Memorandum

To: LANL Work Group

From: LaVon Rutherford

Subject: Weight of Evidence Supports NIOSH's Ability to Bound LANL TA-53 Doses for 1996–2005

Date: August 15, 2023

After designating a Los Alamos National Laboratory (LANL) Special Exposure Cohort (SEC) class for 1976 through 1995, the Advisory Board on Radiation and Worker Health's LANL Work Group questioned the National Institute for Occupational Safety and Health (NIOSH)'s ability to bound doses from exotic radionuclides[1] for the period from 1996 through 2005 [NIOSH 2019]. One area of focus in Work Group discussions of exotic radionuclide exposures was the Los Alamos Neutron Science Center (LANSCE) in Technical Area-53 (TA-53), which included an accelerator and various experimental facilities. With respect to LANSCE, exotic radionuclides included activation and spallation products produced (directly or indirectly) by the proton beam of the accelerator. For the purpose of this NIOSH assessment of LANSCE operations, work activities are identified as routine work and non-routine work.

"Routine work" is work *not* performed under the requirements of a specific radiological work permit (RWP). Worker categories that performed routine work included guards and custodians [ORAUT 2022a, PDF p. 8]. NIOSH and the LANL Work Group consider "routine work monitoring" to include monitoring for plutonium, uranium, and tritium. The ORAU Team demonstrated in ORAUT-RPRT-0101, *Bounding Intakes of Exotic Radionuclides at Los Alamos National Laboratory* [ORAUT 2022a] and ORAUT-RPRT-0103, *Review of Potential Exposure to Exotic Radionuclides Using Radiological Work Permit Data at Los Alamos National Laboratory* [ORAUT 2022b] that LANL Health Physics personnel monitored work areas for air and surface contamination adequately to demonstrate that workers performing such routine work were unlikely to have received intakes resulting in greater than 100 mrem/year committed effective dose (CED). LANL designed their radiological control program to comply with 10 Code of Federal Regulations (C.F.R.) Part 835 [DOE 1993] but with an intended outcome that

[1] The term "exotics" includes everything other than U-234/235/238, Pu-238/239, tritium, Am-241, and Cs-137. This term includes Sr-90, Th-232, Cm-244, Ac-227, Pa-231, Np-237, and others.

unmonitored individuals (including workers performing routine work) would be unlikely to receive doses greater than 100 mrem/year. NIOSH maintains that, by complying with 10 C.F.R. Part 835 [DOE 1993], LANL monitored all workers with a potential to receive a CED in excess of 100 mrem/year.

“Non-routine work” is work performed under the requirements of an RWP and is often performed in posted radiological areas. The ORAU Team demonstrated in ORAUT-RPRT-0103 that LANL Health Physics personnel monitored RWP work in an effort to maintain worker radiation doses under 100 mrem/year. Workers performing non-routine work who were suspected of having the potential for radiation intakes were subsequently monitored by nasal smears or whole body count bioassay.

The data and information included in ORAUT-RPRT-0101 and ORAUT-RPRT-0103 addressed LANL Work Group questions regarding personnel exposures to exotic radionuclides. As a follow-up to those reports, NIOSH completed a LANL site visit that included a tour of LANSCE in TA-53. On that site visit, NIOSH collected additional data and information specific to Work Group questions regarding the possibility of a LANSCE worker gaining access to the accelerator beam area during beam operation or the potential for intakes from isotope production. This information is included in the discussion in the following sections.

LANL’s use of access control systems, surveys, adherence to RWP requirements, and monitoring practices support NIOSH’s position that LANL worked to maintain TA-53 personnel doses at or below 100 mrem/year while performing routine work and that TA-53 personnel doses for workers performing non-routine work can be bounded using whole body count bioassay data.

Access Control Systems

Potential exposure to exotic radionuclides from spallation sources would most likely have occurred during beam operation and within a few minutes after the beam dropped. For the 1996–2005 period, LANL staff tightly controlled entry into the LANSCE beam line area when the beam was in operation. Access control systems engineered for LANSCE accelerator operations were robust and were used to prevent inadvertent access to radiological areas during beam operations. Beginning as early as 1991 [DOE 1991; Sturrock et al. 1996], one of LANL’s access controls included the Radiation Security System (RSS). The RSS automatically terminated beam delivery in response to pre-defined abnormal conditions [Gallegos 1996]. The RSS contained beam-loss interlocks, beam-current interlocks, and area-radiation interlocks [Macek 1996, PDF pp. 7–9]. Beginning January 1996 [Gallegos 1996], additional access controls to areas with potential radiation hazards from an accelerator beam included the Personnel Access Control System (PACS) and Experimental Personnel Access Control System (EPACS). These access control systems and interlocks are described in greater detail in *Beam-Limiting and Radiation-Limiting Interlocks* [Macek 1996].

In general terms, the PACS operation involved a two-key control system. The two-key system provided redundant access control to the accelerator beam area, which prevented personnel from accessing the area when the beam was active but permitted access when the beam was not active.

In addition to PACS, LANSCE also used another access-control system known as EPACS to ensure that LANL staff did not enter a high-radiation testing area while the beam shutter was open to an experiment flight path. EPACS was an experimental-area PACS system for secondary beam-line flight paths in which the experimental scientists, with support from Radiological Control Technicians (RCTs), controlled entry and exit through a radiation interlock system [LANL 2002a, PDF p. 90; LANL 1995–1999, PDF pp. 47–56].

Access to Beam Channel Before and After Operation

Available documentation shows that LANL Health Physics staff ensured that all personnel were clear of beam areas prior to beam operations. *LANSCE Radiation Security System (RSS)*, received in 1996, and Section 5.16 of the 1999 LANSCE Accelerator Operations Manual documented the procedure for entering a beam area (referred to as a sweep) before and after beam operations [Gallegos 1996; LANL 1995–1999, PDF pp. 47–56].

Sweep Before Beam Operation

LANL Health Physics and TA-53 personnel ensured that staff were not present in the beam area prior to starting beam operation. Personnel conducting the sweep verified that all entry doors were closed and latched. Once all checks were validated, the PACS entry door was locked, and approval was given to start the beam. Any breach of the PACS caused the beam operation to immediately shut down [Sturrock et al. 1996; LANL 1995–1999, PDF pp. 47–56].

Sweep After Beam Operation

After beam shutdown, LANL procedure required Health Physics staff to conduct a sweep of the beam area, monitoring for residual activation radioactivity, before allowing personnel to access the area [LANL 1995–1999, PDF pp. 47–56]. Health Physics staff would only release PACS keys once they had ensured the following: beam stops were in place, residual activation was being monitored, appropriate radiological postings were in place, and entry could be conducted safely following RWP requirements.

Access Controls to High/Very High Radiation Areas

Per 10 C.F.R. Part 835, a *High Radiation Area* is designated as any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 sievert) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates [DOE 1993, PDF p. 37]. A *Very*

High Radiation Area is designated as any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at 1 meter from the radiation source or from any surface that the radiation penetrates [DOE 1993, PDF p. 37].

For any work in areas designated as high radiation areas, Health Physics personnel would monitor the work from start to finish. LANL required RCTs to perform weekly inspections of the physical access controls used to prevent unauthorized entries into high and very high radiation areas [LANL 1999a, PDF p. 10; LANL 2002b, PDF p. 8; LANL 2005, PDF pp. 7, 30]. Table 1 shows the areas that required the inspections, including LANSCE and the Isotope Production Facility.

Table 1: High Radiation Access Areas[a]

Location	Description
Sector B Roll-up Door	1 lock
Sector E	Elevator & upper beam channel door
Sector F	Upper beam channel door
Sector G	Door midway down stairwell
Sector H	Elevator & upper beam channel door
TOFI	Time-of-flight isochronous (TOFI) spectrometer deionization cave door
TOFI	Time-of-flight isochronous (TOFI) spectrometer filter banks, 2 locks
South Hot Cell Door	1 lock
Hot Cell Upper Door	1 lock
A-6	2 locks
A East	Door
Isotope Production	2 doors
Isotope Production Stringer	1 lock
LANSCE-7 Boneyard	2 locks
High Resolution Spectrometer	Beam stop entrance door
Land Disposal-2 Pit	1 lock
1L Service Area	Target pump alcove, 1 lock
LANSCE-12 Boneyard	1 lock

[a] Source: [LANL 2005, PDF p. 30]

Diagrams of LANSCE and some of the associated locations mentioned in Table 1 are provided in Figures 1 and 2 below. Attachment One provides an aerial photograph, to help visualize the vast area covered by access controls, as well as an Isotope Production Facility Hot Cell diagram.

Figure 1 shows a diagram of LANSCE in the most recent Isotope Production Facility configuration, from the front to the experimental areas.

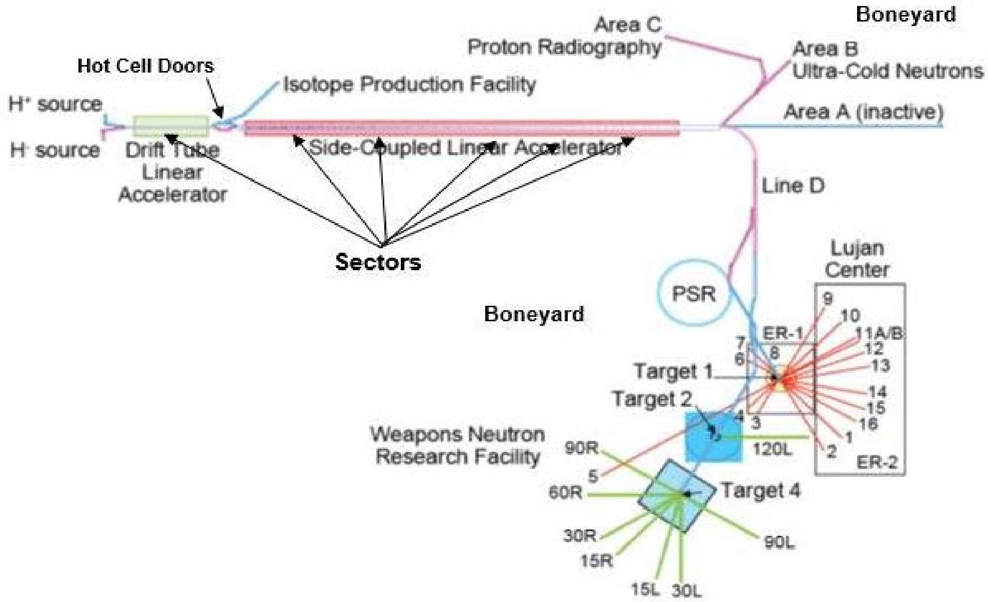

Figure 1: LANSCE diagram, beginning 2003 [LANL 2010, PDF p. 10]

Figure 2 shows the older Isotope Production Facility configuration in Area A.

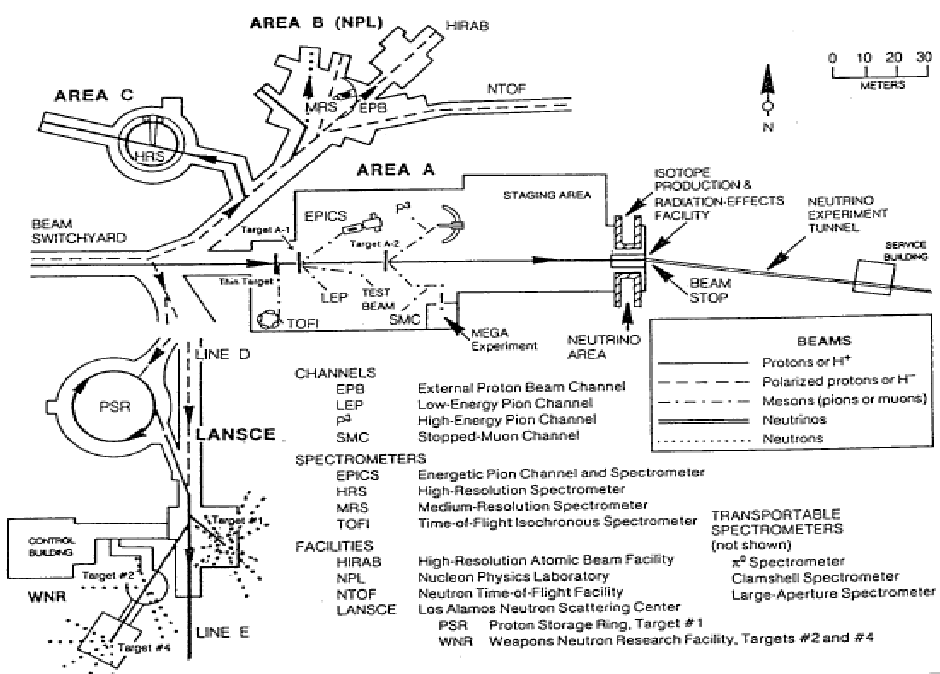

Figure 2: LANSCE diagram, 1990s [Coulson et al., no date, PDF p. 12]

Surveys of Contamination Area Boundaries

LANL required Health Physics personnel to collect smear surveys in areas bordering all established, accessible contamination areas at TA-53 on a weekly basis. The Wednesday night shift completed the survey during beam operations, and the day shift completed the survey during maintenance periods [LANL 1999a, PDF p. 10; LANL 2002b, PDF p. 8; LANL 2005, PDF p. 7]. These areas included the A-6 Contamination Area, 1L Service Area (above 1L Target), and the Switchyard Valve Gallery [LANL 2005, PDF pp. 7–8].

LANL required Health Physics personnel to conduct smear surveys on all primary and secondary beam line areas, Meson Physics Facility (MPF)-3 (Area A), and other areas specified in *HSR-1/TA-53 Routine Monitoring Instructions* on a quarterly basis [LANL 2005]. When beam operations prevented access to these areas, personnel collected smears during the next quarter that they were due [LANL 2005, PDF p. 11].

Entry Controlled by RWP

LANL did not allow employees to perform work in beam line areas unless it followed RWP stipulations. LANL Health Physics staff and the person requesting the work jointly determined RWP requirements, including any additional dosimetry and monitoring in accordance with LANL's As Low As Reasonably Achievable (ALARA) requirements [LANL 1995–1999, PDF pp. 12, 18]. LANL's Radiation Protection Program integrated ALARA into radiological design and control [LANL 1995–1999, PDF p. 18].

LANL staff also followed RWP requirements for other work performed in locations throughout LANSCE; this included areas controlled by PACS or EPACS, including experimental stations, the Blue Room, Building 7 (Weapons Neutron Research), and the Isotope Production Facility. NIOSH has access to a portion of RWPs written for TA-53 during the period from 1996 through 2004, as shown in Table 2. The available RWP documentation demonstrates that LANL Health Physics personnel appropriately monitored work performed under RWPs [ORAUT 2022b]. In cases where contamination incidents did occur, radiological data available with the RWPs show that LANL Health Physics personnel followed up with appropriate monitoring, as required by LANL radiation monitoring procedures.

Table 2: Available TA-53 RWPs

Year	Source
1996-1999	LANL 1995–1999
1998	LANL 1998a
1999[a]	LANL 1999b
1999	LANL 1999c
2000	LANL 2000
2001	LANL 2001a
2002[b]	LANL 2002c,d,e,f,g,h,i,j,k,l
2003[c]	LANL 2003
2004[d]	LANL 2004

[a] LANL [1999b, PDF pp. 536, 584, 603, 1108, 2305] shows examples of RWP worksheets and logbook printouts used completely or partially for sweeps of the beam line and experimental area.

[b] LANL [2002f, PDF pp. 19–20] and LANL [2002j, PDF p. 9] show examples of RWP worksheets used completely or partially for sweeps of the beam line and experimental area.

[c] LANL [2003, PDF p. 22] shows an example of RWPs used completely or partially for sweeps of the beam line and experimental area.

[d] LANL [2004, PDF p. 323] shows an example of an RWP Worksheet used for a sweep of an experimental area.

Portal Monitoring

TA-53 Health Physics personnel used portal monitors as an additional means of identifying worker contamination. Portal monitor locations included:

- MPF-3 M, A-1;
- MPF-3 M, A-East;
- MPF-7, Blue Room Hallway;
- MPF-7, IL Service Area;
- MPF-8, Proton Storage Ring;
- MPF-30, ER-2 (2); and
- MPF-3P, Proton Radiography Facility.

NIOSH has obtained some of the source check logs for TA-53 portal monitors [LANL 1997–1999; LANL 2001–2003].

LANL required workers to self-monitor upon exiting areas with potential contamination and housed with a portal monitor. Attachment A from the 1994 *LANL Radiological Control Manual* [LANL 1994, PDF p. 2] states:

> *1. Personnel exiting Contamination Areas, High Contamination Areas, Airborne Radioactivity Areas, and Radiological Buffer Areas or Controlled Areas established for contamination control shall frisk for contamination as required*

by Article 338. This does not apply to personnel exiting areas containing only radionuclides, such as tritium, that cannot be detected using hand-held or automatic frisking equipment.

2. Monitoring for contamination should be performed using frisking equipment that under laboratory conditions can detect total contamination of at least the values specified in Table 2-2. Use of automatic monitoring units that meet the above requirements is encouraged.

3. Personnel found with detectable contamination on their skin, personal clothing, or company-issued clothing other than noble gases or natural background radioactivity should be promptly decontaminated as described in Article 541.

In regard to monitoring for personnel contamination, the 1994 *LANL Radiological Control Manual* states [LANL 1994, PDF p. 3]:

1. *Personnel shall perform a whole-body frisk* [survey themselves] *under the following conditions:*

   a. *Immediately upon entry into an uncontaminated area after leaving existing Contamination Areas, High Contamination Areas, and Airborne Radioactivity Areas*

   b. *As directed by the radiological work permit, the ESH-1 RCT, or the area exit posting*

2. *In addition to the above, personnel exiting a Controlled Area or Radiological Buffer Area containing Contamination, High Contamination, or Airborne Radioactivity Areas should, at a minimum, perform a hand and foot frisk. The frisk is optional if the Controlled Area or Radiological Buffer Area exit is immediately adjacent to the location where the existing worker has already performed a whole-body frisk.*

3. *Where frisking cannot be performed at the exit from Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas due to high background radiation levels, personnel shall perform the following:*

   a. *Remove all protective equipment and clothing at the exit.*

   b. *Proceed directly to the nearest designated monitoring station.*

   c. *Conduct whole-body-frisk.*

4. *Personnel frisking shall be performed after removal of protective clothing and before washing or showering.*

The 1994 *LANL Radiological Control Manual* states, as action number 5, that personnel should respond to a personnel contamination monitor alarm with the following actions [LANL 1994, p. 5]:

a. *Remain in the immediate area.*

b. *Notify ESH-1 personnel and line supervision.*

c. *Take actions that may be available to minimize cross-contamination, such as putting a glove on a contaminated hand.*

LANL Health Physics personnel were required to collect weekly large-area swipes on walkways leading from contamination areas to personnel contamination monitors to ensure that walkways leading up to the portal monitors were free of removable contamination [LANL 2005, PDF p. 8].

Gate Monitoring

Since at least 1987 [LANL 1988, PDF pp. 9–10], LANL used a gate (exit) monitor to check vehicles and associated equipment for contamination when leaving the TA-53 area. The requirements for an alarm were the presence of a vehicle over the road detector and the detection of radiation at some level above background [LANL 1998b, PDF p. 3]. The gate monitor alarm system was based on monitoring beta/gamma dose rate and gamma-emitting radionuclides.

The gate monitor was source checked nightly by Health Physics personnel [LANL 1999a, PDF p. 6–7; LANL 2001b, PDF pp. 6, 13, 20, 35; LANL 1999d, pp. 2, 6, 22, 27; LANL 2005, PDF p. 5; LANL 2004–2006]. The LANL procedure *Operation and Maintenance of the TA-53 Front Gate Radiation Monitor* details the process used for responding to gate alarms [LANL1998b].

Department of Energy (DOE) REMS Database Review

NIOSH obtained a copy of the DOE Radiation Exposure Monitoring System (REMS) for LANL [LANL 2023]. NIOSH extracted records of LANL workers reported to have exceeded 100 mrem CED in any one year for the period 1996 through 2005 into a separate dataset [ORAUT 2023]. NIOSH found that none of the workers had worked in the LANSCE facility or TA-53 for the period 1996 through 2005, while a majority of the workers had worked in TA-55.

Dose Estimation from Intakes of Exotic Radionuclides at LANSCE

NIOSH acknowledges that while LANL used the access control and other protections mentioned in this memo, it is possible that some workers were exposed to exotic radionuclides. NIOSH reviewed the Department of Energy (DOE)'s Occurrence Reporting and Processing System and incident reports for 1996 through 2005 and found no violations that were reportable to DOE related to the PACS or EPACS systems.

As stated in ORAUT-RPRT-0101, workers performing routine work in TA-53 were unlikely to have received intakes resulting in doses greater than 100 mrem/year CED.

NIOSH is developing a proof-of-concept method to bound doses for routine TA-53 workers who received whole body counts; this method will be described in ORAUT-RPRT-0107, *Dose Estimation from Intakes of Exotic Radionuclides at LANSCE, 1996–2005*. The method estimates the dose to LANSCE workers from intakes of all radionuclides to which they were potentially exposed based on Co-60 body burdens measured with the LANL whole body counter. To accomplish this, dose conversion factors (DCF) are used along with the relative amounts of radionuclides in targets and structural materials to help identify radionuclides in each target organ that are dosimetrically significant. This information is used to derive an effective DCF for the radionuclide mixtures relative to the Co-60 in each target, and ultimately select a reference target for use in bounding doses. Targets used during the 1996–2005 period included the 1L tungsten target and targets at A6 (isotope production through 1998), the new Isotope Production Facility (2003–2005), and the Weapons Neutron Research facilities [Fuehne, no date PDF p. 10; LANL 1999e, PDF pp. 17–20; Kelley 2004, PDF p. 16; LANL 2022]. LANL has reported that the 1L Target provides the most conservative estimate on the radionuclide inventory and is used [LANL 2022] in the proof-of-concept model.

Summary

This memo shows:

1) LANL strictly controlled access to the beam line and hot area. Personnel did not gain access while the beam was operating. LANL Health Physics personnel monitored areas adjacent to the beam areas during beam operation. LANL Health Physics personnel, entering under RWP directives, were the first group to re-enter the beam area after shutdown.

2) All work performed in beam areas, during and after beam operation, was controlled by RWP directives and radiological monitoring.

3) LANL required workers to self-monitor for potential contamination upon exiting posted contamination areas. LANL personnel investigated all alarms. Vehicles leaving TA-53 were monitored for contamination using gate detectors.

4) Data obtained from DOE in the REMS database show no workers in TA-53 received over 100 mrem CED in any year from 1996 through 2005.

5) For workers who performed routine work in TA-53 and who were monitored by whole body counting, doses can be bounded using the method NIOSH will describe in *Dose Estimation from Intakes of Exotic Radionuclides at LANSCE, 1996–2005.*

Based on the conclusions of ORAUT-RPRT-0101 and ORAUT-RPRT-0103, and the fact that LANL maintained adequate administrative and engineering controls discussed in this memorandum, the weight of evidence supports NIOSH's ability to bound radiation doses at 100 mrem/year with sufficient accuracy for unmonitored LANL TA-53 workers from 1996 through 2005.

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Attachment One: LANSCE Images

Figure A-1 shows an aerial view of LANSCE from the front where the beam is started.

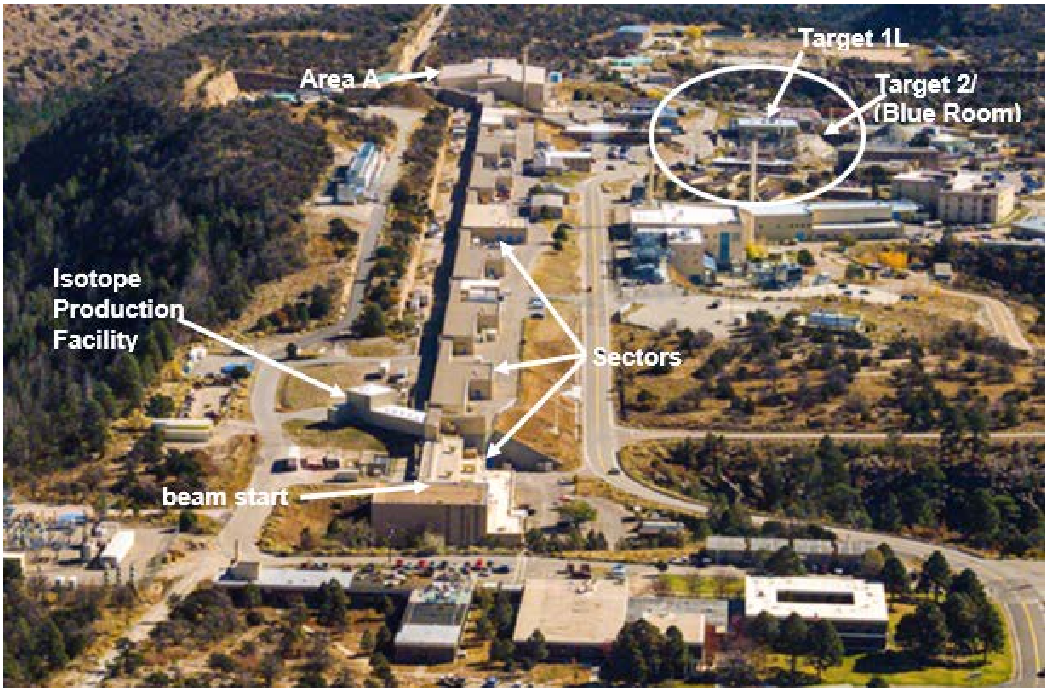

Figure A-1: Aerial view of TA-53 with LANSCE [O'Neill 2020]

Figure A-2 shows a diagram of hot cells located in the LANSCE Isotope Production Facility.

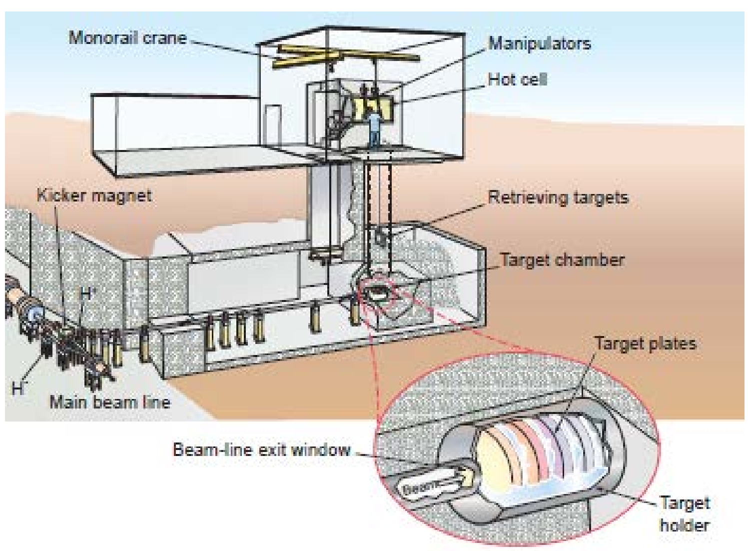

Figure A-2: Diagram of hot cells in the Isotope Production Facility [LANL 2010, PDF p. 9]