SEC Petition Evaluation Report

Petition SEC-00221

Report Rev Number:	0
Report Submittal Date:	February 12, 2016
Subject Expert(s):	Tim Adler, Robert Burns, Roger Halsey, Monica Harrison-Maples
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition Number:	SEC-00221
Petition Type:	83.13
Petition Receipt Date:	October 7, 2014
Qualification Date:	January 6, 2015
DOE/AWE Facility Name:	Lawrence Livermore National Laboratory

Petition Class

Petitioner-Requested Class Definition:	All DOE or DOE contractor employees who worked in any area at the Lawrence Livermore National Laboratory within the 7000 East Avenue location in Livermore, California, or within the Site 300 location in Tracy, California, from January 1, 1975 through October 28, 2014.
Class Evaluated by NIOSH:	All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989.
NIOSH-Proposed Class(es) to be Added to the SEC:	All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

Related Petition Summary Information

SEC Petition Tracking Number(s):	SEC-00092 and SEC-00163
Petition Type:	83.14
DOE/AWE Facility Name:	Lawrence Livermore National Laboratory
Petition Status:	SEC-00092: Class added for to the SEC for January 1, 1950 through December 31, 1973, for employees with an indication of having been in the radiation monitoring program. SEC-00163: Class added to the SEC expanded to include “all employees” for January 1, 1950 through December 31, 1973, eliminating the “who were monitored or should have been monitored” distinction.

Related Evaluation Report Information

Report Title:	SEC Petition Evaluation Report for Petition SEC-00092 SEC Petition Evaluation Report for Petition SEC-00163
DOE/AWE Facility Name:	Lawrence Livermore National Laboratory

ORAU Preparation and Review

ORAU Lead Technical Evaluator:	Robert Burns
ORAU Peer Review Completed By:	Michael Kubiak

DCAS Review and Approval

Peer Review Completed By:	[Signature on File] *Mark Rolfes* February 12, 2016
SEC Petition Evaluation Reviewed By:	[Signature on File] *James W. Neton* February 12, 2016
SEC Petition Evaluation Reviewed By:	[Signature on File] *Stuart L. Hinnefeld* February 12, 2016

Evaluation Report Summary: SEC-00221, Lawrence Livermore National Laboratory (LLNL)

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-00221 was received on October 7, 2014, and qualified on January 6, 2015. The petitioner requested that NIOSH consider the following class: *All DOE or DOE contractor employees who worked in any area at the Lawrence Livermore National Laboratory within the 7000 East Avenue location in Livermore, California, or within the Site 300 location in Tracy, California, from January 1, 1975 through October 28, 2014.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-requested class. NIOSH qualified the following class for evaluation: All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1995.

For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions for uranium-233 (U-233) exposures in Building 251 only through December 31, 1989. NIOSH will continue to review and evaluate remaining dose contributors for the 1974–1989 period as well as for the period 1990–1995 for all areas and buildings of the Lawrence Livermore National Laboratory (LLNL) site. NIOSH evaluated the following class in this report: All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989.

NIOSH-Proposed Class to be Added to the SEC

Based on its research to date of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the SEC. The class under evaluation was accepted (see Section 3.0 below) because information presently available to NIOSH does not provide evidence that the gross alpha bioassay measurements, upon which some coworker analyses are based, include all potential exposure scenarios of concern. Further NIOSH review and assessment will be necessary to fully

complete the evaluation of all internal and external exposures during the period of the proposed class, and during the remaining qualified period of January 1, 1990 through December 31, 1995.

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, 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 (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. 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.

The NIOSH dose reconstruction feasibility findings are based on the following:

- NIOSH finds that it is feasible to reconstruct occupational medical dose for LLNL workers with sufficient accuracy during the period from January 1, 1974 through December 31, 1989.

- Principal sources of internal and external radiation for members of the proposed class included exposures to isotopes of uranium and thorium, highly enriched uranium, plutonium, americium, curium, neptunium, and other exotic materials in Building 251, the Heavy Elements Facility. Potential exposures to the members of the proposed class involved operations such as nuclear tracer fabrication, radiochemical analysis of bomb debris, and chemical research into transuranic radionuclides, including work with high-specific-activity sample processing.

- NIOSH has determined that it has insufficient information to verify that the routine *in vitro* bioassay program for Building 251 workers (combinations of analyses for gross alpha in urine, gross beta in urine, and plutonium in urine) was adequately sensitive for detection of U-233 intakes during the period under evaluation.

- Similarly, NIOSH has determined that photon-emitting decay products and contaminants cannot be assumed to have been sufficiently present in the U-233 source term to verify that the routine *in vivo* bioassay program for Building 251 workers was adequately sensitive for detection of U-233 intakes during the period under evaluation.

- Information available to NIOSH from multiple site inspections performed from 1980 to 1991 indicate deficiencies in LLNL's implementation of the air monitoring program in Building 251. NIOSH has determined the air monitoring data from Building 251 may not be adequately representative of the worker breathing zones, and are consequently not considered sufficient for Building 251 dose reconstruction during the period under evaluation.

- Information currently available to NIOSH contains insufficient access control information or records for Building 251, and insufficient general site worker movement data, to allow NIOSH to accurately assess whether an energy employee, or class of employees, did or did not potentially enter Building 251 during the period under evaluation. NIOSH therefore recommends the extension of the recommended class to include all LLNL workers during the period from January 1, 1974 through December 31, 1989.

- NIOSH review of material inventory records indicates that U-233 was refined into end products in Building 251 through at least 1988. In 1989, the frequency and nature of U-233 transfers changed indicating a possible change in U-233 production or usage. Pending further evaluation, NIOSH recommends an end date of December 31, 1989, for the SEC class recommended in this report. NIOSH finds that it is not feasible to estimate with sufficient accuracy the internal doses for LLNL workers during the period from January 1, 1974 through December 31, 1989.

- For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal exposures other than U-233 during the period from 1974–1989, and all internal exposures during the period from 1990–1995.

- Consistent with the findings of NIOSH's 2010 evaluation of the LLNL SEC-00163, NIOSH finds that external dose for photon, beta, and neutron exposures can likely be reconstructed for all members of the evaluated class for the period from January 1, 1974 through December 31, 1989. NIOSH will continue to perform a full evaluation of external exposures during the period from 1974–1995.

- Pursuant to 42 C.F.R. § 83.13(c)(1), NIOSH determined that there is insufficient information to either: (1) 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 (2) estimate the radiation doses of members of the class more precisely than a maximum dose estimate.

- Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at LLNL during the period from January 1, 1974 through December 31, 1989, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

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 dose for the members of the proposed class.

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class have accumulated chronic exposures through intakes of radionuclides, combined with external exposures to gamma, beta, and neutron radiation. In the absence of high-level incident exposures, 42 C.F.R. § 83.13(c)(3)(ii) requires NIOSH to specify that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under this employment or in combination with work days within the parameters established for one or more other SEC classes.

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SEC Petition Evaluation Report for SEC-00221

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: Robert Burns, NGTS, Inc. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989. 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 Division of Compensation Analysis and Support's (DCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, DCAS-PR-004.[1]

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.[2]

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, then NIOSH must determine that there is a reasonable likelihood that such

[1] DCAS was formerly known as the Office of Compensation Analysis and Support (OCAS).

[2] 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.

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 the health of members of a class when it has been established 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 occurrence of such an exceptionally high-level exposure has not been established, 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 one or more other SEC classes.

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 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. [3]

3.0 SEC-00221, Lawrence Livermore National Laboratory Class Definitions

The following subsections address the evolution of the class definition for SEC-00221, Lawrence Livermore National Laboratory (LLNL). When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of the petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00221 was received on October 7, 2014, and qualified on January 6, 2015. The petitioner requested that NIOSH consider the following class: *All DOE or DOE contractor employees who worked in any area at the Lawrence Livermore National Laboratory within the 7000 East Avenue location in Livermore, California, or within the Site 300 location in Tracy, California, from January 1, 1975 through October 28, 2014.*

[3] 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 petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the LLNL workers in question. Subsequent NIOSH reviews indicate that information presently available to NIOSH does not provide evidence that the gross alpha bioassay measurements, upon which some coworker analyses are based, include all potential exposure scenarios of concern. Consequently, NIOSH determined that an evaluation is warranted into the adequacy of the gross-alpha-based coworker dose methods of ORAUT-TKBS-0035-5. NIOSH deemed the need for further research of LLNL gross-alpha monitoring practices sufficient to qualify SEC-00221 for evaluation.

Based on its LLNL research and data capture efforts, NIOSH determined that it has access to internal and external dosimetry programs and evaluations, monitoring summary reports, annual environmental reports, reviews and assessments of LLNL, evaluations of specific buildings, site surveys, and facility and process descriptions for LLNL workers during the time period under evaluation. However, NIOSH also determined that site monitoring practices were not sufficiently understood for all time periods or for all radionuclides. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that internal radiation exposures and radiation doses were not adequately monitored at LLNL, either through personal monitoring or area monitoring. The information and statements provided by the petitioner, and the subsequent NIOSH review of existing documentation and dose reconstruction methods, qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-requested class to include the period from January 1, 1974 through December 31, 1995. As stated above, information available to NIOSH did not provide evidence that the gross alpha bioassay measurements, upon which some coworker analyses are based, include all potential exposure scenarios of concern. NIOSH noted that gross alpha urine monitoring of transuranic exposures in Building 251 warranted evaluation, including neptunium exposures through 1995. The periods of gross-alpha-related exposures for which NIOSH qualified the petition did not align with the petitioner-proposed dates of January 1, 1975 through October 28, 2014. To coincide with the existing LLNL SEC-00163 class which ends on December 31, 1973, and with periods of transuranic exposures of concern through 1995, NIOSH modified the dates of the class qualifying for evaluation to be January 1, 1974 through December 31, 1995. Therefore, NIOSH qualified the following class for further evaluation: All employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1995.

During its evaluation of the qualified period from January 1, 1974 through December 31, 1995, NIOSH determined that U-233 exposures in Building 251 were inadequately monitored by the site's gross alpha *in vitro* sampling program through December 31, 1989. NIOSH review of material inventory records indicates that U-233 was refined into end products in Building 251 through at least 1988. In 1989, the frequency and nature of U-233 transfers changed indicating a possible change in U-233 production or usage. Pending further evaluation, NIOSH recommends an end date of December 31, 1989, for the SEC class recommended in this report.

To allow NIOSH, the Board, and HHS to complete, without delay, their consideration of the Building 251-related class for whom NIOSH has already determined a dose reconstruction cannot be completed, this evaluation report evaluates only the U-233 exposures in Building 251 during the period from January 1, 1974 through December 31, 1989. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

3.3 NIOSH-Proposed Class to be Added to the SEC

Based on its current research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the SEC. Further NIOSH review and assessment will be necessary to fully complete the evaluation of all internal and external exposures during the period of the proposed class, and during the remaining qualified period of January 1, 1990 through December 31, 1995.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding Lawrence Livermore National Laboratory. The database search included the Department of Energy (DOE) Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment One contains a summary of Lawrence Livermore National Laboratory documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

In addition to the database and Internet searches listed above, NIOSH identified and reviewed numerous data sources to determine information relevant to determining the feasibility of dose reconstruction for the class of employees under evaluation. 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. The Site Profile for a small site may consist of a single document. As part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into LLNL operations or related topics/operations at other sites:

- *TBD for Lawrence Livermore National Laboratory – Introduction*, ORAUT-TKBS-0035-1; Rev. 00; effective July 18, 2005; SRDB Ref ID: 22272

- *TBD for Lawrence Livermore National Laboratory – Site Description*, ORAUT-TKBS-0035-2; Rev. 00; effective July 29, 2005; SRDB Ref ID: 19554

- *TBD for Lawrence Livermore National Laboratory – Occupational Medical Dose*, ORAUT-TKBS-0035-3; Rev. 01; effective August 27, 2010; SRDB Ref ID: 86394

- *TBD for Lawrence Livermore National Laboratory – Occupational Environmental Dose*, ORAUT-TKBS-0035-4; Rev. 01; effective March 16, 2010; SRDB Ref ID: 79861

- *TBD for Lawrence Livermore National Laboratory – Occupational Internal Dose*, ORAUT-TKBS-0035-5; Rev. 02; effective December 13, 2010; SRDB Ref ID: 90961

- *TBD for Lawrence Livermore National Laboratory – Occupational External Dose*, ORAUT-TKBS-0035-6; Rev. 02; February 26, 2010; SRDB Ref ID: 79425

4.2 ORAU Technical Information Bulletins (OTIBs)

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. NIOSH reviewed the following OTIBs as part of its evaluation:

- *OTIB: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 04; June 20, 2011; SRDB Ref ID: 98147

- *OTIB: Guidance on Assigning Occupational X-Ray Dose Under EEOICPA for X-Rays Administered Off Site*, ORAUT-OTIB-0079, Rev. 00; January 3, 2011; SRDB Ref ID: 89563

4.3 Facility Employees and Experts

Numerous interviews were performed with past and present LLNL employees and contractors during calendar year 2015. Formal personnel interviews were conducted during the weeks of January 26th, February 23rd, April 27th, and September 14th. Additional discussions were held with LLNL's radiation protection staff, including the internal and external dosimetry program leads, during other site visits. A total of ten week-long site visits were made between January and December of 2015.

Initially, potential interviewees were identified through discussions with program leads at LLNL. As the interviews progressed, additional personnel identified by the interviewees were interviewed during subsequent site visits. Potential crafts and trades worker interviewees were identified through the assistance of local labor organizations.

LLNL groups and programs represented by the individuals interviewed by NIOSH include:

- Crafts and trades workers
- Engineering
- Global Security (including the former Z Division)
- Hazardous Waste Management
- Laser Programs
- Material Control and Accountability (MC&A)
- Nuclear Chemistry
- Radiation Protection
- Weapons, Control and Integration

The interviews with crafts and trades workers include both LLNL staff and outside contractors. The Society of Professional Scientists and Engineers – University Professional and Technical Employees Local 11 assisted NIOSH in identifying individuals willing to be interviewed. In all, interviews were conducted with fourteen crafts and trades workers, representing the following job positions:

- Electricians
- Health and safety technicians
- Machinists
- Maintenance workers
- Mechanical technicians
- Sheet metal workers
- Waste management technicians
- Welders

All of the formal interviews were conducted in a classified setting to allow for unrestricted discussions. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures for the period January 1, 1974 through December 31, 1995. Such continued evaluation may include additional interviews with facility employees and experts, and will be documented in subsequent NIOSH reports.

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (referred to as NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of February 3, 2016)

Table 4-1: No. of LLNL Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	1047
Total number of claims submitted for energy employees who worked during the period under evaluation (January 1, 1974 through December 31, 1989)	830
Number of dose reconstructions completed for energy employees who worked during the period under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval)	628
Number of claims for which internal dosimetry records were obtained for the period under evaluation (January 1, 1974 through December 31, 1989)	387
Number of claims for which external dosimetry records were obtained for the period under evaluation (January 1, 1974 through December 31, 1989)	757

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. This evaluation report evaluates only the exposures in Building 251 during the period from January 1, 1974 through December 31, 1989. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate reserved internal and external exposures from 1974–1989, and all internal and external exposures from 1990–1995. The claim data for the entire period that qualified for evaluation (January 1, 1974 through December 31, 1995) will be reassessed in subsequent NIOSH reports.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. Five thousand, three hundred and seventy-eight documents in this database were identified as pertaining to LLNL. These documents were evaluated for their relevance to this petition. The documents include historical background on internal and external dosimetry programs and evaluations, monitoring summary reports, annual environmental reports, reviews and assessments of LLNL, evaluations of specific buildings, site surveys, and facility and process descriptions.

4.6 Other Technical Sources

To support dose reconstruction and SEC evaluations, NIOSH has obtained approximately 35,000 laboratory-reported bioassay results in electronic format (NIOSH, 2007). These data were supplied by LLNL via the Maintaining and Preparing Executive Reports (MAPPER) database, a data storage system developed for LLNL by the Sperry Corporation. The LLNL MAPPER database contains only *in vitro* monitoring data, primarily from urinalyses analyzed for uranium (U), plutonium (Pu), gross alpha, gross beta, gross gamma, and mixed fission products.

NIOSH has found that the MAPPER data do not include any *in vivo* analysis results. NIOSH has however captured and evaluated logbooks for two whole-body counter systems used at LLNL (NIOSH, 2007). The information available within these logbooks is of very limited use for dose reconstruction purposes, particularly for the 1975–1989 time frame and U-233 doses. By the early 1970s, the logbooks only recorded the number of people counted on a particular date and much of the

other available information dealt with machine setup, calibration, and experimentation. Further discussion on the infeasibility of dose reconstruction using available *in vivo* data is provided in subsection 7.2.1.2 of this report.

4.7 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners:

- *Form B for Lawrence Livermore National Laboratory*; received October 7, 2014; DSA Ref ID: 120316
- *Employee Verification*; received October 15, 2014; DSA Ref ID: 120341
- *Initial Comments on Lawrence Livermore National Laboratory Site Profile*; Tri-Valley CAREs; correspondence dated April 17, 2006; DSA Ref ID: 120360, PDF pp. 1-6
- *Input on the Site Profile for Lawrence Livermore National Laboratory*; Society of Professionals, Scientists, and Engineers Affiliated with University Professional and Technical Employees (UPTE), Communications Workers of America (CWA) Local 9119, AFL-CIP; correspondence dated April 20, 2006; DSA Ref ID: 120360, PDF pp. 7-10
- *Independent Oversight Review of the Lawrence Livermore National Laboratory Radiological Controls Activity-Level Implementation*; Department of Energy; August 2014; DSA Ref ID: 120361
- *Appendix A-D of Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratory*; Department of Energy; 1992; DSA Ref ID: 120368
- *Select Pages from a Global Security Newsletter regarding Environmental Compliance*; received October 27, 2014; DSA Ref ID: 120369
- *Action Plan to Correct Deficiencies Identified by the DOE Tiger Team Assessment of Lawrence Livermore National Laboratory, June 1990, and by Self-Assessment*; LLNL and Department of Energy; October 5, 1990; DSA Ref IDs: 120476, 120477, 120479

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at LLNL from January 1, 1974 through December 31, 1989, and the information available to NIOSH to characterize particular processes and radioactive source materials, as it relates to Building 251. NIOSH will continue to review and evaluate the entire LLNL site for the period from January 1, 1974 through December 31, 1995, and will proceed with issuing another evaluation report. The information included within this evaluation report is intended only to be a summary of the available information relating to U-233 exposures in Building 251 and is not intended to discuss the entire LLNL site history.

5.1 LLNL Plant and Process Descriptions

LLNL is a multi-program laboratory operated for the DOE. LLNL was formally established in 1952, approximately 40 miles east of San Francisco, in southern Alameda County, California. The Atomic Energy Commission (AEC) began using the property as a weapons design and physics research laboratory, originally known as the University of California Radiation Laboratory at Livermore. The site was a branch of the University of California-Berkeley's radiation laboratory. It later became known as the Lawrence Radiation Laboratory at Livermore. LLNL is comprised of two sites: (1) the 1.5-square-mile Main Laboratory Site located at 7000 East Avenue in Livermore, California, previously known as Site 200; and (2) the nearly 11-square-mile Explosive Test Site, also known as Site 300, located 15 miles southeast of Livermore, near Tracy, California. Figure 5-1 shows a map of the LLNL area, including the Main Laboratory and Site 300.

Source: SRDB DOE, 2005 PDF p. 71

Figure 5-1: Map of LLNL Site

The original mission at LLNL was thermonuclear weapons development. By 1957, the mission was expanded to include diverse scientific and engineering research activities. The current LLNL mission is to serve as a national resource of scientific, technical, and engineering capability with a special focus on national security. This mission includes research and development, strategic defense, arms control and treaty verification technology, energy, the environment, biomedicine, the economy, and education. Past research activities have included development and testing of the nuclear weapons lifecycle, strategic defense research, development of arms control and treaty verification technology, fusion research, atomic vapor laser isotope separation (AVLIS) for defense and commercial applications, magnetic fusion, energy research in basic energy sciences, atmospheric sciences, fossil energy, and commercial nuclear waste (NIOSH, 2007 PDF p. 9). However, for the purposes of timeliness, NIOSH has narrowed the scope of the current evaluation and is issuing this report focusing on available data sufficiency and feasibility conclusions as related to Building 251 for the period from

January 1, 1974 through December 31, 1989. NIOSH will continue to review and evaluate the entire LLNL site for the period from January 1, 1974 through December 31, 1995, and will proceed with issuing another evaluation report. This evaluation report is not intended to discuss the entire LLNL site history.

For the period 1974–1995, the LLNL workforce consisted of more than 8,000 workers (LLNL, 2005 PDF p. 4). The main LLNL laboratory site covered 821 acres, of which approximately 640 acres were developed, and included approximately 500 buildings and structures. Around 50 of the operational buildings contained radiological materials areas. Table 5-1 provides a brief description of the Main Laboratory site buildings and activities. In 1966, building numbers were changed; some of these changes are cross-referenced in the table.

Table 5-1: Main Laboratory Site Building Numbers

Old Building Numbers	Current Building Numbers	Description
101, 102, 106, 117, 118, 147, 176, 192	221, 222, 223, 224, 232, 233, 234, 167, 168, 169	Chemistry: Various radioactive materials, including cobalt-60, fission products, enriched uranium, depleted uranium, natural uranium, U-233, Cm-244, Pu-239, Am-241, and others
153, 154, 157, 173, 180, 194	171, 173, 174, 175, 176, 177, 194, 210, 212, 241, 243, 421, 435	Physics: Accelerators, various activation products, H-3, and others
103, 114, 125, 127, 174, 175	215, 243, 253, 321, 419, 514	Lab services: Various radioactive materials
110	261	Critical Test Facility
115	327	Radiography
121	412	Hot cells: High beta waste, strontium-90
170	131	Weapons Engineering
171	332	Metallurgical Chemistry: Also known as Plutonium Facility
172	331	Gaseous Chemistry: Also known as Tritium Facility
182	162, 165, 166	Laboratory Services: 55 Ci Cobalt-60 (1958)
190	251	Chemistry Heavy Elements Facility: Cm-244, Am-241, U-233, Pu-239, and others
193	281	Livermore Pool Type Reactor (LPTR)

Source: Table is a modified version of Table 2-1 from ORAUT-TKBS-0035-2.

LLNL's Explosive Test Site, known as Site 300, was an experimental, non-nuclear explosive test facility created to support LLNL's missions. Site 300 included approximately 200 buildings and structures including 5 underground, reinforced-concrete bunkers equipped with high-speed cameras, electrical data-acquisition systems, and one bunker with flash X-ray (LLNL, Apr1981 PDF p. 8). Site 300 served as a location to: (1) manufacture and assemble explosive parts for explosive and environmental testing, and (2) conduct both destructive and non-destructive testing of these explosive components. Site 300 activities included: test firing high-explosive materials; surrogate nuclear detonations; physical testing such as vibration and shock testing for devices and hardware; environmental tests such as heat, cold, and long-term-storage tests; and radiography testing using accelerators and radiation sources.

In 1966, Site 300 buildings changed from the 300 series to the 800 series (e.g., 301 changed to 801) (ORAUT-TKBS-0035-2). Table 5-2 provides a general description of the buildings and activities at Site 300 (identifying buildings as 800 series).

Table 5-2: Site 300 Building Numbers

Site 300 Facility Building Numbers	Description
801-East Firing Area	Flash X-ray (FXR) Linear Accelerator and Contained Firing Facility (CFF)
804	Low-Level Waste Staging Area
805, 806 A&B, 807, 827D, and 828	High Explosive Assembly/Machining: Explosives and metal machining
809	Radiographic inspection, High Explosive Pressing Facility
810	Explosives assembly and disassembly
812	Explosives Test Facility
816	Explosives Waste Storage Facility
817	Isostatic high-explosive pressing
823	Radiographic inspection: Portable 9-MV Varian accelerator
825	High Explosive Chemistry: 100 ton press used to form billets of uniform density
826	High Explosive Chemistry: Small-scale mixing and blending
827	High Explosive Chemistry: Large-scale mixing, extrusion, and pressing; synthesis work; and testing and gas extraction
829	Energetic Materials Processing Center
830	Physical properties and thermal aging
831	Long-term thermal aging: Thermal testing of weapons components since the 1950s
832 Complex-Weapons Testing	Tension, compression, thermal expansion, and creep testing: Thermal testing of weapons components since the 1950s
833-Weapons Testing	Physical tests of high explosives including compressive, tensile, thermal expansion, thermal conductivity, creep, and diffusivity testing
834 Complex-Weapons Testing	Thermal environmental testing: Thermal testing of weapons components since the 1950s
836 Complex-Weapons Testing	Dynamic testing. Multiple actuator hydraulic shaker for high force, high amplitude, low-frequency shock and vibration testing
838	Long-term thermal and pressure effects: Thermal testing of weapons components since the 1950s
840	Enclosed small-scale, high-explosive firings
845	High-explosive experiments occurred at this firing table from 1958 to 1963
850-West Firing Area	Firing bunker for high-explosive testing: Over 95% of the tritium used at Site 300 was expended at the Building 850 firing table
851-West Firing Area	Firing bunker for high-explosive testing, with 100-MeV LINAC
854-West Firing Area	Dynamic Test Complex: Facilities for shock and vibration testing of systems, components, and assemblies
855	Remote machining and disassembly
857	Thermal aging
858	Drop tower for testing specimens for effects of various impacts
865-East Firing Area	Advanced Test Accelerator

Source: Information for this table comes from LLNL, Apr1981 and LLNL, Jan1985

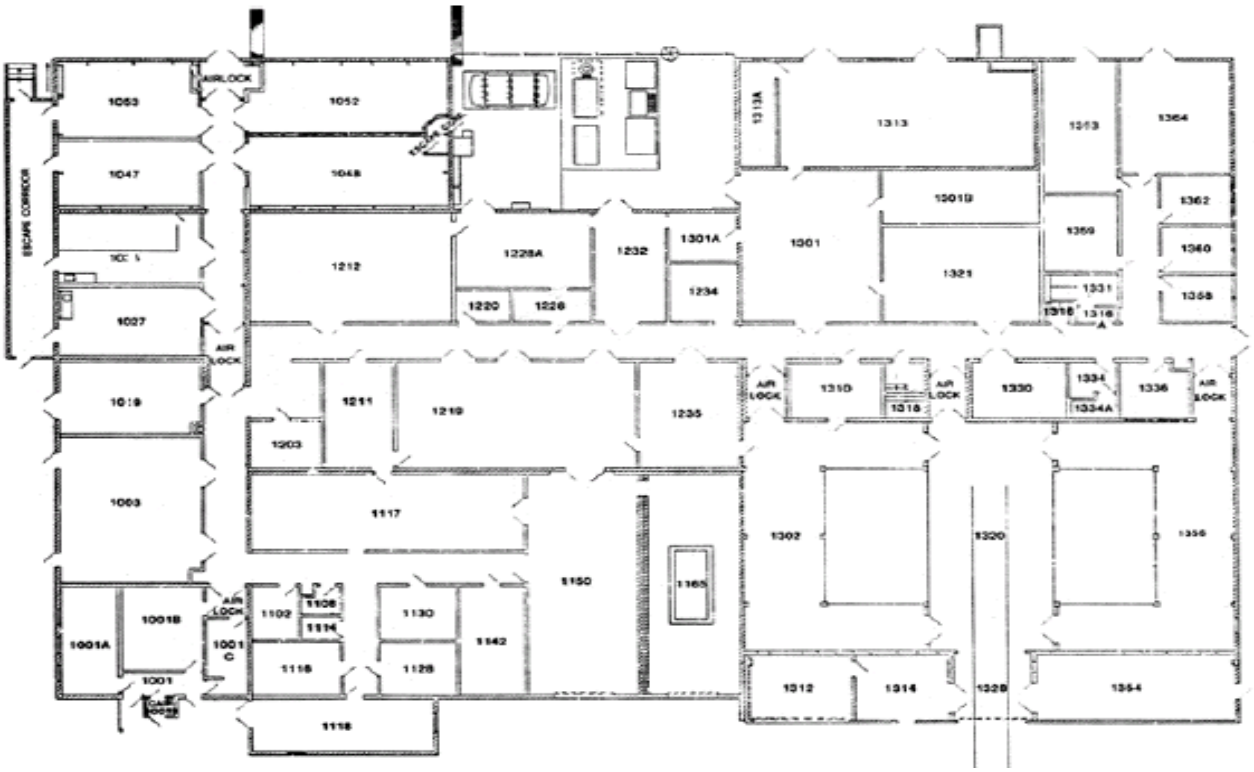
LLNL may be best known for the wide array of strategic defense work in the area of nuclear weapon systems performed by the laboratory staff. This work included weapons-systems research and design, as well as nuclear weapons manufacturing and assembly. LLNL workers have handled a variety of radionuclides as part of their routine work. However, as mentioned previously, this report will focus on Building 251 facilities and U-233 during the period from January 1, 1974 through December 31, 1989.

5.1.1 Building 251

Building 251, the Heavy Element Facility, was a major facility for supporting the U.S. nuclear testing program and for basic research. The steel-framed, concrete block and masonry industrial building is

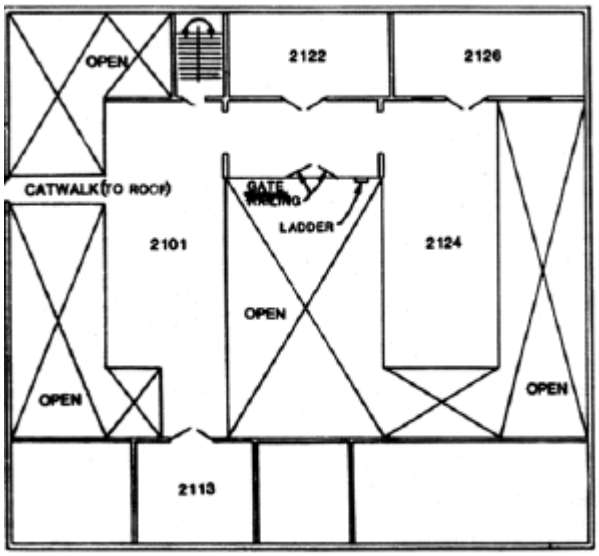
approximately 35,680 square feet (DOE, 1992 PDF p. 27) and is located in the western portion of the main site. It is a one-story building with a mezzanine over the high-bay portion of the building in Increment 7. The building (previously designated as Building 190) was built in eight "increments" between 1955 and 1981. While it is shown in facility documents as one building, it is actually eight individual buildings, abutted together and joined by doorways. The first two "increments" built were designed as a radiochemical laboratory to provide support for nuclear testing at the Pacific Proving Ground. As the nuclear testing program's needs increased, additional increments were added (Sullivan, 2002). Per the 1980 *SAN Review of Building 251 Operations at Lawrence Livermore National Laboratory* report, approximately 11 individuals worked full time in the Building 251 facility, with a peak maximum occupancy of 30 individuals (Keheley, 1980 PDF p. 12).

In its final state prior to decommissioning, the building contained twenty-three laboratories, seven offices, seven mechanical equipment rooms, four storage rooms, five industrial shops, two conference rooms, four hot cells, a pool source storage room, and two change rooms. There were also hallways, janitorial closets, and restrooms (Sullivan, 2002 PDF p. 33), underground storage vaults, hot cells, and the FRED Isotope Separator. The building's pool storage facility (15'x 6') was in room 1165 and was normally filled to a depth of 10 feet. It served as a water-shielded radioactive material storage facility with a continuous water monitor and a calorimeter tank. It also permitted underwater packaging of high-level gamma and neutron emitters. Building 251 also had six storage pits, located at the north end of Room 1165. They were designed to provide shielded storage of radioactive materials. There were an additional 12 storage pits in Room 1320, a Mosler safe for storage of samples sealed in metal cans in room 1235, and the grey cabinet storage in room 1117 (LLL, 1980 PDF pp. 45-47). The entire roof of Building 251 was replaced between 1983 and 1986 (Sullivan, 2002). Figure 5-2 and Figure 5-3 show floorplans of the building and the mezzanine.



Source: Sullivan, 2002 PDF p. 34

Figure 5-2: Building 251, Floor Plan, First Floor



Source: Sullivan, 2002 PDF p. 34

Figure 5-3: Building 251, Floor Plan, Mezzanine

The work in Building 251 involved three main tasks under the nuclear testing program: (1) nuclear tracer fabrication, (2) radiochemical analysis of bomb debris, and (3) chemical research into transuranic radionuclides. Facility operations included preparing radioactive source and heavy-element tracers in support of underground testing, isotopic preparation experiments, high-specific-activity sample processing, fission cross-section experiments, radioactive gas transfer, and theoretical and applied research involving transuranic materials (Keheley, 1980 PDF p. 5). Separations on post-shot samples were also performed in Building 251, after initial sample processing at Building 151.

Building 251 housed specialized equipment designed by in-house researchers specifically for manufacturing tracer sets. Most of the tracer sets used in the U.S. nuclear testing program were manufactured in Building 251 (Sullivan, 2002).

Room 1235 of Building 251 contained the uranium tracer line, used to fabricate tracer sets containing U-233 and U-235. The tracer fabrication process included pressing oxide powders into pellets and then soldering them into brass containers (Gray, 2006).

Basic research involving transplutonic materials, including rare isotopes, was also performed in Building 251. Work in the facility involved numerous exotic isotopes, notably those of curium (Cm) and americium (Am). For curium, the building inventory included Cm-243, Cm-244, Cm-246, and Cm-248. Am-241, Am-243, and Am-242m were also present. NIOSH has indications that Cm-242 was also included in the bioassay program for Building 251. As an indication of how rare some of these isotopes are, only a few milligrams of Am-242m had ever been purified. Work in Building 251 also involved isotopes of californium (Cf-249 and Cf-252) and berkelium, and other higher actinides such as einsteinium. Pure forms of Pu-238 and Pu-242 were routinely used, and weapons-grade plutonium was also present (Gray, 2006 PDF p. 13).

Building 251 had two separate and independent ventilation systems to prevent the release of radioactivity into the environment: (1) a High Efficiency Particulate Air (HEPA)-filtered glove box and enclosure exhaust system and (2) a room-exhaust system (Sullivan, 2002 PDF p. 32).

At the time of its decommissioning, Building 251 contained 49 glove boxes. Forty of these were of the freestanding variety, primarily the "Berkeley" style with a single pair of gloves providing access to the interior of the box (Gray, 2006 PDF p. 27). The remaining nine were "blue cave" enclosures, which were glove boxes surrounded by an external shield. All of the glove boxes and caves had HEPA-filtered exhausts.

Building 251 had a radiation safety program that included As Low as Reasonably Achievable (ALARA) goals. There was a plan for radiation surveys and monitoring to occur any time radioactive material was moved within the building or equipment was removed from the building beyond the routine building radiation survey program. Air monitoring was performed in the building including air sampling, stack monitoring by 45 roof-stack isokinetic samplers, and CAMs (LLNL, Jun1985 PDF p. 4). To prevent any release of radioactive material in the event of a fire or other disaster, Building 251 was surrounded by a drainage system popularly referred to as the moat, which captured liquid waste and diverted it to an underground retention sump. Building 251 also had a nuclear criticality alarm and a fire alarm.

In 1992, the United States ended its underground nuclear testing program and Building 251 lost its principal mission. A decision was made in 1993 to cease programmatic operations in Building 251 (Gray, 2006), and the facility was placed in a standby mode in 1995 (Sullivan, 2002). The facility transitioned to storage mode in September of 2001. At that time a risk reduction program was initiated to remove contaminated glove boxes and the radioactive material inventory from the facility. In 2005, the facility's classification was reduced from DOE Category II Nonreactor Nuclear Facility to Radiological Facility (Gray, 2006).

5.1.2 Building 251 Access Control

At the time of its decommissioning, Building 251 was surrounded by security fencing with access controlled by a Controlled Access by Individual Number (CAIN) booth. The CAIN booth limited entry to LLNL-badged personnel or those under escort (e.g., outside contractors). This is the system currently used for nearly all of the facilities in the limited area within the LLNL main campus. It is unclear how long this particular system of access control has been in place at LLNL, but given its mission, access to Building 251 has always been controlled in some manner. A health physics logbook for Buildings 151 and 251 makes reference to the Building 251 CAIN system in an entry dated March 28, 1980 (LLNL, 1980-1981 PDF p. 9), so the CAIN system was in place at least as of then. The log entry implies that the Building 251 CAIN system required pre-enrollment for access, but the same reference makes it clear that construction workers, electricians, and site visitors were routinely present in the building during that time.

LLNL machinists interviewed by NIOSH indicated that access controls were less stringent during the 1970s and it was more common for them to work in different facilities across the site. Researchers and support staff routinely went back and forth between Building 151 and Building 251 while the latter was in operation. A health physics logbook for Buildings 151 and 251 from 1980 (LLNL, 1980-1981) describes personnel contamination events in Building 251 involving an [Job Title Redacted per Privacy Act] on [Date Redacted per Privacy Act] (LLNL, 1980-1981 PDF p. 16) and a [Job Title Redacted per Privacy Act]on [Date Redacted per Privacy Act] (LLNL, 1980-1981 PDF p. 27). The [Job Title Redacted per Privacy Act] received contamination while "crawling on top of [Redacted per Privacy Act]." The [Job Title Redacted per Privacy Act] received [Redacted per Privacy Act] contamination. An entry dated April 17, 1980, also makes reference to the north door of Building 251 being wedged open while construction was going on in the building (LLNL, 1980-1981 PDF p.12).

An entry dated November 12, 1980, in the same logbook indicates that visitors to Building 151 were going over to Building 251 without wearing dosimeters (LLNL, 1980-1981 PDF p. 36). NIOSH has found no comprehensive records documenting access to Building 251 for site visitors, or for workers that may have spent considerable time in Building 251, but were permanently assigned to other buildings (such as Building 151).

LLNL staff were asked about the existence of historical access control records during the numerous interviews performed by NIOSH, but no actionable information was obtained. NIOSH has been unable to determine if such records existed, were retained, or were sufficiently detailed as to allow explicit determination of who was or was not in a given facility at a given time. During its numerous site visits it did not appear to NIOSH that the CAIN-based access control system would provide information having that level of detail. NIOSH has no information as to whether a different system may have been in place prior to 1980.

NIOSH has determined that information currently available contains insufficient access control information or records for Building 251, and insufficient general site worker movement data, to accurately assess whether an energy employee, or class of employees, did or did not potentially enter Building 251 during the period under evaluation in this report.

5.2 Radiological Exposure Sources from LLNL Operations in Building 251

Workers at LLNL were exposed to radiation from a variety of radioactive materials and radiation-producing machines. The potential for both internal and external radiation exposure existed in all buildings where radioactive materials were handled or stored. Workers in specific buildings had the potential for internal exposure to uranium and plutonium isotopes, tritium, fission products, and other exotic isotopes consistent with the programs and investigations conducted in those buildings. The sources of external exposure included beta, gamma, and neutron radiation. However, this report will focus on U-233 in Building 251.

Workers were monitored for external radiation exposure, categorized as whole body (WB), skin, or extremity dose according to applicable DOE and site specific guidance at the time. Programs to monitor for internal exposure were established with the Hazards Control organization, as determined specific to the identified potential for such exposures. Reviews of potential workplace radiological hazards in LLNL facilities were often performed. Each facility had radiological safety plans that prescribed workplace radiological monitoring and assessments.

The following subsections provide an overview of the internal and external exposure sources for the Building 251 workers during the 1974–1989 period under evaluation in this report.

5.2.1 Internal Radiological Exposure Sources from LLNL Building 251 Operations

Many of the radioactive substances handled at LLNL were alpha particle emitters. Prevention of internal exposures to alpha emitters was recognized as a significant radiological hazard protection challenge.

LLNL workers were potentially exposed to uranium, thorium, highly enriched uranium (HEU), plutonium, americium, curium, neptunium, and other exotic materials in Building 251, the Heavy Elements Facility. As described previously, the Heavy Element Facility work involved nuclear tracer fabrication, radiochemical analysis of bomb debris, and chemical research into transuranic

radionuclides, including work with high-specific-activity sample processing and theoretical and applied research involving transuranics (Keheley, 1980 PDF p. 5).

During its evaluation of transuranic exposures, NIOSH identified the potential for inadequately monitored internal exposures to U-233. Exposures to U-233 in Building 251 will be the focus of the discussion of internal exposure sources below. Workers in Building 251, where operations involving U-233 were known to have occurred almost exclusively, would have potential exposure to this heavy element. Exposure to U-233 entails alpha emissions as an internal dose concern, and gamma radiation associated with the decomposition daughter products, primarily from any impurities.

Review of MC&A records at LLNL indicate to NIOSH that U-233 was refined into end products in Building 251 through at least 1988. Transfers of U-233 between Building 251 and the central storage vault at Building 332 continued beyond 1988, but as of 1989 the records indicate a change in the frequency and nature of those transfers. Pending further NIOSH evaluation of post-1989 U-233 operations, this report focuses on U-233 operations in Building 251 during the period January 1, 1974 through December 31, 1989.

LLNL received U-233 metal and oxide from Rocky Flats Plant for use in tracer applications (Karlsson, 1977). Inventory documents imply U-233 was also received from Oak Ridge National Laboratory. The U-233 exposure potential existed at Building 251, the Heavy Elements Facility during the 1974–1989 period under evaluation in this report. Work in Building 251 required facilities that could accommodate work with high levels of alpha and gamma radioactivity; the building was designed and used primarily as a facility for safe handling, processing, and storing transuranic elements and U-233. Tracer sets were fabricated for all nuclear tests overseen by LLNL, and for select sets of nuclear tests conducted and overseen by Los Alamos National Laboratory (LANL). These bomb fraction tracer sets were used to help determine fission and fusion yields in the post-shot analysis of bomb debris. Bomb fraction tracers were capsules filled with a radioactive isotope that was not produced by the explosion. LLNL fabricated these tracer sets in Building 251.

Surveys, air samples, and bioassay samples via gross alpha analysis were routinely performed in Building 251, as indicated by many documents including the Radiation Safety Program documents and the Health Physics Discipline Action Plans for the building. The LLNL gross alpha technique does not differentiate among the alpha-emitting isotopes.

5.2.2 External Radiological Exposure Sources from LLNL Building 251 Operations

The potential for external radiation dose existed at all locations where radioactive materials were handled or stored, where materials were tested by explosive or radiographic means, and from exposures resulting from accelerators, nuclear reactors, and cyclotrons at LLNL and Site 300. The radiation fields at LLNL are highly variable and radiation sources included a wide variety of radioactive materials and radiation-producing machines such as electron accelerators, X-ray machines, cyclotrons, neutron generators, and a research nuclear reactor. NIOSH has documentation of reviews of potential workplace hazards in LLNL facilities that summarize potential radiation hazards in the respective facilities. Table 2-2 in ORAUT-TKBS-0035-2 summarizes building activities and radionuclides that workers could have encountered. Sources of potential external exposures included primarily beta and photon radiations. The beta and photon (X-ray and gamma) energy ranges and geometries varied across operations. The potential for exposure to neutrons existed in several operations.

As part of its defense mission, LLNL staff conducted atmospheric (1952-1963) and underground (1957-1992) weapons tests at both the Pacific Proving Ground and at the Nevada Test Site. These tests were conducted offsite; test planning and preparation were done at LLNL.

Fission products contained in the blast media resulting from test shots at other locations were part of the sample materials brought onsite for analysis at Building 251. Radioelements likely to have been captured and counted would have included strontium, barium, radium, most of the transition metals unless they form strong amine complexes (such as cobalt, nickel, copper, zinc, and silver), all the rare earths, and all the actinides. This means that beta-emitting progeny of thorium and uranium were likely to be included in the gross beta results.

5.2.2.1 Beta/Photon

External radiation dose at LLNL was evaluated and well understood by the LLNL's Hazards Control organization. Evaluations of potential beta and photon (gamma and X-ray) radiation hazards at LLNL facilities have been performed on numerous occasions, as noted in Attachment A, Section A.2 of ORAUT- TKBS-0035-6. Table 6-6 of ORAUT- TKBS-0035-6 lists numerous beta/photon radiation sources potentially encountered at LLNL over the years, the approximate energy category, and the associated dose fraction.

Building 251 had potential photon energies predominately in the 30-250 keV range, and beta energies all within the >15 keV range.

5.2.2.2 Neutron

Evaluations of potential neutron radiation hazards at LLNL facilities have also been performed on numerous occasions, as noted in Attachment A, Section A.2 of ORAUT-TKBS-0035-6. Table 6-7 of ORAUT-TKBS-0035-6 lists neutron radiation sources potentially encountered at LLNL over the years, the approximate energy category, and the associated dose fraction. Building 251 handled curium, californium, and other potential sources of neutrons, especially during transuranic radiochemistry experimentation (ORAUT-TKBS-0035-6). Workplace neutron radiation energies of potential external radiation exposure significance to workers in Building 251 are expected to be between 10 keV and 20 MeV. Sources of neutron radiation were normally shielded, during operations and when in storage (Inventory, 2004-2005; Gray, 2006).

5.2.3 Incidents

LLNL retains radiological incident records in numerous locations at the site. Evidence of radiological incidents was observed in internal monitoring records for individuals known to have worked in Building 251. However, these incidents involved radioactive materials other than U-233, and are not relevant for this evaluation. Full evaluation of radiological incidents is therefore being reserved for a future NIOSH evaluation of internal and external exposures for the period from January 1, 1974 through December 31, 1995.

6.0 Summary of Available Monitoring Data for the Class Evaluated by NIOSH

The following subsections provide an overview of the state of the available internal and external monitoring data for the LLNL class under evaluation. Though the focus on Building 251 continues in the following subsections, some descriptions applicable to the overall LLNL monitoring program and resultant data are presented as appropriate. Further details regarding the LLNL Radiation Protection Program approach, sampling types, various analyses, detection limits, and information on additional available data can be found in the various LLNL Site Profile documents (ORAUT-TKBS-0035-1 through ORAUT-TKBS-0035-6).

NIOSH has identified and reviewed numerous LLNL data sources to determine the availability of personnel monitoring, workplace monitoring (discussed below), and radiological source term data. Occupational monitoring data for LLNL have historically resided in a number of repositories and databases over the years. Data have also been stored in logbooks, as hard copies in personal files, and in some cases such as incident data, in facility "building files."

6.1 Available LLNL Internal Monitoring Data

Throughout the evaluated period, the selection of workers for internal monitoring at LLNL was based on the potential for internal exposure. Worker selection for bioassay, whole body, and/or specific organ counting was based on recommendations from applicable program supervisors and the health physics staff assigned to the work area. Bioassays were commonly supplemented and/or triggered by workplace air monitoring (Mansfield, 1989). However, LLNL apparently did not typically use data acquired from the air monitoring program to prepare the dose of record for employees; these air data are not readily associated with individual exposures. In addition to *in vitro* monitoring (primarily urinalysis) and *in vivo* monitoring (primarily whole body and lung counting), nasal smears were collected after incidents as a means of assessing intake potential.

6.1.1 *In Vitro* Bioassay (General)

LLNL maintains its official *in vitro* bioassay records in the form of hard copies stored in personal files. Despite these hard copies being the dose of record, LLNL has also developed and utilized various database systems for storing and manipulating occupational *in vitro* monitoring data. These include MAPPER (used until approximately 1995), SYMPHONY (initially used in the latter 1990s), and currently uses the Bioassay Laboratory Information Management System (BLIMS) database. Other databases used by LLNL's internal dosimetry group include: (1) Bioassay Information Tracking System (BITS) and (2) Dose Assessment Tracking System (DATS). BITS is used for tracking investigations, and data within DATS is fed into DOE's Radiation Exposure Monitoring System (REMS) for dose reporting purposes. None of the aforementioned databases contain *in vivo* (lung or whole body) counting results.

Though no longer used by LLNL, *in vitro* data contained within the MAPPER database span the January 1, 1974 through December 31, 1989 period. MAPPER has utility for assessing monitoring data availability. The MAPPER database contains monitoring data from the early 1960s through ca. 1995 and is believed to be complete from approximately the mid-1970s forward. NIOSH initially obtained a names-redacted version of MAPPER in 2007 to support earlier LLNL SEC evaluations, dose reconstruction work, and coworker model development. A "fully identified" version of the

database was received in 2015. The MAPPER database contains just over 35,000 records; approximately 16,100 records are from within the 1974–1989 evaluation period. Results are predominantly for urinalysis (just 354 fecal samples).

A review of site records has shown that routine *in vitro* monitoring was accomplished through a combination of four procedures: (1) gross alpha urinalysis, (2) gross beta urinalysis (also called mixed fission product, MFP), (3) plutonium urinalysis, and (4) uranium urinalysis. Querying the entire MAPPER database, over 2,300 individuals and 167 locations (largely buildings) can be identified. The locations listed, however, are known to not necessarily represent an employee's potential exposure location.

6.1.2 *In Vitro* Bioassay Results for Building 251

Table 6-1 presents a summary obtained from MAPPER of the number and types of urinalysis results that have been associated specifically with Building 251 and the 1974–1989 evaluation period.

Table 6-1: *In Vitro* Results for Building 251

Analyte	Number of Urinalysis Results	Number of Fecal Results
MFP	9	0
U-238	5	0
Alpha	135	6
Am-241	12	7
Beta	79	0
Cm-242	5	0
Cm-244	7	0
Pu-239	134	6
Sm-145	1	0

The available results do not indicate evidence of routine *in vitro* monitoring for uranium associated with Building 251. Though not presented in detail in Table 6-1 above, analysis of the MAPPER database reveals only five urinalysis results for uranium associated with Building 251 from 1979–1989. All five results are from 1980. LLNL used either fluorometric or phosphorescence measurements in its uranium urinalysis program. The sample results are therefore all in terms of total uranium by mass. Discussed further in Section 7.2.1 of this report, this is problematic relative to determining U-233 plus U-232 intakes due to large uncertainties associated with the necessary conversion from mass to activity.

6.1.3 *In Vivo* Bioassay (General)

In vivo monitoring at LLNL was accomplished via whole-body scanning and/or organ counting. As with *in vitro*, selection of workers for monitoring was based on potential exposure as determined by appropriate supervisory and health physics personnel. Baseline and termination counts were also utilized during the 1979–1989 period. LLNL has no electronic repository for *in vivo* monitoring data precluding efficient, comprehensive summarization of available monitoring records. The "official" *in vivo* records are in the form of hard copies stored in personnel files.

As was the case throughout the industry, *in vivo* counting systems at LLNL were still evolving rapidly and struggling with stability issues through the 1960s and early 1970s. The systems were better

developed, calibrated, and stabilized however by 1974 and were generally considered useful for monitoring and detecting certain gamma spectra. LLNL dosimetry staff recalled that phoswich detectors were used for chest counting from 1975 to approximately 1985, and sodium iodide detectors were used in a bed scanner for whole-body counts. The utility of the resultant counting data for determining depleted uranium intakes is discussed in Section 7.2 of this report.

Though no efficiently searchable repository for *in vivo* counting results exists, NIOSH has obtained logbooks for two whole-body counter systems used at the site. Logbooks captured include those from years 1974–1981, the early portion of the current evaluation time period. Captured logbooks indicate that a range of approximately 50–200 *in vivo* counts were performed at LLNL each year. Unfortunately, by 1970 logbook entries became more limited in that they only recorded the number of people counted on particular dates and documented information regarding machine set-up, calibration, and experimentation.

In addition to reviewing the captured logbooks, a detailed review of *in vivo* records and worker details was performed on received EEOICPA claims stored within the NIOSH claims tracking system (NOCTS). The review was limited to all previously identified LLNL claims that were known to contain *in vivo* data for the period 1974–1995. As possible, information such as job title, assignment location, and counting dates were extracted. Data were found for whole-body scans, lung scans, thyroid counts, and one wound count. It should be noted that it cannot be determined with certainty that recorded worker assignment locations correlate with actual exposure potential locations.

6.1.4 *In Vivo* Bioassay Results for Building 251

Assessment of EEOICPA claims documentation revealed *in vivo* monitoring results for seven LLNL employees with at least some assigned or indicated association with Building 251 from 1974–1995. Though some whole-body counts were performed, most of the monitoring was for lung scans as would be expected for a Transuranic (TRU) facility. NOCTS i*n vivo* monitoring was found for only two workers associated with Building 251 during the 1974–1989 evaluation period. Of these two workers, there were seven lung counts, fourteen whole-body counts, and one liver count.

6.1.5 Air Monitoring

LLNL utilized workplace air monitoring in an attempt to identify any increased potential for intakes. Bioassays were commonly supplemented and triggered by workplace monitoring (Mansfield, 1989). However, LLNL did not typically use data acquired from the air monitoring program to prepare the dose of record for employees; available air data are not readily associated with individual exposures and are also often difficult to associate with high-risk work areas.

NIOSH has found no evidence of a comprehensive repository for air monitoring data, making assessment and summarization of its availability site-wide, or specifically for Building 251 impossible. Though NIOSH has captured some air monitoring data, very few of the results are from within the 1974–1989 evaluation period and/or from Building 251.

NIOSH has, however, captured documents indicating that even if air monitoring data are made available for Building 251 they would be deemed insufficient to support dose reconstruction. For example, a review of Building 251 operations performed by the DOE San Francisco Operations Office in 1980 noted an “excessive” failure rate for the CAMs used in the various laboratories in Building 251 and recommended that LLNL “vigorously pursue” improving the air monitoring in the building

(Keheley, 1980 PDF p. 11). Though slightly after the current evaluation time period, a 1990 DOE Tiger Team assessment of LLNL (DOE, 1990) noted that air monitors and air samplers did not appear to be strategically placed with respect to capturing representative samples of potential airborne releases. This document further noted that breathing zone monitors were not used at LLNL and CAM placement appeared to emphasize general room air monitoring rather than representative workplace monitoring.

6.2 Available LLNL External Monitoring Data

The personal dosimeter is the primary data type used to reconstruct the external doses for LLNL workers. Those data are specifically used to reconstruct a worker's measured and missed external doses. For the period under evaluation in this report, the LLNL site monitored all workers for external photon and beta doses via their own dosimeters. The 1977 *Health and Safety Manual* for LLNL states:

> *A record of the occupational radiation dose of each LLL employee shall be obtained by means of a continuous personnel monitoring program. Normally, non-LLL employees in areas under direct Laboratory control shall be monitored in the same manner as LLL employees with the exception that deliverymen, visitors, contractors, and other transient personnel are not required to wear dosimeters unless they enter buildings where there is a potential for exposure to ionizing radiation* (LLNL, 1977 PDF p. 11).

The neutron dosimetry is described in a 1980 site memo with the subject "Personnel neutron dosimetry at LLNL":

> *Personnel neutron dosimetry at the Lawrence Livermore National Laboratory is performed using three dosimetry methods: TLD dosimeters, albedo dosimeters, and polycarbonate and monocarbonate foils. The TLD and albedo dosimeters contain thermoluminescent crystals of lithium. The TLD dosimeters is issued to all employees and allows determination of the employees [sic] beta, gamma, x-ray and thermal neutron exposure. …To assure accurate readings, we routinely issue albedo dosimeters to all personnel who may be receiving neutron exposure* (Hankins, 1980).

NIOSH has obtained copies of the Radiation Safety Programs for various buildings at LLNL. In the 1985 program for Building 251 are the statements "All employees and visitors at LLNL are issued a thermoluminescent dosimeter (TLD)" (LLNL Nov1981, PDF p. 113**)** and "CR-39 track etch neutron badges are assigned to workers at Building 251 who work with neutron-emitting radionuclides" **(**LLNL, Nov1981 PDF p. 113).

Certain operational safety procedures required the use of extremity monitoring. For example, the safety procedure for U-233 Metal Scrap Recovery in Building 251 (LLNL, Nov1981 PDF pp. 267-269) described an operation in a glove box involving 21 Ci of U-233 and included the requirement "finger ring dosimeters must be worn."

Specific for Building 251, NIOSH has reports from the site for the period between 1982 and 1990 that list monthly, quarterly, or annual totals for individuals who worked in that building. These reports list individuals who worked in Building 251 along with their whole-body gamma and neutron exposures (LLNL, Jun1985 PDF p. 3; Monitoring, 3rd Quarter 1986; Monitoring, Jul 1982; Monitoring, 2nd Quarter 1988; Monitoring, 3rd Quarter 1987; Monitoring, 2nd Quarter 1987; Monitoring, 1986;

Monitoring, 1st Quarter 1988; Monitoring, 3rd Quarter 1988; Monitoring, 2nd Quarter 1990 PDF p. 3; Gibson, 1983; LLNL, Nov1981 PDF p. 284). Note that some reports (e.g., Monitoring, 1986 PDF p. 4) state that the exposure for some workers was assigned to Building 151, although the actual exposure occurred in Building 251.

NIOSH does not possess a complete set of the dosimeter data. However, DOE does have a complete set and provides the external dosimetry records for each energy employee who files an EEOICPA claim.

NIOSH has a copy of the historical LLNL external database, REX. The database contains 2,818,811 total records with 686,415 records for LLNL employees between 1975 and 1989. Each record has a date, name, and one or more dose values for gamma, neutron, skin, and extremity. Although not used for dose reconstruction purposes, the database gives an indication of the numbers of people who were monitored. There are 16,210 individuals in this database.

Specifically for Building 251, there are 1,705 records associated with the location "251," although site procedures used either the person's location or the location of the work interchangeably as the location stored the database.

For medical X-ray exposure, NIOSH has descriptions of the program including the type and frequency of the required X-rays (DOE, 1987 PDF p. 23; LLNL, 1991) and the types of machines used and their settings (Graham, 1975; Myers, 1979). Details regarding the various analyses used and the associated minimum detectable activities are presented in ORAUT-TKBS-0035-6.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determination for the class of employees under evaluation in this 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 would be 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. 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. This approach is discussed in DCAS'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-00221 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of LLNL 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.

7.1.1 Internal Monitoring Data Pedigree Review

As explained in the following sections, NIOSH has not found internal monitoring data considered sufficient to determine potential doses from internal exposures to U-233 in Building 251 for the 1974–1989 period evaluated in this report. NIOSH considers the U-233-related data available for *in vitro*, *in vivo*, and air monitoring to each be insufficient in terms of quantity and quality. Available records are, however, in the form of hard copies and as such are considered primary data sources.

Analysis of *in vitro* data available in MAPPER (Section 6.1 of this report) indicates a focus on transuranic material monitoring, but does not provide evidence of routine monitoring for uranium. In addition to a resultant insufficient quantity of uranium monitoring results for Building 251, the results that are available have unacceptable associated accuracy uncertainties due to the types of analytical procedures used and unit conversions required. Neither i*n vivo* nor air monitoring records are stored electronically; total availability of these records therefore cannot efficiently be determined. Using captured and/or submitted *in vivo* counting results to determine U-233 intakes involves unacceptable uncertainties regarding the presence of gamma emitting decay products (see Section 7.2 of this report). Available air monitoring results are judged unrepresentative of immediate working environments due to documented sampler placement issues and unacceptably high sampling device failure rates (DOE, 1990).

7.1.2 External Monitoring Data Pedigree Review

Consistent with NIOSH's previous evaluation of SEC-00163 (NIOSH, 2010), NIOSH has found LLNL's external monitoring data to be of sufficient quality and quantity to represent external doses measured for the 1974–1989 period in this report. Doses of record are maintained in hard-copy form representing primary data sources. Captured and reviewed LLNL policies, monitoring procedures, assessments, and descriptions of monitoring equipment all indicate the presence of a comprehensive monitoring program and that the resultant monitoring data are sufficient to adequately assess doses from all potential radiation sources incurred by the evaluated class. No data quantity issues have been observed during claims processing or otherwise during this SEC evaluation.

7.2 Evaluation of Bounding Internal Radiation Doses at LLNL

The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction for potential intakes of U-233 by workers in Building 251 during the period 1974–1989. As presented in Section 5.2.1 above, NIOSH review of material inventory records indicates that U-233 was refined into end products in Building 251 through at least 1988. In 1989, the frequency and nature of U-233 transfers changed indicating a possible change in U-233 production or usage. Pending further NIOSH evaluation of post-1989 U-233 operations, this report focuses on U-233 operations in Building 251 during the period January 1, 1974 through December 31, 1989. Full evaluation for other internal dose contributors during this period, and for all dose contributors during the period 1990–1995, will be performed by NIOSH subsequent to this initial evaluation for U-233.

7.2.1 Evaluation of Bounding Process Related Internal Doses

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

7.2.1.1 Urinalysis Information and Available Data

Documents defining bioassay assignments for individuals that routinely worked in Building 251 were reviewed to identify such individuals by name. The names were then used in queries of the MAPPER database to examine their *in vitro* monitoring history. The MAPPER results did not show evidence of routine *in vitro* monitoring for uranium, though occasional uranium urinalyses are seen for some of the Building 251 workers. The Building 251 workers were routinely monitored by urinalysis for transuranic materials using a gross alpha method. In addition, gross beta urinalysis appears to have been added for at least some of these individuals as of 1984.

Evaluation of urinalysis data for internal dose contributors other than U-233 during the period 1974–1989, and for all internal dose contributors during 1990–1995, will be performed by NIOSH subsequent to this initial evaluation for U-233.

7.2.1.2 *In Vivo* Counting Information and Available Data

No database or similar compendium of *in vivo* monitoring data for LLNL workers currently exists. Review of LLNL *in vivo* monitoring data included in claim files showed LLNL workers were monitored using chest/lung counting, whole-body scans, or both. Workers in Building 251 were included in the routine *in vivo* monitoring program.

7.2.1.3 Airborne Levels

The 1990 Tiger Team assessment of LLNL (DOE, 1990) documented that air monitoring was the key element of the LLNL internal dose control program, and that air monitoring results were used to trigger more frequent bioassay measurements.

A review of Building 251 operations performed by the DOE San Francisco Operations Office during the period August 21–October 22, 1980 (Keheley, 1980) noted an "excessive" failure rate for the continuous air monitors used in the various laboratories in Building 251 and recommended that LLNL "vigorously pursue" improving the air monitoring in the building. The 1990 Tiger Team assessment

of LLNL noted that air monitors and air samplers did not appear to be strategically placed with respect to capturing representative samples of potential airborne releases. It further noted that breathing zone monitors were not used at LLNL, and placement of CAMs appeared to emphasize room air monitoring rather than representative workplace monitoring (DOE, 1990). Later documents (Howe, 1991) also identified issues with the air monitoring program in Building 251. Air monitoring data from Building 251, therefore, are not considered sufficient for dose reconstruction during the period 1974–1989.

Further evaluation of LLNL's air monitoring program for the remainder of the site during 1974–1989 and for the entire site for the period 1990–1995 will be performed by NIOSH subsequent to this initial evaluation of U-233 usage in Building 251.

7.2.1.4 Alternative Data Sources for Bounding Internal Dose

The coworker methodology presented in Attachment B of ORAUT-TKBS-0035-5 includes information for assigning intakes of uranium. However, the underlying data are from LLNL's mass-based uranium urinalysis methods, requiring that an assumed specific activity be used to convert the results to activity units. The specific activity for different enrichments or isotopic mixtures of uranium can vary widely. The specific activity of U-233 exceeds that for natural uranium by more than four orders of magnitude. U-232, present as an impurity in U-233, further increases the specific activity of the mixture.

Given what appears to be a lack of routine *in vitro* monitoring for uranium for workers in Building 251, an evaluation of whether the uranium coworker model sufficiently represents potential intakes of U-233 by those individuals cannot be made.

Evaluation of alternative data sources for internal dose contributors other than U-233 in the period 1974–1989, and for all internal dose contributors during 1990–1995, will be performed by NIOSH subsequent to this initial evaluation of U-233.

7.2.2 Evaluation of Bounding Ambient Environmental Internal Doses

Building 251 discharged its process area exhausts through a local stack. Evaluation of ambient environmental internal doses at LLNL from all sources in the period 1974–1995 will be performed by NIOSH subsequent to this initial evaluation of U-233 usage in Building 251.

7.2.3 Methods for Bounding Internal Dose at LLNL

The following subsections summarize the methods for bounding internal dose at LLNL.

7.2.3.1 Methods for Bounding Operational Period Internal Dose

Review of the MAPPER database indicated that routine *in vitro* monitoring for workers in Building 251 during 1974–1989 focused on transuranic materials via gross alpha and plutonium urinalyses. Additional routine monitoring for mixed fission products appears to have been specified for those individuals around 1984.

With respect to sensitivity for U-233, the chemistry used for the LLNL gross alpha procedure (see Miller, 1979) appears to have excluded uranium. The LLNL gross alpha procedure was essentially

identical to the americium urinalysis procedure used at Los Alamos as of the late 1950s. In addition to americium and plutonium, the procedure states it also carried actinium, curium, neptunium, and thorium. There is no mention of uranium. It would have been desirable to exclude uranium from the analysis since any uranium present would have interfered with the assay for the transuranic analytes of interest, notably americium. The LLNL gross alpha procedure employed a bismuth phosphate extraction to pull the actinides of interest from the sample solution. This was the same chemical process employed initially at the Hanford site for large-scale extraction of plutonium from irradiated nuclear fuel. A key step in the bismuth phosphate process at Hanford was the addition of sulfate to the solution prior to the bismuth phosphate extraction. The presence of the sulfate kept the uranium in solution while allowing the plutonium to form an insoluble precipitate. Sulfate was also added to the sample solution just prior to the bismuth phosphate extraction step in the LLNL gross alpha urinalysis procedure. It seems reasonable that this was done for the same purpose (i.e., to keep the uranium in the solution so it did not interfere with the analysis).

NIOSH determined that it cannot assume thorium decay products from U-233 (or the U-232 impurity) would have been sufficiently present in the gross alpha analysis given the fact it could have been removed during production, either directly or indirectly (Moment, 1999; Karlsson, 1977). Gross beta analysis, if performed, was deemed insufficient for U-233 given the lack of countable electron emission from U-233 + U-232 and the fact the beta-emitting decay products cannot be assumed to have been present. The plutonium procedure was specific for plutonium.

In vivo monitoring at LLNL was accomplished via whole-body scanning and/or chest/lung counting. It is unknown what *in vivo* methods were used for Building 251 workers, though chest/lung counting would seem likely given the wide variety of transuranic materials handled there. Regardless, using LLNL's *in vivo* data to assign potential doses from intakes of U-233 + U-232 would be highly uncertain given the gamma-emitting decay products cannot be assumed to have been present.

In summary, none of the *in vitro* or *in vivo* monitoring methods evaluated are determined by NIOSH to be sufficient for bounding potential internal doses from U-233 for workers in Building 251.

Full evaluations of LLNL's bioassay methods for other dose contributors during the period 1974–1989, and for all dose contributors for 1990–1995, will be performed by NIOSH subsequent to this initial evaluation of U-233 use in Building 251 during 1974–1989.

7.2.3.2 Methods for Bounding Ambient Environmental Internal Dose

Evaluation of ambient environmental internal doses at LLNL from all sources during 1974–1995 will be performed by NIOSH subsequent to this initial evaluation of U-233 use in Building 251 during 1974–1989.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

As presented in Section 5.2.1 above, NIOSH review of material inventory records indicates that U-233 was refined into end products in Building 251 through at least 1988. In 1989, the frequency and nature of U-233 transfers changed indicating a possible change in U-233 production or usage. Pending further NIOSH evaluation of post-1989 U-233 operations, this report focuses on U-233 operations in Building 251 during the period January 1, 1974 through December 31, 1989.

As presented in Section 7.2.3.1 above, NIOSH has determined that it has insufficient information to verify that the routine *in vitro* bioassay program for Building 251 workers (combinations of analyses for gross alpha in urine, gross beta in urine, and plutonium in urine) was adequately sensitive for detection of U-233 intakes during the period under evaluation. Similarly, NIOSH has determined that photon-emitting decay products and contaminants cannot be assumed to have been sufficiently present in the U-233 source term to verify that the routine *in vivo* bioassay program for Building 251 workers was adequately sensitive for detection of U-233 intakes.

As presented in Section 7.2.1.3 above, information available to NIOSH from multiple site inspections from 1980 to 1991 indicate deficiencies in LLNL's implementation of the air monitoring program in Building 251. NIOSH has determined the air monitoring data from Building 251 may not be adequately representative of the worker breathing zones, and are consequently not considered sufficient for Building 251 dose reconstruction during the period under evaluation in this report.

NIOSH has therefore concluded it is not feasible to reconstruct internal dose with sufficient accuracy from potential intakes of U-233 by workers in Building 251 during the period January 1, 1974 through December 31, 1989. Additionally, as presented in Section 5.1.2 above, NIOSH has determined that information currently available contains insufficient access control information or records for Building 251, and insufficient general site worker movement data, to allow NIOSH to accurately assess whether an energy employee, or class of employees, did or did not potentially enter Building 251 during the period under evaluation in this report. Consequently, NIOSH is unable to define a class of LLNL workers for whom potential exposures in Building 251 are not possible, and therefore recommends the extension of the recommended class to include all workers during the period from January 1, 1974 through December 31, 1989.

NIOSH does not have access to sufficient personnel monitoring, workplace monitoring, or source term data to estimate potential internal exposures to uranium-233 associated with operations in Building 251. NIOSH is unable to identify workers that did not potentially enter Building 251 during the period from January 1, 1974 through December 31, 1989. Consequently, NIOSH finds that it is not feasible to estimate with sufficient accuracy the internal doses for LLNL workers during the period from January 1, 1974 through December 31, 1989. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from January 1, 1974 through December 31, 1989, NIOSH intends to use any internal monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at Lawrence Livermore National Laboratory during the period from January 1, 1974 through December 31, 1989, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.3 Evaluation of Bounding External Radiation Doses at LLNL

The principal source of external radiation doses for members of the evaluated class included a wide variety of radioactive materials and radiation-producing machines such as electron accelerators, X-ray machines, cyclotrons, neutron generators, and a research nuclear reactor. Table 2-2 in ORAUT-TKBS-0035-2 summarizes building activities and radionuclides that workers could have encountered.

The following subsections address the ability to bound external doses, methods for bounding doses, and the feasibility of external dose reconstruction.

7.3.1 Evaluation of Bounding Process-Related External Doses

The following subsections summarize the extent and limitations of information available for reconstructing the process-related external doses of members of the class under evaluation. For the purpose of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date for internal exposures in Building 251, but will continue to review and evaluate all process-related external exposures for the period 1974–1995.

7.3.1.1 Personnel Monitoring

Photon and Beta

The LLNL site used TLDs for personal dosimetry during the period under evaluation. LLNL constructed the TLDs used from 1969–1984 using Harshaw TLD-100, TLD-200, TLD-600, and TLD-700 elements. The use of Panasonic 802 and 810 dosimeters began in 1985 and has continued to the present. The dosimeter types, exchange frequencies, limits of detection, and estimates of missed doses are listed in Table 6-4 in ORAUT-TKBS-0035-6.

NIOSH has found specific requirements for Building 251 that state that "[a]ll employees and visitors at LLNL are issued a thermoluminescent dosimeter (TLD)" (LLNL, Nov1981 PDF p. 113). In addition, monthly, quarterly and annual summaries of worker exposure for Building 251 have been identified that list individual whole-body gamma and neutron totals by name. Many of these summaries included individual extremity exposures listed as "hand dose."

As all LLNL employees and visitors to the LLNL site wore dosimetry in the form of personal TLD badges, and as DOE provides the monitoring data from these badges to NIOSH upon request, external photon and beta exposure may be reconstructed using the guidance in ORAUT-TKBS-0035-6. Data that have been made available to NIOSH have proven sufficient to estimate doses for the members of the class under evaluation for photon and beta exposures.

Neutron

Site procedures required neutron dosimetry for workers who may have been exposure to neutron radiation. As noted above, track etch neutron badges were assigned to workers at Building 251 who work with neutron-emitting radionuclides (LLNL, Apr1985 PDF p. 9). LLNL constructed the dosimeters used from 1969 through 1985, which contained Harshaw TLD-100, TLD-200, TLD-600, and TLD-700 elements (Hankins, 1982). The CR-39 track etch dosimeter was adopted in 1985 after several intercomparison studies (Hankins, 1987). Table 6-5 in ORAUT-TKBS-0035-6 lists the time periods for the types of neutron dosimetry, the exchange frequencies, limits of detection, and estimated annual missed dose.

Neutron monitoring TLDs and CR-39 track etch dosimeters were used during the period being evaluated and provide adequate results to reconstruct neutron dose. DOE provides the dosimetry data upon request and ORAUT-TKBS-0035-6 may be used to reconstruct neutron dose from these data for workers with documented neutron exposure.

As the routine TLDs used for photon and beta dosimetry would detect neutron exposure, LLNL had a procedure to investigate any potential neutron exposures and quantify the spectrum using survey instruments (Hankins, 1982).

7.3.1.2 Area Monitoring

NIOSH has many examples of LLNL procedures that require routine and non-routine gamma, beta, and neutron surveys. For example, the Radiation Safety Program for Building 251, the Heavy Elements Facility, required that:

> *Any time that radioactive material is moved to a new location in the building (e.g., from one box to another, from floor storage to a box, etc.), beta, gamma and neutron surveys will be conducted when appropriate in that area to ensure that the workplace is providing proper shielding* (LLNL, Jun1985 PDF p. 3).

Routine neutron monitoring was performed at accelerators (Powell, 1979), cyclotrons (Monitoring, 3rd Quarter 1983), and at Building 332 (Ozaki, 1982). NIOSH has examples of documents describing the requirements for these measurements and documents containing survey results. Neutron surveys were performed using dosimeters placed in buildings (Ozaki, 1982) and using neutron instrumentation (LLNL, 1989 PDF p. 25).

NIOSH has examples of gamma and neutron survey results for some operations, in many cases collected together. Survey results for gamma are described in certain monthly reports from the Health Physics group (Powell, 1978; Campbell, 1981). Examples of gamma and neutron data are reported for the Metal Production Line in Building 332 (Wilson, Jun1987; Gordon, 1989; Wilson, 1986; Wilson, Feb1987), for Building 231 (Wilson, 1983; Surveys, 1987), and for Building 212 (Willhoite, 1979). An extensive neutron survey of many locations at LLNL, including Building 251, was performed in 1982 (Hankins, 1982 PDF pp. 18-19).

NIOSH has not located beta radiation area monitoring data in the over 5,000 documents acquired from LLNL. The general intent of the beta measurements required by site procedures was for confirmation of limits for materials release, working conditions, etc., and generally would not have been collected for reports or for dosimetric purposes. For the purpose of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date for internal exposures in Building 251, but will continue to review and evaluate all ambient environmental external exposures for the period 1974–1995.

7.3.2 Evaluation of Bounding Ambient Environmental External Doses

As all LLNL employees wore TLD dosimeters and workers in areas with neutron radiation wore TLD or track etch neutron dosimeters, all photon, beta, and neutron exposure would have been tallied, regardless of the source. Any ambient exposure would have been included in the results and reported as part of the worker's occupational exposure.

7.3.3 LLNL Occupational X-Ray Examinations

Baseline and periodic chest X-rays were performed for all employees at LLNL for the years between 1952 and approximately 1993 (LLNL, 2002). Periodic X-rays were conducted "no more often than yearly and in many instances only every 2 years" (Schaer, 1964). ORAUT-TKBS-0035-3 describes

the assumptions for estimating medical X-ray exposures at LLNL. Table 3-2 in ORAUT-TKBS-0035-3 lists the dates and specific equipment used, along with their operating parameters. In addition, a radiation survey made by LLNL of the X-ray machine in use in 1975 provides specific parameters, including the "exposure at the skin from a typical radiograph" (Graham, 1975 PDF p. 2). Therefore, consistent with the findings of NIOSH's 2010 evaluation of SEC-00163, NIOSH concludes that it is feasible to reconstruct occupational medical dose for LLNL workers with sufficient accuracy for the period from January 1, 1974 through December 31, 1989.

7.3.4 Methods for Bounding External Dose at LLNL

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

- Photon Dose
- Beta Dose
- Neutron Dose
- Medical X-ray Dose (as applicable per Section 7.3.3)

7.3.4.1 Methods for Bounding Process-Related External Dose

Photon Dose

The primary method is the use of individual records. All LLNL employees wore TLD dosimetry. The types of TLD used in the LLNL badges along with the applicable dates are known. Estimates of annual missed dose for these badges are listed Table 6-4 of ORAUT-TKBS-0035-6. External photon dose can likely be reconstructed using the methods and assumptions listed in ORAUT-TKBS-0035-6. NIOSH will continue to review and evaluate all photon external exposures for the 1974–1995 period.

Beta Dose

The primary method for bounding beta dose is the use of individual records. All LLNL employees wore TLD dosimetry. The types of TLD used in the LLNL badges along with the applicable dates are known. Missed dose may be calculated using the limits of detection for these badges along with the exchange frequencies as reported by DOE for individual workers. External beta dose can likely be reconstructed using the methods and assumptions listed in ORAUT-TKBS-0035-6. NIOSH will continue to review and evaluate all beta external exposures for the 1974–1995 period.

Neutron Dose

The primary method for bounding neutron dose is the use of individual records. Workers who were expected to incur exposure to neutron radiation wore TLD or track etch monitoring badges. Estimates of annual missed dose for these badges are listed Table 6-5 of ORAUT-TKBS-0035-6. All workers wore TLD badges that would have detected neutron radiation. Those who may have been exposed to neutron radiation and without neutron dosimetry would have been assigned neutron exposure using site procedures. External neutron dose can likely be reconstructed using the methods and assumptions listed in ORAUT-TKBS-0035-6. NIOSH will continue to review and evaluate all neutron external exposures for the 1974–1995 period.

Medical X-ray Dose

Site documents list frequencies for required X-rays and types of machines used along with applicable dates. As presented in Section 7.3.3 above, NIOSH concludes that it is feasible to reconstruct occupational medical dose for LLNL workers with sufficient accuracy for the period from January 1, 1974 through December 31, 1989, using ORAUT-TKBS-0035-3.

7.3.4.2 Methods for Bounding Ambient Environmental External Doses

Any ambient exposure would have been included in the results and reported as part of the workers' occupational exposures. Ambient external dose can likely be reconstructed using the methods and assumptions listed in ORAUT-TKBS-0035-4. NIOSH will continue to review and evaluate all ambient external exposures for the period 1974–1995.

7.3.5 External Dose Reconstruction Feasibility Conclusion

Consistent with the findings of NIOSH's 2010 evaluation of SEC-00163 (NIOSH, 2010), external dose for photon, beta, and neutron exposures can likely be reconstructed for all members of the evaluated class for the period from January 1, 1974 through December 31, 1989. A full evaluation of external dose feasibility will be performed by NIOSH, for the period from January 1, 1974 through December 31, 1995, subsequent to this initial evaluation of Building 251 exposures during 1974–1989.

Also consistent with the findings of NIOSH's 2010 evaluation of SEC-00163, NIOSH concludes that it is feasible to reconstruct occupational medical dose for LLNL workers with sufficient accuracy for the period from January 1, 1974 through December 31, 1989.

7.4 Evaluation of Petition Basis for SEC-00221

The following subsections evaluate the assertions made on behalf of petition SEC-00221 for LLNL.

7.4.1 Implementation of Workplace Radiological Controls

Issue: The petitioner submitted a report from the DOE Office of Environment, Safety, and Health Assessments, dated August 2014. The petitioner stated that the document "*directly fits the requirements for an SEC Petition Section F-4 document.*" The report includes one "Finding" and 10 "Opportunities for Improvement." The finding stated that LLNL line management had not ensured that sufficient contamination controls and radiological surveys were implemented during radiological work, as needed to prevent the potential for inadvertent spread of contamination to clean areas. The audit finding did not indicate that any actual contamination was found or if any internal exposure resulted. The "opportunities for improvement" included management, procedural, and training recommendations and specific recommendations for more frequent verification surveys for contamination control.

Response: A NIOSH review indicated that none of the deficiencies listed in the DOE oversight report identified dosimetry and related information that are unavailable (due to either a lack of monitoring or the destruction or loss of records) for estimating radiation doses. NIOSH did not find support for qualification under the F.4 basis. This current NIOSH evaluation addresses specific exposures in Building 251 during the period from January 1, 1974 through December 31, 1989. NIOSH is issuing

this report covering available data sufficiency and feasibility conclusions to date (see Sections 7.2 and 7.3 of this report), but will continue to review and evaluate LLNL workplace radiological controls as they relate to internal and external exposures during the entire period qualified for evaluation, January 1, 1974 through December 31, 1995.

7.4.2 Adequacy of the NIOSH LLNL Site Profile

Issue: The petitioner submitted a 2006 letter sent to NIOSH by a third party (Tri-Valley CAREs) which included criticism of NIOSH's LLNL Site Profile, primarily about known incidents and a 1990 Tiger Team Report that were not considered in the Site Profile. The letter states that "*The Site Profile does not acknowledge that many records have been destroyed, misplaced or are inaccurate.*"

Response: A NIOSH review indicated that, while it was asserted that records have been lost, the letter does not specifically indicate instances of monitoring records being lost, or when they may have been lost. The statement was not submitted as an affidavit and NIOSH did not find support for qualification from the submitted documents. However, NIOSH's review of the Site Profile methodologies indicated that information presently available to NIOSH does not provide evidence that the gross alpha *in vitro* bioassay measurements, upon which some coworker analyses are based, include all potential exposure scenarios of concern. Consequently, NIOSH determined that an evaluation was warranted into the adequacy of the gross-alpha-based coworker dose methods of ORAUT-TKBS-0035-5. NIOSH deemed the need for further research of LLNL gross-alpha monitoring practices sufficient to qualify SEC-00221 for evaluation. This current NIOSH evaluation addresses specific exposures in Building 251 during the period from January 1, 1974 through December 31, 1989. NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date (see Sections 7.2 and 7.3 of this report), but will continue to review and evaluate internal and external exposures during the entire period qualified for evaluation, January 1, 1974 through December 31, 1995.

7.4.3 Adequacy of the LLNL Radiological Protection Program

Issue: The petitioner directed NIOSH to a June 1990 assessment titled "Tiger Team Assessment of the Lawrence Livermore National Laboratory, DOE/EH-0142," and to the site response action plan for the assessment. As supporting evidence, the petitioner also provided internet links to excerpts from the LLNL Environmental Impact Statements (EIS). The Tiger Team assessment's key findings were organized into the headings: Environmental, Occupational Safety and Health Act Compliance; Environmental Assessment; Safety and Health Assessment; and Occupational Safety and Health Act Compliance Assessment. Under Safety and Health Assessment was a category named Radiological Protection. The petitioner did not direct NIOSH to any specific report sections as support of any petition basis.

Response: As noted above, this current NIOSH evaluation addresses specific exposures in Building 251 during the period from January 1, 1974 through December 31, 1989. Some issues relating to NIOSH's infeasibility determination for the period 1974 through 1989 are supported by the Tiger Team observations in the 1990 assessment. NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date (see Sections 7.2 and 7.3 of this report), but will continue to review and evaluate the Tiger Team and EIS reports as they relate to internal and external exposures during the entire period qualified for evaluation, January 1, 1974 through December 31, 1995.

7.5 Other Potential SEC Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00221, a number of issues were identified that needed further analysis and resolution. The issues and their current status are identified in the subsections below.

7.5.1 Adequacy of Gross Alpha *In Vitro* Monitoring Program

Issue: As presented in Section 3.0, information available to NIOSH did not provide evidence that the gross alpha bioassay measurements, upon which some coworker analyses are based, include all potential exposure scenarios of concern. NIOSH noted that gross alpha urine monitoring of transuranic exposures in Building 251 warranted evaluation, including neptunium exposures through 1995. NIOSH qualified petition SEC-00221 for evaluation based on observed transuranic operations through 1995 that were potentially inadequately monitored using gross-alpha *in vitro* bioassay methods.

Response: During its evaluation of the qualified period from January 1, 1974 through December 31, 1995, NIOSH determined that U-233 exposures in Building 251 were inadequately monitored by the site's gross alpha *in vitro* sampling program through December 31, 1989 (see Sections 7.2 and 7.3 of this report). For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date for U-233 exposures in Building 251, but will continue to review and evaluate the site *in vitro* and *in vivo* bioassay monitoring programs as they relate to internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

7.5.2 Adequacy of Internal Dose Coworker Distributions

Issue: From reviews of the LLNL site profile and available documents, NIOSH determined there is potential for neptunium and/or thorium exposures at both the main campus site and Site 300 that may not be reflected in the current coworker models.

Response: NIOSH has determined in this report that U-233 exposures in Building 251 were inadequately monitored by the site's gross alpha *in vitro* sampling program through December 31, 1989 (see Sections 7.2 and 7.3). NIOSH will continue full feasibility evaluation for other dose contributors during the 1974–1989 period (including HEU, thorium, neptunium, metal tritides, and all external exposures), and for all dose contributors in the period 1990–1995. These evaluations will consider the applicability of the existing coworker methods for LLNL.

7.5.3 Representativeness of Workplace Air Monitoring

Issue: A review of Building 251 operations performed by DOE during the period August 21–October 22, 1980 noted an "excessive" failure rate for the continuous air monitors used in the various laboratories in Building 251 and recommended that LLNL "vigorously pursue" improving the air monitoring in the building. The report identified other concerns with radiological operations in Building 251, including the standard practice of removing materials from glove boxes via open-air transfer. The 1990 Tiger Team assessment of LLNL noted that air monitors and air samplers did not appear to be strategically placed with respect to capturing representative samples of potential airborne releases. It further noted that breathing zone monitors were not used at LLNL.

Response: NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date (see Sections 7.2 and 7.3 of this report) for the period 1974 through 1989, but will continue to review and evaluate the LLNL air monitoring program adequacy, including its use as a trigger for follow-up bioassay, during the entire period qualified for evaluation, January 1, 1974 through December 31, 1995.

7.6 Summary of Feasibility Findings for Petition SEC-00221

This report evaluates the feasibility for completing dose reconstructions for employees at LLNL from January 1, 1974 through December 31, 1989. NIOSH found that the available monitoring records, process descriptions, and source term data are not sufficient to complete dose reconstructions for the class of employees evaluated in this report. NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate the internal and external exposures during the entire period qualified for evaluation, January 1, 1974 through December 31, 1995.

Table 7-1 summarizes the results of the feasibility findings at LLNL for each exposure source during the evaluated time period from January 1, 1974 through December 31, 1989.

Table 7-1: Summary of Feasibility Findings for SEC-00221 (January 1, 1974–December 31, 1989)

Source of Exposure	Reconstruction Feasible
Internal[1]	**No**
U-233 in Building 251[2]	No
All other radionuclides	Reserved for further evaluation[3]
External	**Reserved for further evaluation[3]**
Gamma	Reserved for further evaluation[3]
Beta	Reserved for further evaluation[3]
Neutron	Reserved for further evaluation[3]
Occupational Medical X-ray	Yes

[1] Internal includes an evaluation of urinalysis (*in vitro*), workplace/airborne contamination, and lung (*in vivo*) data.

[2] NIOSH is unable to identify workers that did not potentially enter Building 251 during the period from January 1, 1974 through December 31, 1989. Therefore, the recommended SEC class includes all workers during the period from January 1, 1974 through December 31, 1989.

[3] For the purpose of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

As of February 3, 2016, a total of 830 claims have been submitted to NIOSH for individuals who worked at LLNL during the period under evaluation in this report. Dose reconstructions have been completed for 628 individuals (~76%).

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at LLNL during the period from January 1, 1974 through December 31, 1989, but who do not qualify for

inclusion in the SEC, may be performed using these data as appropriate. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

8.0 Evaluation of Health Endangerment for Petition SEC-00221

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 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 occurrence of such an exceptionally high-level exposure has not been established, 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.

NIOSH's evaluation determined that it is not feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Therefore, the resulting NIOSH-proposed SEC class must include a minimum required employment period as a basis for specifying that health was endangered. NIOSH has determined that members of the class were not exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. However, the evidence reviewed in this evaluation indicates that some workers in the class accumulated chronic radiation exposures through intakes of radionuclides and from direct exposure to radioactive materials. 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 the 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.

9.0 Class Conclusion for Petition SEC-00221

Based on its research to date of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees of the Department of Energy, its predecessor agencies, and its contractors and subcontractors who worked in any area at the Lawrence Livermore National Laboratory in Livermore, California, during the period from January 1, 1974 through December 31, 1989, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

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 Database (SRDB), for information relevant to SEC-00221. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. For the purposes of timeliness, NIOSH is issuing this report covering available data sufficiency and feasibility conclusions to date, but will continue to review and evaluate internal and external exposures other than U-233 from 1974–1989, and all internal and external exposures from 1990–1995.

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 the feasibility or infeasibility of reconstructing dose for the class under evaluation.

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ORAUT-TKBS-0035-4, *Lawrence Livermore National Laboratory – Occupational Environmental Dose*, Rev. 01; ORAU Team Dose Reconstruction Project for NIOSH; effective March 16, 2010; SRDB Ref ID: 79861

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Attachment One: Data Capture Synopsis

The primary source for data added to the SRDB for LLNL was the Lawrence Livermore National Laboratory.

Data Capture Information

Primary Site/Company Name: Lawrence Livermore National Laboratory DOE 1950-Present

Physical Size of the Site:

1) Main site, which is 820 acres housing 497 facilities that cover 6.7 million sq. feet.

2) Site 300, which is 7,000 acres housing 216 facilities that cover 0.4 million sq. feet.

Site Population: Currently the site has 6,300 employees. The employee population in 1958 was 3,000.

Data Capture Description

10 CFR 835 assessments of the Lawrence Livermore National Laboratory (LLNL), annual report of environmental levels of radioactivity, beta and alpha counter efficiency data, computer printout listing employee numbers and film badge numbers, aerial survey results for SNL/CA and LLNL, bioassay turnaround time report, dose summary, radiation doses in various buildings, radiation safety annual facility report, effluent monitoring report, AVLIS radiological safety, quarterly report on external dosimetry, stack emissions reports, dosimetry records for plutonium building workers, ALARA goals, area air monitoring results, hazard analysis of uranium inhalation at the Lawrence Livermore Laboratory, tritium release from Lawrence Radiation Laboratory, neutrons inside the containment of a pressurized water reactor, accident investigation report puncture wound by glass contaminated with transuranic material, accidental radon overexposure, accuracy of bioassay analyses, activation experiments at Super-Kukla, air sampling locations - Site 300, air transfers of radioactive materials, area swipe data sheets, AVLIS decontamination and demolition plan, personnel bioassay sample results, NESHAPS report, accidental removal of Cf-252 source from safety shield, perchloric acid tube explosion in glove box, contamination surveys, vault layout with radiation survey readings, background and efficiency data record, bioassay laboratory procedure manual, bioassay results, building floor plans, LINAC Health Physics notes, dosimetry study, radioactive isotope inventory log, special saliva bioassay sample, personnel external dosimetry report, Albedo neutron dosimeter list, Dale Hankins' notebook, neutron yield measurements at Shiva, discipline action plan Health Physics, am fecal samples, fecal samples, Co-60 and P-32, dosimetry from Tango T-15, E Beam test equipment, environmental backgrounds, environmental monitoring at the Lawrence Livermore Laboratory annual report, estimate of employee whole-body radiation exposure with plutonium lab survey, external exposure records, facility safety plan waste storage facilities and building, film badge and pocket dosimeter information, radiation safety report, fluorometric uranium urinalysis, hazard classification, hazards control quarterly reports, Health Physics program review and responses, internal dose assessments, lapel samples, building deactivation, decontamination, decommissioning, and demolition project execution plan, LLNL operational safety procedures, lung counter MDA data, maps of contaminated material burial pits, medical X-ray exposure evaluation, MTX ionizing radiation shielding requirements and facility layout, neutron exposures, neutron shielding, Nevada Test Site (NTS) personnel gamma radiation exposures summary, NTS exposure for Lawrence Rad

Lab (LRL) personnel, off-site radiation dose from buildings, phantom details and checklist, phoswich source checks, PLUTO quarterly reports, plutonium bioassay sampling, curves for Pu and Am, post shot bioassays, project pluto staff meeting minutes, neutron source strength of Tory II, radiation safety inspections, radiological analysis of Special Isotope Separation (SIS) decon facility, radiological hazards survey Astron operations, radiological safety analysis for conducting D-T shots in the nova target vessel, Ramjet Reactor tests begin in Nevada, results of building 321 fire, retention tank log April 1972 and U, Th, Am and Pu extraction calculations, dose from remelting heterogeneous plutonium metal, RML data GAB air spreadsheet, rotating target neutron source radiation safety program, safety analysis for neutron radiography, shielding measurements, Shiva Nova interim report laser fusion program, Site 300/400 air monitoring, skyshine, status of operational safety procedure, facility safety procedures and accident reports, storage of fuel grade plutonium in MBA-100, technical safety appraisal of building, history of radiobioassay analysis at LLNL, Livermore Pool Type Reactor (LPTR) design data, LLNL CR-39 personnel neutron dosimeter, National Ignition Facility Laser and Target Area Building conventional facilities environmental, safety, and health report, thyroid radioiodine intercomparison program, Tiger Team assessment of Lawrence Livermore National Laboratory, TLD calibration curves, Tory II-A report, Tory IIC reflector thickness total power study, tritium bioassay results, tritium releases from buildings, uranium in urine bioassay results, and whole-body count logs.

Date Completed

12/21/2015

Number Uploaded into SRDB

3,069

Additional SRDB holdings for LLNL

Table A1-1 contains additional data capture information reviewed for the development of the LLNL SEC Petition Evaluation Report.

Table A1-1: Summary of Holdings in the SRDB for LLNL

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
State Contacted: NA	Contacting the state was not considered necessary since Lawrence Livermore National Laboratory is an active DOE site and cooperates with relevant data collection.	12/29/2015	0
Albany Research Center (ARC)	Production and chemical isolation of Cm-242, Health Physics operating instructions, measurement of high-intensity gamma radiation, underground nuclear detonation of September 19, 1957 Operation Plumbbob, disposition of metal inventory, shipment of depleted uranium and tantalum, and operating procedures for Project Owl vacuum melting laboratory.	03/21/2013	8
Argonne National Laboratory East (ANL-E)	Monthly operation clean sweep status reports 1983.	03/24/2008	1
Battelle Memorial Institute - King Avenue	Low-level solid radioactive waste burial, radiological waste calculations and shipment material, and radioactive waste management.	07/30/2013	2
Brookhaven National Laboratory (BNL)	Brookhaven National Laboratory annual report 1957, compilation of ambient air monitoring parameters at DOE facilities, Cu-64 production with BNL's High Flux Beam Reactor, radiological control evaluation, and accelerator radiation exposures.	05/21/2009	5
Cincinnati Public Library	History of the United States Atomic Energy Commission Volume III and an environmental regulatory guide for radiological effluent monitoring and environmental surveillance – 1991.	02/18/2009	2
Claimant Provided	Explanatory notes from summary of bioassay results from individual dosimetry records, links between exposure to occupational hazards and illnesses in the DOE contractor workforce, re-suspension and ingestion of radioactive particles in the air, heavy ion fusion program 1999-2002, Spheromak magnets 1999-2001, and the Toshiba Project 1996-1998.	07/13/2009	9
Colorado Mesa University - Tomlinson Library	Techniques in tritium monitoring by proportional counters.	10/16/2012	1
Colorado State University	Hazards Control Department annual report, Lawrence Livermore National Laboratory fifty years of accomplishments, environmental assessment for the Explosive Waste Treatment Facility at Site 300, environmental monitoring annual report, workplace investigation of increased diagnosis of malignant melanoma, offsite hazardous waste shipment data validation report, national laboratory decontamination and waste treatment facility design waste characterization, X-ray imaging and X-ray source development, accelerator capability, design and operation of 140 ghz gyrotron oscillators, and an aerial radiological survey.	04/10/2006	16
Dade Moeller	In-vivo thyroid monitoring for iodine-131 in the environment.	03/19/2007	1
DOE Albuquerque	Final environmental impact statement for the continued operation of the Pantex Plant and hazard level classification of nonreactor nuclear facilities.	04/15/2010	2

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
DOE Carlsbad	Waste acceptance criteria certification committee audit report, transuranic waste inventory stored at the Nevada Test Site, and assessment of radium septic waste recommendation for disposal, packaging and transport.	08/10/2010	7
DOE Environmental Management Consolidated Business Center (EMCBC), Denver	Investigation of the tritium release occurrence at the Rocky Flats Plant, investigation of neptunium crossover 1967, and production-scale plutonium-neptunium separation and residue recovery at Rocky Flats Plant.	12/12/2013	4
DOE Germantown	Toxic hazards of beryllium, Nuclear Metals Inc. site description, certification docket of Gilman Hall, potential production of U-233 at Hanford, and handwritten notes taken during trip to DOE Germantown to review classified documents.	03/18/2014	14
DOE Legacy Management - Grand Junction Office	Request for equipment from CANEL Plant, survey work conducted at Albany Metallurgical Research Center, radioactive waste shipment, concentrations of plutonium in soil, containment practices in alpha and alpha-gamma facilities, radiological conditions of real property, evaluation of 1986 bioassay data, and a technical basis document for bioassay support services.	11/11/2010	12
DOE Legacy Management - Morgantown	Hazardous Chemical Defense Waste Management Program, National Emission Standards For Hazardous Air Pollutants proposed standards for radionuclides, department monthly progress report, Fernald shipments and receipts, bioassay analysis results, personnel dosimetry history, technical basis document for internal dosimetry, and a technical basis for bioassay sampling.	09/19/2011	54
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Annual review of Mound Laboratory, a history of the operation of the Feed Materials Production Center by NLO, incineration of radioactive solid wastes, DOE temporary stoppage of shipments to commercial burial grounds, effluent information system executive summary, annual radionuclide air emission report, progress reports of research departments efforts, incident investigations, plutonium shipments 1959-1964, reexamination of transuranic waste quantities planned for disposal, report for research on substitute materials, report on Mound Laboratory activities, polonium-208 research monthly progress, notes on Livermore project – 1955, Mound-Vue, major thorium campaigns at Fernald, neutron source progress report Monsanto Chemical Company – 1948, and In-vivo count data.	02/01/2012	62
DOE Legacy Management - Westminster	Actions resulting from the tritium incident, annual report on mortality, body counter calibration procedure, body counter inter-calibration study, history of incineration and landfill operations Rocky Flats Plant, history of tritium detection at Rocky Flats, internal dosimetry quality assurance plan, lifetime dose calculations conversion of systemic burden and lung count data, outline an investigation of Building 123 H-3 MDA, plutonium metal recovery, status of special tritium compounds.	10/22/2014	25
DOE National Nuclear Security Administration (NNSA)	NURE contracted activities.	01/17/2012	1

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
DOE Oak Ridge Operations Office	Definitions of weapons-usable uranium-233, strategy for the future use and disposition of uranium-223, and an environmental, safety, and health self-assessment report for the Oak Ridge K-25 site.	07/25/2013	5
DOE Oak Ridge Operations Office - Records Holding Task Group (RHTG)	ORNL neptunium requirements for the Ichiban Program, a monthly production report, uranium production statistics, thorium inventory, and U-233 deliveries.	04/08/2011	6
DOE Office of Scientific and Technical Information (OSTI)	Report on survey of irradiation facilities, human radiation experiments, annual reports of radioactive waste shipments, performance testing of personnel dosimetry services, nuclear science abstracts, electronuclear conversion of fertile to fissile material, stable isotope and heavy element inventories, isotope sales documents, thorium documentation involving thorium oxide, research and development semiannual progress report, uranium 233-235 crossover incident, neptunium processing at the Rocky Flats Plant, ORNL Health Physics appraisal, PLUTO Program quarterly progress report, and possible eye damage from ARGUS shot.	11/13/2014	37
DOE / SC&A	Tritium contamination/weapons components.	02/22/2012	1
Department of Labor (DOL)	Pinellas Plant hazard listing.	01/23/2012	1
DOL - Paragon	Tritium activities in the United States, information related to low-level mixed waste inventory characteristics, safe operating procedures for assembly, handling, testing, and disassembly of the EPW RSP-101 rocket test vehicle, and an Industrial Hygiene inspection report.	02/25/2013	4
Eastern Kentucky University Library	A newsletter from 1962.	05/07/2009	1
EML / HASL	Thorium sampling and storage.	03/08/2005	1
Energy Technology Engineering Center (ETEC)	Summary of industrial accidents in USAEC facilities.	09/11/2002	1
Federal Records Center (FRC) - Denver	Special radiation work permits, final radiological report for X-tunnel, photodosimetry evaluation book Volume IV, mixed waste streams, and options for recovery of Pu-244 in the MARK 18a targets at the Savannah River Site.	01/31/2012	7
Federal Records Center (FRC) - Ft. Worth	Visitor external dosimetry files.	06/26/2006	1
Federal Records Center (FRC) - Kansas City	Urine bioassay results.	10/09/2013	1

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Federal Records Center (FRC) - San Bruno	Corrective action plan to the report of the task group on operation of Department of Energy tritium facilities, environmental sampling results 1966, procedure for preparation, issuance, and return of radioactive sources, quarterly environmental report, Health Physics aspects of whole-body radioisotope therapy, waste disposal procedure for drums containing greater than 10 mc, Health Physics department environmental radiation measurements, boundary exposure summary 1962, alpha activity in air samples taken in conjunction with the demolition of room 309, source control and evaluation, request for disposition instructions for plutonium-containing wastes, investigation of radioactivity on swipes from various shipping containers, UCRL-Berkeley air samplers, summary of whole-body radiation exposures to external penetrating radiation accumulated during the year 1958, the percentage breakdown of the dry active waste at LRL with respect to the radioactive content 1959, information on 184 inch cyclotron, decontamination group report, report on Conway - McLaughlin radiation exposure incident 1954, reactor operations procedure, Lydia Project ventilation, air and rain sample data summary, Radcon procedures, contamination monitoring 1955, Livermore and Site 300 area air sampling 1955, film badge accumulations maintained by Health Chemistry, Radiation Protection Program at UCRL, Radiation Laboratory Health Chemistry procedures for radioisotope safety, Lawrence Radiation Laboratory environmental radiation levels - Berkeley and Livermore, 1962, complete control of tritium water vapor by the use of silica gel, special equipment for the Carbon-14 Laboratory, fallout and natural background in the San Francisco Bay Area, Lawrence Berkeley Laboratory ALARA, HILAC radiation surveys, summary of whole-body radiation exposures to external penetrating radiation accumulated during the year 1959-1971, annual radiation dose 1977-1986, Building 71 floor plans, urinalysis record card, bioassay methods, Health Physics quarterly reports, bioassay logbooks, bioassay reports, procedure for nose swipes 1958, air sampling experience, and analysis of neutron shipping container.	04/16/2015	251
Federal Records Center (FRC) - San Bruno/SC&A	Absolute containment of a kilocurie 3H target at a low energy research accelerator, ventilation system for use in transcurium processing, disposal of radioactive waste materials, high-level spill at the HILAC 1959, and Lawrence Livermore National Laboratory use of dosimeters internal audit report.	01/17/2006	5
General Electric - Vallecitos	Papers on dosimetry.	05/18/2007	1
Hagley Museum & Library	Savannah River Site production reactor information, Hanford story, and exposures exceeding DOE standard.	09/30/2010	4

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Hanford	Response concerning beta-emitting radionuclides counted in the LLNL gross beta radiochemistry procedure, American National Standard for dosimetry, history and stabilization of the Plutonium Finishing Plant (PFP), Hanford Laboratories operation monthly activities report, annual report Hanford atomic products operation, radionuclides background information, surplus neptunium-237, Health Division annual report, summary of information on neptunium oxide shipment from Hanford, highlights and significant changes of Internal Dosimetry Program monthly reports, and summary of appraisal of the Internal Dosimetry Project.	06/30/2015	42
Health Physics Journal	Effect of air-scattered beta particles and beta and gamma dose measurements of Godiva IV.	12/03/2009	3
Idaho National Laboratory (INL)	Personnel dosimetry and exposure control, lung and thyroid counter calibration information, Health Physics annual and upgrade status report, dosimetry branch activity monthly reports, CPP employee health case files, bioassay reports, radiation exposures, summary of all incidents 1959-1969, radioactive shipment records, Health Physics log sheets, progress reports, unreviewed safety question documentation, and standard operating procedures from 1982.	04/29/2015	35
Idaho National Laboratory - Idaho Nuclear Technology and Engineering Center (INTEC)	Documented communication.	09/10/2014	1
Interlibrary Loan	Environmental levels of radioactivity at Atomic Energy Commission installations, tenth conference on hot laboratories and equipment alpha-gamma-neutron facilities, proceedings of the 1993 Incineration Conference, and proceedings of the Health Physics Society 1956.	08/22/2012	17
Internet - CDC	Exposure assessment.	02/12/2007	1
Internet - Defense Technical Information Center (DTIC)	Occupational dose reduction at Department Of Energy contractor facilities, Sandia Corporation bibliography radiation effects, plutonium stabilization and disposition, establishment of a facility for intrusive characterization of transuranic waste at the Nevada Test Site, annual report to Congress, toxicological profile for ionizing radiation, and nuclear weapons testing at the Nevada Test Site.	07/30/2015	15
Internet - Defense Technical Information Center (DTIC) / SC&A	Idaho National Laboratory environmental annual report.	01/09/2012	1
Internet - DOE	Guide of Good Practices for Occupational Radiological Protection in Plutonium facilities.	05/11/2007	1
Internet - DOE Environmental Management	Linking Legacies Chapter 3 - Wastes.	10/28/2007	1
Internet - DOE Legacy Management Considered Sites	Interim mixed waste inventory report.	04/24/2012	1

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Internet - DOE OpenNet	Declassification of today's highly enriched uranium inventories, human radiation studies, the nuclear weapons program history summary, manufacturing statement for weapons production schedule of transfers, AEC financial report, Operation Teapot radioactivity concentrations in water, plutonium balance, Mound Pu-238 shipments, report on 8-inch isostatic press explosion at Site 300, protocol concerning the counting of subjects, and the impact of the revised 10 CFR 835 on the neutron dose rates.	09/17/2015	28
Internet - DOE OpenNet / NIOSH	Annual report to Congress 1960.	01/11/2008	1
Internet - DOE OSTI	Annual NESHAP report 1994 and a Pluto quarterly report.	07/14/2014	9
Internet - DOE OSTI Energy Citations	Historical doses from tritiated water, environmental report, fast burst reactors in the U.S.A., resuspension of plutonium, annual report of waste generation, criticality safety at the department of energy Rocky Flats Plant, emergency response capability, radioactive waste disposal practices, Tiger Team assessment of the Lawrence Berkeley Laboratory, radioactive waste processing and disposal, characterization of particulate plutonium release in fuel cycle operations, removal of particulates from nuclear offgas, environmental survey preliminary report Nevada Test Site Mercury, DOE 2011 occupational radiation exposure, research and ecology semiannual progress report, nuclear waste management quarterly progress report, seventeenth nuclear accident dosimetry intercomparison study, and a Pacific Northwest Laboratory annual report.	05/07/2013	44

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Internet - DOE OSTI Information Bridge	Small-quantity-site transuranic waste disposition alternatives, actinide properties, introduction to Mound Facility, annual report of shipments to and from the Nevada Test Site (NTS), assessment of plutonium storage safety issues, characterization of transuranium-contaminated solid wastes residues, Chemical Processing Department monthly report, personnel dosimetry practices, Environmental Management progress and plans, Hanford operation monthly activities report, hazardous waste certification plan, Heavy Ion Fusion Accelerator research (HIFAR) half-year report, historical doses from tritiated water and tritiated hydrogen gas released to the atmosphere, Imperial Valley environmental progress report, integrated data base report of spent nuclear fuel and radioactive waste inventories, inventory and sources of transuranic solid waste, Lawrence Livermore National Laboratory's book of minimum detectable activity for direct measurement of internally deposited radionuclides, list of DOE radioisotope customers, Mound Facility annual report, operational accidents and radiation exposure experience, plutonium-bearing materials feed report, preparation of plutonium waste forms with ICPP calcined high-level waste, Project Gasbuggy gas quality analysis, Pu-238 fuel-form processes quarterly report, radionuclide air emission report for 2009, Savannah River Laboratory monthly report, summary of radionuclide air emissions from Department Of Energy facilities, the application of neutron multiplicity counting to the assay of bulk plutonium bearing materials at Rocky Flats and LLNL, accreditation program for radiobioassay, user facilities at the Lawrence Berkeley Laboratory, worker radiation doses in the united states at the dawn of the atomic era 1940-1960.	12/02/2013	125
Internet - DOE OSTI Information Bridge / SC&A	Appraisal of reported dose at boundary of University of California Laboratory and environmental assessment for off-site transportation of low-level waste.	08/31/2009	2
Internet - DOE OSTI SciTech Connect	Annual Health Physics 2009, analysis of the technical capabilities of DOE sites for disposal of residuals from the treatment of mixed low-level waste, characterization of the neutron fields in the LLNL Radiation Calibration Laboratory low scatter calibration facility, creating the Nuclear Weapons Laboratory, environmental monitoring plan, history and reflections of engineering at Lawrence Livermore National Laboratory, identification of buried structures, annual environmental report, NESHAPS annual report, Radiation Protection Program (RPP), low-level plutonium bioassay measurements, plutonium decontamination, qualifying radioactive waste forms for geologic disposal, review of mixed waste streams, semi-annual report on strategic special nuclear material inventory differences, and technical safety requirements for the waste storage facilities.	11/04/2015	61
Internet - DOE NNSA Nevada Site Office	No relevant documents identified.	06/11/2015	0
Internet - Energy Employees Claimant Assistance Project (EECAP)	Nuclear criticality safety evaluation of Facility X-705 (Portsmouth), exposure rates from fallout at the Trinity Site, and Project Rio Blanco definition.	01/28/2014	3

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Internet - Google	A 2013 site annual environmental report Lawrence Livermore National Laboratory, LLNL - facts and figures, ALARA analysis of radiological control criteria associated with alternatives for disposal of hazardous wastes, site 300 contour maps, annual transuranic waste inventory report, Building 331 tritium operations documented safety analysis, depleted uranium hexafluoride management program, occupational radiation exposure, report to Congress, laboratory accreditation program for personnel dosimetry systems, toxicological profile for uranium, environmental assessment conducted at the Kansas City Plant, environmental monitoring at the Lawrence Livermore Laboratory annual report, federal shipments of transuranic radioactive waste in California, final environmental impact statement and environmental impact report for continued operation of Lawrence Livermore National Laboratory and Sandia National Laboratories Livermore, site-wide environmental impact statement, finding aid for the K.Z. Morgan papers, groundwater contamination, in-situ chelation/reduction process, investigation of tritium in groundwater at Site 300, Lawrence Livermore National Laboratory experimental test Site 300 compliance monitoring program, environment, safety and health manual, NESHAPS annual report, prototype TLD badge, mixed analyze performance evaluation program, Paducah Gaseous Diffusion Plant site profile, plutonium storage, puncture wound causes internal plutonium contamination, radionuclide air emission report, RCRA facility investigation report, report on low-level nuclear waste shipments, review of environmental monitoring for radionuclides, Rocky Flats Plant Metal Research and Development Laboratory Building 865 photographs, record of decision Lawrence Livermore National Laboratory Site 300, annual site environmental report, determination of curium in fecal and chelated urine samples, portable tritium processing system, transuranic waste baseline inventory report, and a worker contaminated while working in a glovebox.	09/25/2015	383
Internet - Hanford DDRS	Discussion of dose rate shot test samples, Hanford laboratories operation monthly activities report, 200 area monthly report, trip report meeting of industrial safety group Rocky Flats.	05/15/2015	17
Internet - Health Physics Journal	Establishing bounding internal dose estimates for thorium activities at Rocky Flats, intercomparison study of Np-237 determination in artificial urine samples, characterization of the world's first nuclear explosion, dose to the public from tritium released to the atmosphere from LLNL 1953 – 2005, the Livermore phantom history and supplementation, Monte Carlo simulation of the in vivo measurement of lung activity, surveillance monitoring of soils for radioactivity: Lawrence Livermore National Laboratory.	06/11/2015	15
Internet - Journal of Occupational and Environmental Hygiene	No relevant documents identified.	06/11/2015	0

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Internet - Lawrence Berkeley National Laboratory (LBNL)	Site environmental report.	10/18/2006	4
Internet - Lawrence Livermore National Laboratory (LLNL)	Environmental monitoring plan.	02/07/2007	1
Internet - Los Alamos National Laboratory (LANL)	Radiochemistry of the elements.	07/10/2013	1
Internet - National Academies Press (NAP)	Management for Health, Safety and Environmental within the Nuclear Weapons Complex, vitrification.	06/24/2015	2
Internet - National Institute for Occupational Safety and Health (NIOSH)	Beryllium contamination, evaluation report summary, Savannah River Site facts.	10/29/2015	6
Internet - NRC Agency wide Document Access and Management (ADAMS)	Annual report to congress on federal government energy management and conservation programs, characterization project at Lawrence Livermore National Laboratory, audit report of the civilian radioactive waste management, quality assurance surveillance report, DOE office of civilian radioactive waste management office of quality assurance audit report, environmental restoration wastes, export license for transport logistics international to export natural uranium to Canada, Hanford site solid waste program environmental impact statement, high-level waste quality assurance task force summary of activities, Nevada Nuclear Waste Storage Investigations (NNWSI) project weekly highlights, NRC safety evaluation for quality assurance program plan, quality assurance audit plan, Savannah River Site long range comprehensive plan, surplus plutonium disposition final environmental impact statement summary, National Ignition Facility management, plutonium spill , Waste Isolation Pilot Plant annual report, USAEC byproduct material license 6-550-2, Yucca Mountain Project Argonne National Laboratory annual progress report, Yucca Mountain Project status report, Yucca Mountain quality assurance division quality assurance surveillance report of Lawrence Livermore National Laboratory.	12/15/2014	195
Internet - Oak Ridge National Laboratory (ORNL) Library	"Chemical Technology Division annual progress report, disposal of radioactive wastes, Health Physics division annual progress report, measurements of fission and activation products for Oak Ridge National Laboratory transuranic waste characterization, operating experience summary, Operations Division monthly report, ORNL status and progress report, radioisotope distribution program progress report, status report on the disposal of radioactive wastes."	05/29/2015	44
Internet - University of California Berkeley - Bancroft Library	Interview with Anne Low-Beer Dettner.	04/01/2008	1
Internet - US Army Corps of Engineers (USACE)	No relevant documents identified.	11/07/2014	0
Internet - US Environmental Protection Agency NEPIS	Superfund record of decision.	11/10/2014	4

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Internet - US Transuranium and Uranium Registries	USTUR 0102: University of California wound, chronic inhalation 241AMO2.	08/23/2012	1
Kansas City Plant	Statement of Assistant Secretary for Defense Programs, Department Of Energy, before the subcommittee on military procurement committee, annual environmental summary reports, source program and survey data 1989-1990, radioactive material inventory lots 1958-1960, accidental x-ray exposure at the E-Beam Test Facility of Lawrence Livermore Laboratory , TMA Eberline radiation dosimetry services, daily operations reports.	10/20/2014	10
Knolls Atomic Power Laboratory (KAPL)	Radiological history report.	08/30/2007	1
Lawrence Berkeley National Laboratory (LBNL)	Radiological status of Gilman Hall, Health Chemistry accident reports, floor surveys and log entries from the dismantling project of Gilman Hall, individual personnel exposure record, bioassay cards early years pre 1968, temporary badge exposures 1951-1955, bioassay lab logbook, general description and operating characteristics of the Berkeley 88-inch cyclotron, proposed use of Np-237 at Site 300, LBNL site environmental reports, report on personnel radiation exposure incident 1954.	06/11/2009	141
Los Alamos National Laboratory (LANL)	Radioactive waste disposal issues, accelerator health physics characterization report, request for Np-237.	08/15/2014	6
Los Alamos National Laboratory - LAHDRA	History of critical experiments at Pajarito Site 1947-1983, Health Division annual report 1953, Pu incidents, environmental monitoring report 1987, interview with Mr. Harold l. Rarrick Albuquerque, New Mexico, quantities and characteristics of the contact-handled low-level mixed waste streams for the DOE Complex.	12/06/2007	7
Mel Chew & Associates	Heavy Element Inventory in Building 251, authorization basis and readiness assessment lessons learned in the Building 251, safety considerations during the Building- 251 nuclear facility transition.	10/22/2009	3
Missouri Department of Natural Resources	Environmental impact statement, plutonium working group report.	10/01/2008	2
National Archives and Records Administration (NARA) - Atlanta	Powder from CANEL 1965, operational accidents and radiation exposure experience 1943-1964, report concerning the explosion in laboratory E-21, building 4500 north - ORNL/1965, accidents and related radiation exposures, Department of Energy indoor radon study volumes 1 and 2	05/20/2008	8
National Archives and Records Administration (NARA) - College Park	Radiological condition surveys of real property, radiation contamination clearance report for parcel number 3, Site 300.	04/14/2010	5
National Archives and Records Administration (NARA) - Kansas City	Survey and certification document of Gilman Hall.	01/12/2005	2
National Archives and Records Administration (NARA) - San Bruno	Radiation exposure present in the public environment, air sampling sites and progress reports.	11/17/2008	2

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
National Institute for Occupational Safety and Health (NIOSH)	Semiannual report to the Congress by the United States Atomic Energy Commission, documented communication, Los Alamos National Laboratory tritium technology deployment, protocol for the epidemiological evaluation of cancer and occupational exposures at the Rocky Flats Environmental Technology Site, summary of Rocky Flats Plant waste buried, worker outreach meeting notes.	08/27/2014	43
National Institute for Occupational Safety and Health (NIOSH) / SC&A	Interview notes, highly enriched uranium working group report.	02/22/2012	6
Nevada Test Site (NTS)	Closure report for corrective action at Nevada Test Site, double play Operation Flintlock on-site radiological safety report, final environmental impact statement for the Nevada Test Site and off- site locations, final environmental impact statement for the Nevada Test Site, LLNL NTS underground radionuclide source-term inventory, Plowshare Program Project Chariot an outline of phase iv activities, radionuclides in surface soil at the Nevada Test Site.	10/08/2014	15
New York State Archives	Waste disposal at Lake Ontario Ordnance Works.	03/19/2012	1
NIOSH DCAS Claims Tracking System (NOCTS)	Tiger team action plan.	02/19/2015	1
Nuclear Metals and Equipment Corporation (NUMEC)	Essential reference material for BIDUG.	06/01/2005	1
Nuclear Regulatory Commission Public Document Room	Analysis of the terminal waste form selection for the West Valley Demonstration Project, audit report of the civilian radioactive waste management system management and operating contractor at the Lawrence Livermore National Laboratory, briefing on AVLIS uranium enrichment deployment plan, heap leach reclamation plan UMETCO Mineral Corporation, meeting summary - AVLIS meeting with U.S. Enrichment Corporation, Portsmouth GDP compliance plan for National Emission Standards For Hazardous Air Pollutants, quality assurance for gamma knives, safeguards research at Lawrence Livermore Laboratory.	12/19/2014	20
Oak Ridge Institute for Science and Education (ORISE)	Chelation DTPA data.	08/06/2009	4
Oak Ridge Library for Dose Reconstruction	Review of transfer factors for assessing the dose from radionuclides in agricultural products, evaluation of radiological exposure from Plowshare applications, Isotopes division annual report, Oak Ridge Y-12 plant historical uranium and radionuclide release report.	05/10/2011	6
Oak Ridge National Laboratory (ORNL)	Electronuclear Research division annual progress report, Isotope Program progress report, Isotope Separations progress report, Isotopes Development center newsletter, ORNL status and progress report, request for special work forms plutonium returns and transfers, source and special nuclear material accountability report, transuranium processing plant semiannual report for production, status, and plans.	03/21/2014	39

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
ORAU Team	Evaluation of NTA film in an accelerator environment and comparisons with cr-39, development of the 1996 proposed amendment to 10CFR835 occupational radiation protection, documented communication for SEC-00068, documented communication doe SEC-00192, documented communication for SEC-00195, DOE adoption of 1990 ICRP recommendations on neutron weighting factors, annual report radiation exposures for DOE and DOE contractor employees, exotic radionuclides at the Savannah River Site, Hanford site - occupational external dose, implementation of the combination neutron dosimeter and the field neutron spectrometer, internal dosimetry coworker data for Lawrence Livermore National Laboratory, LLNL Heavy Element Facility, Building 251: a short history of the risk reduction program, standard methodology for overestimating external doses measured with thermoluminescent dosimeters, technical basis document for the Lawrence Livermore National Laboratory - occupational external dose / occupational internal dose / occupational environmental dose.	02/24/2014	70
Pantex Plant	Benefits study on special isotope separation, records transfer control documents, Tweezer Operations final report.	12/31/2008	3
Pantex Plant / SC&A	Tritium contamination/weapons components.	06/23/2011	1
Rocky Flats Environmental Technology Site (RFETS)	Assessment of the flammability and explosion potential of defense transuranic waste.	05/17/2006	1
Science Applications International Corp (SAIC)	Radiation exposure summary.	09/02/2004	9
Savannah River Site (SRS)	Dosimetry visitors cards, Health Protection monthly summary 1969, in vivo comparison report, Savannah River irradiated thorium, Savannah River laboratory monthly report, specifications for neptunium slugs interim irradiation program, trip report for neptunium information meeting.	01/12/2012	13
Sandia National Laboratory (SNL/CA)	Proposed standardization of personnel film badges for Sandia Corporation, monthly and summary employee dosimetry data, environmental summary for SLL, film badge dosimetry results, internal/ external positive exposures and follow-up actions, LLNL radiation control areas, memorandum of agreement - Los Alamos/Sandia/Lawrence Livermore tritium processes lead laboratory assignment, review and evaluation of present film badge radiation monitoring program, Sandia Corporation, Livermore Laboratory, safe operating procedures, interview notes, Sandia - Livermore contaminated water waste disposal issue with tie in to GE Vallecitos.	04/29/2013	33

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Sandia National Laboratory (SNL/NM)	"Description of the external QC program for in-vivo and in-vitro bioassay located at Oak Ridge National Laboratory 1991-1993, environmental analysis of metal particle dispersion from an explosive test at Tonopah test range, bioassay results, description of facility at Sandia Livermore and Tonopah, incident that includes plutonium and Oak Ridge National Laboratory 1957, radiation incident reports 1960 through 1978 with index, Ross aviation lab surveys, shipment surveys and shipping documents 1982, environmental monitoring report for Sandia laboratories from 1964 through 1972, tritium bioassay records, webdose database external doses."	02/17/2012	18
Sandia National Laboratory (SNL/NM) / SC&A	Health Physics aspects of operation Roller Coaster 1964.	03/28/2006	1
S. Cohen & Associates (SC&A)	Neutron dose and energy spectra measurements at Savannah River Plant 1987, Operation Grommet, Operation Toggle - onsite radiological safety report, environmental sampling at Lawrence Radiation Laboratory, Berkeley, personnel dosimetry associated with the handling of large numbers of 3-kg Pu-239 billets, proposal for expanded operations at Site 300, thorium hydrodynamic shots at Site 300, site environmental report, documented communication, annual radiation safety review - LRL Berkeley, Chemistry Division annual report, Medical And Health Physics quarterly report, operational safety procedures, neutron depth dose from alpha-neutron (a, n) and gamma-neutron (y, n) sources in a tissue-equivalent phantom, Am-241 hand incident and other incidents, radiation levels around UCRL accelerators, measurement of average neutron energies for (a, n) neutron sources, history of Donner laboratory, experimental shielding studies at high energy proton accelerators, LBL pursuit of DOELAP accreditation: a chronology, radiation studies at a medium energy accelerator, some energy spectra of stray neutrons from the Bevatron, survey of program Donner laboratory and Donner pavilion, environmental reports, Gilman hall decontamination project, stack releases, Nuclear Science division 1annual report, accuracy of very-high-energy radiation monitoring, accelerator neutron spectra and spectra to dose conversion, report of the bioassay program, SNM licensing, shipping reports, air sample data and urinalysis information 1956-1971, SLAC today newsletter.	08/05/2011	103
SC&A / INL	Health physics tritium control, airborne radionuclide waste management, transuranic elements in the environment.	06/24/2010	3
SC&A / Internet - DOE OpenNet	Plutonium - the first 50 years.	10/28/2014	1
SC&A / NIOSH	Environment, safety and health progress assessment of the Pantex Plant.	06/01/2011	1
SC&A / Pinellas Plant	Annual report on waste generation and minimization progress.	06/24/2010	1
SC&A / San Bruno FRC	Adsorption of Xenon in an activated charcoal column.	07/31/2014	1
SC&A / SNL/CA	Tritium release occurrence reports, Management Assurance department quarterly status report.	03/31/2009	9
SC&A / SSFL	Tritium symposium trip report.	06/24/2010	1

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Stanford Linear Accelerator Center (SLAC)	Calibration of PuLi 238 source.	08/18/2006	1
Southern Illinois University, Edwardsville, IL	AEC construction cost differentials.	10/15/2008	1
Tri Valley Cares	Environmental impact statement, Type B Accident investigation report, Curium intake by shredder operator.	03/14/2005	3
University of Colorado - Norlin Library	AEC workshop on neutron dosimetry, environmental impact statement, aerial radiological survey of LLNL 1975.	06/07/2007	5
University of Tennessee Library	Report of Am-241 content in whole body, five compartment model for the kinetic distribution of americium in man, estimation of initial distribution of Am-241 in adult male human skeleton.	03/18/2010	4
Unknown	Chemistry and Materials Science radiation safety report of the tritium facility, new model for evaluating internal dose from the intake of Polonium-210, albedo-neutron dosimetry studies at Lawrence Livermore Laboratory, examination of the pathways from soil to man for plutonium, overview of the history of Y-12 (1942-1992), angular dependence of Eastman type a (NTA) personnel monitoring film, average annual air concentrations 1961-1969, Brookhaven National Laboratory site environmental report for calendar year 1997, californium-252, proceedings of a symposium, bioassay report, decommissioning information, investigations and summary reports of thorium, occupational radiation exposure report, Gasbuggy on-site radiological safety during production testing January 25, 1968 to December 31, 1969, Gasbuggy preliminary post-shot summary report, history of personnel external dosimetry program at the Dayton project and Mound laboratory 1946-1993, NYOO records 1948-1958, processes and characteristics of major isotopes handled at Mound, project Gasbuggy radiation contamination clearance report, radiation doses - Building 331 - 1984-1985, results of calculations of external gamma radiation exposure rates from fallout and the related radionuclide compositions operation Plumbbob 1957, Rocky Flats site history, Sylvania Corning plant and FEMP (FMPC) recycled uranium receipts and shipments.	03/30/2007	59
Unknown / SC&A	Pantex Plant personnel dosimetry records - Clarksville reports, operation Fusileer onsite radiological safety report, operation Charioteer onsite radiological safety report, technical plan for project GasBuggy, project GasBuggy on-site radiological safety report Plowshare program, operation Latchkey on-site radiological safety report, operation Phalanx onsite radiological safety report.	03/30/2007	8

Data Capture Information	Data Capture Description	Date Completed	No. Uploaded into SRDB
Washington University Library	Film technique for dosimetry of Am-241, radiation and temperature distributions resulting from the Logan event, hazards summary report for the LRL critical facility, Health Chemistry and Health Physics sections from "Medical and Health Physics quarterly report" 1955, properties of the environment of underground nuclear detonations at the Nevada Test Site Rainier event, radiation and temperature measurements of the Neptune event, radioactivity associated with underground nuclear explosions, radiochemical procedures in use at the University of California Radiation Laboratory Livermore, the Neptune event a nuclear explosive cratering experiment, urinalysis for curium by electrodeposition.	04/27/2007	13
Weldon Spring	Skin contamination during gage removal final report.	11/29/2004	1
West Valley Demonstration Project (WVDP)	Shipment information.	11/28/2006	1
Y-12	Y-12 plant uranium discharges, Y-12 plant cultural resources survey, verification and validation of the Y-12 lung counting system.	08/18/2008	3
TOTAL	**N/A**	**N/A**	**5,378**

Table A1-2: Database Searches for LLNL

Database/Source	Keywords/Phrases	Hits	Uploaded into SRDB	Viewable Hits
Defense Technical Information Center (DTIC) https://www.dtic.mil/ COMPLETED 07/30/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	15,872	2	15,872
DOE Hanford DDRS http://reading-room.labworks.org/Catalog/Search.aspx COMPLETED 05/15/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	2	1	2
DOE Legacy Management Considered Sites http://www.lm.doe.gov/considered_Sites/ COMPLETED 11/02/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	310	0	N/A
DOE Nevada Site Office - National Nuclear Safety Administration (NNSA) http://nnsa.energy.gov COMPLETED 06/11/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	0	0	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 11/06/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	4,816	9	N/A
DOE OSTI SciTech Connect http://www.osti.gov/scitech COMPLETED 11/05/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	500,399	45	N/A
Energy Employees Claimant Assistance Project (EECAP) http://www.eecap.org COMPLETED 06/11/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	0	0	N/A
Google http://www.google.com COMPLETED 12/19/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	1,516,164,034	68	N/A
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 06/11/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	33	12	33
Journal of Occupational and Environmental Hygiene http://www.tandfonline.com/loi/uoeh20#.VtS2f00o670 COMPLETED 06/11/2015	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	345	0	345

Database/Source	Keywords/Phrases	Hits	Uploaded into SRDB	Viewable Hits
National Academies Press http://www.nap.edu/ COMPLETED 11/07/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	1,012	0	N/A
NEPIS http://nepis.epa.gov/ COMPLETED 11/10/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	10,062	3	N/A
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 11/07/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	8,855	97	N/A
United States Army Corps of Engineers (USACE) http://www.usace.army.mil/ COMPLETED 11/07/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	0	0	N/A
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 11/07/2014	Database search terms are available in the Excel file called "Copy of Lawrence Livermore National Laboratory Rev 00 (83 13) 01-11-16."	11	0	N/A