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PUBLICATION RECORD

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07/29/2005	00	New technical basis document for the Lawrence Livermore National Laboratory – Site Description. First approved issue. Initiated by Jay J. Maisler.
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Ci	curie
HEPA	high-efficiency particulate air
LINAC	linear accelerator
LLNL	Lawrence Livermore National Laboratory
LPTR	Livermore Pool Type Reactor
kg	kilogram
MeV	megavolt-electron, 1 million electron volts
mi	mile
MV	megavolt
NTS	Nevada Test Site
U.S.C.	United States Code
U-AVLIS	uranium atomic vapor laser isotope separation
USEC	United States Enrichment Corporation

2.1 INTRODUCTION

Technical basis documents (TBDs) and Site Profile documents are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)" [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the [probability of causation] guidelines established under subsection (c) …." [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all radiation exposures in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

This technical basis document, which is part of the Lawrence Livermore National Laboratory (LLNL) Site Profile, describes the site (Section 2.2) as well as major facilities and activities at them.

2.2 SITE DESCRIPTION

LLNL was founded in 1952 on the site of a closed U.S. Naval Air Station. It was known originally as the University of California Radiation Laboratory at Livermore then later as the Lawrence Radiation Laboratory at Livermore. LLNL consists of two sites, the main Laboratory site, which is in a densely

populated 1.5-mi^2 area in Livermore, California (Figure 2-1), and the 11-mi^2 Explosive Test Site near Tracy, California, which is also known as Site 300.

Figure 2-1. Aerial view of LLNL main site (LLNL 2005a).

In the beginning, the Laboratory's single mission dealt with thermonuclear weapons development. Over the years, the mission expanded to include diverse scientific and engineering research activities. These activities, not all of which were related to the development of nuclear weapons have included the following (DOE 1992):

- Research, development, and test of the nuclear weapons life cycle and related tasks
- Strategic defense research emphasizing kinetic- and directed-energy weapons
- Arms control and treaty verification technology
- Inertial confinement fusion for weapons physics research and for civilian energy applications
- Atomic vapor laser isotope separation for defense and commercial applications
- Magnetic fusion, including leadership of the U.S. effort on the International Thermonuclear Experimental Reactor
- Other energy research in basic energy sciences, atmospheric sciences, fossil energy, and commercial nuclear waste
- Biological, ecological, atmospheric, and geophysical sciences relevant to weapons, energy, health, and environmental issues, including assessment and guidance in the event of accidents and other emergencies
- Charged-particle beam and free-electron laser research for defense and energy applications
- Advanced laser and optical technology for military and civilian applications

- Support of the U.S. intelligence community, the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission, and other Federal agencies

- Participation in the nationally directed initiative to understand the human genome at the molecular level

Table 2-1 provides a general description of LLNL buildings and activities. In 1966, building numbers were changed; some of these changes are cross-referenced in the table. In addition, the Site 300 buildings changed from the 300 series to the 800 series (e.g., 301 changed to 801). Attachment A provides a complete cross reference from the old to the current building numbers, with the exception of the 300 to 800 change. Unless noted otherwise, this document uses the current building numbers.

Table 2-1. Summary of major buildings and activities.

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 Co-60, fission products, enriched uranium, depleted uranium, natural uranium, U-233, Cm-244, Pu-239, Am-241, 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, 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, Sr-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 Co-60 (1958)
190	251	Chemistry Heavy Elements Facility: Cm-244, Am-241, U-233, Pu-239, others
193	281	Livermore Pool Type Reactor (LPTR)
Site 300		Explosives Testing: Linear accelerators, depleted uranium, H-3, radiography

2.3 MAJOR FACILITIES DESCRIPTIONS AND ACTIVITIES

This section discusses activities in the various buildings at the LLNL main site and Site 300. The discussion for each of the buildings or building complexes provides information on the general nature of activities at that facility. Figure 2-2 is a map of the main site, and Figure 2-3 is a map of Site 300. Table 2-2 summarizes building activities and radionuclides that workers could have encountered. Section 2.3.1 describes the buildings, Section 2.3.2 describes known soil contamination in the Southeast Quadrant of the main site, Section 2.3.3 describes Site 300, and Section 2.3.4 describes personnel involvement in nuclear weapons testing.

This discussion is not intended as a complete radiological history, but rather as a discussion to familiarize dose reconstructors with the types and variety of activities that have occurred at LLNL. Other sections of the LLNL Site Profile provide information about radiological conditions at various facilities throughout the LLNL site in relation to external and internal dosimetry as well as environmental occupational dose.

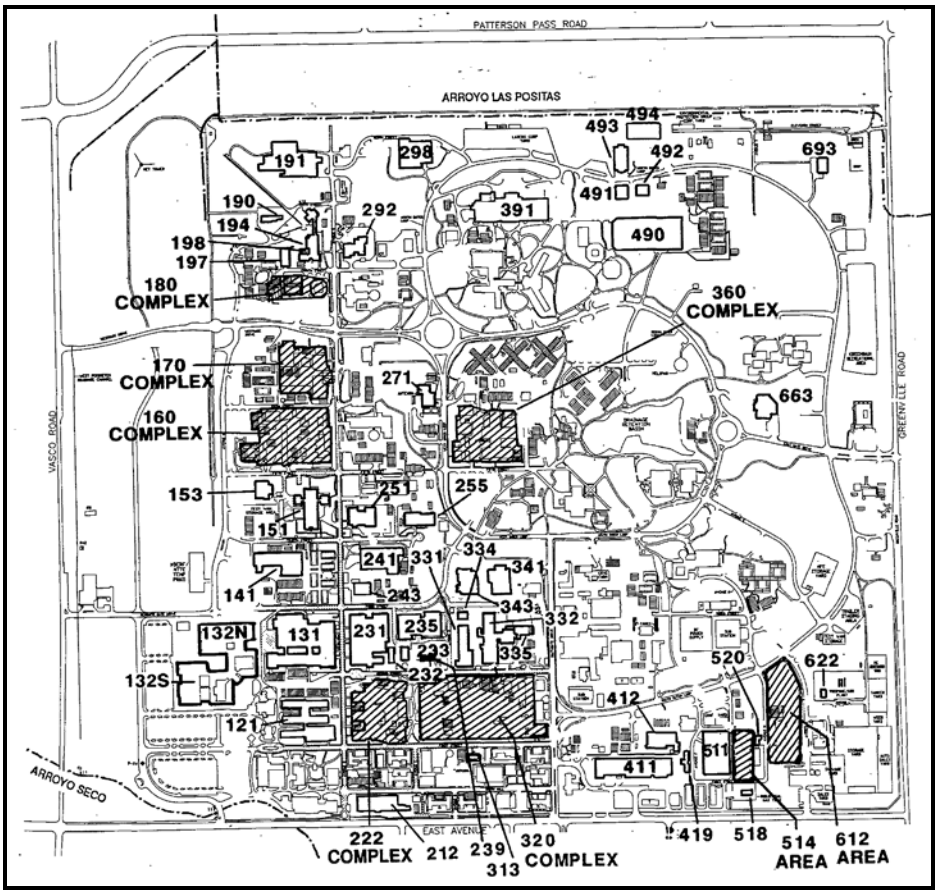

Figure 2-2. Map of LLNL main site (DOE 1992, Figure A-7).

2.3.1 Buildings (Main Site)

Building 121
The Test Program facility, Building 121, is in the southwest quadrant of the LLNL site. Operations in this facility have included the use of X-ray and electron generators, high-voltage pulsers, lasers, mechanical and electronic equipment, and use of radioactive and toxic materials to perform measurements for the development of diagnostic techniques for interpretation of experiments on nuclear weapons.

Other operations included laser irradiation of toxic materials, a Febetron electron beam to develop diagnostic systems for gathering data from nuclear tests, measurement of leakage current on resistance of photoconductive detectors when illuminated by laser light, concurrent operation of multiple Class III and IV lasers, a ruby laser, a mode-locked flash lamp pumped dye laser, and a nitrogen laser with dye cell for the purpose of pico- and nanosecond pulse generation used for streak camera calibrations.

This facility also housed the Pulsed Calibration Laboratory, Hyjacs X-ray Laboratory, and Vacuum Barrier Permeation Leak Testing Laboratory (DOE 1992).

Building 131
The Building 131 complex is a large office and laboratory facility housing both the Mechanical and Electrical Engineering Divisions. The shops and laboratories have supported weapons testing and assembly as well as microelectronic and microfabrication work. In addition, the facility has a high bay

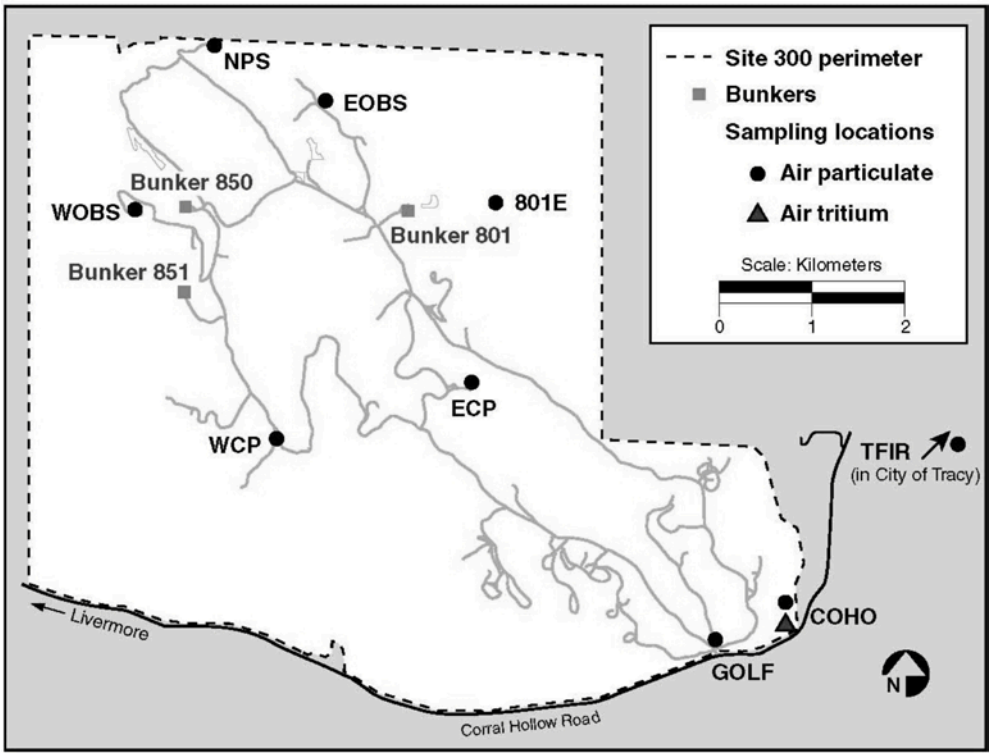

Figure 2-3. Site 300 map with bunkers and air-sampling stations (Gallegos et al. 2002, Figure 5-3).

containing a large laboratory and shop operation as well as a Materials Management Vault that has stored controlled materials to support the weapons testing program.

The use of radiation sources has been limited primarily to the high bay area, and sealed sources or radioactive material in solid form has been used. Small antistatic blowers containing sealed sources have been used in the microfabrication laboratories. Use of a hood or glovebox enclosure has been required for operations that could potentially expose workers (DOE 1992). Nondestructive use of depleted uranium was reported in the documentation.

Building 132
Building 132 provides office and laboratory space for a range of activities including the Directorate Offices for Chemistry and Materials Sciences; laboratories in the Analytical and Nuclear Chemistry Division and the Chemistry and Chemical Engineering Division; and Nonproliferation Arms Control and International Security Directorate Forensic Sciences Center offices and laboratories. The facility consists of the Defense Program Research Facility (132N) and the Nuclear Test Technology Complex (132S).

Radiological activities have been limited and included operations associated with the use of X-ray generators, electron beam generators, laser equipment, and sealed radioactive sources (DOE 1992).

Building 151
Building 151 houses the Isotope Sciences Division, which applies nuclear and isotope sciences to a wide range of problems including stockpile stewardship, nonproliferation, safeguard technologies, forensic science, and waste characterization and analysis. In addition, Building 151 contains the Chemistry and Materials Sciences Environmental Services laboratory where samples of waste

Table 2-2. Individual building activities and associated radionuclides.

Current building # (old #)[a]	Building activity	Radionuclides
131	Mechanical & Engineering Divisions, Weapons	Th-232, U-234, U-235, U-238
132	Analytical & Nuclear Chemistry Labs; forensic Sciences Center	H-3, Co-60, Sr-90, Cs-137, Th-228, Th-230, Th-232, U-234, U-235, U-238, Pu-238, Pu-239, Pu-241, Pu-242, Am-241
151	Isotope Sciences, Environmental Services Lab	H-3, C-14, Na-22, corrosion products, mixed fission products, transuranics, uranium, plutonium, thorium
162, 165, 166 (182A-E)	Lab services	55 Ci Co-60 source (1958)
167, 168, 169	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
171	Physics: Accelerators	Various activation products, H-3, others
173	Physics: Accelerators	Various activation products, H-3, others
174	Physics: Accelerators	Various activation products, H-3, others
175	U-AVLIS	U-234, U-235, U-238
176	Physics: Accelerators	Various activation products, H-3, others
177	U-AVLIS	U-234, U-235, U-238
179		U-234, U-235, U-238
194	LINAC	N-13, O-15, Na-22, U-233, U-234, U-235, U-236, U-238
210	Physics: Accelerators	Various activation products, H-3, others
212	Physics and Space (rotating target neutron source)	H-3
215	Lab services	Various radioactive materials not specified
221	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
222	Chemistry	H-3, C-14, Co-60, Ni-63, Th-232, U-233, U-234, U-235, U-238, Cm-244, Am-241, fission products, others
223	Chemistry	Co-60, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Am-241, Am-243, Cm-244, fission products, others
224	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
226		H-3, U-238
227		U-234, U-235, U-238
231	Safeguards and engineering	The-232, U-234, U-235, U-238
232	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
233	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
234	Chemistry	Various radioactive materials including Co-60, fissions products, enriched uranium, natural uranium, U-233, Cm-244, Am-241, others
235	Characterization studies and ion beam experiments	Th-232, U-234, U-235, U-238, Pu-238, Pu-239, Pu-241, Pu-242, Am-241
241	Physics: Accelerators	H-3, C-14, P-32, Th-232, U-234, U-235, U-238, various activation products
243	Lab services	Various radioactive materials not specified
251 (190)	Heavy Element Facility	U-233, Pu-238, Pu-239, Pu-243, Am-241, Cm-243, Cm-244, Cm-248, Cf-252
253	Labs and counting rooms	H-3, C14, P-32, Sr-90, Y-90, Cs-137, Bi-214, Po-218, Ra-226, Th-230, U-234, U-235, U-238, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241
254	Bioassays and analytical services	H-3, C14, P-32, P-33, S-35, Sr-90, Y-90, I-125, Po-209, Ra-226, Th-230, U-232, U-233, U-234, U-235, U-236, U-238, Np-237, Np-239, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-243, Cm-242, Cm-244, Cf-249, Cf-252
255	Calibration laboratory	H-3, C14, P-32, S-35, Sr-90, Y-90, I-125, I-131, Th-230, Th-232, U-233, U-234, U-235, U-236, U-238, Np-237, Np-239, Pu-239, Pu-242, Am-241, Am-243, Cm-242, Cm-244, Cf-252
261 (110)	Critical test facility	U-235, Pu-239
281 (193)	Reactor; tracer and dissolution studies	During reactor operations, fission and activation products. Later, trace amounts of various radionuclides.
282	Neutrino detection experiments	H-3
292	Residual contamination rotating target neutron source	H-3

Table 2-2 (Continued). Site activities by building and associated radionuclides.

Current building # (old #)[a]	Building activity	Radionuclides
298	Laser fusion program	H-3, U-234, U-235, U-238
321A	Milling and shaping	U-234, U-235, U-238
321B	Milling and shaping	U-234, U-235, U-238
321C	Milling, machining and shaping	U-234, U-235, U-238
322	Maintenance and engineering	U-234, U-235, U-238
327 (115)	Maintenance and engineering; radiography	U-234, U-235, U-238
331 (172)	Gaseous chemistry; Tritium Facility	H-3 (HT, HTO), U-238
332 (171)	Metallurgical chemistry; Plutonium Facility	Pu-239, transuranics
341	Lasers Directorate	U-234, U-235, U-238
361	Research and development	H-3, C-14, P-32, P-33, S-35
362	Research and development	H-3, C-14
363	Research and development	H-3, C-14
364	Research and development	H-3, C-14, P-32
365	Research and development	H-3, C-14
366	Research and development	H-3, P-32, P-33
377	Research and development	H-3, P-32, Ni-63
378		Co-57, Co-60, Sr-85, Cd-109, Cs-134, Cs-137, U-233, U-234, U-235, U-238, Pu-236, Pu-239, Pu-240, Pu-242, Pu-244, Np-237, Am-241, Am-243
381		H-3
391		H-3
412 (121)	Hot cells: High beta waste	Ni-59, Ni-63, Sr-90
421	Physics: Accelerators	Various activation products, H-3, others
435	Physics: Accelerators	Various activation products, H-3, others
491, 492, 493, 494	U-AVLIS	U-238
513	Waste processing	H-3, C-14, P-32, K-40, Mn-54, Co-57, Co-60, Sr-90, Nb-95, Zr-95, Ru-106, I-125, I-131, Ba-133, Cs-134, Cs-137, Cs-138, Ce-141, Ce-144, Eu-152, Eu-154, Eu-155, Tl-206, Bi-212, Bi-214, Pb-210, Pb-212, Pb-214, Ra-223, Ra-226, Ra-228, Ac-228, Pa-231, Th-226, Th-227, Th-228, Th-232, Th-234, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Cm-244, Cf-249
514	Waste processing	H-3, Be-7, C-14, Na-22, P-32, S-35, K-40, Sc-46, Cr-51, Fe-55, Mn-54, Co-56, Co-57, Co-58, Co-60, Ni-63, Zn-65, Y-88, Sr-89, Sr-90, Nb-94, Nb-95, Zr-95, Ru-103, Ru-106, Cd-109, Sb-125, I-125, I-131, Ba-133, Cs-134, Cs-137, Ce-139, Ce-141, Ce-144, Gd-148, Pm-147, Sm-151, Eu-152, Eu-154, Eu-155, Hf-172, Lu-173, Lu-174, W-185, Po-209, Po-210, Bi-207, Bi-210, Pb-210, Ra-226, Th-228, Th-229, Th-230, Th-232, U-232, U-233, U-234, U-235, U-236, U-237, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Np-237, Np-239, Am-241, Am-243, Cm-244, Cf-249
514 Tank Farm	Waste processing	H-3, Be-7, C-14, Na-22, P-32, P-33, S-35, K-40, Sc-46, Cr-51, Fe-55, Fe-59, Mn-54, Co-56, Co-57, Co-58, Co-60, Ni-59, Ni-63, Zn-65, Y-88, Y-91, Sr-90, Nb-95, Mo-99, Tc-99, Ru-103, Ru-106, Cd-109, Sn-113, Ag-110m, I-125, I-131, Sb-110m, Sb-124, Sb-125, Te-132, Ba-133, Ba-140, Cs-134, Cs-136, Cs-137, La-140, Ce-139, Ce-141, Ce-144, Nd-147, Pm-147, Gd-148, Sm-151, Eu-152, Eu-154, Eu-155, Eu-156, Tb-160, Hf-172, Hf-181, Lu-173, Lu-174, W-185, Au-195, Hg-203, Bi-207, Bi-210, Po-209, Po-210, Pb-210, Ra-226, Pa-233, Th-228, Th-229, Th-230, Th-232, U-232, U-233, U-234, U-235, U-236, U-237, U-238, Pu-236, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Np-237, Np-239, Am-241, Am-243, Cm-244, Cf-249
612	Waste storage and repackaging	H-3, Be-7, C-14, Na-22, P-32, P-33, S-35, Cl-36, K-40, Sc-46, Cr-51, Fe-55, Mn-54, Co-56, Co-57, Co-58, Co-60, Ni-63, Zn-65, Se-75, Y-88, Y-91, Sr-85, Sr-89, Sr-90, Kr-85, Nb-94, Nb-95, Zr-90, Zr-95, Mo-99, Tc-99, Rh-102, Rh-103, Rh-103m, Ru-106, Cd-109, Cd-115, Ag-110m, I-125, I-131, Sb-124, Sb-125, Ba-133, Ba-140, Cs-134, Cs-137, Ce-139, Ce-141, Ce-144, Nd-147, Pm-147, Pm-151, Sm-151, Gd-146, Gd-148, Eu-149, Eu-152, Eu-154, Eu-155, Eu-156, Tb-160, Hf-172, Lu-173, Lu-174, Ta-182, W-185, Ir-192, Au-195, Pt-195m, Hg-203, Bi-207, Bi-210, Po-209, Po-210, Pb-210, Ra-223, Ra-226, Th-228, Th-229, Th-230, Th-232, Th-234, U-232, U-233, U-234, U-235, U-237, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Np-237, Np-239, Am-241, Am-242, Am-242m, Am-243, Am-244, Cm-244, Cf-249, Cf-250

Table 2-2 (Continued). Site activities by building and associated radionuclides.

Current building # (old #)[a]	Building activity	Radionuclides
612 Yard	Waste storage	H-3, C-14, P-32, S-35, K-40, Cr-51, Mn-54, Co-57, Co-60, Ni-59, Ni-63, Se-75, Sr-90, Nb-95, Tc-99, Sb-125, Cs-134, Cs-137, Ce-144, Pm-147, Sm-151, Eu-152, Eu-154, Eu-155, Bi-207, Bi-214, Ra-226, Ra-228, Th-228, Th-230, Th-232, Th-234, U-233, U-234, U-235, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-244, Np-239, Am-241, Am-242, Am-243, CM-243, Cm-244, Cm-253
625	Waste operations	H-3, C-14, P-32, K-40, Mn-54, Co-57, Co-60, Y-88, Sr-90, Zr-95, Ru-106, Cd-109, Sb-125, Ba-133, Cs-134, Cs-137, Ce-141, Ce-144, Eu-152, Eu-154, Eu-155, Bi-214, Pb-212, Pb-214, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, Th-234, U-233, U-234, U-235, U-238, U-239, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Np-237, Am-241, Am-243, Cm-243, Cm-244, Cm-253
2561		U-234, U-238
Site 300 – Explosives testing: linear accelerators, depleted uranium, H-3, radiography.		
801	Flash X-ray (FXR) linear accelerator	H-3, N-13, Ar-41, U-234, U-235, U-238
810A		U-234, U-235, U-238
810B		U-234, U-235, U-238
827	Industrial radiography (portable X-ray machines)	Radionuclides not specified
823	Portable 9-MV Varian accelerator	Radionuclides not specified
850		H-3, U-234, U-235, U-238
851	100-MeV LINAC	H-3, N-13, O-15, Ar-41, U-234, U-235, U-238
865	Advanced Test Accelerator	Various activation products
300 Pit 7		H-3
300 Well 8 Spring		H-3

a. Source: LLNL (2005b).

streams and environmental media (air, water, soil, etc.) have been analyzed for their radionuclide content.

Buildings 175 and 177
Buildings 175 and 177 were part of the Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program affiliated with the United States Enrichment Corporation (USEC). In June 1999, USEC suspended further development of the U-AVLIS technology. Building 175 is sometimes referred to as the MARS Facility (for Mirror Advanced Reactor System), which used an electron beam to vaporize natural or depleted uranium for evaluation of ion extraction, source development, and material handling subsystems.

Building 177 underwent decontamination and decommissioning in early 2002, and the sampling system was removed.

Building 190
Building 190 is operated by the Physics Department and has included a 10-MV tandem accelerator laboratory, accelerator mass spectrometry, and other accelerator uses (DOE 1992).

Building 193
The Livermore Pool Type Reactor was operated from Building 193 from 1957 to 1980.

Building 194
Building 194 is operated by N-Division for the Physics and Space Technology Directorate (formerly the Physical Sciences Directorate). The facility has included a high-energy (100 MeV) linear accelerator (LINAC) and research laboratories. The accelerator beam has produced small quantities of short-lived air activation products.

Building 212
Building 212 is administered by the Physics and Space Technology Directorate for miscellaneous physics experiments. Historically, the building housed a Cockcroft Walton accelerator and a 90-inch cyclotron. Experiments include the use of uranium, plutonium, and tritium. Radionuclide emissions are a result of contamination from past operations of the rotating target neutron source, which is no longer in operation.

Building 222 Complex
The Building 222 Complex in the southwest quadrant of the LLNL at the Livermore site consists of nine buildings (221 through 229) and several trailers. The complex includes chemical laboratories, offices, and machining and storage facilities. The wide range of work performed here includes the bench-scale synthesis and testing of chemical compounds, intralaboratory and consulting services, chemical analysis, bench-scale polymers and composite technology development, and other special bench-scale research and development projects (DOE 1992).

The chemistry facility, Building 222, is the main facility for the study of analytical and physical chemistry at LLNL. Buildings 224 and 226 are used for environmental analytical work. Building 225 activities have included energy research, surface science, and other similar bench-scale research. Building 227 has provided a facility for polymer research and work associated with LLNL intelligence and treaty verification support. Building 228 is the waste retention system for Building 226. Building 229 has stored beryllium hydride.

The hazards associated with the Building 222 Complex include handling small quantities of hazardous materials involved in research and development activities. These include radioactive materials, laser dyes, high explosives, solvents, inorganic acids, bases and salts, organic compounds, halogens, organometallics, and inorganic compounds (DOE 1992).

Building 231
The Development and Assembly Facility, Building 231, is a large experimental, manufacturing, assembly, test, and materials-handling facility in the southwestern quadrant of the site. Building 231 houses research and development activities conducted by Chemistry and Materials Science (Materials Division), Engineering (Engineering Sciences, Materials Fabrication, Nuclear Energy Systems, Nuclear Test Engineering, and Weapons Engineering Divisions), Safeguards and Security (Materials Management Division), and Special Projects Program (J Division). Management oversight for Building 231 is provided by the Engineering Directorate through Engineering Sciences Division.

Small amounts of depleted uranium have been used in Building 232.

Building 235
Building 235 is a part of the Chemistry and Materials Sciences Directorate known as the Weapons Materials Research and Development Facility. Operations in the facility began in 1987 and have included examination of material structure, surface, and subsurface; precision cutting; ion implanting; and metallurgical studies. Most of the depleted uranium in this building has been used for characterization studies; some has been used for ion beam implantation experiments.

Building 241
Building 241 is administered by the Chemistry and Material Sciences Directorate for material properties research and testing as well as study of soil bacteria. The history of the facility included the use of a LINAC.

Building 251
Building 251 is the Heavy Element Facility managed by the Safety, Security, and Environmental Protection Directorate as a standby, nonoperational facility in which transuranic isotopes are stored until they can be disposed. One area of the facility has been hardened to resist damage from earthquakes. Room air in the hardened area is exhausted through two high-efficiency particulate air (HEPA) filters; glovebox exhausts are triply HEPA filtered. Exhausts from the unhardened areas are also HEPA filtered and are continuously sampled by sample filter systems.

Buildings 253, 254, and 255
Building 253 houses the Hazards Control Department, and the facility includes laboratories for the chemical analysis and counting of radioactive samples. Hazards Control also operates Building 254 to conduct bioassays and provide analytical services and Building 255, which houses a radiation calibration and standards laboratory.

Many operations involve the use of sealed sources.

Building 281
Building 281 is part of the Energy and Environment Directorate. Tracer work, dissolution studies, and flow studies have been conducted in this building.

The Livermore Pool Type Reactor was operated from Building 281 (which was Building 193 before 1966). The reactor operated from 1957 to 1980.

Building 282
Building 282 contains residual contamination from past operations.

Building 292
Building 292 contains residual contamination from the past operation of a rotating target neutron source. Emissions result from tritium-contaminated water that leaked from an underground storage tank. Vegetation in the area transpires water with elevated tritium concentrations.

Building 298
Building 298 is the Fusion Target Fabrication Facility, a part of the Laser Fusion Program. Small amounts of tritium have been used in this facility in conjunction with fusion target research and development.

Building 321 Complex
Buildings 321, 321A, 321B, and 321C are the Material Fabrication facility. Operations in this complex include milling, shaping, and machining of depleted uranium. Uranium pieces were worked in single locations or were moved from machine to machine. In addition, depleted uranium parts occasionally underwent heat treatment. The amount of depleted uranium handled depended on programmatic demands and varied from month to month. Machining only occurred in 321C.

Building 327
Building 327 is a radiography facility and, along with Building 239, has conducted nondestructive evaluation in support of LLNL Site 300, Nevada Test Site (NTS), Tonopah Test Range, DOE contractor laboratories, and the Lawrence Berkeley National Laboratory. Equipment in these buildings has included lasers, linear accelerators, isotope sources, and flash X-ray equipment (DOE 1992).

Building 331
Building 331 is the Hydrogen Research Facility or Tritium Research Facility. The building houses the tritium research facility and associated laboratories. The bulk of the tritium inventory is in elemental form or metal hydrides capable of being turned into elemental form by heating. A small amount of tritium has been used for labeling compounds or synthesizing lithium hydride. There has been no deliberate experimental use of tritiated water. Some tritiated water is formed in the tritium cleanup systems during the removal of tritium from glovebox atmospheres (DOE 1992).

Building 332
Building 332 is the Plutonium Facility. Exhausts from glovebox operations and the workplace are triply HEPA filtered. Exhausts are monitored with both continuous filter sampling and plutonium-specific, continuous real-time monitors. The major activities at the facility have included testing plutonium-bearing engineering assemblies, developing and demonstrating improved plutonium fabrication techniques, and fundamental and applied research in plutonium metallurgy.

Building 334
Building 334, the Hardened Engineering Test Building, is in the southwest quadrant of the LLNL site and provides laboratory space. This facility performs two main activities. The first is intrinsic radiation measurements. Nonexplosive, plutonium-bearing assemblies are used in these experiments to determine the occupational radiation exposure to personnel during transportation, storage, and handling of nuclear weapons. The second activity is physical testing of components to various combinations of vibration, acceleration, mechanical and thermal shock, and thermal cycling. These tests simulate the harsh conditions to which the components could be subjected over their lifetime in storage, transportation, and use.

Building 341
Building 341 is one of the Lasers Directorate facilities. Experimental studies include the use of high-energy electrical systems, explosives, high-velocity experiments using gun systems, development and testing of optics, laser systems, flash X-ray generators, and hydro-diagnostics equipment.

Building 361 Complex
The research complex for the Biology and Biotechnology Research Directorate includes Buildings 361, 362, 363, 364, 365, 366 and 367. Building 365 contains small amounts of tritium, ^{14}C and ^{35}S used in animal research and incorporated in animal carcasses stored frozen pending disposal. The building air is filtered through at least two HEPA filters and one charcoal filter before being exhausted. Most of the organs that contained radionuclides have been removed from the animals for examination. The radionuclide sources in Building 361 include tritium, ^{14}C, ^{32}P, ^{33}P, and ^{35}S, mostly incorporated as constituent atoms (tracers) in organic compounds.

Building 378
Building 378 is part of the Energy and Environment Directorate. Small quantities of radioactive tracers have been handled in this building.

Building 391
Building 391 is the Inertial Confinement Fusion Laser Facility. The building contains a master oscillator room and film calibration facility; a laser bay and switchyard; a 10-beam target bay; a Nova 2-beam target bay; and Nova power-conditioning and control systems. Radiation and radioactive materials may be encountered in the form of neutrons, X-rays, and possible contamination of the target chamber with tritium.

Building 412
Building 412 is used for environmental research and includes service shops and laboratories in which experiments involving lasers and spectrometers are conducted. Other experiments have involved extremely high temperatures and pressures. The eastern section of the building contains six hot cells that are no longer used. These cells and the associated air filtration and scrubber system are contaminated with low levels of mixed fission products and are in caretaker standby condition with a maintenance and monitoring program (DOE 1992).

Building 435

Building 435 houses two magnetic fusion energy experiments: the Sustained Spheromak Physics Experiment, operated by the Physics and Advanced Technology Directorate, and the Davis Diverted Tokamak, operated by the University of California, Davis, Department of Applied Science. Experiments are conducted in these facilities on the confinement and heating of plasmas as part of the U.S. Fusion Energy Program. Plasmas are formed in large vacuum vessels and studied using diagnostics including a laser interferometer and laser Thompson scattering (DOE 2004). This building has also housed the Sherwood Project (magnetic fusion energy experiment) and the International Thermonuclear Experimental Reactor.

Building 490 Complex
This complex of buildings in the northern quadrant of the LLNL at the Livermore site includes Buildings 490, 491, 492, 493, and 494. The complex supports operation of the laser demonstration facilities (Buildings 490, 492, and 494) and the separator demonstration facilities (Buildings 490, 491, 493, and 494) as well as related research and development activities. Chemical processing has been performed in Building 494.

The operations performed at the 490 Complex supported both the U-AVLIS process for uranium enrichment and waste treatment development activities. In June 1999, USEC suspended further development of the U-AVLIS technology. The Separator Demonstration Facility in Building 490 contained the uranium separator and areas for receipt, inspection, and storage of the separator pod assemblies and parts. Pods were transported for refurbishment from Building 490 to Building 491 through an enclosed transporter equipped with a HEPA filter and an inert gas supply.

Building 491 housed the separator pod disassembly area, oxidation ovens, grit blasters, coating equipment, change rooms, a receiving and shipping area for component storage and assembly of sealed containers of natural or depleted uranium and of small quantities of enriched uranium. Building 493 was used for component storage and assembly and for sealed storage of U-AVLIS feed, classified materials, and low-level radioactive wastes. Building 493 stored up to 80,000 kg of uranium at one time.

Buildings 513 and 514 Area
Building 513 is operated by the Radioactive and Hazardous Waste Management Division. The Stabilization Unit is a mechanized mixing device used to make homogeneous mixtures of waste. Solidification agents are added during mixing to transfer sludges to solids. The Microfiltration Unit filters out waste radioactive particles. Small quantities of waste materials are sampled, treated, and stored. No releases are assumed to occur from waste storage because the wastes are fully contained.

Building 514 and the 514 open area are operated by the Radioactive and Hazardous Waste Management Division. The wastewater treatment tank farm and storage tank area process the liquid waste from facilities on site. The treatment process can involve any of batch chemical treatment

consisting of neutralization, flocculation, oxidation, reduction, precipitation, separation, or filtration. Areas used for storage are not considered to release radionuclides because the wastes are fully contained.

Building 612 Area
Building 612 is operated by the Radioactive and Hazardous Waste Management Division. It is a facility where waste has been repackaged for shipment off site. The Building 612 Yard is operated by the Radioactive and Hazardous Waste Management Division. The Yard consists of several areas where containers of radioactive wastes are stacked outdoors. The containers, which are not air tight, can outgas tritium.

Building 625
Building 625 is operated by Radioactive and Hazardous Waste Management. The building houses the handling and storage of wastes that are not subject to the Resource Conservation and Recovery Act, such as polychlorinated biphenyls, asbestos, and transuranic wastes.

2.3.2 Southeast Quadrant (Main Site)

The Southeast Quadrant of the Livermore site has slightly elevated levels of ^{239}Pu in the surface soil and air (presumably from resuspension). The source of the ^{239}Pu was past waste management operations.

2.3.3 Site 300

Explosives tests in which radionuclides can be present have been conducted on open-air firing tables. These tests have depleted uranium material as part of the material inventory. There are multiple tests per year. Air activation products are created at the flash X-ray and LINAC. Experiments involving tritium were conducted in the past as well.

Throughout its history, Site 300 has included several LINACs and flash X-ray units. These devices include:

- XR2 Machine, late 1950s
- ASTRON LINAC, 1963
- Electron Test Accelerator, 1983
- Electron Test Accelerator II, late 1980s

Some selected operations at Site 300 are discussed below.

Bunker 801
Bunker 801 is the Contained Firing Facility but in the past has been used with open-air firing tables. This facility contained the Flash X-Ray (FXR) LINAC, which began operations in 1982. Workers could have encountered depleted uranium, tritium, and accelerator-produced air activation products.

Bunker 851
This facility housed a 100-MeV LINAC. Open-air firing tables were also used. Workers could have encountered depleted uranium, tritium, and accelerator-produced air activation products.

Bunker 865
The Advanced Test Accelerator is housed in Bunker 865. Workers are likely to have encountered accelerator-produced air activation products.

2.3.4 Nuclear Weapons Testing

LLNL personnel supported a variety of nuclear weapons testing from 1952 through the late 1980s. Specific information about these tests is not provided in the Site Profile. Individual exposure records should include information for personnel who traveled to the Nevada Test Site, Pacific Proving Ground, or other nuclear weapons testing locations (Alaska, Colorado, New Mexico, and Mississippi). These records should include external dosimetry results as well as any bioassay that might have been performed.

For external dose, LLNL employees working at the NTS may have been double badged, wearing dosimetry from both the NTS and LLNL. For other nuclear weapons tests, only LLNL dosimetry was provided. For internal dose, LLNL might have performed bioassay upon a worker's return to LLNL.

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GLOSSARY

depleted uranium
The uranium remaining after removing ^{235}U from natural uranium. The remaining isotopic content is typically on the order of 99.8% ^{238}U, 0.2% ^{235}U, and a trace amount (0.001%) of ^{234}U.

dosimetry
The science of assessing absorbed dose, dose equivalent, effective dose equivalent, etc., from external and internal sources of radiation.

Febetron
A field emission beta ray device that produces high-energy pulses.

fission products
Isotopes formed during fission of uranium or plutonium.

flash X-ray
A linear-induction electron beam accelerator.

natural uranium
Uranium is a naturally occurring radioactive element consisting of three isotopes: ^{238}U (99.276%), ^{235}U (0.719%), and a trace amount of ^{234}U (0.0057%).

transuranic elements
Elements with an atomic number greater than uranium (92).

ATTACHMENT A. BUILDING NUMBER CROSS REFERENCE

Table A-1. Cross reference of main site building number changes in 1966 (LLNL 2005b).

Building name	Old number	Current number
Dept. of Applied Sciences		615
Dept. of Applied Sciences		616
Storage		284
Chemistry	101	222
Development & Assembly	102	221
Security Vault	103	215
Chemistry Storage	104	228
Maintenance Shop	105	211
Chemical Engineering	106	223
High Explosive Chemistry	107A	225
High Explosive Chemistry	107B	226
High Explosive Chemistry	107C	227
Field Test Staging	108	141
EE Field Test Staging	108-116	141
Accounting	109	214
Critical Test	110	261
Auditorium	111	123
Experimental Physics	112	121
Administration-P	112	415
Mechanical Shops	113	415
Mech. Shop/Lunch Room	114	321
ME Nondestruct. Test Lab	115	327
High Explosive Chemistry	117	224
Process Research	118	234
1st Plating	119	433
Computer	120	115
Computer Programming	120C	116
Computer	120D	117
Biomedical Lab.	121	412
Cold Storage	121B	414
Marine Biology Lab.	121C	413
Theoretical and Comp.	122	113
Telephone Central	123	313
Craft Material Assembly	124A	512
Equipment Storage	124B	515
Assay Lab.	125	419
Craft Shops	126	511
Waste Disposal	127	514
Temp. Lab. and Shop	128	516
Warehouse	129	517
East Cafeteria	130	312
Experimental Phys. & Engr.	131	315
Administrative-Q	132	314
Administrative-Unclassified	133	310
Heating Plant	134	401
Garage	135	402
Graphic Arts	136	316
Gas Cylinder Dock	137	518
Garage	138	403
Police	139	416
Development Lab.	140A	326
Sheet Metal Shop	140B	322
Administrative-Unclassified	143	319
Administrative-P	144	219
Emergency Water Reservoir	145A	318
Multipurpose	145B	317
Dormitory	146	213
Chem. High Pressure Lab.	147	232
Fire House	148	323
Maintenance Shop	149A	324
Utilities Control	149B	325
Assembly and Test	150	432
Mechanical Engineering	151	217
Experimental Phys. & Engr.	152	218
Accelerators	153	212
Scintillator	153C	210
Special Research	154A	171
Special Research	154B	176
Special Research	154C	173
Special Research	154D	174
Special Research	154E	177
Special Research	154F	175
Experimental Phys. & Engr.	155	216
Experimental Phys. & Engr.	156	426
Experimental Physics	157	431
Research Power Supply	158	423
Electrical Substation	159	424
Central Stores	160	411
Central Stores	160C	410
Glove Box Storage	160D	417
Experimental Phys. & Engr.	161	119
Warehouse	166	404
Warehouse	167	405
Power Supply	168	434
Mechanical Engineering	170	131
Metallurgical Chemistry	171	332
Gaseous Chemistry	172	331
Diagnostic Engineering	173A	243
Refractory Materials	173B	241
High Pressure	174	243
Hazards Control	175	253
Toxicology	175C	254
Classified Storage	176	233
Paint Shop	177	418
[No Building Name]	178	333
Salvage	179	523
Experimental Physics	180	435
Power Supply	180A	435
Experimental Physics	180B	442
Coil Shop	181A	443
Magnet Coil Storage	181B	444
Special Research	182A	166
Special Research	182B	165
Special Research	182C	162
Special Research	182D	165
Special Research	182E	165
Detonator Research	183A	345
Detonator Research Mag.	183B	344
Pulsed Energy Research	184	341
Biomedical	185	362
Biomedical	187	361
[No Building Name]	188	437
Animal House	189	363
Diagnostic Chemistry	190	251
Radiochemistry	191	151
Special Research	192A	169
Special Research	192B	168
Special Research	192C	167
Pool Type Reactor	193	281
Electron-Positron Accel.	194	194
Instrument Calibration	196	283
Water Pump House	197	295
West Cafeteria	199	125
Experimental Physics	200	111
[No Building Name]	203	314
Plant Engineering & Pers.	205	311
Storage	214	321
[No Building Name]	216	142
[No Building Name]	222	617
Storage	223	614
Dry Waste	224	612
[No Building Name]	225	613
Propane Plant/Compressor	230A	622
Propane Plant/Vaporizer	230B	623
[No Building Name]	248	315
[No Building Name]	254	181
Special Research	255	186
[No Building Name]	257	256
[No Building Name]	260	256
[No Building Name]	268	400
[No Building Name]	269	239
[No Building Name]	271	334
[No Building Name]	272	242
[No Building Name]	273	244
[No Building Name]	275	255
[No Building Name]	280	445
[No Building Name]	285	461
[No Building Name]	286	378
[No Building Name]	287	377
Animal House	289	364
Cow Barn	290	592
Sheep Shed	291	593
[No Building Name]	292	595
[No Building Name]	293	594
[No Building Name]	294	282
[No Building Name]	296	299
Classified Waste Disposal	297	297
[No Building Name]	298	499
[No Building Name]	299	399