality was being approached too rapidly for routine measurements. While the cart was moving at about 0.2 inch per second, the system became prompt critical, a burst occurred, and the scram system retracted beryllium control rods (reducing reactivity) and reversed the motion of the cart. The burst yield was 3.2E16 fissions. There was no damage and no contamination. Because it was remotely controlled from a distance of 1/4 mile, no one received any radiation.

12. December 30, 1958: *Plutonium organic solution in an organic treatment tank; single excursion; one fatality, two significant exposures.* The operations performed at the facility where the accident occurred were those chemical steps used to purify and concentrate plutonium from slag, crucible, and other lean residues that resulted from recovery processes. Typical and expected solutions contained less than 0.1 g Pu/ l and traces of americium. An annual physical inventory was in progress at the time of the accident; thus, the normal flow of process streams into the area was interrupted so that residual materials in all process vessels could be evaluated for plutonium content. A reconstruction of significant events indicates that unexpected plutonium-rich solids, which should have been handled separately, were washed from two vessels into a single large vessel that contained dilute aqueous and organic solutions. After most of the aqueous solution had been removed from this vessel, the approximately 200 liters of material remaining, including nitric acid wash, was transferred to the stainless steel tank in which the accident occurred. The tank contained about 295 liters of a caustic stabilized aqueous organic emulsion, and the added acid is believed to have separated the liquid phases. The aqueous layer (330 liters) is estimated to have contained 60 g of plutonium; the organic layer (160 liters) contained 3.1 kg of plutonium. When the stirrer was started, the initial action forced solution up the tank wall, displacing the outer portion of the upper layer and thickening the central region. The motion changed the system reactivity to superprompt critical, and an excursion occurred. The excursion yield was 1.5E17 fissions. The accident resulted in the death, 36 hours later, of the operator who was looking into a sight glass when the motor was turned on. The dose to his upper torso was estimated to have been 12,000 rem. Two other persons apparently suffered no ill effects after receiving radiation doses of 134 and 53 rem. No equipment was contaminated or damaged even though the shock associated with off-axis bubble generation displaced the tank about 10 mm at its supports.

13. June 17, 1960: *235-U metal, graphite-reflected, assembly; single excursion; insignificant exposures.* The critical parameters of highly-enriched (93% U-235) uranium metal cylinders in thick graphite (about 9 inches) and near-infinite water reflectors were being investigated. In the experiment of interest, an approximately 48 kg uranium annulus was built up on a cylinder of graphite that, in turn, rested on a hydraulic lift device. This annulus was raised by remote control into a reflector of graphite resting on a stationary steel platform. The system became critical before complete assembly and was scrammed both manually and automatically at about one inch from closure. Following the scram signal, the lift dropped rapidly and the system became subcritical, but about one–third of the metal mass stuck in the graphite reflector for a few seconds before falling to the floor. The yield was 6E16 fissions. There was no contamination or damage to the fissile metal and personnel radiation doses were immeasurably small.

14. December 11, 1962: *Zepo critical assembly; 235-U foils, graphite moderated; single excursion; insignificant exposures.* The critical assembly consisted of a large cylindrical enriched uranium–graphite core on a lift device and a stationary platform holding a reflector of graphite and beryllium into which the core was raised. Most of the U-235 was placed in the graphite in the form of thin foils; therefore, the excursion characteristics should be similar to those of the honeycomb assembly. The experiment was concerned with measurements of the axial fission distribution, which was perturbed from its normal value by an end reflector of layers of graphite and polyethylene. For this reason, some fresh U-235 foils had been placed in the assembly to obtain a reasonably precise value of the fission energy release. The crew assumed the assembly had been run and checked the previous day; however, this was not the case. The system became critical with the core in motion upward. The instrumentation scrammed the assembly when the power was about 200 watts. Before the lift could coast to a stop and start down, the system reactivity exceeded prompt criticality and the yield was 3E16 fissions. No damage was done and personnel radiation doses were not measurable. The laboratory was entered within 30 minutes.

The remaining accidents/incidents involved contamination incidents, personnel internal or external overexposures from radioactive materials or radiation-generating devices, or inadvertent releases of effluents with elevated radioactive material concentrations. These events are described in multiple historical monthly and annual Health Division reports. In addition, these various group reports contain much anecdotal evidence of other small-scale contaminations, radioactive material release events, and external/internal exposures occurring that may or may not have been formally recorded because the associated levels were less than the limits in effect at the time. The various operational reports reviewed described other personnel exposures that did not exceed the protective guides applicable at the time and were, therefore, discussed accordingly.

6.0 Summary of Available Monitoring Data for the Proposed Class

The primary sources of information for this evaluation are the LANL Occupational Internal Dose and Occupational External Dose TBDs (ORAUT-TKBS-0010-5 and ORAUT-TKBS-0010-6). These documents contain: (1) information for dose reconstruction; (2) monitoring data that pertain directly to the class under evaluation; (3) the identities and maximum quantities of radionuclides of concern; (4) descriptions of the processes through which the radiation exposures of concern may have occurred and the physical environment in which they may have occurred; and (5) discussions regarding data availability and limitations. Thus, much of the discussion that follows represents summaries of information in the TBDs.

Monitoring data are available from the onset of LANL operations in 1943. Initially, the "Health Group" was responsible for establishing health standards; specifically, for safe levels of exposure to radiation and to radioactive chemical materials. The Health Group's primary concern was to protect the health of laboratory employees. Until mid-1951, for want of adequate staff, the Group accepted help for monitoring radiation-related activities from the Chemistry and Metallurgy Research (CMR) staff. Over the years, the Health Group evolved into the Health Division (and its successors, Environmental, Safety, and Health [ESH] and Health, Safety, and Environment [HSE] Divisions), with multiple subgroups that addressed health physics, medical, (industrial) safety, biomedical research, industrial hygiene, industrial waste treatment, and environmental studies. While several division and group name changes have occurred since 1943, the generic Health Physics Group has existed since 1951.

The following subsections summarize the numbers and types of monitoring records available that are applicable to reconstruction of LANL employee internal and external doses. In addition, general monitoring program goals, monitoring frequencies, and programmatic changes are summarized. Details regarding the specific analyses used, associated MDAs, biases, and uncertainties are not presented in this report but can be found in the internal and external TBDs.

6.1 LANL Internal Monitoring Data

The following LANL monitoring produced data that are available and applicable to internal dose reconstruction for the class period under evaluation:

- Air Sampling Data: Intermittent data for some radionuclides, or as gross activity, available for selected buildings from 1945 through 1971. (Section 6.1.1)

- *In Vitro* Bioassay Data: Primarily urine samples for select radionuclides, primarily plutonium, polonium, uranium and tritium; however, isolated bone, lymph node, blood, and organ autopsy samples were also taken. Earliest data available are for urine samples collected in 1944. (Section 6.1.2)

- *In Vivo* Analysis Data: Primarily whole-body and chest counts, and to a lesser extent, chest, thyroid, liver, and wound counts. Earliest data available are from whole-body counts performed in 1963. (Section 6.1.3)

6.1.1 Air Sampling Data

Maximum and average airborne contamination levels in buildings with high exposure potential are listed in Table 6-1. Airborne concentrations are not available for all years of operation and are deficient for fission products and some of the exotic radionuclides. The predominant data identified was provided as gross alpha activity, gross beta activity, plutonium, or uranium. Many of the original count room records did not specify the type of analysis performed or provide the year of the analysis on the laboratory form. Blanks in Table 6-1 indicate that no information was available for that period (ORAUT-TKBS-0010-5). Average concentrations are calculated from general air samples as simple averages or averages obtained directly from LASL reports. Recently, limited air sampling data for fission products and other less-prevalent radionuclides such as curium, thorium, and actinium have been located. However, these data are intermittent and not inclusive of all areas. Furthermore, the data have not been validated or incorporated into databases and will require significant additional evaluation and validation before their usefulness for dose reconstruction can be determined.

Table 6-1: Summary of Airborne Concentrations from Selected LANL Buildings

Building	Nuclide[a,b]	Year[k]	Maximum airborne concentration[c] (dpm/m^3)	Average airborne concentration[c] (dpm/m^3)
D	Alpha	1945	674.0	
D	Alpha U	1945	2,564.400	
H	Alpha Po	1945	48.00	
DP East	Alpha (EU)	1945	2,458.0	68.2
DP West	Alpha	1945	254.0	
D	Alpha (Pu)	1945	480.0	151.0
D	Alpha (Pu)	1946	2,590.0	46.86
DP East	Alpha (EU)	1946	147,400.0 (Po)	271.27
TU Building	Alpha	1946	1,958.400	43.400
DP West	Alpha	1946	2,400.0	
TU Building	Alpha	1947	515.000	
H	Alpha Po	1947		8.80
Sigma	Total alpha U	1947	187.20	
D	U	1947	55.00	
D	Pu	1947	134.00	
D	Cold lab alpha	1947	15.0	
Sigma	U	1948	1,393.80	124.60
U	Pu	1948	379.40	66.67
H	Po	1948	52.80	4.50
D	U	1948	2,564.40	21.23
D	Pu	1948	860.80	11.53
D	Cold lab alpha	1948	882.4	5.675
Am Lab	Am alpha	1948	6.2	1.6
Sigma	Total alpha U	1948	1,393.80	124.60
DP West	Alpha	1949	1,694.0	
Am Lab	Am alpha	1949	18.0	
Press Rm	Alpha	1949		198.0
TU Bldg Furnace	Alpha	1949		4,095.0
Waste Treatment	Alpha	1949	13.8	

Table 6-1: Summary of Airborne Concentrations from Selected LANL Buildings				
Building	**Nuclide[a,b]**	**Year[k]**	**Maximum airborne concentration[c] (dpm/m^3)**	**Average airborne concentration[c] (dpm/m^3)**
Lab				
M	Alpha	1949	580.8	84.0
DP East	Polonium	1949	2,344.0	
U	Alpha	1949	37.2	
D	Pu	1952		2.4
CMR	Pu	1952		1.9
M	U	1952		4.6
D	Pu	1953	600.4	3.2
CMR	Pu	1953	388.7	1.0
U	Pu	1953	4.5	1.4
M	U	1953	210.6	2.4
D[d]	U	1953	1,969.3	4.3
CMR	U	1953	21.1	1.2
CMR	Pu	1954	2,851.3	1.3
CMR	Pu	1955	527.2	0.7
CMR	Pu	1956	162.7	0.7
CMR	Pu	1957	351.0	0.8
CMR	Pu	1958	1,370.2	1.0
CMR	Pu	1959	6,712.9	1.0
CMR	Pu	1960	518.1	0.9
CMR	Pu	1961	426.0	1.0
CMR	Pu	1962	4,680.0	1.0
CMR	Pu	1963	166.0	1.0
CMR	Pu	1963	4.0	0.0
CMR	Pu	1967	285.0	1.0
CMR	Pu	1968	5,370.0	1.0
CMR	Pu	1968	11.0	0.0
CMR	Pu	1969	685.0	1.0
CMR	Pu	1969	11.0	0.3
CMR	U	1954	77.4	0.8
CMR	U	1955	112.1	0.7
CMR	U	1956	67.8	1.0
CMR	U	1957	2,231.1	1.4
CMR	U	1958	51.3	1.3
CMR	U	1959	24.0	1.2
CMR	U	1960	94.1	1.2
CMR	U	1961	35.0	1.0
CMR	U	1962	43.0	1.0
CMR	U	1963	65.0	1.0
CMR	U	1963	11.0	0.0
CMR	U	1967	80.0	1.0
CMR	U	1968	53.0	1.0
CMR	U	1968	14.0	0.6
CMR	U	1969	65.0	1.0
CMR	U	1969	258.0	2.4
Laundry	Total alpha	1948	844	450.533
Laundry	Total alpha	1949	2,268	583.067
Laundry	Total alpha	1950	78	42.2857
TA-21[e]	I-131	1961	1.4E4	NA

Table 6-1: Summary of Airborne Concentrations from Selected LANL Buildings				
Building	**Nuclide[a,b]**	**Year[k]**	**Maximum airborne concentration[c] (dpm/m^3)**	**Average airborne concentration[c] (dpm/m^3)**
DP West	I-131	1964	302	5.5
Sigma	Beta -gamma[f]	1947	1.82E+06	
H	Beta -gamma[f]	1947		0.0
U	Beta -gamma[f]	1947		5.95E+05
Sigma	Beta -gamma[f]	1948	1.86E+09	8.21E+07
H	Beta -gamma[f]	1948	3.33E+08	7.39E+07
U	Beta -gamma[f]	1948	1.47E+09	1.95E+08
CMR	Mixed fission[f]	1961	78.0	12.8
CMR	Mixed fission[f]	1962	11,627.0[g]	19.7[g]
CMR	Mixed fission[f]	1963	518.0	15.0
CMR	Mixed fission[f]	1964	19,256.0[h]	39.0[h]
CMR	Mixed fission[f]	1965	13,404.0[i]	22.0[i]
CMR	Mixed fission[f]	1966	93,887.0[j]	366.7[j]
CMR	Mixed fission[f]	1967	19,256.0	39.0
CMR	Mixed fission[f]	1968	13,404.0	22.0
CMR	Mixed fission[f]	1969	93,887.0	366.7
CMR	Mixed fission[f]	1970	14,163	
CMR	Mixed fission[f]	1971	18,104	

Notes:

a. Guidance on adjusting for different enrichments of uranium or mixtures of plutonium is in ORAU TKBS-0010-5, Section 5.2.
b. Information on specific mixtures of fission products is not readily available
c. Results prior to January 1, 1953 were reported as cpm/L. Listed results have been converted to dpm/m^3 assuming a nominal counting efficiency of 50%. Values shown are as reported by LANL; no estimation of the level of precision may be made based on the number of significant figures without the associated analytical error.
d. D Building demolished in 1954.
e. This information located in Dummer, 1961
f. Mixed Fission Products (assume gross beta/gamma) tolerance is 1×10^{-7} µCi/cc (2.22×10^5 dpm/m^3) through 1948; MAC is 6.7×10^3 dpm/m^3 from 1961 to 1969.
g. Highest concentration of 11,627 dpm/m^3 is in "uranium cell corridor - no personnel exposure." Next highest concentration is 207 dpm/m^3. Average concentration would be 11.8 dpm/m^3.
h. "No personnel exposure" to highest concentration of 19,256 dpm/m^3. Next highest concentration is 2,551dpm/m^3. "No personnel exposure" to highest concentration of 13,404 dpm/m^3. Next highest concentration is 2,233 dpm/m^3.

i. "No personnel exposure" to highest/next highest concentrations of 93,887 and 45,997 dpm/m^3. Next highest concentration is 21,553 dpm/m^3.
j. "No personnel exposure" to highest concentration of 13,404 dpm/m^3. Next highest concentration is 2,233 dpm/m^3.
k. Some additional airborne monitoring data have been located. Research to identify further data is on-going. These data have not been validated, compiled, analyzed, or modeled at the time of this report.

6.1.2 *In Vitro* Bioassay Sampling Data

Prior to the 1970s, individual assignments to the bioassay program were determined by the area health physics monitors. Until the early 1950s, nasal swipes with alpha activity more than 50 cpm indicated the need for follow-up bioassay. Excreta bioassay methods for determining internal exposures were developed in late 1944 for Pu and Po; in 1949 for U; and in 1950 for H-3. Starting in 1944, blood tests were performed following potential exposures. These blood tests were for blood count levels related to external radiation exposure rather than for radioactive content of the blood. Therefore, any such blood counts would not be directly applicable to internal dose calculations. The above topics are discussed in greater detail in Section 7.2, *Internal Radiation Doses at LANL*.

In the 1970s, LANL initiated an Employee Health Physics Checklist. This checklist allowed the evaluation of each individual for potential internal and external exposure. Individuals were placed on the appropriate monitoring schedule based on this checklist. The checklist is still used and was computerized in 1998 as the Dosimetry Enrollment System.

Table 6-2 summarizes the urinalysis data currently available to NIOSH. In Table 6-2, the following applies:

- Results = Number of analytical results available
- People = Number of people monitored
- N/A = Not Available
- Plutonium results were not initially isotope-specific and are based on the plutonium isotopes historically present at LANL

Table 6-3 summarizes the miscellaneous *in vitro* data available to NIOSH.

Table 6-2: LANL Urinalysis Data												
	Am-241[a]		H-3		Po		Pu-238		Pu239		U-235/U-238	
Year	results	people	results	people	results	people	results	people	results	people	results	people
1944									6	N/A		
1945									347	204		
1946									1069	525		
1947					537	49			1118	468		
1948					473	50			1582	626		
1949					406	55			1621	758		
1950			234	35	328	60			1678	766	1223	112
1951			824	76	395	105			1863	1041	511	108
1952			795	92	447	80			1610	816	759	121
1953			2514	145	951	308			977	613	1222	135
1954			3132	218	378	57			2031	1026	2852	180
1955			1579	125	1105	266			2525	1120	2081	204
1956			1374	126	116	38			2330	1086	1797	230
1957			1800	104	1	1			2422	1169	1159	174
1958			1903	161	13	N/A			2177	1057	1033	170
1959			845	74					2314	1086	1383	200
1960			379	54					2148	1011	1350	229
1961			467	57					2025	981	1501	210
1962			731	91					2098	970	2316	241
1963			1022	108					1961	975	3578	294
1964			631	69					2155	1017	3234	342
1965			841	109	3	N/A			1560	975	3209	284
1966			936	101					1346	825	3161	279
1967			852	73					1347	868	3275	253
1968			685	70			227	98	1319	824	3303	275
1969			970	101			253	121	1385	841	3096	283
1970			1549	154			305	142	1457	913	2812	258
1971			936	86			1265	765	1621	923	2375	269
1972			946	82			1430	851	1448	860	2341	237
1973			737	75			1869	1045	1869	1048	1786	204
1974			828	61			2207	1239	2211	1243	1845	172
1975			1005	72			2441	1648	2443	1650	1962	164

Footnote:

[a] Some additional Am-241 data have recently been located with the earliest known time period of 1949. Research to identify further data is on-going. These data have not been validated, compiled, analyzed, or modeled at the time of this report.

Table 6-3: Miscellaneous LANL *In Vitro* Monitoring Data

	Blood			Bone	Fecal[a]			Liver			Lung			Lymph Nodes		
Year	Po	Pu-238	Pu-239	Am-241	Am-241	Po	Pu-238	Am-241	Pu-238	Pu-239	Am-241	Pu-238	Pu-239	Am-241	Pu-238	Pu-239
1948						1										
1949																
1950																
1951																
1952																
1953						4										
1954																
1955	6					34										
1956						1										
1957																
1958																
1959																
1960																
1961																
1962																
1963																
1964																
1965																
1966																
1967																
1968																
1969																
1970																
1971																
1972			1							1			1			1
1973																
1974																
1975		1	2	1				1	1	2	1	1	2	1	1	2

Notes:
Data values = Number of analytical results available. Blood results shown were for analysis of intakes and are not the same as discussed in other sections of this report where blood samples were drawn as indicators of external exposure during the early years of LANL operations. Bone, liver, lung, and lymph node are autopsy samples.

Footnote:
[a] Some additional fecal monitoring data have recently been located. The specific radionuclides to which these data apply have not been determined at this time. Research to identify further data is on-going. These data have not been validated, compiled, analyzed, or modeled at the time of this report.

6.1.3 *In Vivo* Analytical Data

In vivo counting equipment and techniques were developed in the late 1950s and have been in routine use for measuring X-ray and gamma-ray-emitting radionuclides since 1970 (possibly as early as 1960). There is some indication that some of the counts recorded between 1955 (program onset) and the 1960s were performed for program development rather than actual suspected intakes. NIOSH has been unable to locate any records of these early *in vivo* measurements.

The first whole-body counter used was the HUMCO I. This "human counter" became operational in 1955. The counter consisted of a large double cylinder with a liquid scintillation fluid (possibly trichloroethylene) filling the annular space between the cylinders. The scintillation fluid was viewed with an array of 5-in. photomultiplier tubes on the outside wall of the cylinder. The individual was placed inside the count chamber. The count rate was compared to the background count rate. The system typically used two energy windows, one for K-40 (1-2 MeV) and one for Cs-137 + K-40 Compton counts between 0.5 and 0.8 MeV. The result was obtained by subtracting out the contribution of K-40. The system was not used for photons below 100 keV. This system was used to screen individuals who might have been exposed to fission products at the reactors or in fly-overs during weapons testing. It was also used to detect the *Bremsstrahlung* from Sr-90 intakes. The energy resolution of these counters was poor. When an elevation of the background in a region of interest was observed, the individual was referred for screening with either the shadow shield or full shield 4-in by 8–in. NaI(Tl) crystals (Healy, 1970). The sensitivities of the NaI(Tl) crystal were approximately the same as those for the HUMCO, except the count time was significantly longer.

The HUMCO II became operational in 1958. The HUMCO II was housed in a count room (SB-16) made of seven inches of pre-World War II steel. The resolution was improved, but it remained a screening counter. As both of the early *in vivo* monitoring systems (HUMCO I and II) were used as screening counters, NIOSH has not identified that quantitative data are available.

In 1970, an *in vivo* counter capable of measuring four separate regions of the body began operation (Vasilik, 1983). Twin Phoswich (CsI and NaI) detectors were placed over the lungs. The two layers of the detector were capable of simultaneously, yet separately, monitoring chest burdens for 10- to 250-keV photons (NaI), for plutonium and uranium isotopes and Am-241, and 200- to 2,000-keV photons (CsI) for a qualitative assessment of a variety of fission and activation nuclides. A planar Hyper Pure Germanium (HPGe) detector monitored the region between 10 and 250 keV with excellent energy resolution and could be positioned over the liver or thyroid, as needed. Finally, an HPGe (formerly a GeLi) detector was positioned under the prone subject. This detector was primarily for whole-body assessment. This system could both identify radionuclides and quantify the burdens. All individuals who received lung counts were monitored for Pu-239 and Am-241. In recent years, routine U-235 and Th-234 (as U-238) were added to the routine *in vivo* analysis library.

In August 1959, the Health Physics group acquired a probe to be used to monitor wounds contaminated with plutonium. This probe was capable of detecting soft plutonium X-rays. Wound counting was used primarily as a tool for surgeons to locate plutonium in the wound, not as results used to calculate internal dose.

Tables 6-4, 6-5, and 6-6 summarize LANL *in vivo* data available to NIOSH. The listed radionuclides represent the gamma spectroscopy photopeak identification system capability. Blank entries indicate that the corresponding radionuclide was not positively identified.

Table 6-4: LANL Chest Monitoring Data																			
Year	**Am-241**	**As-72**	**C-11 N-13**	**Cd-109**	**Cm-244**	**Co-57**	**Co-60**	**Cs-137**	**Eu-152**	**Hg-197**	**Hg-203**	**Pb-212**	**Pu-238**	**Pu-239**	**Sc-46**	**Ta-179**	**Th-234**	**U-235**	**U-237**	**U-238**
1969	41												4	45						
1970	351												12	358						
1971	187							2					80	177						
1972	384												60	359						
1973	461												14	416						
1974	481												2	477						
1975	834							2					2	820					6	

Notes:
Data values = Number of analytical results available, radionuclides with no results indicate there were no records with positive results. Some data are available post-1975.

Table 6-5: LANL Other *In Vivo* Monitoring Data									
Year	**Back**	**Hand**			**Hand Wound**	**Liver**	**Skull**	**Thyroid**	
	Pu-238	**Am-241**	**Co-60**	**Pu-239**	**Am-241**	**Am-241**	**Am-241**	**I-125**	**I-131**
1969									
1970									4
1971									
1972									
1973	2								
1974									
1975									

Notes:
Data values = Number of analytical results available, radionuclides with no results indicate there were no records with positive results

Table 6-6: LANL Whole Body Monitoring Data																						
Year	**As-72**	**Be-7**	**Bi-214**	**Br-76**	**Br-77**	**C11 N13**	**Cd-109**	**Ce-141**	**Cf-249**	**Co-56**	**Co-57**	**Co-58**	**Co-60**	**Cr-51**	**Cs-134**	**Cs-137**	**Cu-64**	**Cu-67**	**Eu-152**	**Fe-59**	**Hg-195M**	**Hg-197**	**Hg-197M**
1963																							
1964																							
1965																							
1966																							
1967																							
1968																							
1969													1		1								
1970		2				2							16		16	16							
1971													3		3	3							
1972		1				1							7		6	6							
1973													47		55	47							
1974		1				1							8		8	8							
1975		2				2							13		13	13							

LANL Whole Body Monitoring Data (cont.)																							
Year	**Hg-203**	**MAP**	**FP**	**Mn-54**	**Na-22**	**Na-24**	**Nd-147**	**Os-185**	**P-32**	**Ra-226**	**Rb-83**	**Rb-84**	**Sb-124**	**Sc-46**	**Se-75**	**Sm-145**	**Ta-179**	**Tl-201**	**Tl-202**	**V-48**	**Zn-65**	**Zn-95**	**Zr95 Nb95**
1963		14																					
1964																							
1965																							
1966																							
1967																							
1968																							
1969																							
1970				2		2				4											10		
1971				1																			
1972			2	1		1			4	2												2	
1973																							
1974				1		1																	
1975			1	2		4																	

Notes:
Data values = Number of analytical results available; MAP = Mixed Activation Products; FP = Fission Products, radionuclides with no results indicate there were no records with positive results. Additional data are available post-1975.

6.2 LANL External Monitoring Data

The following information provides a general summary of the LANL external monitoring program, as well as the types, quantity, and quality of the data that can be used for external dose reconstruction. Details regarding the various analyses used, the associated MDAs, the calibration procedures employed, and missed doses are available in the LANL Occupational External Dose TBD (ORAUT-TKBS-0010-6).

Records of individual radiation doses determined from personnel dosimeters worn by the worker and co-workers are available for LANL operations beginning in 1943. Doses from these dosimeters were recorded at the time of measurement and routinely reviewed by operations and radiation safety staff for compliance with radiation control limits. The NIOSH External Dose Reconstruction Implementation Guidelines (OCAS-IG-002) have identified these data as the highest-quality records for retrospective dose assessments.

Radiation dosimetry practices were initially based on experience gained during several decades of radium and X-ray medical diagnostic and therapeutic applications. These methods were generally well advanced by 1940 when the Manhattan Engineer District (MED) program was organized to develop nuclear weapons. The primary challenges encountered by MED (and later, the Atomic Energy Commission) in attempting to accurately measure worker dose from external radiation arose from operations with:

- comparatively large quantities of high-level radioactivity.
- mixed radiation fields involving beta, photon (gamma and X-ray), and neutron radiation with low, intermediate, and high energies.
- neutron radiation.

Historically, LANL had an extensive radiation safety monitoring program using portable radiation instruments, contamination surveys, zone controls, and personnel dosimeters for measuring exposure in the workplace (Littlejohn, 1960; LASL PEBs: 1959, -69, -77a, 77b, -79, -80; LANL PEBs: 1986, -89, -96, 2001, -03). This program was conducted directly by, or under the guidance of, a specially-trained group of radiation monitors or radiation protection technologists. Results from the dosimeters were used to evaluate and record doses from external radiation exposure to workers throughout the history of LANL operations. Dosimeters that have been used fall into the following categories:

- Personnel whole-body (WB) beta/photon dosimeters
- Pocket ionization chamber (PIC) dosimeters
- Personnel extremity dosimeters
- Personnel whole-body neutron dosimeters

Shortly after operations began in 1943, some workers were monitored with PICs alone. LANL dosimeter designs differed somewhat from the early to mid-1940s designs at the MED Metallurgical and Clinton laboratories, but capabilities to measure doses were similar. By 1945, film badges were used by a number of LANL groups, and in 1949 a new badge was introduced to support evaluation of beta exposures. Beta/gamma film badge designs changed several times through the 1950s, 1960s, and 1970s, as filters of various types were used to address the energy dependence of film response.

LANL officially switched to the use of thermoluminescent dosimeters (TLDs) in 1980, after the timeframe of the class currently under evaluation. Neutron dosimetry was implemented prior to 1949 for selected workers, beginning with the use of PICs that incorporated Bakelite chambers and graphite coatings. In 1949, nuclear track plates were first used; in 1951, badges incorporated Nuclear Track Type A (NTA) emulsion film.

Dosimeters were exchanged on routine schedules. In the earliest operations, daily measurements with PICs were performed. When film badges came into use in 1943, daily PIC measurements continued, but film measurements provided a check of the daily measurements and formed a permanent record of worker exposures. Film packets were exchanged and processed monthly for most workers, but were exchanged more frequently (as often as daily) for certain operations with high exposure potential. Beta/gamma dosimeters were exchanged at 1- or 2-week intervals, with 2-week intervals predominating (LASL PEB, 1959). Nuclear track plates (NTPs) were exchanged at 4-week intervals.

Table 6-7 summarizes the LANL dosimetry exchange frequencies during the evaluated time period.

Table 6-7: Summary of Typical Exchange Frequencies for LANL Dosimeters

Dosimeter type	Date range	Exchange frequency
PICs	Prior to 1945	Daily
Film Badges	1943 – 1979	Monthly for some, biweekly for some, up to daily for some operations
NTPs	1949 – approx. 1951	4-week interval
NTA Film	1951 – 1995	4-week interval

Table 6-8 presents a listing of reported numbers of workers monitored by LANL from 1944 through 1975 (LANL, 2004).

Table 6-8: Annual LANL External Radiation Doses, 1944–1975

Year	Number of workers monitored
1944	9
1945	812
1946	508
1947	1,237
1948	2,080
1949	3,177
1950	3,895
1951	4,257
1952	2,366
1953	1,878
1954	2,068
1955	1,984
1956	2,287
1957	2,539
1958	3,032

Table 6-8: Annual LANL External Radiation Doses, 1944–1975	
Year	**Number of workers monitored**
1959	2,930
1960	3,622
1961	3,973
1962	4,119
1963	4,176
1964	4,103
1965	4,222
1966	4,446
1967	4,072
1968	3,861
1969	3,980
1970	4,031
1971	3,775
1972	3,877
1973	3,866
1974	4,337
1975	4,716

Details regarding the various analyses used and the associated MDLs are presented in the Technical Basis Document for LANL Occupational External Dose (ORAUT-TKBS-0010-6).

6.3 LANL Air Sampling Data

Prior to 1971, air monitoring data for most TAs were not available, or if available, do not provide a complete record. Estimates of occupational intakes provided in the LANL Internal TBD rely on emissions data provided by LANL. These data indicated several years prior to 1971 in which potentially significant releases (and thus intakes) might have occurred. In particular, early plutonium releases at TA-1 are high in relation to other years, and there are two years of very high Th-232 releases (i.e., TA-15 in 1967-68). These apparently-high releases, surrounded by years of either zero releases or missing emissions information, suggest that more investigation is needed regarding the accuracy of the reported releases and the completeness of the emissions data before pre-1971 intakes can be adequately addressed. Therefore, estimated worker intakes in the TBD are restricted to post-1970 years. Efforts are currently in progress to develop pre-1971 intakes for a future revision of the TBD. Recently, approximately 4,000 documents were obtained from LANL, including monthly effluent stack release summaries and raw count room log book data. Reviews of these documents identified stack and room monitoring data from the 1940s through the 1970s. The majority of the results were limited to TA-3, although some results were provided for TA-1, -21, and -35. In some instances, the data provided the type of radionuclide or gross activity analysis performed; however, many of the data sheets provided no information on the type of testing. Summary Radioactive Effluent Release Reports provided total activity released as a roster of relevant radionuclides from a given stack. A typical example roster make-up was: 1967, TA-3-29-CMR Bldg., (stack) 5 FLMX-1: Pu-239, U-235, U-238, Np-237, Th (natural), Am-241, tritium. (Chelius, 1970).

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient information either to estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or to estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, NIOSH would then determine that it was feasible to conduct dose reconstructions.

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class (discussed in Section 9.0 of this report). If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.6. This approach is discussed in OCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- the sufficiency and reliability of the available data. (Section 7.1)
- the feasibility of reconstructing internal radiation doses. (Section 7.2)
- the feasibility of reconstructing external radiation doses. (Section 7.3)
- the bases for petition SEC-00051 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of LANL Data

This subsection answers questions that need to be asked before performing a feasibility evaluation. Data Pedigree addresses the background, history, and origin of the data. It requires looking at site methodologies that may have changed over time; primary versus secondary data sources and whether they match; and whether data are internally consistent. All these issues form the bedrock of the researcher's confidence and later conclusions about the data's quality, credibility, reliability, representativeness, and sufficiency for determining the feasibility of dose reconstruction. The feasibility evaluation presupposes that data pedigree issues have been settled.

Extensive work to determine the pedigree of 1943-1970 LANL monitoring data has not been performed because those years are being recommended for SEC inclusion. This recommendation is based on an identified lack of monitoring data necessary to perform dose reconstructions for the proposed class for that time period. Data retrieval efforts have been made over the past several years to identify sufficient worker, area, and environmental monitoring records for many of the lesser radionuclide source terms. These efforts have identified the availability of some air sampling results for specific rooms or buildings. However, in many cases the results are reported as gross activity, or the analysis type is not specified. Even when radionuclide-specific, the data are too limited in scope

for adequate modeling of all the potential exposure scenarios that would have to be taken into account in order to address the data gaps in bioassay monitoring.

Summaries of currently-identified internal and external data pedigree information are presented in the following subsections.

7.1.1 Internal Data Review

Initial acquisition and use of pre-1990 LANL internal monitoring data for EEOICPA claimant dose reconstructions was problematic. Most of the original LANL bioassay data were archived from legacy computer systems and was recorded in a variety of formats that made it very difficult to use, particularly by non-LANL personnel. Data retrieval proved to be a daunting task for LANL staff as they attempted to provide timely, complete, and accurate claimant data sets to NIOSH dose reconstructors. In addition, older bioassay data had not been validated when it was converted into electronic data after the original dose calculations were completed. *In vivo* data did not have assigned MDAs and only records with positive results were retained. Older *in vivo* data were stored in a different location from the newer data.

As a result, in the summer of 2004, LANL and NIOSH representatives agreed to undertake a joint effort to collect, validate, verify, and upload LANL internal monitoring data into a central repository suitable for efficient retrieval during the NIOSH dose reconstruction process. Results of this effort have been documented in *Los Alamos National Laboratory (LANL) Bioassay Data Project Final Report* (ORAUT-OTIB-0063, draft). This report has served as the source for the summary LANL internal data review information presented below. Because of the nature of the effort, not all results summaries are limited to the 1943-1975 class timeframe.

7.1.1.1 *In Vitro* Monitoring Data

Original urine assay results for tritium, uranium, and polonium (TUPo) were recorded in bound Los Alamos Notebooks (LANBs). The notebooks were not dedicated to a specific process or procedure, but rather were issued to individuals. Consequently, urine assay results prior to 1990 are distributed among 120 LANBs. A specific notebook may contain several thousand records, or only a few, depending on the use of the notebook by the assigned individual. During early LANL operations (pre-1970), it was not uncommon for the lab to record only positive bioassay results and to not report MDA values. In addition, record-keeping standards have changed significantly through the years, creating data retrieval challenges.

Around 1955-1956, LANL began the process of recording dosimetry records on IBM punch cards. Since that time, the data have existed in electronic format on several different systems. The data were first on Control Data Corporation (CDC) computers using the Network Operating System (NOS); then the CDC system was replaced by Digital Equipment Corporation (DEC) VAX.

Documentation of the VAX file data fields was not found. Delineation and definition of data fields was determined through personnel interviews and examination of lab notebooks. The data fields of the VAX files varied from nuclide to nuclide, and from file to file for a specific nuclide. It was necessary to work with each file individually to determine what data were provided and in what format.

The VAX ASCII data files were written to a compact disc (CD) and then individually imported to Microsoft Excel spreadsheets in order to determine and define the record fields. The spreadsheets were in turn exported to a Microsoft Access Database and merged into a single flat table. Finally, the table data were imported into an Oracle Database for incorporation into the LANL Bioassay Enrollment, Scheduling and Tracking (BEST) system. The total number of records for the TUPo data is in excess of 147,000.

From the VAX data files, 120 LANBs were identified as containing TUPo data through 1990. A request for access to the physical notebooks was made and, to date, 90 notebooks have been provided. Of the 90 notebooks, it is evident that references to 12 of these notebooks are incorrect, as they contain no TUPo data. However, the notebooks that have been provided represent nearly 90% of the TUPo records through 1990. Thirty physical LANBs remain to be reviewed. It is possible that some LANB references in the VAX files are incorrect or are typos. If so, the remaining referenced notebooks may be at LANL archives, may not actually exist or, if they do, may not contain TUPo information.

Just over 11 percent (16,692 out of 147,690) of the TUPo records were validated. Data comments were inserted on 4882 records and approximately 1300 records were in some way corrected. Errors were found in the reporting of sample results, sample date, and notebook and page references. One hundred thirty-four records that had been omitted from the VAX files were added to the database. A significant number of the data comments do not reflect actual corrections or data changes. These comments may indicate that the data reviewer had unresolved questions about the record or may indicate errors that were apparent but could not be corrected (e.g., an obviously-incorrect notebook reference – but the actual notebook could not be determined). Data validation results for TUPo analyses are summarized below followed by a short description of "Other Radionuclide Data."

Tritium Data

Approximately 10% (5,170 out of 50,141) of the tritium records were validated. Thirty-four records that were present in the LANBs but not in the VAX files were added to the database. Data comments were inserted on 3,563 records and corrections were made to about 138. The tritium data for the period 6/23/50 through 12/31/90 were extracted from the six VAX data files listed in Table 7-1.

Table 7-1: Tritium VAX Data Files

File Name	No. of Records	Comments
seza5063	17,737	Tritium records from 6/23/50 through 12/31/63
seza6475	9,932	Tritium records from 1/2/66 through 12/31/74
seza7683	9,961	Tritium records from 1/3/75 through 12/30/83
seza8488	8,099	Tritium records from 1/3/84 through 12/30/88
st389	1,989	Tritium records from 1/3/89 through 12/28/89
st390	2,389	Tritium records from 1/2/90 through 12/31/90

In comparing the LANB data with the VAX files, it was evident that the bioassay results had been adjusted in some manner yet to be determined. In general, the VAX file results values were 1-10% higher than those documented in the LANBs; approximately 3,460 records were affected. NIOSH assumes that some global correction was made to the data upon entry into the VAX files, but currently this difference remains unresolved. Results of the tritium data validation are summarized in Table 7-2.

Table 7-2: Tritium Data Validation Summary

Total No. of Records	No. of Validated Records	Records Added	Corrected Fields				No. of Data Comments
			Sample Results	Sample Date	Notebook Reference	Page Reference	
50,141	5150	34	45	2	12	51	3564

Uranium Data

The TUPo database contains 43,668 results for U-235, and 48,169 results for U-238, for a total of 91,837 records. For U-235, the bioassay data covered the period from 4/6/55 through 12/31/1990. The U-238 data covered a period from 11/18/49 through 12/31/1990. Uranium data were extracted from the 15 VAX files listed in Tables 7-3 and 7-4.

Table 7-3: VAX Data Files Containing Uranium-235 Data

File Name	No. of Records	Comments
sag5574	8,953	U-235 records for last names "A" to "G" from 4/08/55 through 12/20/74
shn5574	7,352	U-235 records for last names "H" to "N" from 4/11/55 through 12/20/74
soz5574	10,151	U-235 records for last names "O" to "Z" from 4/06/55 through 12/20/74
su57581	11,594	U-235 records from 1/03/75 through 12/25/81
su235a-z.1982-88	4,929	U-235 records from 12/25/81 through 12/19/88. (Also includes two data records dated 7/09/62 that are of questionable value based on examination of LANB data.)
su5o89	272	U-235 records from 1/03/89 through 12/18/89
su5o90	400	U-235 records from 1/02/90 through 12/31/90

Table 7-4: VAX Data Files Containing Uranium-238 Data

File Name	No. of Records	Comments
su238a	9,889	U-238 records for last names "A" to "G" from 11/18/49 through 12/13/74
su238b	9,699	U-238 records for last names "H" to "N" from 11/18/49 through 12/13/74
su238c	10,014	U-238 records for last names "O" to "Z" from 11/18/49 through 12/13/74
su87581	11,830	U-238 records from 1/03/75 through 12/25/81
su238a-z.1982-88	5,159	U-238 records from 2/19/81 through 12/21/88
su8o89	604	U-238 records from 1/03/89 through 12/19/89
su8o90	959	U-238 records from 1/02/90 through 12/31/90
sPOL4765.dat	6	These records were found in the polonium VAX data, but LANL information indicated these were U-238 results dated 2/17/56.

In addition to the VAX data files identified as containing uranium bioassay data, six U-238 records were found in the file "sPOL4765.dat" that should have contained only polonium data. The fact that these records were uranium assay results, and not polonium, was verified through examination of the laboratory notebooks.

Seventeen U-235 and fifteen U-238 records that were present in the LANBs but not in the VAX files were added to the database (this included the six U-238 records found in file "sPOL4765.dat"). Corrections and comments were made on 76 U-235 records and 803 U-238 records. Results of the uranium data validation are summarized in Table 7-5.

Table 7-5: Uranium Data Validation Summary

Nuclide	Total No. of Records	No. of Validate Records	Records Added	Corrected Fields				No. of Data Comments
				Sample Results	Sample Date	Notebook Reference	Page Reference	
U-235	43,668	4436	17	32	0	1	79	76
U-238	48,169	4841	15	60	10	2	6	803
Total	91,837	9,277	32	92	10	3	85	879

Polonium Data

Polonium data available for the period 3/11/47 through 3/24/65 were extracted from a single VAX data file. Comparing to retrieved notebook values, nearly 40% (2,245 of 5,712) were validated. Thirty-six records that were present in the LANBs but not in the VAX files were added to the database. Corrections and comments were made on 439 records. Results of the polonium data validation are summarized in Table 7-6.

Table 7-6: Summary of Errors in Validated Polonium Data

Total No. of Records	No. of Validated Records	Records Added	Corrected Fields				No. of Data Comments
			Sample Results	Sample Date	Notebook Reference	Page Reference	
5,712	2,245	36	72	0	553	395	439

Other Radionuclide Data

Bioassay data were not found for LANL workers who worked with radioactive lanthanum (RaLa). Similarly, other less-common radionuclides like strontium-90 (a RaLa contaminant), Th-232, Ac-227, and Cm-244 were not part of the routine bioassay program. However, LANL did record a very limited number of Sr-90 results using gross beta analyses.

In vitro data for mixed fission products (MFP) are in the same category as the RaLa data – in general, they do not exist. While isolated results may exist in the laboratory notebooks, no regular programmatic sampling data exist. Limited *in vivo* counting was accomplished for MFP; however, the number of results are insufficient to provide a co-worker data set.

7.1.1.2 *In Vivo* Monitoring Data

Prior to the recent consolidation efforts by LANL and NIOSH (see Section 7.1.1 and ORAUT-OTIB-0063, draft), *in vivo* counting data from 1960-2003 were maintained in a legacy system called "OMNIS7". This older database does not provide MDA values and only contains count data for positive results. Some *in vivo* measurements are available for the pre-1960 period; however, these measurements were not considered routine, and therefore are not described as a regular part of the LANL *in vivo* bioassay program. The *in vivo* program expanded in 1970, and began using more sensitive instrumentation (see Section 6.1.3). Some paper records do exist, such as "beige" and "white" cards that contain analyst comments regarding how the radionuclide activities were calculated for individuals as well as important physiological information (e.g., chest wall thickness).

As a result of LANL and NIOSH consolidation efforts, the 1960-2003 *in vivo* data have been combined with post-2003 data into one Oracle database. Resource constraints prevented importing and scanning the historical "beige" and "white" cards; however, the database is configured so that after these cards are scanned, the values can be entered later. Tables containing typical MDA values for older *in vivo* counting systems were also added to the Oracle database so that MDAs could be assigned to all counts performed based on time period. At this point, it appears that not much can be done to recreate the actual MDA values for older measurements.

7.1.2 External Data Review

LANL dosimetry capabilities during the early years were in line with the prevailing stage of technological development. Over time, LANL's radiation dosimetry technology developed considerably, keeping up with technological developments as they became accepted. Administrative practices are described in the Photodosimetry Evaluation Book (Littlejohn, 1960; LASL PEBs: 1959, -69, -77a, 77b, -79, -80; LANL PEBs: 1986, -89, -96, 2001, -03). and LANL technical reports. Detailed information for each worker is in the NIOSH claim documentation. Based on the claim documentation, there do not appear to have been significant administrative practices jeopardizing the integrity of the recorded dose of record.

From 1943 through 1952, external radiation evaluation results were recorded in standard "LA notebooks" that eventually found their way to the document room for permanent storage (LASL PEB, 1959). In August 1950, H Division started supplying PICs and film badges for use by the "GMX-1" (the early Radiography Group) during "extraordinary work" (LASL PEB, 1959). Prior to that time, dosimetry for the GMX-1 group was reportedly handled by GMX-1 personnel at GT Site; apparently, no long-term records of these early measurements were retained.

According to a February 16, 1956 memorandum, in January 1953 a "Cardex" system for filing exposure data on paper cards was put into use (LASL PEB, 1959). In January 1956, LANL started noting all nuclear track plates (NTPs) issued on Personnel Exposure Cardex records. Prior to this time, only plates that were "read" were recorded (LASL PEB, 1959).

According to an April 3, 1957 memorandum, in 1957 a computerized "IBM" system was first employed at LANL to record personnel exposures to radiation (LASL PEB, 1959). Also in 1959, IBM equipment was first used to evaluate film exposures (Littlejohn, 1960). This record-keeping has been computerized since that time.

In September 1978, it was reported that, for the previous 10 years, no entry was made in the computerized records system for any visitor's film badge exposure reading less than 0.04 rem (LASL PEB, 1980). For purposes of reporting to the visitor's primary employer, a non-zero exposure recorded by the LANL Cycolac film badge was defined as a total-rem exposure of 0.04 rem or more. (For regularly-issued film badges, all measured values from 0.00 rem upward were recorded and attributed to the worker in the H-1 dosimetry records system.) This visitor film badge policy was in place to preclude dose reporting of <0.04 rem (which would have required tracking down each visitor to obtain employer name and address). An October 30, 1979 memorandum indicated that on January 1, 1976, LANL had to start reporting zero exposures for all Energy Research and Development Administration (ERDA) visitors, because ERDA had just established a radiation exposure record system for all its employees (LASL, 1980).

As mentioned earlier, the scope of data pedigree investigations has been limited due to recommendation of the 1943-1975 timeframe for SEC status. Consistency checks between older external monitoring data repositories and reports are, therefore, not necessary for this timeframe.

7.2 Internal Radiation Doses at LANL

The principal sources of internal radiation doses for members of the proposed class were inhalation, ingestion, or absorption of plutonium isotopes, Am-241 (as pure Am-241, separate from the typical association with plutonium), uranium isotopes, Po-210, Ac-227, Th-232, H-3, mixed fission and activation products (primarily Cs-137 and Sr-90), and radium. The isotopic composition of the plutonium was consistent with weapons-grade material. The chemical forms for plutonium that could potentially be encountered included metal, nitrate, and fluoride. Depleted uranium (DU) metal and uranium oxide were most commonly encountered, but natural and enriched uranium were used as well, as was U-233. Po-210 and Ac-227 were used to construct nuclear weapon initiators. Oxide and metallurgical activities involving Th-232 were noted. Tritium was involved in various aspects of weapons research and was a by-product of accelerator operation. There were several research reactors operational over the life of the site that resulted in mixed fission product contamination that could have resulted in personnel exposure during operation, maintenance, and demolition of the facilities, and during investigations of spent fuels (ORAU-TKBS-0010-2).

Intake of these radionuclides could have resulted from either routine or off-normal events. Processes involving these materials included machining, casting, grinding, blending, chemical reactions, testing (including explosive testing), or other operations that could directly cause airborne radioactivity or release contamination to work surfaces where it could be re-suspended.

When LASL operations began in 1943, the only method of monitoring intake was through loose contamination swipes. Lightly-oiled filter papers were swiped across surface areas likely to be contaminated. Any swiped area with an activity of more than 500 cpm (1,000 dpm) alpha required decontamination. The efficiency of the stationary counters used to count the swipes approached 50%. In addition, nasal swipes (also called "nose counts") were used to indicate potential intakes. Nasal

swipes with alpha activity more than 50 cpm indicated the need for follow-up urinalysis. The first air samplers became available in fall 1944. However, the swipe technique continued as the primary method of detection in many areas until the early 1950s. Respiratory protection equipment (e.g., assault gas masks or respirators) was used as early as 1944.

In 1943, project hazards were limited to external radiation from the cyclotron, the Van de Graaff accelerator, radium sources, and a few micrograms of plutonium that arrived that summer. In addition, there were some internal and external radiation hazards from uranium.

In 1944, the radiological hazards of plutonium had been recognized, but it was not yet realized that plutonium was more hazardous than radium. Safety regulations were established based on experience with radium dial paint plants. Measures to control personnel exposures included multiple changes of clothing, showering before leaving the building, use of surgical gloves and respirators, and use of closed systems whenever possible. These measures were primitive by current standards. Most workers cooperated with safety rules to the best of their ability, but the potential for contamination and intakes was present. During the tension and feverish activity of developing the first atomic bomb, it was difficult to avoid some shortcuts in the observation and enforcement of safety rules. In addition, the first experimental reactors went on line in TA-2 in 1944.

The Laboratory went from handling a few micrograms of plutonium in 1943 to kilogram quantities in 1945. This provided little time for the usual development of safe methods of handling and safety equipment design. As research determined that plutonium was more hazardous than radium, tolerance levels and maximum permissible burdens were reduced significantly.

Early safety efforts were based on working in safe contamination levels. In 1954, contamination-level measurements were based on contact with a shield open Geiger-Mueller (GM) tube for beta/gamma and a Pee Wee probe of 55 cm^2 area for alpha. The efficiency of these portable probes is approximately 10% to 15%. Swipes counted on a fixed proportional counter had an efficiency of approximately 40% to 50%, although the oil used on the swipes (to increase collection efficiency) might have decreased the counting efficiency slightly. A total alpha count rate of 500 cpm on a swipe corresponded to 0.007 μg or 0.0004 μCi of the plutonium isotopic mixture of the times.

The tolerance for wounds was 10 cpm for alpha and 0.15 mrep/hr beta/gamma, except for wounds contaminated with Sr-90 for which the tolerance was 0.05 mrep/hr. The skin contamination tolerance was 1 mrep/hr beta/gamma, except for Sr-90, which was 0.05 mrep/hr. The skin contamination tolerance for alpha emitters was 1,000 cpm for polonium, 500 cpm for Tuballoy (natural uranium) or Oralloy, and 250 cpm for plutonium. The tolerance for floor counts was 100 cpm/swipe alpha but definitely less than 500 cpm/swipe alpha, and bench tops were usually 50 cpm/swipe alpha or less. Floors in laboratories were mopped once or twice a day to maintain safe contamination levels. Early Health Group reports indicate contamination present inside many of the respirators signifying improper storage, handling and/or poor fit during use.

Kilogram quantities of plutonium began to arrive at LASL in April 1945. At that time, portable alpha counters, continuously-operating air samplers, supplied air lines, and specially-made positive pressure masks were available. Procedures were performed in open hoods and wooden dry boxes, which were the precursor to the modern glovebox. Research indicated that there was a potential for work-related

and casual encounters with plutonium and other radionuclides at various air concentrations and/or surface contamination levels, including levels that exceeded radiation exposure or control limits.

Given that these operations were, in many cases, the first of their kind and that health physics practices were being developed and implemented at the same time plutonium processes were being brought online, some level of chronic or episodic intake during this period would be a reasonable assumption. From 1943, the Health Group was responsible for establishing health standards, specifically for safe levels of exposure to radiation and to radioactive and chemical materials. The Health Group's primary concern was to protect the health of laboratory employees. Until mid-1951, for want of adequate staff, the Group accepted help in monitoring radiation-related activities from the Chemistry and Metallurgy Research (CMR) organization staff. Over the years, the Health Group evolved into the Health Division [and its successors, Environmental, Safety, and Health (ESH) and Health, Safety, and Environment (HSE) Divisions], with multiple groups therein to address health physics, medical, (industrial) safety, biomedical research, industrial hygiene, industrial waste treatment, and environmental studies. While several division and group name changes have occurred since 1943, the generic Health Physics Group has existed since 1951. Throughout this period, that group has had the responsibility for assigning and scheduling bioassay analyses for intakes of all radioactive materials. Until the late 1990s, the Industrial Hygiene Group performed all bioassay analyses. Since the late 1990s, bioassays have been performed by one of the chemistry groups. The Medical group has treated individuals accidentally exposed to radiation and radioactive materials, performed physical examinations, and treated industrial accidents.

Over the years, many improvements have been made in monitoring, bioassay techniques, safety equipment, and safety procedures. Nevertheless, the potential for monitored and unmonitored intakes has existed throughout the history of the site.

Excreta bioassay methods for determining internal exposures were developed in late 1944 for plutonium (fully implemented in April 1945) and polonium; for uranium in 1949; and for tritium in 1950. Although the number of monitored individuals increased over the years, not all individuals working at LANL were monitored. Emphasis was placed on monitoring workers with the highest exposure potential or who had incurred a suspected intake. A survey taken in 1986 estimated that approximately 350 persons had known burdens of plutonium.

Starting in 1944, blood tests were performed following potential exposures. However, these blood tests were performed for blood count levels related to external radiation exposure rather than the radioactive content of the blood. Therefore, any records of blood counts performed on an individual or mentioned in the claimant interviews will not be directly applicable to internal dose calculations.

Air samples, identifiable with an individual's record, were performed beginning in 1944. However, since these samples were used to indicate potential elevated airborne conditions, and thus to select personnel for bioassay, there is no clear-cut method to derive a dose estimate for individuals unless a bioassay was performed. Records of chelation therapy for plutonium and americium are noted in the bioassay record.

As state-of-the-art of radiation detection progressed, whole-body counting for fission products began in 1955, wound counting began before 1967, and chest counting began in 1970. However, as noted previously, NIOSH has been unable to locate these early whole-body counting results

7.2.1 Process-Related Internal Doses at LANL

The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the proposed class.

7.2.1.1 Urinalysis Information and Available Data

Two sources of urinalysis data are available, although they undoubtedly arose from the same database:

1. The Microsoft Access database, "LANL Co-Worker Data-Rev 1", contains urinalysis results for Pu-238, Pu-239, and Po-210 from 1945 through 1988. Data for these three radionuclides were used to develop the draft technical information bulletin ORAUT-OTIB-0062 (draft). Tritium urinalysis results for 1950 through 1988 can be found in "LANL CO-Worker Complete". As noted previously, Am-241 urinalysis data have recently been identified but are not contained within this database.

2. The "LAMULW02 Working Data" file set was prepared by LANL for epidemiological studies for workers from 1944-1978. This database was queried by the NIOSH Task 5 Co-worker Team to provide specific information contained in the following files (http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lamulw02):

    - Labfile1, Labfile2, Labfile3, and Labfile4: Contain plutonium bioassay data from 1944 through October 1985. There are 43,693 records in each file. All urine bioassays before 1968 were for Pu-239. Thereafter, results are labeled Pu-238, Pu-239, or (a small number) Pu-242.

    - LATFILE: Contains 6,662 revised annual tritium readings from 1950 to 1988.

Prior to the 1970s, individuals were assigned to a bioassay program as determined by the area Health Physics monitors. LANL deemed this program sufficient to ensure that all workers who might require monitoring were monitored. However, instances might have occurred (especially in the early years) in which a person not normally assigned to radiation work was asked to participate as a substitute in a task involving radiation or radioactive materials. These persons were not likely to have regularly, or possibly ever, participated in the bioassay program. It is possible that their participation in these tasks was never recorded. Dose reconstructors may learn information about this type of exposure from their review of the claimant interviews (CATIs).

The Zia Company was the service workers' contractor. Zia employees participated in a separate monitoring program from that used for laboratory employees. It appears that sometime in 1976, Zia employees had a special computer program that locked out access to plutonium areas if participation in a plutonium bioassay program was not recorded within 425 days.

In the 1970s, LANL initiated an Employee Health Physics Checklist. This checklist allowed the evaluation of each individual for potential internal and external exposure. Individuals were placed on a monitoring schedule based on this checklist. The checklist is still used and was computerized in 1998 as the Dosimetry Enrollment System.

Plutonium

The most serious intakes at LANL have involved isotopes of plutonium. The first urinalysis performed for evidence of plutonium uptake was performed on July 18, 1944 using a chemical procedure developed at the University of Chicago Metallurgical Laboratory in June 1944. However, Health Group personnel soon discovered that the procedure, using a 50 cm^3 aliquot of a 24-hour urine sample, did not have the sensitivity to meet the tolerance level of a 5-μg (0.33-μCi) burden of plutonium. The first recorded accident in which a human was subjected to a possible intake of plutonium occurred on August 19, 1944. This accident resulted in LASL being authorized to proceed with development of a more sensitive procedure. Current and historical bioassay results are stored with the plutonium results in the Los Alamos Bioassay Data Repository database. Data are available and internal plutonium doses can be reconstructed for the period after 1945. However, the plutonium isotopic distribution is not available and early results are reported as plutonium or Pu-239. For dose reconstruction, the values should be considered total plutonium alpha counts, which would include Pu-239, Pu-240, and Pu-238. Data providing the nominal isotopic distribution for weapons-grade plutonium are available in ORAUT- TKBS-0010-5. Missed dose can be estimated using the information for this timeframe presented in Table 5-5 of ORAUT-TKBS-0010-5. The optimum source of data to estimate doses to unmonitored workers is co-worker data analyzed per ORAUT-OTIB-0019. This analysis has been performed and documented in ORAUT-OTIB-0062 (draft). The co-worker data were evaluated to model intakes to derive dose estimates for Pu-239 prior to 1945 and for Pu-238 prior to 1968. Intakes prior to these timeframes would require extrapolation of the intake models.

Americium

At LANL, Am-241 is usually encountered as a trace contaminant in plutonium; however, there is potential for exposure to pure Am-241. No exposure to pure Am-241 was likely prior to the beginning of the americium bioassay program in 1954, although a procedure for determining Am-241 in urine was in development in 1948. Current and historical bioassay results are stored with the plutonium results in the Los Alamos Bioassay Data Repository database.

There is an indication that workers participated in the americium bioassay program only if there was a potential for exposure to pure americium. Therefore, plutonium mixtures cannot be inferred from americium bioassay results. Conversely, the dose contribution from Am-241 cannot be excluded based on the absence of (Am-241) bioassay data since it is a known component of plutonium mixtures. Doses from unmonitored intakes of Am-241 associated with plutonium exposure can be inferred from plutonium bioassay results using isotopic ratios typical of weapons-grade plutonium found in ORAUT-OTIB-0053 (draft). For the pre-1970 (pre-*in vivo*) time period, the ability to reconstruct Am-241 dose will be extremely limited if plutonium and/or americium data are not available (from bioassay, co-worker, source term, or area monitoring data), or until such time that the newly-identified data have been validated and made available for use in dose reconstructions.

Tritium

Tritium was encountered in several forms: tritiated water (HTO), tritiated gas (HT), organically-bound tritium (OBT), and metal tritide (MT). Each form has unique characteristics. Since 1950, an average of around 100 individuals per year has been monitored for tritium intakes at LANL. The form generally encountered was HTO. There are no records of tritium monitoring prior to 1950. Therefore, the ability to reconstruct tritium contribution to internal dose to workers in applicable TAs will be extremely limited, pre-1950, given the lack of a surrogate evaluation model, a developed co-worker study, or an established extrapolation methodology. Urinalysis for tritium began on January 1, 1950; data are available in the Los Alamos Bioassay Data Repository database. The co-worker data were sufficient to derive dose estimates for tritium after this date.

Uranium

Historically, uranium at LANL was primarily depleted or enriched with a variety of isotopic ratios. Depleted is the most common form of uranium encountered at LANL, although natural uranium (Tuballoy) was used in conventional weapons testing from 1949 to 1970.

The most commonly-encountered chemical forms of uranium were oxides and metal. LANL has always treated uranium as either solubility class D or W. Urine assay data suggested that "all known LANL exposures to uranium were to a relatively soluble form (not Class Y)". However, the partition between Class D and W could not be determined. Historically, Class W was used for reporting results (Lawrence, 1992) because it produced larger doses. Monitoring for uranium consisted of routine urinalysis starting in 1949 for employees identified as being at risk for exposure (ORAUT-TKBS-0010-5, Table 5A-14). Nasal swipes with more than 50 cpm indicated the need for follow-up bioassay. Unless a suitable co-worker cohort can be established for uranium workers who may have terminated employment prior to the advent of uranium urinalysis, contributions to internal dose from uranium intakes by workers in TAs where uranium was handled cannot be reconstructed prior to 1949. Another potential alternative is estimating hypothetical intake rates for workers based on either the average or maximum enriched uranium air sampling data where available for the early site years. Internal monitoring data are available in the Los Alamos Bioassay Data Repository database and internal uranium doses can be reconstructed for the period after 1949. However, isotopic results are not available from this early program, although isotopic fractions can be inferred using the information in Section 5.2.4 of ORAUT-TKBS-0010-5. Other information useful to dose reconstruction (i.e., solubility fraction, analytical methods, MDAs, etc.) can be found in ORAUT-TKBS-0010-5. The co-worker data were sufficient to derive dose estimates for unmonitored workers for uranium after January 1, 1950.

Fission Products

The first gross beta urine count was devised in 1947. References to the site's ability to perform urinalysis to monitor for fission product intakes have been seen in various Health Division reports. However, no bioassay data have been identified or other internal monitoring data for fission products until whole-body counting was fully implemented in 1970. A 1958 procedure lists gross beta urine analysis from Sr/Y-90, Ba/La-140, Ce/Pr-144, Sr-89, and gross fission products. This might be the same as the procedure referenced in 1947; no sensitivity is listed. According to the procedure, background was counted before and after each sample. Non-specific sensitivities of 50 to 100 dpm/L

with an investigation level of >200 dpm/L have been found. A similar procedure of oxalate co-precipitation and beta counting, effective in 1974, lists a sensitivity of 1 to 2 dps/L and an MDA of 25 pCi/L. This procedure might have been effective as early as 1950. No further mention of a gross fission product procedure has been found, nor any associated data. However, a gamma spectroscopy procedure for Cs-137 in urine lists an effective date of May 1965 and an MDA of 100 pCi/L.

The abundances of all the fission products, in relation to each other, varied considerably. Certain reactors at LANL operated only briefly. Some exposures are known to have occurred during reactor operations when gas lines and related systems leaked, and also were possible during decommissioning operations, weapons testing, and spent fuel evaluation. No discussions are available for interpreting fission product mixtures. Interviews with current and past LANL personnel involved with bioassay indicate that fission products were not considered a significant source term for intake among LANL workers. However, site reports contain references to high airborne fission product concentrations. (LASL HD, 1951)

During the late 1940s and early 1950s, atmospheric testing of nuclear weapons was still on-going. After such tests in Nevada in the 1950s, the environmental background radiation in Los Alamos was as high as 5 mR/hr from fresh fission products. As discussed above and also in ORAUT-TKBS-00010-5, a method for measuring gross beta activity in urine had been developed. These data have not been located; therefore, there is no means for reconstructing with sufficient accuracy the internal dose contribution from fission and activation products. Whole body counting was initiated in 1955; however, no data have been found prior to the 1970s. Without gross beta urinalysis or whole-body counting results, an individual MFP and MAP dose cannot be reconstructed with sufficient accuracy for members of the NIOSH-proposed class prior to 1975. After 1970, whole-body-counting data has been determined to be insufficient for developing a co-worker data set.

Strontium-90

Records of routine or special Sr-90 urinalyses are very sparse. The historical compilations of procedures do not specify a Sr-90 urinalysis procedure. It appears that any record of Sr-90 analysis actually indicates that LANL performed a gross beta analysis or sent a sample to an outside laboratory. Sr-90 dose currently can be reconstructed only when Sr-90 results are actually listed for an individual. Estimates of the total Sr-90 source term from the RaLa program ranged from several hundred millicuries to 40 curies (Bayo). There are no data available that permits internal dose contributions from Sr-90 to be reconstructed with sufficient accuracy.

Polonium

Work with Po-210 was of a limited scope at LANL, consisting of initiator construction with usage levels ranging from 100 Ci/month to 500 Ci/month. Initiator work was performed from 1945 until 1959. After 1959, Po-210 was encountered only in the form of sealed Po-Be sources.

Initially, the urine bioassay analysis procedure could not distinguish adequately between plutonium and polonium. During 1944, the total alpha results were assigned to either plutonium or polonium based on the individual's work history. The procedure was modified in the fall of 1944 to extract the plutonium. Data are available in the Los Alamos Bioassay Data Repository database. Internal polonium doses can be reconstructed for monitored individuals after 1944. The analysis of co-worker

data provided in ORAUT-OTIB-0062 (draft) found sufficient data to allow reconstruction of the bounding (maximum) dose from Po-210 for unmonitored workers from 1947 to 1956.

Other Radionuclides

LANL has always been a center for research. As such, small-scale use of various radionuclides not addressed above has occurred throughout the history of LANL ("small-scale" as in number of persons or activity of the source). Little or no documentation has been found on bioassay for these nuclides, which included: Ac-227, P-32, C-14, Cm-244, Th-232, Th-230, and Pa-231. Even so, most of these radionuclides received considerable discussion in monthly reports. From these discussions, it can be surmised that, during some periods, these radionuclide represented significant source terms. Such discussions addressed the need for bioassay, listing of these radionuclides as significant environmental effluents, and identification of the lack of monitoring as an assessment finding. Th-230 may have been present as a natural component of uranium. Th-232 is believed to have been a significant source term during intermittent time periods. No monitoring results have been found for these radionuclides from 1943 to 1950, which would imply that isotopic techniques were either not available or not implemented. It can be assumed that the alpha emitters (Th-232, Cm-244, and Pa-231), if present, would be included in the total alpha urinalysis and attributed to either polonium or plutonium. After 1970, with the onset of chest counting and improved analytical capabilities, LANL possessed the ability to monitor for all ROCs with the exception of Ac-227, Cm-244, and Pa-231. Ac-227 and Pa-231 possibly could be quantified by the chest count procedure. However, no information has been found that would indicate an attempt at this process or that any such data are available. Inventory records to establish the significance of the source term of these "exotic" radionuclides is limited. Most available information is limited to waste activity reports.

7.2.1.2 Lung Counting Information and Available Data

Two sources of *in vivo* data were located, although they undoubtedly arose from the same database:

1. *In vivo* data from 1965 to 1988 are available from a Microsoft Access database named "LANL-Bioassay Co-Worker Data-Complete" (ORAUT-OTIB-0063, draft). The database contains approximately 100,000 records consisting mostly of chest or whole-body measurements, although a few counts of specific organs or body regions can also be found. Data for Pu-238, Pu-239, Am-241, and Cs-137 are available. Few data for other radionuclides are available prior to the 1980s when the use of germanium detectors became more common. Data through 1975 are insufficient for developing co-worker data for MFP/MAP.

2. The "LAMULW02 Working Data" file set was prepared by LANL for epidemiological studies for workers from 1944 to 1978. This database was queried by the NIOSH Task 5 Coworker Team to provide specific information. (http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs/def?DATASET=lamulw02). The LACFILE file contains estimated plutonium whole-body burdens as of January 1, 1987. There are 16,315 records. Results are given separately for Pu-238 and Pu-239.

In vivo counting equipment and techniques were developed in the late 1950s and have been in routine use for measuring X-ray and gamma-ray-emitting radionuclides since 1970, and possibly as early as 1960. There is some indication that some of the counts recorded between the beginning of the program (in 1955) and the 1960s were for program development rather than actual suspected intakes.

Whole-body and Chest Counters

The first whole-body counter to be used at LASL was the HUMCO I. This "human counter" became operational in 1955. The counter consisted of a large double cylinder with a liquid scintillation fluid (possibly trichloroethylene) filling the annular space between the cylinders. The scintillation fluid was viewed with an array of 5-in. photomultiplier tubes on the outside wall of the cylinder. The system was not used for photons below 100 keV. This system was used to screen individuals who might have been exposed to fission products at the reactors or in flyovers during weapons testing. It was also used to detect the *Bremsstrahlung* from Sr-90 intakes. The energy resolution of these counters was poor. When an elevation of the background in a region of interest was observed, the individual was referred for screening with either the shadow shield or full shield 4- by 8–in. NaI(Tl) crystals. The sensitivities of the NaI(Tl) crystal were approximately the same as those for the HUMCO, except the count time was significantly longer.

The HUMCO II became operational in 1958. The HUMCO II was housed in a count room (SB-16) made of 7 inches of pre-World War II steel. The resolution was improved, but it remained a screening counter. Whole-body counting data are available for monitored employees for the dates indicated in the discussion above. Co-worker data are insufficient to permit the estimation of internal dose to unmonitored employees.

An *in vivo* counter capable of measuring four separate regions of the body began operation in 1970. Twin Phoswich (CsI and NaI) detectors were placed over the lungs. The two layers of the detector were capable of simultaneously (yet separately) monitoring chest burdens for 10- to 250-keV photons (NaI), for plutonium and uranium isotopes and Am-241, and 200 to 2,000 keV photons (CsI) for a qualitative assessment of a variety of fission and activation nuclides. A planar Hyper Pure Germanium (HPGe) detector monitored the region between 10 and 250 keV with excellent energy resolution and could be positioned over the liver or thyroid, as needed. Finally, a HPGe (formerly a GeLi) detector was positioned under the prone subject. This detector was primarily for whole-body assessment. This system could both identify radionuclides and quantify the burdens.

7.2.1.3 Other Types of Bioassay/Workplace Indicators

Nasal Swipes

Nasal swipe data can be found in LABFILE 1, LABFILE2, and LABFILE3 records for 1944. Until the first urine bioassay analysis was perfected and available in February 1945, "nose counts" were relied on as a qualitative indicator of plutonium intake. After the development of urine bioassay techniques, nasal swipes were used to indicate the need for follow-up bioassay, although bioassay was not always performed immediately following a positive nasal swipe. The MPL was 50 dpm, alpha, per nostril. In addition, in 1944 LASL adopted a policy that if the two nasal counts varied significantly, the higher nasal count was considered spurious. Information concerning a positive nasal swipe can often be found in the incident line of the Microsoft Access "LANL Co-Worker Data-Rev-1" database entry for the individual (ORAUT-TKBS-0010-5). Nasal swipe results in a case file, although not used specifically to reconstruct dose, may provide positive indications that a potential uptake occurred that should be accounted for during dose reconstruction.

Wound Counts

Wound count and accident data involving potential plutonium uptake can be found in LABFILE 1, LABFILE2, and LABFILE3 records for 1944. In August 1959, the H-6 Group acquired a probe to be used to monitor wounds contaminated with plutonium. Wound counting was used primarily as a tool for surgeons to locate plutonium in the wound, not as results used to calculate internal dose. Wound monitoring continues to be performed. In most cases, intake and dose will not be assessed directly from the wound count but rather from the resultant urine bioassay data. Follow-up studies of wounds found that, in the majority of incidents, plutonium does not readily migrate from the wound site to uptake. No other information on instrumentation or sensitivities is available (ORAUT-TKBS-0010-5). Wound count results in a case file, although not used specifically to reconstruct dose, may provide positive indications that a potential uptake occurred that should be accounted for during dose reconstruction.

7.2.1.4 Airborne Levels

Maximum and average airborne concentrations can be helpful in establishing boundary conditions for intakes. Maximum and average airborne contamination levels in buildings with high-exposure potential are listed in Table 5-20 in ORAUT-TKBS-0010-5 and are summarized herein in Table 6-1. Airborne concentrations are available for some years of operation, but are deficient for all ROCs. The recently-obtained additional monitoring records may serve to better define and bound exposure conditions. Average concentrations are calculated from general air samples as simple averages or averages obtained directly from LASL reports. Blanks in the table indicate that no information is currently available for that period (ORAUT-TKBS-0010-5). Limited environmental air monitoring data are available for the period prior to 1971; air sampling began in 1944. Although the data available for the earlier years are incomplete and not radionuclide-specific, they may provide a mechanism for establishing bounding conditions. With area and environmental monitoring data missing for some time periods and deficient for all ROCs, a complete assessment of potential dose cannot be performed without the use of unsubstantiated assumptions. The data that are available, together with the application of dose-maximizing approaches provided in the Project's technical information bulletins, will only provide a mechanism for partial estimations of worker intakes for those buildings, time periods, and radionuclides for which data are available.

7.2.1.5 Radon

A search of the Site Description (ORAUT-TKBS-0010-2) and Occupational Internal Dose (ORAUT-TKBS-0010-5) TBDs found only two references to radon. In TA-1 and Buildings O and Q, the presence of radon is reported in relation to the use, preparation, or failure of radium calibration sources or radium-beryllium neutron sources. In addition, Health Division Reports for 1947 and 1951 reference air monitoring and breath sampling for radon related to a radium storage vault and the resultant installation of a vent (LASL HD, 1947 and 1951). However, results of these analyses are not available.

7.2.1.6 Application of Co-Worker Data for Internal Dose Reconstruction

A draft technical information bulletin (ORAUT-OTIB-0062, draft) has been developed for dose reconstruction using co-worker data for specific radionuclides during discrete time periods. The intake rates provided in the OTIB cover the following radionuclides and time periods:

- Plutonium-239: 1/1/1945 through 12/31/1988
- Plutonium-238: 1/1/1968 through 12/31/1988
- Uranium: 1/1/1950 through 12/31/1988
- Tritium: 1/1/1950 through 12/31/1988
- Polonium: 1/1/1947 through 12/31/1956
- Cesium: 1/1/1970 through 12/31/1988

7.2.2 Ambient Environmental Internal Radiation Doses at LANL

The Technical Basis Document for Environmental Occupational dose for the LANL Site Profile (ORAUT-TKBS-0010-4) lists relevant monitoring or other data pertinent to estimating environmental internal dose. No data were provided for years prior to 1970 that would allow dose reconstruction. From 1970 through 1975, a substantial amount of data is provided for several ROCs in each of the TAs. However, gaps exist for specific radionuclides and periods of time. It is possible that the data gaps for certain radionuclides may be filled by assuming or calculating a ratio to others for which data exist. The feasibility of such an analysis has not been investigated because no developed and approved methodology exists at this time.

7.2.3 Internal Dose Reconstruction

There are numerous scenarios involved with the SEC-00051 petition that must be independently evaluated prior to determining if the internal dose for each scenario can be reconstructed using assumptions that are favorable to the claimant. These scenarios are a result of the broad historical timeframe of the site, the multiple monitoring programs in place over the timeframe under evaluation, and multiple ROCs. Table 7-7 provides 24 combinations of worker categories and ROCs. The time span of each category loosely coincides with the implementation of monitoring programs for the major ROCs identified in site historical documents, or summaries provided in the LANL Site Profile (ORAUT-TKBS-0010) and the draft technical information bulletin ORAUT-OTIB-0062 (draft). It is critical to note that many of the following internal dose reconstruction scenario discussions rely on the analysis and on-going development of co-worker data sets for various ROCs. Draft ORAUT-OTIB-0062 provides co-worker *in vitro* and/or *in vivo* data analyses and intake modeling for only the following radionuclides for the date ranges discussed below: H-3, Pu-239, Pu-238, Po-210, U, and Cs-137.

NOTE: The determination whether claimant-favorable estimates of potential internal dose can be performed for each worker category/ROC combination is discussed in turn. In the discussions below, the numbers to the left refer to the corresponding scenario number in the Table 7-7 cells.

Table 7-7: LANL Internal Dose Scenarios by Worker Category and ROCs

Worker Category	Internal Dose Radionuclides of Concern (ROCs)			
	Uranium	**Plutonium**	**Tritium**	**Fission Products/ Misc. Transuranics/ Thorium /^{210}Po /^{241}Am**
Monitored/ Terminated Pre-1950[1]	1	2	3	4
Unmonitored/ Terminated Pre-1950[2]	5	6	7	8
Monitored/Employed 1950 through 1969[1]	9	10	11	12
Unmonitored/Employed 1950 through 1969[2]	13	14	15	16
Monitored/Employed 1970 through 1975[1]	17	18	19	20
Unmonitored/Employed 1970 through 1975[2]	21	22	23	24

Notes:

[1] The monitored category represents those workers who were radiologically monitored, or those who should have been monitored (by then-current monitoring standards).

[2] The unmonitored category represents those workers who were not radiologically monitored because they worked in areas with low exposure potentials by then-current monitoring standards (i.e., exposure scenarios in which ambient environmental dose was typically assigned).

Monitored/Terminated Pre-1950

Only workers perceived to be at risk, or those involved in incidents, submitted samples for bioassay. Also, workers assigned to temporary assignments may not have been required to submit a sample regardless of the exposure potential (i.e., worked in areas where they should have been monitored).

1) Uranium: Uranium may have been the primary ROC prior to 1950, and certainly prior to 1945 when significant (kilogram) quantities of plutonium arrived on site. Monitoring for uranium consisted of routine urinalysis starting in 1949 for employees identified as being at risk for exposure (ORAUT-TKBS-0010-5, Table 5A-14). Nasal swipes with more than 50 cpm indicated the need for follow-up bioassay. Contributions to internal dose from uranium intakes to workers for TAs where uranium was handled can be reconstructed using the unmonitored worker methodology described in Section 5.6 of ORAUT-TKBS-0010-5 (prior to the advent of the uranium bioassay program in 1949). This approach recommends estimating hypothetical intake rates for workers based on either the average or maximum enriched uranium air sampling data from the DP East site. As bioassay monitoring data are available after 1949, internal uranium doses can be reconstructed for the period after 1949 using the inferred isotopic fractions and described methodology in Section 5.2.4 of ORAUT-TKBS-

0010-5. Other information useful to dose reconstruction (i.e., solubility fraction, analytical methods, MDAs, co-worker data, etc.) can be found in ORAUT-TKBS-0010-5 and draft ORAUT-OTIB-0062.

2) Plutonium: Only milligram quantities of plutonium existed in 1943, but this amount increased to kilograms by 1945. A routine urinalysis program was implemented in 1944 but not perfected until 1945. For workers in TAs where plutonium was handled and who may have terminated employment prior to the onset of routine bioassays, the plutonium contribution to internal dose could be reconstructed by using the unmonitored worker methodology described in Section 5.6 of ORAUT-TKBS-0010-5. This approach recommends estimating hypothetical intake rates for workers based on either the average or maximum plutonium air sampling data from Building D. Data are available and internal plutonium doses can be reconstructed for the period after 1945. However, the plutonium isotopic distribution is not available and early results are reported as plutonium or Pu-239. For dose reconstruction, the values should be considered total plutonium alpha counts, which would include Pu-239, Pu-240, and Pu-238. Data providing the nominal isotopic distribution for weapons-grade plutonium are available in ORAUT-TKBS-0010-5. Co-worker data and intake modeling beginning in 1945 are provided in draft ORAUT-OTIB-0062.

3) Tritium: Site documents indicate operation of an accelerator, a Van de Graaff generator, and other operations during this timeframe that may have been sources of tritium exposure. In addition, tritium was used in TA-1 as early as 1946. There are no records of tritium monitoring prior to 1950. Tritium contributions to internal dose to workers in applicable TAs cannot be reconstructed prior to this time because available Project technical information bulletins do not provide a method for estimating the maximum plausible tritium contribution to internal dose.

4) Mixed Fission Products/Mixed Activation Products: Historical documentation indicates the implementation in 1947 of a gross-beta-in-urine analysis for mixed fission products (MFP)/mixed activation products (MAP). These materials would have been present in TAs associated with reactors, spent fuel handling, accelerators, and residual contamination in RaLa-associated TAs. However, bioassay records for these radionuclide analyses are not available. This, combined with the lack of air monitoring data available at the time of this evaluation, precludes reconstruction of internal doses from MFP/MAP during this time period. Recently-obtained records may permit future maximizing-dose reconstructions for specific areas for which air limited monitoring data records have now been identified.

Americium: Am-241 is a contaminant in aged weapons-grade plutonium. The fraction of the total alpha activity is small, typically less than 10%. Pure Am-241 was used for various purposes at LANL, including the manufacture of Am-Be sources. However, it can be reasonably assumed that exposure to pure Am-241 was unlikely prior to full implementation of the americium bioassay program in 1954, which coincides with the beginning of work with pure sources of Am-241. Prior to this time, little Am-241 monitoring data have been identified; recently-obtained data show an earliest date of 1949. If plutonium bioassay data are available, a claimant-favorable value for Am-241 can be inferred from nominal isotopic fraction values found in ORAUT-TKBS-0010-5. The maximum dose from unmonitored Am-241 intakes associated with plutonium operations can be reconstructed if associated plutonium data are available from individual records or co-worker data. Other bounding-exposure

scenarios may be possible by applying monitored worker data discussed above that include doses from unmonitored intakes of Am-241 associated with plutonium exposure, or by using methods described in ORAUT-TKBS-0010-5.

Polonium: Work with Po-210 was of limited scope and duration from 1944 to 1959, primarily consisting of construction of nuclear weapon initiators. Personnel monitoring was performed for the entire duration. The urinalysis method during 1944 could not distinguish between plutonium and polonium so the results were assigned based on the individual's work history. (Note: This approach has some validity because during 1944 there was a limited quantity of plutonium and work was restricted to specific facilities). From 1944 onward, plutonium was extracted from urine samples prior to counting. Claimant-favorable conditions are provided in ORAUT-TKBS-0010-5 when estimating internal monitored or missed dose from polonium. The analysis of co-worker data being developed for ORAUT-OTIB-0062 (draft) should allow reconstruction of the bounding (maximum) dose from Po-210 from 1950 to 1956 for workers who should have been monitored but were not. There is a gap in co-worker data from 1956 to 1959 (when polonium operations ceased). However, if it is assumed that routine operations were consistent from year to year, the co-worker information may possibly be extrapolated. Co-worker data and intake modeling beginning in 1947 are provided in draft ORAUT-OTIB-0062.

Thorium, Actinium, Curium, Protactinium: There are numerous references in Health Division reports to the use of and monitoring for these radionuclides. However, specific information on processes and quantities is not available. Th-230 may have been present as a natural component of uranium. There is a listing for a procedure for Th-230 noted in 1958, but no monitoring data has been identified to support this. No monitoring results have been found for the remaining radionuclides (Th-232, Cm-244, and Pa-231) from 1943 to 1950, which would suggest that isotopic techniques were either not available or not implemented. Should beta-emitter urinalysis data be identified in the future, Ac-227 activity would be included in the total beta urinalysis and be attributed to mixed fission product beta (Sr-90/Y-90) which would again be non-conservative. ORAUT-TKBS-0010-05 mentions that one notebook was found containing 15 bioassay results for actinium.

Unmonitored/Terminated Pre-1950

Workers who were not perceived to be at risk or were not involved in incidents were not monitored (because they worked in areas with low exposure potentials by then-current monitoring standards (i.e., exposure scenarios in which ambient environmental dose was typically assigned).

5–7) Uranium, Plutonium, Tritium: The optimum source of data to estimate doses to this category of unmonitored workers is dose from ambient environmental exposures. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible by applying monitored worker data that include co-worker data analyzed per ORAUT-OTIB-0019 (which has been performed and documented in ORAUT-OTIB-0062 [draft]) or by using methods described in ORAUT-TKBS-0010-5.

8) Polonium: The optimum source of data to estimate doses to this category of unmonitored workers is dose from ambient environmental exposures. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible through the application of monitored worker data which include the analysis of co-worker data provided in ORAUT-OTIB-0062 (draft) (to bound dose from Po-210 from 1947 to 1950) or methods described in ORAUT-TKBS-0010-5.

Americium: The optimum source of data to estimate doses to this category of unmonitored workers is dose from ambient environmental exposures. Available data are insufficient. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible through the application of monitored worker data which include doses from unmonitored intakes of Am-241 associated with plutonium exposure or methods described in ORAUT-TKBS-0010-5.

MFP/MAP, Th-232, Th-230, Ac-227, Pa-231: Insufficient coworker data were available for dose reconstruction for MFP/MAP, Th-232, Th-230, Ac-227, or Pa-231.

Monitored/Employed 1950 through 1969

Only workers perceived to be at risk, or those involved in incidents, submitted samples for bioassay. Also, workers assigned to temporary assignments may not have been required to submit a sample regardless of the exposure potential (i.e., worked in areas where they should have been monitored).

9-11) Uranium, Plutonium, Tritium: As noted, urinalyses for uranium, plutonium, and tritium have been performed during this entire period. In addition, plutonium bioassay data from 1968 on may be reported as Pu-238 or Pu-239. Pu-238 results reflect employees involved in the production of radioisotope power-generation devices. Data sufficient to reconstruct the dose from these radionuclides are reported in ORAUT-TKBS-0010-5.

12) Mixed fission Products/Mixed Activation Products: There were no analytical techniques in use prior to 1955 that would provide an isotopic result for MFP/MAP activity. According to ORAUT-TKBS-00010-5, a method for measuring gross beta activity in urine had been developed. If these results are available, the maximum dose from MFP/MAP might be estimated by assuming all beta activity consists of Sr/Y-90. At the time of this report, this assumption has not been validated. Whole body counting was initiated in 1955. If these results are available, they can be used to estimate the dose for gamma-emitting species for monitored individuals. If neither gross beta urinalysis nor whole-body counting results are available, a claimant's dose cannot be reconstructed.

Americium: Prior to 1954, little bioassay was identified for Am-241; recently-obtained data show an earliest date of 1949. As noted, the dose from americium may be bounded by using a conservative ratio to plutonium, if those data exist. After 1954, bioassay results should be available for monitored employees but are likely to reflect operations using "pure" Am-241 and should be added to Am-241 associated with plutonium results, as described previously. The data available for the years between 1949 and 1954 require validation, review, and incorporation into the project database.

Polonium: As stated above, analysis for polonium in urine was initiated in 1944. From 1944 until 1945, bioassay counts were attributed based on job assignment since the technique could not distinguish between polonium and plutonium. The use of polonium ceased in 1959, with the exception of sealed sources. The possibility of a polonium intake after this date is remote.

Thorium, Actinium, Curium, Neptunium, Protactinium: There are numerous references in site documentation regarding the use of these radionuclides as well as the apparent absence or unsuccessful development of a bioassay program (see Section 7.4.3). These references began in the early 1950s and remained a concern through the early 1990s. Evidence of this latter concern was included as a finding in the DOE Tiger Team Report for LANL (Tiger Team, 1991), as follows:

> *Personnel of the Isotope and Structural Chemistry Group, the Ceramic Science and Technology Group working with Th-232 and its decay products during chemistry operations in TA-21 and TA-3 Building SM-66 are not enrolled in the bioassay program of assessment of potential internal exposures. Line managers were not aware that thorium and its decay products were internal hazards and that workers handling gram quantities of dispersible thorium oxide powders…should be identified for participation in the bioassay program.*

Furthermore, no records have been identified that specifically identify forms, quantities, or processes for which these various radioactive materials were used during the evaluation period. Th-230 may have been present as a natural component of uranium. No monitoring results have been found for the remaining radionuclides (Th232, Cm-244, and Pa-231), which would suggest that isotopic techniques were either not available or not implemented. Should beta-emitter urinalysis data be identified in the future, Ac227 activity would be included in the total beta urinalysis and be attributed to mixed fission product beta (Sr-90/Y-90) which would again be nonconservative. ORAUT-TKBS-0010-05 mentions that one notebook was found containing 15 bioassay results for actinium. See the discussion under Scenario 4 above. Note: Although neptunium is not specifically discussed in Scenario 4, the conclusion therein is applicable for Np-237.

Unmonitored/Employed 1950 through 1969

Workers who were not perceived to be at risk, or were not involved in incidents, were not monitored (because they worked in areas with low exposure potentials by then-current monitoring standards (i.e., exposure scenarios in which ambient environmental dose was typically assigned).

13-15) Uranium, Plutonium, Tritium: The optimum data source for estimating doses to this category of unmonitored workers is dose from ambient environmental exposures. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible through the application of monitored worker data which include the analysis of co-worker data provided in ORAUT-OTIB-0062 (draft) or methods described in ORAUT-TKBS-0010-5.

This analysis has been performed and documented in ORAUT-OTIB-0062 (draft) and provides daily intake estimates for the following radionuclides over the time periods indicated:

- Plutonium-239: 1945 through 1975+
- Plutonium 238: 1968 through 1975+
- Uranium: 1949 through 1975+
- Tritium: 1950 through 1975+

16) Mixed Fission Products/Mixed Activation Products: Co-worker *in vivo* monitoring data are insufficient from 1970 through 1975. Before 1970, there appear to be no data other than the recently-identified, but limited area airborne monitoring data.

Americium: The optimum data source for estimating doses to this category of unmonitored workers is dose from ambient environmental exposures. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible through the application of monitored worker data which include the analysis of co-worker data provided in ORAUT-OTIB-0062 (draft) or methods described in ORAUT-TKBS-0010-5. As previously discussed, Am-241 associated with plutonium operations can be inferred from isotopic ratios for weapons-grade plutonium (if plutonium bioassay results exist) using the isotopic ratios found in the Wingfield inventory (Wingfield, 1974)**.** The potential dose from unmonitored intakes of "pure" Am-241 (after 1954 until 1970 when *in vivo* monitoring data are available) can only be reconstructed by assigning a hypothetical intake.

Polonium: The optimum data source for estimating doses to this category of unmonitored workers is dose from ambient environmental exposures. In the absence of ambient environmental exposure data, bounding exposure scenarios may be possible through the application of monitored worker data which include the analysis of co-worker data provided in ORAUT-OTIB-0062 (draft) or methods described in ORAUT-TKBS-0010-5. The analysis of co-worker data provided in ORAUT-OTIB-0062 (draft) will allow reconstruction of the bounding (maximum) dose from Po-210 from 1947 to 1956. There is a gap in co-worker data from 1956 to 1959 (when polonium operations ceased). However, if it is assumed that routine operations were consistent from year to year, the co-worker information may possibly be extrapolated. At the time of this report, that analysis has not been completed. After 1959, it can be assumed that the chance of a polonium intake is remote, and if it occurred, a bioassay would have been performed.

Thorium, Actinium, Curium, Neptunium, Protactinium: See the discussion under Scenario 12 above.

Monitored/Employed 1970 through 1975

Only workers perceived to be at risk, or those involved in incidents, submitted samples for bioassay. Also, workers assigned to temporary assignments may not have been required to submit a sample regardless of the exposure potential (i.e., worked in areas where they should have been monitored).

17–20) Uranium, Plutonium, Tritium, MFP/MAP: After 1970, with the onset of chest counting and improved analytical capabilities, LANL possessed the ability to monitor for all ROCs with the exception of Ac-227, Cm-244, and Pa-231. Ac-227 and Pa-231 possibly could be quantified by the chest count procedure. However, no information has been found that would indicate an attempt at this process.

Unmonitored/Employed 1970 through 1975

Workers who were not perceived to be at risk, or were not involved in incidents, were not monitored (because they worked in areas with low exposure potentials by then-current monitoring standards (i.e., exposure scenarios in which ambient environmental dose was typically assigned).

21-24) Uranium, Plutonium, Tritium, MFP/MAP: Doses can be reconstructed from co-worker data for the following ROCs from 1970 on: Pu-238, Pu-239, uranium, and tritium (significant operations involving polonium ceased in 1959).

Americium: The maximum dose from unmonitored Am-241 intakes can be reconstructed if associated plutonium data are available, and for pure sources, by evaluating the *in vivo* chest count data. See the discussion under Scenario 16 above.

Thorium, Actinium, Curium, Neptunium, Protactinium: See the discussion under Scenario 4 above.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Through December 2006, 657 EEOICPA claims from LANL workers with employment dates between March 15, 1943 and December 31, 1975 had been submitted to NIOSH. Of those 657 claims, dose reconstructions have been completed for 300 claims, and three claims are awaiting a response to NIOSH's request for monitoring data. These claims cover the entire range of the LANL evaluation period in this report and include claims with internal monitoring data. There are 384 claims with hire dates within the petition timeframe that have internal monitoring data available: five have data between 1943 and 1945, 68 have data between 1946 and 1950, and 308 have data between 1951 and 1975.

Based on the information provided in the previous discussion, the dose from intakes cannot be reconstructed for specific radionuclides for varying periods spanning a significant percentage of the period from 1943 to 1975. Since information on a claimant's exact work location is rare, it will be necessary in most cases to assume exposure to all ROCs. For these reasons, dose reconstructors will be unable to provide an estimate of a claimant's maximum internal dose for this period. The dose from exposure to some of the major ROCs (H-3, Pu-239, Pu-238, Po-210, U, and Cs-137).can be reconstructed for the majority of the time period using co-worker data or other assumptions. The

exceptions are Am-241 from operations involving "pure" sources which started in 1954 (although this conclusion may be altered based on the newly-identified data), MFP/MAP, Th-230, Th-232, Ac-227, Cm-244, Np-237, and Pa-231. At this point, the cumulative effect of the doses from these ROCs must be considered significant. This conclusion is based on the reporting of these radionuclides in effluent release and waste records as well as various other documents discussed throughout this evaluation. With no information to the contrary, and to be claimant-favorable, it must be assumed that doses from these radionuclides are not negligible. This could lead to the conclusion that major components of the potential dose cannot be reconstructed over the entire period of interest (1943 to 1975).

Table 7-8 presents a summary of the data deficiencies listed by period and radionuclide.

Table 7-8: Summary of LANL Data Deficiencies

Period	Radionuclides with No Reconstruction Data or Method
1943 -1949	Tritium, MFP/MAP, Am-241 (if no Pu data and pending validation of newly-identified bioassay data), Th-232, Th-230, Ac-227, Pa-231, and Cm-244.
1950 - 1969	MFP/MAP, (without the validation of the newly-identified air monitoring data), Am-241 (if no Pu data or from "pure" process), Th-232, Th-230, Ac-227, Pa-231, Np-237, and Cm-244.
1970 – 1975[1]	MFP/MAP, Am-241 (if no Pu data or from "pure" process), Th-232, Th-230, Ac-227, Pa-231, Np-237, and Cm-244.

[1] Some radionuclide maximum intakes possibly could be inferred from the chest counting data. However, at the time of this report, an analysis of this technique has not been performed. This technique most likely could not be used for Cm-244 due to the 18.7 y half-life and with only a 10% yield 14 keV X-ray. References to direct work with Cm end in 1975, other than burial grounds and minor residual contamination in TA-1 Building 3 and ML.

7.3 External Radiation Doses at LANL

The principal sources of external radiation doses for members of the proposed class were exposures to photon, neutron, and beta radiations (ORAUT-TKBS-0010-6). The radiation sources contributing to external doses were:

- Reactors/accelerators/X-ray-generating equipment/criticality facilities (gamma, X-ray, neutron, and beta radiation)
- Plutonium chemistry and metallurgy (gamma and neutron radiation)
- Uranium chemistry, metallurgy, machining, and testing applications (gamma and beta radiation)
- Initiators (neutron radiation)
- RaLa (photon and beta radiation)

- Spent fuel or waste handling and processing (gamma and beta radiation)
- Calibration and other miscellaneous sources (gamma, neutron, and beta radiation)
- Periodic medical examinations (X-ray radiation)

7.3.1 Process-Related External Radiation Doses at LANL

The following subsections summarize the extent and limitations of information available for reconstructing the process-related external doses of members of the proposed class.

7.3.1.1 Radiation Exposure Environment

The diverse nature of the LANL mission resulted in innumerable external exposure environments ranging from low-energy photons shielded by dry boxes in the plutonium operations, to full immersion in beta-gamma fields from reactor gas line leaks, direct exposure to X-ray and accelerator beams, and criticality neutron bursts. In the reactor, accelerator, X-ray-generating, radiography, and criticality facilities, exposures were possible from gamma, X-ray, neutron, and beta (or electron) radiations.

Operating reactors were a source of gamma, beta, and neutron radiation. Exposures during operation were possible from: mixed fission and activation products present in systems, system leaks that periodically developed, off-gas systems, and activated components; and to neutrons from core leakage or from neutron beam ports. Exposures to beta-gamma radiation from mixed fission and activation products present in reactor components and systems, wastes, and spent fuel were possible when reactors were in shutdown mode, during spent fuel handling and evaluation, waste handling, or during decommissioning. TA-2 (Omega Site) was the primary reactor technical area. Other reactor areas included the Project Rover Kiwi Reactors developed in TA-18, the Molten Plutonium and Power Reactor experiments in TA-35, and the UHTREX Reactor in TA-52.

External exposures from accelerators were from neutrons, electrons, and X-rays while the beam was operating, and mixed air activation products and activation products in the target and accelerator structure both during operation and after the beam was shut down. The highest external dose rates would be directly in the beam path. Typically, there would be varying degrees of access controls in place (from warning lights to automatic interlocks) to warn or prevent personnel from entering the unit while the beam was operating. There were multiple accelerators at LANL located in TA-1, -3, and -53.

Radiation from X-ray and radiography equipment would have consisted primarily of photons when the equipment was operating or when a radiography source was raised from the source well. Activities involving these systems were located in TA-8, -13, -15, -16, -24, -35, and -51.

In the plutonium processing areas of TA-1, -3, -21, and -55, the primary sources for external radiation exposure were low-energy photons from plutonium and Am-241, a progeny of the Pu-241 present in weapons-grade plutonium (WGPu). Also present were neutrons from spontaneous fission of even isotopes of plutonium, alpha-neutron reactions, and low abundance neutron-induced fissions.

In the uranium chemistry, metallurgy, machining, and testing applications processing areas, the primary external radiation exposure concern was high-energy beta emitters from uranium progeny and

impurities. During processes such as melting and casting, these daughter elements may concentrate on the surface of the castings and equipment, producing elevated beta dose rates. Photon doses from uranium were typically a small fraction of the beta doses; however, storage of large amounts of uranium would have had associated low-level gamma radiation fields (DOE-STD-1128-98). Similar conditions would have also existed in areas involved with thorium.

Initiator production primarily involved polonium-210 processing; lesser quantities of radium-226 and actinium-227 were also used. Gamma intensities during production of the PoBe neutron sources were considered very low; fast neutron exposures were considered the limiting exposure scenario. Therefore, after an initial film badge monitoring trial period showed no gamma exposures, workers discontinued wearing film badges in DP East (TA-21).

The primary radioactive materials associated with the radioactive lanthanum (RaLa) program were Ba-140, La-140, Sr-89, and Sr-90 (with half-lives of 12.7 days, 1.7 days, 50.6 days, and 28.5 years, respectively). The evaluation report for Petition SEC-00061 extends 16 months beyond the date of the final RaLa implosion test. During those 16 months, the relatively short-lived radionuclides (Ba-140, La-140, and Sr-89) would have decayed to insignificant levels. Therefore, residual Sr-90 (with its daughter product yttrium-90) is the only contaminant associated with the RaLa program that pertains to this present evaluation. Sr-90 was present as a production contaminant in the Ba/La-140 that was processed and was distributed to the environment during the test shots. External exposure to these materials would be primarily from beta radiations.

External exposures during spent fuel handling and processing (primarily fission products) or waste handling and processing (potentially all known radionuclides used at LANL) would have been primarily from gamma radiation with some potential for beta radiation. In many cases of waste handling, beta exposures would have been limited if the waste was containerized. Spent fuel would have been handled remotely due to the high radiation levels, with processing also done remotely within shielded hot cells.

External exposures to gamma, beta, and neutron radiation were also possible from the handling and use of calibration, radiography, and other miscellaneous sources. Calibration sources would have included Co-60, Ra-226, Cf-252, and others for calibrating and evaluating film badge response. Radiography sources included curie level sources of Cs-137 and Co-60.

Lastly, periodic medical examinations at LANL required chest X-rays on an annual or semi-annual basis.

Beta and Photon Characterization

For activities related to weapons production, including H-3 production; plutonium processing and production; uranium processing, machining, and test firing; and RaLa, the exposure spectrum was dominated by a wide energy range for beta (0.019 Mev to 2.29 MeV) and low-to-middle energy range for photons (<0.030 to 0.250 MeV). Higher-energy photons (>0.250 MeV) that would have been associated with the RaLa program are addressed in another petition (SEC-00061) and are not considered in this evaluation.

Radiations from reactor and accelerator operations would have encompassed a broad spectrum of energies, primarily from 0.030 to greater than 0.250 MeV for photons, but also including a lesser abundance of photons less than 0.250 MeV as well as beta energies greater than 0.015 MeV.

Waste-handling spectrums are source-specific and would have encompassed the range of energies previously described.

Neutron Field Characterization

The energy spectrum encountered from reactors, accelerators, plutonium production, and calibration sources ranged from the thermal energy region (0.025 eV) through the fission spectrum (0.1 to 6.0 MeV) with a predominant energy range of 0.7 to 1.0 MeV; the spectrum also included high-energy, accelerator-produced neutrons with energies up to 20 MeV.

7.3.1.2 History of Whole Body External Monitoring

The procedures for monitoring and interpreting the external exposures of LANL workers were continually being evaluated and refined. The initial external exposure hazards were primarily associated with radiation generated from the early accelerators and, to a lesser extent, uranium chemistry and metallurgy. Beginning in 1943, these initial exposures were monitored by PICs issued to individuals thought to have the highest exposure potential. The PIC exposure measurements were read and recorded on a daily basis.

By mid-1944, film badges containing dental X-ray film were gradually phased in, originally as a means to evaluate the PIC exposure measurements. Film dosimetry started when site operations were expanded to include reactors, critical assemblies, expanded plutonium work and inventories, and chemical processing and test shots involving RaLa. These early film badges were exchanged and analyzed on a monthly basis and were only used to measure the photon deep dose; shallow beta exposure doses and neutron doses were not monitored. Although film badges were originally assigned to those individuals thought to have the greatest exposure potential, within three years badge assignments had expanded to over 1,000 workers. Following a fatal criticality accident, separate catastrophe badges began to be issued in 1945 to workers who could be involved in future criticalities. Uranium workers also may have been monitored for extremity dose with ring film badges or film badges within work gloves, which were later replaced by wrist film badges.

There was no monitoring of beta shallow dose exposure prior to 1949. Early thermal neutron monitoring was performed until 1949 using PICs. There was no fast neutron monitoring until 1949 when nuclear track plates began to be issued. However, a 1968 site study determined that these early neutron dosimeters lacked adequate neutron sensitivity to provide meaningful exposure results.

Recognition of the energy dependence of film response to the highly-variable photon fields present within the various TAs, and the need to monitor beta radiation exposures, led to replacement of the original film badge. Unless calibrated to the photon environment in a given workplace, the interpretation of film badge response would result in reporting higher-than-actual whole-body exposures in low-energy photon fields, and lower-than-actual whole-body exposures in higher-energy fields. A brass clip badge capable of separating beta from gamma exposures was instituted in 1949, immediately followed in 1950 by a brass-lead clip film badge for differentiating various gamma

energies. A 1951 changeover to a brass-cadmium badge added NTA film for fast neutron dosimetry. The multi-element Cycolac badge was introduced in 1962 and was designed to provide gamma/X-ray, beta, neutron, and accident neutron dosimetry. Thermoluminescent dosimeters (TLDs) replaced the Cycolac badge in 1978 (after the period addressed in this evaluation). Numerous studies have been conducted to evaluate and account for the energy dependence of the various dosimeters, and ultimately how doses were reported.

Exchange frequencies for the various badge types were typically every two to four weeks, but may have been more frequent, in some cases daily for operations with high exposure potential. Exchange frequency directly affects the minimum detection level (MDL), and hence, potential missed dose; shorter exchange frequencies have higher MDLs.

LANL worker external exposure monitoring practices concentrated on those individuals or operations with the greatest potential for exposure. However, site documentation provides significant information that the enforcement of administrative monitoring procedures and requirements may have been inadequate during some of the time period under evaluation. Recognition of these issues was documented and procedural changes recommended. Relevant excerpts from various reports available on the site research database are provided in Section 7.4.3 below.

7.3.1.3 History of Extremity Monitoring

The available historical documentation indicates that extremity monitoring began in 1951 when a finger film badge was developed. These badges were worn directly on the hand or placed inside leather work gloves. Issues with discomfort while wearing the ring badges led to replacement of ring badges with wrist badges. Studies were performed to develop exposure dose ratios between the finger badges and wrist badges. Extremity badging was used for workers involved in the production of "urchin" type initiators and uranium metal operations.

7.3.1.4 Neutron Dosimetry Issues and Dose Reconstruction

Throughout LANL's operating history, neutron dose has been a primary constituent of the collective site dose. However, personnel neutron monitoring was not implemented until 1949 when NTA films were added to film badges to monitor fast neutron exposure. Monitoring of thermal neutron exposure began in 1953. A series of Atomic Energy Commission workshops were held beginning in 1969 to address issues related to accurately measuring neutron dose at AEC facilities. Studies determined that neutron doses had been significantly underestimated for fast neutrons in the intermediate energy range. This was the result of the NTA neutron energy response threshold of 700 keV. Therefore, worker dosimetry worn to monitor fast neutron exposures would not have responded to neutron fluences below this threshold; hence, a worker's contemporary neutron dose of record may have shown no exposure or been underestimated. Because of this monitoring gap, uncertainty about where individuals may have worked, and whether they were exposed to fluences below the threshold, neutron doses cannot be directly reconstructed using the neutron monitoring records or co-worker data.

7.3.1.5 Dosimetry Records

Table 7-9 summarizes the chronological events related to types of dosimetry, methods of calculation, units of reporting, and record-keeping practices.

Table 7-9: LANL Dosimetry Records Chronology

Year	Relevant Events
1943	Monitoring for external radiation exposures begins using pocket ionization chambers (PICs); gamma exposures are recorded in units of roentgen (R). External radiation evaluation results are recorded in notebooks that eventually find their way to the Document Room for permanent filing (LASL PEB, 1959; 01/20/51 document). This practice continues until the onset of the Cardex system in 1953.
1944	Beginning mid-year, the transition to film badge dosimetry begins; only the photon component is measured.
1945	Film badges come into use by more and more LANL groups; only gamma exposures were evaluated (in roentgens).
1946	*NOTE: A NIOSH review of LANL dose reconstruction cases found that, for cases corresponding to the relevant timeframe, there were no external monitoring results available prior to 1946.*
1949	Sometime prior to 1949, some LANL personnel who work with the cyclotron and other neutron sources wear Victoreen pencil PICs to determine their neutron dose (LASL, 1969; 11/12/68 memorandum). The results are recorded in "n-units," which are defined as "the quantity of neutron radiation that will produce the same ionization in a 100-R Victoreen chamber (red bakelite) as 1 R of gamma radiation." *NOTE: While "n-unit" data were recorded in medical records of some individuals, they were apparently never converted to the computerized database of exposure records (Widner, 2004).* Starting in January, the following values were recorded on personnel exposure sheets: pocket ionization chamber readings (R), gamma exposure (R), beta exposure in roentgens equivalent physical (rep). Beta exposure was reported only when "it forms a significant part of the total exposure" (LASL PEB, 1959; 01/10/49 memorandum). No entry in the beta exposure column indicated that a negligible amount of beta exposure was present. For DP Site personnel working with plutonium and for soft X-ray evaluations, special calibration curves are used, and gamma R exposures are multiplied by 0.6 to convert to gamma rem (LASL PEB, 1959; 07/01/56 document). *NOTE: The comparable DOELAP roentgen-to-rem dose conversion value is 0.38 for 16 keV photons (*DOE/EH-0027*).* In August, separate Nuclear Track Plates (NTPs) come into use to monitor fast neutron exposure. Shallow dose exposure monitoring begins. The basic film badge is modified to a brass clip film badge to permit separating the beta and photon exposure components.
1950	The brass clip film badge is replaced by a brass-lead clip film badge that can differentiate various gamma energies.
1951	The brass-lead clip film badge is replaced by a brass-cadmium badge with Nuclear Track, Type A emulsion (NTA) film for fast neutron exposure monitoring. Tolerances for neutrons are stated in terms of neutrons cm^{-2} sec^{-1} (LASL PEB, 1959; Jan. 1953 document). *NOTE: It was determined in the late 1960s that the neutron monitoring performed using NTA film from 1951 up until that time was not adequate.*
1952	In uranium areas (e.g., foundry, HT shop, Sigma area), only beta exposures are directly monitored; this practice continues until 1956. *NOTE: Some gamma exposures should have been recorded for workers at those facilities (LASL PEB, 1959; 04/03/57 document).*

Table 7-9: LANL Dosimetry Records Chronology	
Year	**Relevant Events**
1953	In January, a "Cardex" system for filing exposure data on paper cards is put into use (LASL PEB, 1959; 02/16/56 memorandum). Only plates that are "read" are recorded (LASL PEB, 1959; 02/27/56 document). Neutron doses are reported in terms of rem. *NOTE: This practice possibly occurs before 1953 (LASL PEB, 1959; Jan. 1953 document). It was determined in the late 1960s that the neutron monitoring performed using NTA film from 1951 up until that time was not adequate.*
1956	In January, LANL starts noting all issued NTPs on Personnel Exposure Cardex records. As of February, NTPs are evaluated by assuming that all 10-100 micron tracks represented 3.75 MeV neutrons, and that all longer tracks represent the maximum average energy of the higher-energy neutrons in the workplace. *NOTE: It was determined in the late 1960s that the neutron monitoring performed using NTA film from 1951 up until that time was not adequate.* Beta and gamma exposures are now directly monitored in uranium areas.
1957	A computerized IBM system is first employed to record personnel exposures to radiation (LASL PEB, 1959; 04/3/57 memorandum). To convert radiation exposure records for IBM entry, gamma exposure was retrospectively calculated from the gamma-plus-beta exposure dosimetry values by using a factor of 1/10 of the total exposure measured. The theoretical ratio of gamma to beta plus gamma is reported to be about 1/17 for normal uranium. In July, the roentgen-to-rem dose conversion factor is changed to 0.5 for body badges exposed to low-energy X-rays and plutonium; this practice continues until 1963 (LASL, 1969; 03/20/63 memorandum).
1959	IBM equipment is first used to evaluate film exposures (Littlejohn, 1960). *NOTE: Record-keeping has been computerized ever since.*
1960	Thermal neutron monitoring begins. The following external radiation dose data are recorded (Littlejohn, 1960): gamma dose (rem), beta dose (rad), thermal neutron dose (from cadmium optical density minus brass optical density, rem), fast neutron dose (from NTA film, rem). *NOTE: It was determined in the late 1960s that the neutron monitoring performed up until that time was not adequate.*
1962	The brass-cadmium film badge is replaced by the multi-element Cycolac badge. The Cycolac is designed to provide gamma/X-ray, beta, neutron, and accident neutron dosimetry. *NOTE: It was determined in the late 1960s that the neutron monitoring performed up until that time was not adequate.*
1963	Around March 20, the use of the 0.5 roentgen-to-rem dose conversion factor for body badges exposed to low-energy X-rays and plutonium is discontinued (LASL, 1969; 03/20/63 memorandum).
1972	On January 1, LANL evaluates the assignment of neutron dose equal to TLD-measured gamma dose for workers handling Pu-238 (LASL, 1974; 12/03/71 memorandum). *NOTE: This appears to have been a special study for a relatively small group of workers, possibly using hand-fabricated badges with loose chips, because TLDs were in relatively short supply at that time (Widner, 2003).*

7.3.1.6 Application of Co-Worker Data for External Dose Reconstruction

Co-worker external data can be used to assign doses for workers at DOE sites who have incomplete or no individual monitoring data. Such workers may not have individual monitoring data because: (1) the worker was unmonitored and, even by today's standards, did not need to be monitored; (2) the worker was unmonitored, but by today's standards would have been monitored; (3) another worker was monitored as representative of a group of similar workers; (4) the worker may have been monitored, but the data are not available; or (5) the worker may have partial information but the available information is insufficient to facilitate a dose reconstruction.

Development of site-specific data summaries and dose distributions requires a careful examination of the available data sources to identify the most complete and accurate data set. Prior to this examination, a sampling of the site-wide data set is compared to the claim-specific data submitted to NIOSH by the DOE site. This comparison can provide information needed to adjust the site-wide data set to account for missed dose or for data that may be skewed by an event that would normally impact a small number of workers (e.g., a criticality). Should this comparison shed doubt on the accuracy or completeness of the data selected for analysis, additional evaluations will take place to ensure that a valid data set has been selected.

Selected co-worker data sets are analyzed to develop annual 50^{th} and 95^{th} percentile doses. Prior to these calculations, the doses are adjusted to account for missed dose based on badge exchange frequency and dosimeter MDL. For example, the median annual reported dose might be zero at a particular site in a particular year, but it would not be appropriate to assign a dose of zero as a median value because of the potential for missed dose which must be included in claimants' dose estimates. Specifically, one-half of the maximum annual missed doses are added to the reported annual doses with this exception: when there are reported positive doses, the maximum missed dosed is reduced by the dose corresponding to one badge exchange (because it is not possible that all individual badge results were zero if a positive annual dose was reported). The 50^{th} and 95^{th} percentile annual penetrating doses are then derived by ranking the data into cumulative probability curves and extracting the 50^{th} and 95^{th} percentile doses for each year. A co-worker external exposure technical information bulletin has not been prepared for LANL exposure data at this time. Data summaries of exposure records and recommendations on the incorporation of missed photon dose in the site co-worker data are provided in the LANL Occupational External Dose TBD, ORAUT-TKBS-0010-6.

Available records indicate that between 1944 and 1975, an average of 3,100 workers was annually monitored for external radiation doses. The number of workers monitored ranged from a low of nine workers in 1944 to 4,716 workers in 1975. The limitations in the application of these data as co-worker data will, of course, be subject to those same data gaps that resulted from the limitations of the available direct-monitoring technology.

7.3.2 Ambient Environmental External Radiation Doses at LANL

External ambient photon, and in some cases beta, radiation submersion exposures were possible to workers from several sources in a number of TAs. TAs included reactor, criticality, and accelerator operations as well as waste disposal areas. One of the primary external environmental exposure sources would have been noble gases emitted from the Omega reactor stack in TA-2. Similarly, exposures to air activation products from accelerator operation, as well as beam leakage outside of the accelerator facilities, were also possible sources of increased levels of gamma radiation. Increased gamma radiation was also noted in several Health Division reports on the criticality facilities in TA-18. Direct exposure to gamma-emitting contaminants in soils was also possible where spills had occurred, or in waste areas (e.g., Acid Canyon) which received direct liquid waste discharges from TA-45. Historical reports refer to the placement of area monitoring film badges at various site locations. However, the associated data have only been located and available after 1965. Contributions to the total external exposure from ambient environmental pathways are primarily a concern for unmonitored workers because dose from these pathways would have added to the film badge exposure of monitored workers, provided that area monitoring results were not subtracted as

background contribution from the employees' dose records. Based on these conditions, contributions and missed dose from environmental external exposure may be accounted for through co-worker data evaluations.

7.3.3 LANL Occupational X-Ray Examinations

As part of its occupational health and safety program, the site required pre-employment and periodic physical medical examinations. These examinations typically included diagnostic chest X-rays. The doses from these diagnostic procedures depended on not only the characteristics of the X-ray machine and the procedures used, but also examination frequency. The required frequencies were, at a minimum, semi-annual through 1963; during the remainder of the evaluation period, examinations were performed annually. For all or part of the evaluation period, examinations may have included two chest views (posterior-anterior view and/or lateral view). Prior to 1957, site records indicate that photofluorography (PFG) equipment was used for exams. Conventional film radiography equipment replaced PFG exams after 1957, with the specific equipment and procedures modified over time (e.g., beam filters and collimation were added).

The Occupational Medical Exposure TBD, ORAUT-TKBS-0010-3, combined with complex-wide technical information bulletins, International Commission on Radiological Protection (ICRP) guidelines, and related agency publications provide methods, recommendations, and default claimant-favorable parameters needed to reconstruct the medical exposure portion of a worker's dose. Claim files reviewed include medical records with notations regarding X-ray occurrence.

7.3.4 External Dose Reconstruction

Through December 19, 2006, 657 EEOICPA claims from LANL workers with employment dates between March 15, 1943 and December 31, 1975 had been submitted to NIOSH. Of those 657 claims, dose reconstructions have been completed for 300 claims, and three claims are awaiting a response to NIOSH's request for monitoring data. These claims cover the entire range of the LANL evaluation period in this report and include claims with external monitoring data. Of these claims, zero have external monitoring data between 1943 and 1945, 124 have data between 1946 and 1950, and 478 have data between 1951 and 1975.

There is an established protocol for assessing external exposure when performing dose reconstructions (these protocol steps are discussed in the following subsections):

- Photon Dose
- Electron Dose
- Neutron Dose
- Unmonitored Individuals Working in Production Areas
- Medical X-ray

7.3.4.1 Photon Dose

The site's recognition of film dosimeter energy dependence and the impact of varying exposure scenarios led to the decision to calibrate and process film badges in-house in order to take these conditions into account. Numerous studies are noted in the site Photodosimetry Books in which film responses to varying exposure conditions were studied and correction factors developed. Furthermore, these issues have been evaluated complex-wide for the dose reconstruction project; the results are documented in technical information bulletin ORAUT-OTIB-0010. Film badge over- or under-response, and the consequent potential for over- or under-reporting of doses, requires an evaluation of a worker's environment and, when it is claimant-favorable to do so, the application of correction factors to the reported dose. In addition, special considerations are required for the TAs with low-energy (<30 keV) photons from plutonium where both the deep dose and non-penetrating dose are not reliably estimated, and for exposures to mixed gamma and beta fields. The assumptions for overestimating dose provided in ORAUT-OTIB-0010 are, therefore, not applicable to LANL's plutonium work areas. The Occupational External Dose TBD, ORAUT-TKBS-0010-6, does provide the necessary site-specific evaluation and recommended guidance to account for the lack of dosimeter response to low-energy photons.

1943 through 1945

During this period, monitoring was primarily performed using PICs. For dose reconstruction cases with employment dates that include this timeframe, none of the cases had external dose monitoring records before 1946. NIOSH's review indicates that individual data may not be available, and therefore, external dose could not be reconstructed for this period. However, the External Occupational Dose TBD does provide summary collective dose data and the number of individuals monitored in 1944 and 1945, as well as other years through 2003 (as supplied by LANL). If the individual records used in this compilation were available, some reconstructions could be performed, although the limited number of monitored workers during 1944 is insufficient to serve as co-worker data for the variable exposure conditions of unmonitored workers. ORAUT-OTIB-0010 does not allow for application of methodologies for calculating overestimates of external exposure for processes or facilities with low-energy photons, and specifically disallows such applications for plutonium facilities. These factors and the collective lack of internal monitoring data for several of the primary ROCs (as previously described for internal dose reconstruction) preclude the need for further evaluation of external doses reconstruction for this time period.

1946 through 1950

During this period, the film badge monitoring program was well established; case reviews show that approximately one-half include external monitoring data records. The dosimetry transitioned from unfiltered film badges to lead cross badges, brass-enclosed film badges, brass clip badges, and finally to the brass-lead film badge during 1950. The various badge types in use during this time also were subject to the energy dependence previously discussed. The addition of the brass clip reduced the required assumptions for determining the beta and gamma components of the film response, and the addition of the lead filter supported differentiation of the gamma energy response. NIOSH contends that adequate records of monitored external photon radiation doses are available for dose reconstruction for this period. Additionally, there is adequate process-specific information and documentation regarding the estimated relative percentages of the photon energy bins (<30,

30-to-250, and >250 keV) applicable to specific processes, TAs, or buildings. Correction factors have been developed that may be applied when warranted and it is claimant-favorable to do so. In addition, the minimum detection capability of the film dosimetry has been evaluated and, together with known exchange frequencies, allows missed doses to be factored in for reconstruction. However, the lack of internal monitoring data for MFPs and other radionuclides (as previously described for internal dose reconstruction) precludes the need for further evaluation of external dose reconstruction for this time period.

1951 through 1970

In 1951, a brass-cadmium film badge replaced the brass-lead film badge and was used until 1962. The multi-element Cycolac badge was used from 1962 through the remainder of the evaluation period (1975). In addition to the various filters for reducing photon energy dependence, both of these badge types included an open window for beta and low-energy gamma evaluation, neutron dosimetry capabilities, and activation foils for criticality accident dosimetry. Although the photon energy dependence response was reduced with the Cycolac badge, continuing site evaluations of response to exposure conditions determined that the brass-cadmium badge underestimated the dose in the low-energy plutonium photon environment by a factor of two to three, depending on whether the photons were filtered by glovebox glass or steel. The Cycolac badge in similar configurations was found to correctly estimate the dose from the higher-energy component, but overestimated the dose from the lower-energy component in the presence of glass or steel filtration. NIOSH contends that adequate records of monitored external photon radiation doses are available for dose reconstruction during this period. In addition, there is adequate process-specific information and documentation regarding the estimated relative percentages of the photon energy bins (<30, 30-to-250, and >250 keV) applicable to most specific processes, TAs, or buildings. Correction factors have been developed that may be applied when warranted and it is claimant-favorable to do so. One exception is the uranium-handling areas, for which exposures prior to 1957 were assigned as pure beta exposures. These results were retrospectively converted to include gamma exposure by including a factor of 1/10 the total exposure measured. In addition, the minimum detection capability of the film dosimetry has been evaluated and, together with known exchange frequencies, may allow missed doses to be factored into the reconstruction. However, the lack of internal monitoring data for MFPs and other radionuclides (as previously described for internal dose reconstruction) precludes the need for further evaluation of external dose reconstruction for this time period.

1971 though 1975

During this time period, the multi-element Cycolac badge was in use and provided a more accurate estimation of external doses for the intermediate to higher-energy photon bins, with the previously-discussed over-response to filtered, low-energy photons. These dosimetry records are available and permit reconstruction of individual dose and are sufficient to develop co-worker data for assigning dose for unmonitored workers. Because of the minimization of the energy dependence, the need to apply correction factors to the recorded dose is also minimized. Recommended adjustments (if needed and claimant-favorable) as well as photon energy distributions for assigning deep dose by process are provided in the Occupational External Dose TBD, ORAUT-TKBS-0010-6. Missed dose may be accounted for via review of exchange frequencies and corresponding minimum detection limits.

7.3.4.2 Electron Dose

1943 through 1948

During this time period, beta (electron) shallow doses were not specifically monitored, although beta radiation was the dominant external radiation hazard during uranium handling. Historical documentation indicates numerous instances of beta overexposures from uranium, fission products, and other unspecified sources. Shallow-dose-to-deep-dose ratios have been evaluated for LANL workers over a ten-year period from the onset of shallow dose monitoring in 1949 until 1958. The evaluation calculated a median annual shallow and deep dose and recommended that a dose of 1.008 times the reported deep dose be attributed to beta radiation for dose reconstruction. Provided that the exposure scenarios and source terms for the period from which the ratio was developed are similar to the unmonitored period currently under evaluation, beta external dose reconstruction would be possible for a portion of the 1943-48 period (i.e., 1946 and after), or for individuals with external photon monitoring records. However, the lack of internal monitoring data for MFPs and other radionuclides (as previously described for internal dose reconstruction) precludes the need for further evaluation of shallow external dose reconstruction for this time period.

1949 through 1975

Throughout this period, beta radiation fields continued to be a source of exposure from most operations. Exposure records are available and include the skin dose from which the non-penetrating dose may be estimated and attributed as the beta category after subtracting any reported deep, neutron and tritium doses. Missed dose may be applied based on the MDL for the time period and the exchange frequency. However, the lack of internal monitoring data for MFPs and other radionuclides (as previously described for internal dose reconstruction) precludes the need for further evaluation of shallow external dose reconstruction for most of this time period.

7.3.4.3 Neutron Dose

Throughout the period under evaluation, neutrons were a significant source of external dose in plutonium, metallurgy, and research TAs, and in those TAs with operating reactors, accelerators, and criticality experiments. In some areas, it is possible that up to 90% of the total dose was attributable to the neutron component. There was no neutron monitoring dosimetry until 1949 when NTPs were issued for monitoring fast neutrons. Thermal neutron monitoring began in 1953 by comparing the optical densities beneath the cadmium and brass filters in the brass-cadmium film badges; monitoring ceased in 1955 and resumed in 1956. While studying the implementation of thermoluminescent dosimeters, the AEC (predecessor to DOE) determined that neutron doses had been underestimated as a result of the NTA response threshold of 700 keV. A review of the neutron fluence energy spectrums for various plutonium areas provided in the TBD show that most of the neutron energies are below this threshold (ORAUT-TKBS-0010-6). Together, the lack of monitoring and the identified under-response of the neutron dosimetry impede the reconstruction process, increase the missed dose that must be accounted for, and increase the overall uncertainty of the calculated dose.

The reconstruction of neutron dose would require assigning all neutron doses as missed doses for the period. Technical Information Bulletin ORAUT-OTIB-0023 provides guidance on applying missed neutron dose for monitored workers. However, the recommended method cannot be applied for LANL because the TIB excludes use of the recommended guidance in cases where the doses were not reliably measured, or if the neutron dose would have exceeded 75% of the photon dose; the TBD (ORAUT-TKBS-0010-6) provides a range of neutron-to-photon dose from 0.30 to 5.5. In the absence of reliable monitoring data, neutron dose reconstruction for monitored workers requires application of neutron-to-photon ratios. The ratio method is based on the assumption that, in most cases, neutrons would be present with an associated gamma radiation field. The required information to apply this approach for the various neutron sources includes estimations of the gamma-to-neutron ratio, the percentage of neutrons in each of the energy bins by area/process, the exposure geometry and distance, and the neutron dose fraction for each energy bin. The TBD provides the recommended factors. Site-specific issues that may hinder the recommended approach are situations where specific work groups were not issued film badge dosimetry; for example, when the issuance of film badges to workers preparing Po-Be initiators was discontinued after a three-month study showed no gamma exposure and the primary dose concern to be neutrons. Such situations require evaluation on a case-by-case basis. The lack of internal monitoring data for MFPs and other radionuclides (as previously described for internal dose reconstruction) precludes the need for further evaluation of neutron dose reconstruction for most of this time period. From 1971 to 1975, the data used in the development of ratios and other process/area-specific variables for applying neutron-to-photon dose ratios are considered appropriate for reconstructing doses for that specific timeframe because the data used to develop the relationships presented in the TBD were generated near this time period and should represent the contemporary exposure conditions.

7.3.4.4 Unmonitored Individuals Working in Production Areas

There is possibly a large population of production area workers who were not monitored, especially before 1946, because the site never adopted a monitoring program that included all workers. Documentation of these and other concerns arising from the review of site records is provided in Section 7.4.3. There are co-worker data available that can be analyzed and applied for assigning dose to unmonitored production-area workers, especially for 1946 and beyond. Assurance of assigning claimant-favorable doses to such workers must account for the combined effects of instances of inconsistent monitoring (as described in Section 7.4.3), inadequacy of the neutron dosimetry program, lack of beta radiation monitoring prior to 1949, and adjustment to photon radiation doses.

7.3.4.5 Medical X-ray

Medical X-rays were initially performed semi-annually; later they were done annually. The year X-rays were taken will impact the assigned medical X-ray dose. Prior to 1957, the use of PFG equipment would result in assigning higher doses compared to the conventional film radiography equipment used after 1957. It would be claimant-favorable to assume two chest x-rays for each examination, one AP and one LAT.

The Occupational Medical Dose TBD, ORAUT-TKBS-0010-3, combined with complex-wide technical information bulletins and ICRP and related agency publications provide methods, recommendations, and default claimant-favorable parameters needed to reconstruct the medical exposure portion of a worker's dose.

7.3.5 External Dose Reconstruction Feasibility Conclusion

This evaluation has established that NIOSH does not have sufficient information to either: (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate for the period 1943 through 1949. However, it is possible that some external doses for some members of the proposed class could be reconstructed for this early time period. With appropriate claimant-favorable assumptions addressing missed doses, maximizing external radiation dose estimations for the 1950 to 1975 timeframe can be performed provided that appropriate, claimant-favorable missed neutron doses are applied.

7.4 Evaluation of Petition Basis for SEC-00051

The following subsections evaluate the assertions made on behalf of petition SEC-00051 for the Los Alamos National Laboratory.

7.4.1 Evaluation of Major Topics Detailed in Petition SEC-00051

The following major topics were detailed in petition SEC-00051. Italicized statements are from the petition; the comments that follow are from NIOSH.

7.4.1.1 Insufficient Data

SEC-00051: *The National Institute of Occupational Safety and Health (NIOSH) is not able to estimate with sufficient accuracy radiation doses for members of the identified class.*

Accurate data required for NIOSH to conduct precise dose reconstructions of members of the specified class does not exist for some employees (It has been determined that there is insufficient information to estimate the maximum radiation dose incurred by any member of the class being evaluated.)

With respect to these employees it has been determined that there is insufficient information to estimate either the maximum radiation dose incurred by any member of the class being evaluated. The information available from the site profile and additional resources is insufficient to document or estimate the maximum internal and external potential exposure to members of the class during the period of radiological operations at LANL.

NIOSH has stated that such data does not exist for the early years of the Los Alamos National Laboratory. The site profile clearly states that no definitive historical information exists. As cited, in reports as current as the ORAU Team Dose Reconstruction Project Report for NIOSH, dated August 16, 2005, no environmental exposure data exists prior to 1965. Also, there are references made in the U.S. Department of Energy Environment, Safety, and Health, Tiger Team Assessment, November 1991, to the lack of documentation and administrative requirements for evaluating personnel exposures from unusual internal exposures to radioactive materials.

Workers with potential exposures to fission or activation products prior to 1955 (possibly 1958) were not monitored.

The primary data used for determining internal exposures are personal monitoring data, such as urinalyses, fecal samples, and whole-body counting results. If such data are unavailable, then air monitoring data from breathing zone and general area monitoring are used to estimate potential internal exposure. If both personal monitoring and breathing zone area monitoring are unavailable, internal exposures can sometimes be estimated using more general area monitoring, process information, and information characterizing and quantifying the source term. The LANL *in vitro* and *in vivo* databases have been found to contain only data specific to internal exposure to tritium, polonium, plutonium, and uranium. There are no fission product internal monitoring data available from September 1, 1944 through July 18, 1963, as established in the evaluation report for petition SEC-00061. Additional independent reviews have resulted in an extension of the time period designated as lacking internal monitoring for fission products and other primary ROCs through December 31, 1975. In addition, the determination has been made that there are insufficient air monitoring data available with which intake modeling could be performed for the period March 15, 1943 through December 31, 1971.

The same data hierarchy is used for determining external exposures to the cancer site. Personal monitoring data from film badges or thermoluminescent dosimeters (TLDs) are the primary data used. If there are no personal monitoring data, exposure rate surveys, process, and source-term modeling can sometimes be used to reconstruct the potential exposure. The external radiation hazards associated with LANL were recognized from the beginning of operations. Dosimetry badges were provided to workers who had significant exposure potential and the monitoring records from this program are available to NIOSH.

NIOSH has compiled and published a more complete summary of the available LANL external monitoring information, including detailed descriptions of the dosimeters used and the radiological operations at LANL. This information is summarized in the LANL TBD (ORAUT-TKBS-0010) and is available online at: http://www.cdc.gov/niosh/ocas.

A more detailed discussion of the information required for dose reconstruction can be found in OCAS-IG-001, *Internal Dose Reconstruction Implementation Guide,* and OCAS-IG-002, *External Dose Reconstruction Implementation Guide*. These documents are available at: http://www.cdc.gov/niosh/ocas/ocasdose.html.

The goal of NIOSH dose reconstructions is, at a minimum, to overestimate the maximum possible dose an energy employee could have reasonably received during his or her work at the facility. Where records do not exist for whatever reason, this overestimation causes the dose reconstruction to be "claimant favorable." Guidance for reconstructing doses using the overestimating methodology is provided in programmatic technical information bulletins. However, it has been determined that certain site-specific conditions specifically exclude application of these methods for LANL workers for the period 1943 through 1971.

7.4.1.2 Records Do Not Exist

SEC-00051: *In many cases from 1943-1975 personal exposures in some job categories with significant radiation exposures were unrecorded.*

There are many incidents and accidents documenting the history of occurrences at the LANL which are not included or made available in the dose reconstruction process.

The potential for unmonitored intakes was significant in the early years (1944-1946) for any site worker.

Valid radiological readings for individuals do not exist for this class.

NIOSH's approach to dose reconstruction has always been to provide the claimant with an estimate of dose that will allow the Department of Labor to arrive at the correct compensation decision (i.e., the probability of causation is on the correct side of 50%). To accomplish this, individual monitoring data have been given the highest emphasis. NIOSH has worked with LANL and obtained extensive monitoring record data sets for the period March 15, 1943 through December 31, 1975. These data sets include individual worker external dosimetry reports and internal bioassay results for the major radionuclides (plutonium, uranium, polonium, and tritium). Summary results show that 80.5% of cases have external data for at least a portion of their work history, and 58.9% have some internal bioassay data. When reconstructing doses for even infrequently-monitored workers, the dose reconstruction will often rely on missed dose. The calculation of missed dose attempts to answer the question: Given the individual monitoring data, what is the maximum plausible dose that could have been received by the worker without being detected by the monitoring program? This approach, coupled with the assumption of chronic exposure conditions (where applicable) is inclusive of any exposure that might have been received as a result of an incident. For unmonitored workers, who were in exposure conditions in which they should have been monitored, NIOSH applies a co-worker model that assumes that these workers were exposed to the upper end of the distribution of results collected from the monitored population.

The purpose of the LANL site profile (ORAUT-TKBS-0010) is not to report every incident or accident (collectively referred to as occurrences) that ever transpired at LANL, but rather to serve as a guide to dose reconstructors for uniformly assessing LANL claims. While it is known that some reported occurrences resulted in worker radiation exposures, it is also known that an equal or larger number of occurrences resulted in minimal or no exposures at all.

The site profile provides useful data to the dose reconstructors for completing claimant dose assessments. To this end, the site profile provides a summary of major events highlighting potentially significant releases or exposure events. Upper-bound values for the types and magnitudes of incidents that occurred can allow dose reconstructors to develop conservative estimated intakes for both monitored and unmonitored workers. Work continues on characterizing and quantifying the intakes for both maximizing and general conditions. Other approaches being used to account for missed dose or to assign dose to unmonitored workers include the use of co-worker data and other workplace survey data (when available).

7.4.1.3 Lack of Bioassay Data

SEC-00051: *Travel throughout areas of LANL to perform work assignments was often necessary for some classes… Even though this individual traveled to these areas, he or she was not required to participate in the bioassay program.*

The lack of bioassay data raises the issue of possible chronic exposure to external sources of radiation.

There is a lack of internal dose (bioassay data) data and occupational environment dose (air sample test results) data for the stated class of employees.

No environmental exposure data exists prior to 1965.

Bioassay programs were not set up for all employees.

The primary data used for determining internal exposures are personal monitoring data, such as urinalyses, fecal samples, and whole-body counting results. If these are unavailable, air monitoring data from breathing zone and general area monitoring are used. If both personal monitoring and breathing zone area monitoring are unavailable, internal exposures can sometimes be estimated using more general area monitoring, process information, and information characterizing and quantifying the source term.

As stated previously, bioassay results for specific radionuclides or categories of radionuclides are not available for all time periods covered by the petition. This evaluation has established that neither *in vivo* nor *in vitro* data are available for mixed fission products prior to the consistent use of the whole-body counter in 1970, and that these data are insufficient for developing co-worker scenarios after this time. In lieu of bioassay data, air monitoring data may be applied to assign worker intakes and associated internal doses. However, it has also been established that currently available radionuclide-specific air monitoring data are insufficient prior to 1971; records after 1971 may not be representative of potential exposure conditions earlier in the site's history. Further validation, analysis, and review of the newly-identified records would be required to alter this conclusion. Furthermore, there is sufficient documentation of numerous other unsealed (and in some cases more exotic) radionuclides being used. These other radionuclides were present in much lower quantities than the primary ROCs and their use generally affected more limited areas. These radionuclides are presented in Section 7.2 and included Th-232, Cm-244, Ac-227, Cf-252, Np-237, Am-241, and U-233. Internal bioassay data or *in vivo* data have not been identified for most of these radionuclides through 1975. Some data may be available for the later years.

7.4.3 Evaluation of General Concerns Raised in Petition SEC-00051

The following excerpts from LANL historical documentation corroborate the general concerns raised in petition SEC-00051 for a substantial portion of the timeframe under evaluation. These general concerns include the absence of bioassay data, undocumented overexposures, and inadequate monitoring procedures.

History of the Health Group (A-6) (March 1942 – November 1945) (Hempelmann, 1945):

- *The following is a compilation of the criticism which can be directed against the health group with justification: 1) Failure to inspect regularly all technical operations on this project for health hazards…Occasionally the Health Group did not learn of potentially dangerous experiments until they were completed. 2) Incomplete record of dosage received by all persons exposed to external radiation and lack of negative exposure records (for legal purposes) of persons not working with radiation.*

- *Since the Health Group could not be policemen and monitor every technical operation, the only means to obtain records of exposure of personnel to radiation was to depend on the cooperation of persons involved. All people did not cooperate to the fullest extent; hence, records of exposure are incomplete in the cases of some individuals. Exposure records were complete until the fall of 1944 and then less so.*

Annual Report, Health Division, 1951 (LASL HD, 1951):

- *Two problems which need further work are the fission product air contamination around the Omega Water Boiler and the beta exposure rate while working Water Boiler Soup.*
  NIOSH Note: There are no fission product internal monitoring data available for this time period.

- *Casting, machining, and other operations on thorium metal were undertaken by several Laboratory Groups this year.*
  NIOSH Note: There are no bioassay data available for thorium.

- *Method for determining curium in urine, while still having certain deficiencies, was being used to some extent.*
  NIOSH Note: There are no bioassay data available for curium.

- *At DP East, an experimental program with actinium has been carried out by CMR-3. As far as we have been able to determine, the personnel have not been subject to overexposure. The health program on this work has not been too satisfactory. An adequate urine analysis is not available and it is difficult to evaluate air samples.*
  NISOH Note: There were only 15 bioassay results available for actinium.

Annual Report, Health Division, 1949 (LASL HD, 1949):

- *Starting about the first of the year, the personnel film badges were changed to provide an unshielded area of film that will respond to beta or soft-gamma radiation. The main result of this change was the discovery of many cases of high exposure, and fair number of overexposures to beta radiation from normal uranium.*

- *Past experience has shown that many maintenance and construction jobs have been started without adequate health clearance. Failures have occurred mainly because of lack of knowledge of the existence of health hazards in various locations…*

- *…many cases of contamination, overexposure, misuse of radiation sources, etc. have been discovered more or less by accident.*

Photodosimetry Evaluation Book, Volume II, 1960-1969 (LASL PEB, 1969):

- *…the monitoring section leader estimates that 25 percent of the 1,500 University employees now issued film badges do not wear them at all times when working with radiation…*
  NIOSH Note: The word "now" in the above text means 1960.

- *Although film badges are required in order to gain access to certain sites, at present there is no way of determining if they are worn inside the site. It is interesting to note that three people have been killed by radiation at Los Alamos and that none of them were wearing film badges.*

Photodosimetry Evaluation Book, Volume 1a (LASL PEB, 1959):

- *Investigations of Sigma and* illegible *personnel film result outliers were investigated and determined that the personnel left the badges on benches with material, wore improperly on wrist, or left the badge in another building. Other notations of personnel badges being stored in dirty smocks, drawers, and work areas. Notation regarding not reading the film badges of DP East polonium workers as alpha and neutron radiation the primary concern, the wearing of film was not applicable and to monitor by finger impressions. Notation for DP West plutonium workers to only issue catastrophe badges.*

7.5 Other Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00051, a number of issues were identified that needed further analysis and resolution. The issues and their current status are:

- ISSUE: What type of bioassay data is LANL providing to NIOSH/ORAU? Does it include data from all radionuclides handled at LANL?

  APPROACH: As discussed in Section 7.2, *in vitro* bioassay data are available for part of the evaluation period for uranium, plutonium, tritium, polonium, and to a lesser extent, americium. *In vivo* measurements began in the late 1960s for gamma-emitting fission and activation products and plutonium and americium. In later years, uranium was also added to the standard *in vivo* analytes. There was some screening done in the 1950s through 1970, but the *in vivo* program was not well-established at that time and there are no data available. The capabilities and available data for assessing intakes of all ROCs applicable to *in vivo* monitoring were determined to be incomplete through 1975. NIOSH is continuing to review the feasibility of LANL dose reconstruction for the post-1975 time frame.

  Some bioassay results may be available for other radionuclides handled in limited amounts, such as Sr-90 and Ac-227. However, these data have not been provided by LANL to date.

- ISSUE: How can dose reconstruction be accomplished for fission products and other radioisotopes where the TBD, page 30, notes that many are not accounted for in the site's exposure analysis of generated fission product sources?

  APPROACH: At this time, internal dose reconstructions cannot be performed for MFP during the period 1943 through 1969. The capabilities and available data for assessing intakes of all ROCs conducive to *in vivo* monitoring require further evaluation from 1970 on, and also evaluation of the newly-identified records for the years prior to 1970.

- ISSUE: The TBD recognizes that effluents from many TAs have not been well-reported over the last several decades and that LANL has not provided effluent data for the years 1945-1971. Since it does not exist, what assurance is there that use of rather sparse environmental measurements, and very few source terms, will enable adequate overall environmental dose estimates?

  APPROACH: Recently-released LANL documents associated with the Los Alamos Historical Document and Assessment project are being reviewed to determine whether additional information is available to fill sampling and effluent data gaps. Another source of on-going work involves development of co-worker data that could possibly be used, in some instances, to account for doses from releases.

- ISSUE: How will claimant-favorable neutron doses for workers be accounted for when most of the entire neutron spectrum is below the practical 1-MeV detection limits of NTA film used in the workers' badges or for the periods in time when there was no neutron monitoring?

  APPROACH: Section 7.3.4.3 discusses limitations of the neutron dosimetry and recommendations for application of photon-to-neutron ratios in deriving neutron dose.

7.6 Summary of Feasibility Findings for Petition SEC-00051

This report evaluated the feasibility for completing dose reconstructions for LANL employees in all TAs from March 15, 1943 through December 31, 1975. NIOSH found that the monitoring records, process descriptions, and source-term data available are not sufficient to complete dose reconstructions for the proposed class of employees, at a minimum, through December 31, 1975.

Table 7-10 summarizes the results of the feasibility findings at LANL for each exposure source for the time period March 15, 1943 through December 31, 1975.

Table 7-10: Summary of Feasibility Findings for SEC-00051
March 15, 1943 through December 31, 1975

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]		
H-3	1950 – 1975	1943 – 1949
Po	1944 – 1956	
Pu	1944 – 1975	
U	1943 – 1975	
Ac, Cm, Np, Th, Sr		1943 – 1975
Various isotopes of concern		1943 – 1975
MFP/MAP		1943 – 1975
External[2]		
Gamma	1946 – 1975	1943 – 1945
Beta	1949 – 1975	1943 – 1948
Neutron	1946 – 1975	1943 – 1945
Occupational Medical X-ray	1943 – 1975	---

[1] Limited environmental air monitoring data and whole-body/chest count data are available beginning in 1970.

[2] Gamma, beta, and neutron dose reconstruction is feasible for 1943-1969 provided that NIOSH has the individual monitoring/source term/area monitoring/co-worker data.

As of December 19, 2006, a total of 657 claims have been submitted to NIOSH for individuals who worked at LANL. Dose reconstructions are complete for 300 individuals (~46%).

Reiterating the discussion in Section 4.4, the review of completed and pending cases included a wide variety of job titles, including: carpenter, electrician, machinist, chemist, security guard, technician, physicist, custodian, animal caretaker, vehicle inspector, and research scientist. Years of service ranged from less than one year up to 42 years. Completed reconstructions used various approaches, both underestimates (partial reconstructions) and overestimates. Reconstructions that have been completed for monitored worker cases applied available external and internal monitoring data as well as missed dose. For cases with monitoring gaps, or where the worker did not have either internal or external monitoring data, the reconstructions relied on co-located worker data (e.g., when the worker was involved in an incident), technical information bulletins ORAUT-OTIB-0002 and ORAUT-

OTIB-0018, ambient on-site doses from other DOE sites, internal co-worker data from across the DOE complex, radiological protection guide values, or TBD-tabulated values.

The dose reconstructions completed to date do not demonstrate that NIOSH can estimate with sufficient accuracy the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or that sufficient information is available to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose. Of the 66 cases that were reviewed for this evaluation, 27 cases had been completed, 15 of which were partial reconstructions using available monitoring data. The remaining 12 cases were overestimates for workers whose job descriptions did not indicate significant, if any, involvement with radioactive materials, or whose individual claim information (including employment information, exposure information/potential, and incurred cancer) sufficiently supports the performance of an overestimating dose reconstruction in the evaluation of the probability of causation.

8.0 Evaluation of Health Endangerment for Petition SEC-00051

The health endangerment determination for the class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. Section 83.13 requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that it is not feasible to reconstruct (the incident) exposures for the class and that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the feasibility determination of the inability to reconstruct doses from an exceptionally high-level exposure has not been established, but NIOSH has determined that it is not feasible to reconstruct other (long-term) exposures, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

This evaluation determined that it is not feasible to estimate the long-term radiation dose for members of the proposed class with sufficient accuracy based on the sum of information available from available resources. A modification to the class definition regarding health endangerment and minimum required employment periods, therefore, is required.

NIOSH has determined that some members of the class may have been exposed to radiation during documented discrete criticality incidents (as previously discussed) that were likely to have involved high levels of exposure.

The evidence reviewed in this evaluation indicates that some workers in the class may have accumulated chronic (long-term) radiation exposures through intakes of radionuclides and from direct exposure to radioactive materials. Relevant data are not available from which an estimate of all radionuclide source terms can be developed; nor are adequate and complete area, environmental, *in*

vivo, or *in vitro* monitoring data. Therefore, NIOSH is unable to estimate maximum doses associated with internal exposures and, in some cases, external exposures. Consequently, NIOSH is specifying that health was endangered for those workers covered by this evaluation who were employed for a number of work days aggregating at least 250 work days within parameters established for this class, or in combination with work days within the parameters established for one or more other classes of employees in the SEC, or were otherwise involved in an incident.

9.0 NIOSH-Proposed Class for Petition SEC-00051

Based on its research, NIOSH reduced the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all job titles and/or job duties for all employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working in operational Technical Areas with a history of radioactive material use at the Los Alamos National Laboratory for an aggregate of at least 250 work days during the period from March 15, 1943 through December 31, 1975, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. This definition excludes TA-1-Z, TA-17, -19, -28, -34, -38, -57, -64, -65, -69, -70, and -74. The class was modified in order to: (1) specify the date when project staff began work at the site (March 15, 1943); (2) confine the class to those TAs that had a history of radioactive material use and were also operational during the evaluation period; and (3) explicitly include all personnel who worked for the DOE, DOE contractors, or subcontractors (including all former MED/AEC workers) who were monitored or should have been monitored for radiological exposure. NIOSH will continue its evaluation to determine at what historical point (after the evaluation period addressed herein) that available information and data become adequate to: (1) estimate the maximum radiation dose incurred by any site worker; or (2) estimate radiation doses more precisely than a maximum dose.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Data Base (SRDB), for information relevant to SEC-00051. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining that it would not be feasible to reconstruct the dose for the class proposed in this petition.

10.0 References

42 C.F.R. 81, *Guidelines for Determining the Probability of Causation Under the Energy Employees Occupational Illness Compensation Program Act of 2000;* Final Rule, Federal Register/Vol. 67, No. 85/Thursday, p 22,296; May 2, 2002; SRDB Ref ID: 19391

42 C.F.R. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

42 C.F.R. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 28, 2004; SRDB Ref ID: 22001

42 U.S.C. §§ 7384-7385 [EEOICPA], *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended

DOE/EH-0027, *Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems*, U.S. Department of Energy; 1986; SRDB Ref ID: 12294

DOE/EIS-0238, *Sitewide Environmental Impact Statement for the Continued Operation of the Los Alamos National Laboratory*, U.S. Department of Energy; 1999; SRDB RefID: 13468

DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities,* Section 6.2.3., Change Notice 3; Department of Energy Standard; February, 2005; SRDB Ref ID: 22723

OCAS-IG-001, *External Dose Reconstruction Implementation Guide*, NIOSH, Office of Compensation Analysis and Support (OCAS); Rev. 1; August, 2002; SRDB Ref ID: 22401

OCAS-IG-002, *Internal Dose Reconstruction Implementation Guidelines*, Rev. 0; Office of Compensation Analysis and Support; August 2002; SRDB Ref ID: 22402

OCAS-PR-004, *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, NIOSH, Office of Compensation Analysis and Support (OCAS); Cincinnati, Ohio; September 23, 2004; SRDB Ref ID: Not currently available in the SRDB

ORAUT-OTIB-0002, *Maximum Internal Dose Estimates for Certain DOE Complex Claims*, Rev. 01 PC-2; May 7, 2004; SRDB Ref ID: 19409

ORAUT-OTIB-0010, *A Standard Complex-Wide Methodology for Overestimating External Doses Measured with Film Badge Dosimeters*, Rev. 01; June 5, 2006; SRDB Ref ID: 19429

ORAUT-OTIB-0018, *Internal Dose Overestimates for Facilities With Air Sampling Programs*, Rev. 01; August 9, 2005; SRDB Ref ID: 19436

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, Rev. 01; October 7, 2005; SRDB Ref ID: 19438

ORAUT-OTIB-0023, *Assignment of Missed Neutron Doses Based on Dosimeter Records*, Rev. 00; March 7, 2005; SRDB Ref ID: 19444

ORAUT-OTIB-0053, draft, *Dose Reconstruction Considerations for Recycled Uranium Contaminants*; Oak Ridge Associated Universities; Oak Ridge, Tennessee; SRDB Ref ID: Not currently available in the SRDB

ORAUT-OTIB-0062, draft, *Internal Dosimetry Coworker Data for Los Alamos National Laboratory,* Oak Ridge Associated Universities; Oak Ridge, Tennessee; SRDB Ref ID: Not currently available in the SRDB

ORAUT-OTIB-0063, draft, *Los Alamos National Laboratory Bioassay Data Project Final Report*; Oak Ridge Associated Universities; Oak Ridge, Tennessee; SRDB Ref ID: Not currently available in the SRDB

ORAUT-PROC-0095, *Generating Summary Statistics for Coworker Bioassay Data;* Rev. 00; June 5, 2006; Oak Ridge Associated Universities; Oak Ridge, Tennessee; available on ORAUT Intranet

ORAUT-TKBS-0010-1, *Technical Basis Document for Los Alamos National Laboratory – Introduction*, Rev. 00; January 25, 2005; SRDB Ref ID: 19560

ORAUT-TKBS-0010-2, *Technical Basis Document for Los Alamos National Laboratory – Site Description*, Rev. 00; May 7, 2004; SRDB Ref ID: 19561

ORAUT-TKBS-0010-3, *Technical Basis Document for Los Alamos National Laboratory – Occupational Medical Dose*, Rev. 00; December 29, 2004; SRDB Ref ID: 19562

ORAUT-TKBS-0010-4, *Technical Basis Document for Los Alamos National Laboratory – Occupational Environmental Dose*, Rev. 00; October 8, 2004; SRDB Ref ID: 19564

ORAUT-TKBS-0010-5, *Technical Basis Document for Los Alamos National Laboratory – Occupational Internal Dose*, Rev. 00; December 21, 2004; SRDB Ref ID: 19565

ORAUT-TKBS-0010-6, *Technical Basis Document for Los Alamos National Laboratory – Occupational External Dose*, Rev. 00; May 10, 2005; SRDB Ref ID: 19566

Bayo, *Estimates of Materials at the Bayo Canyon Firing Sites*; author unknown; date unknown; Los Alamos Scientific Laboratory; SRDB RefID: 7895

Chelius, 1970, memo from L.G. Chelius to H.J. Blackwell; *Radioactive Effluents and Releases*; Los Alamos Scientific Laboratory; April 10, 1970; SRDB Ref ID: 28829

Dummer, 1961, *Iodine Activity from DP West Hot Cells*, Compilation of Office Memoranda; J. E. Drummer; Los Alamos Scientific Laboratory; 1961; SRDB Ref ID: 14523

Glasstone p. 481-3, *Sourcebook on Atomic Energy*, Third Edition; Samuel Glasstone; D. van Nostrand Company, Inc.; New York; 1967; SRDB Ref ID: Not available in the SRDB - publicly available

Groves, p. 110, *Now It Can Be Told*, Leslie R Groves; Harper and Brothers, New York; 1962; SRDB Ref ID: Not available in the SRDB - publicly available

Hacker p. 200-205, *Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing 1947-1974;* Barton C. Hacker; Berkeley/Los Angeles/London: University of California Press; 1994; SRDB Ref ID: Not available in the SRDB - publicly available

Healy, 1970, *Los Alamos Handbook of Radiation Monitoring*; J. W. Healy; Los Alamos Scientific Laboratory; 1970; SRDB Ref ID: 943

Hempelmann, 1945, *History of the Health Group (A-6) (March 1942 - November 1945)*, L. H. Hempelmann, MD; LANL; 1945; SRDB Ref ID: 12894

Hewlett and Anderson, pp. 164, 212, 229-230, 243-245; *The New World 1939/1946.* Volume 1 of *A History of the United States Atomic Energy Commission;* Richard G. Hewlett and Oscar E. Anderson, Jr.; University Park: The Pennsylvania State University Press; 1962; SRDB Ref ID: Not available in the SRDB - publicly available

Hewlett and Duncan, pp. 583-4; *Atomic Shield 1947/1952*. Volume 2 of *A History of the United States Atomic Energy Commission;* Richard G. Hewlett and Francis Duncan; U. S. Atomic Energy Commission Report; WASH 1215; 1972; SRDB Ref ID: Not available in the SRDB - publicly available

Kathren, Gough and Benefiel, pp. 277-8, *The Plutonium Story: The Journals of Professor Glenn T. Seaborg 1939-1946;* Ronald L. Kathren, Jerry B. Gough, and Gary T. Benefiel, Editors; Columbus: Battelle Press; 1994; SRDB Ref ID: Not available in the SRDB - publicly available

LANL, 2000, *A Review of Criticality Accidents*; 2000 Revision; LA-13638; May, 2000; SRDB Ref ID: 895

LANL, 2004, *Annual Worker Deep, Neutron, Shallow, and Collective Dose Values Supplied by LANL for 1944 through Part of 2004*; Los Alamos National Laboratory; SRDB Ref ID: 27261

LANL PEB, 1986, *Photodosimetry Evaluation Book,* Volume IVb, 1981-1986; Los Alamos Scientific Laboratory; 1986; SRDB Ref ID: 8209

LANL PEB, 1989, *Photodosimetry Evaluation Book,* Volume VI, 1989; Los Alamos National Laboratory; 1989; SRDB Ref ID: 27288

LANL PEB, 1996, *Photodosimetry Evaluation Book,* Volume VII, 1996; Los Alamos National Laboratory; 1996; SRDB Ref ID: 27273

LANL PEB 2001, *Photodosimetry Evaluation Book,* Volume VIII, 1996-2001; Los Alamos National Laboratory; 2001; SRDB Ref ID: 27292

LANL PEB, 2003, *Photodosimetry Evaluation Book,* Volume IX, 2002-2003; Los Alamos National Laboratory; 2003; SRDB Ref ID: 27301

LASL HD 1947, *H-Division Progress Report, 20 October 1947 – 20 November 1947*; LAMS-651; December 12, 1947; SRDB Ref ID: 7885

LASL HD, 1949, *Annual Report, Health Division, 1949*; Thomas L. Shipman; Los Alamos Scientific Laboratory; February 28, 1950; SRDB Ref ID: 984

LASL HD, 1951, *Annual Report, Health Division, 1951*; Thomas L. Shipman; Los Alamos Scientific Laboratory; May 12, 1952; SRDB Ref ID: 972

LASL PEB, 1959, *Photodosimetry Evaluation Book, Volume 1a*; Los Alamos Scientific Laboratory; 1959; SRDB Ref ID: 8181

LASL PEB, 1969, *Photodosimetry Evaluation Book, Volume II, 1960-1969*; Los Alamos Scientific Laboratory; 1969; SRDB Ref ID: 8173

LASL PEB, 1977a, *Photodosimetry Evaluation Book "Bible", Volume III, 1970-1977*; Los Alamos Scientific Laboratory; 1977; SRDB Ref ID: 8176

LASL PEB, 1977b, *Photodosimetry Evaluation Book, Volume IIIb, 1974-1977*; Los Alamos Scientific Laboratory; 1977; SRDB Ref ID: 8192

LASL PEB, 1979, *Photodosimetry Evaluation Book, Volume 5, 1979*; Los Alamos Scientific Laboratory; 1979; SRDB Ref ID: 27271

LASL PEB, 1980, *Photodosimetry Evaluation Book, Volume IVa, 1978-1980*; Los Alamos Scientific Laboratory; 1980; SRDB Ref ID: 8206

Lawrence, 1992, Internal memorandum from J. N. Lawrence to Internal Dosimetry; Volume 3 of *Americium, Polonium, Uranium: Internal Doses from Uranium Urine Assays after 1991 Data*; Los Alamos National Laboratory, May, 1992; SRDB Ref ID: 12932

Littlejohn, 1960, *Photodosimetry Procedures at Los Alamos*; G. J. Littlejohn; Los Alamos Scientific Laboratory; August, 1960; SRDB Ref ID: 951

Smyth 1945, p. 207, *Atomic Energy for Military Purposes;* Henry D. Smyth; Princeton: Princeton University Press; 1945; SRDB Ref ID: Not available in the SRDB - publicly available

Tiger Team, 1991, *Tiger Team Assessment of the Los Alamos National Laboratory*; U. S. Department of Energy; Div. of Environment, Safety, and Health; November, 1991; SRDB RefID: 23620

Vasilik, 1983, *In Vivo Assessment of Whole Body Radioisotope Burdens at the Los Alamos National Laboratory*; D. G. Vasilik and I. C. Aikin; Los Alamos National Laboratory; August, 1983; SRDB Ref ID: 925

Widner, 2003, *Interviews and Personal Communications with J. N. P. Lawrence by T. E. Widner (2003)*; James N. P. Lawrence, former Los Alamos health physicist; documented by T.E. Widner of ChemRisk, Inc., and the ORAU Team; 2003; SRDB Ref ID: 27882

Widner, 2004, *Personal Communications Between Tom Widner and James N. P. Lawrence (2004)*; James N. P. Lawrence, former Los Alamos health physicist; documented by T.E. Widner of ChemRisk, Inc., and the ORAU Team; 2004; SRDB Ref ID: 27884

Wingfield, 1974, *Inventory of Quantities and Locations of Radioactivity in the Environment On and Near AEC Sites*; Wingfield; Los Alamos Scientific Laboratory; 1974; SRDB Ref ID: 12978