National Nuclear Security Administration

Federal Accident Investigation

Accident Investigation into Contamination at the Los Alamos Neutron Science Center on or about August 21, 2012

September 2012

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RELEASE AUTHORIZATION

On August 29, 2012, I appointed a Federal Accident Investigation Board (AIB) to investigate the accident which occurred at the Los Alamos Neutron Science Center (LANSCE), Los Alamos, New Mexico on or about August 21, 2012. The AIB's responsibilities have been completed with respect to this investigation. The analyses and the identification of the contributing causes, the root causes and the Judgments of Need resulting from this investigation were performed in accordance with DOE Order 225.1B, *Accident Investigations*.

I accept the report of the AIB and authorize the release of this report for general distribution.

Thomas P. D'Agostino
Administrator
National Nuclear Security Administration

Date

This report is an independent product of the Federal Accident Investigation Board (AIB) appointed by Thomas P. D'Agostino, Administrator, National Nuclear Security Administration (NNSA).

The AIB was appointed to perform a Federal Investigation of the accident and prepare an investigation report in accordance with DOE O 225.12B, *Accident Investigations.*

The discussion of the facts, as determined by the AIB, and the views expressed in this report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

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ACRONYMS

AIB	Federal Accident Investigation Board
ALARA	As Low As Reasonably Achievable
APIC	Alternate Person in Charge
CAS	Contractor Assurance System
CFR	Code of Federal Regulation
CoO	Conduct of Operations
COR	Contracting Officer Representative
DOE	Department of Energy
dpm	Disintegrations Per Minute
EE	Effectiveness Evaluation
ER-1 and ER-2	Experimental area rooms 1 and 2 in the Lujan Center
EM	Emergency Management
EOC	Emergency Operations Center
FAMs	Functional Area Managers
FOD	Facility Operations Director
FP-04	Flight Path 4
FP-04 S	FP-04 Scientist
FR	Facility Representative
FRPR	Facility Radiation Protection Requirements
HA	Hazard Analysis
HIPPO	High-Pressure Preferred Orientation Neutron Diffractometer
HPI	Human Performance Improvement
HQ	Headquarters
IN	Instrumentation Technician
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
IS(PIC)	The Instrument Scientist/Person-in-Charge,
IWD	Integrated Work Document
IWM	Integrated Work Management
IPF	Isotope Production Facility
JON	Judgments of Need
K	Kelvin
KeV	Kilo-electron volt
KOP	Knowledge of Process

LANL	Los Alamos National Laboratory
LANS	Los Alamos National Security LLC
LANSCE	Los Alamos Neutron Science Center
LASO	Los Alamos Site Office
MeV	Million-electron volt
M&O	Management and Operating
mCi	Millicurie
mg	Milligram
MOV	Management Observation Verification
MP	Management Procedure
NDA	No Detectable Activity
NNSA	National Nuclear Security Administration
OE	Operational Emergency
OP	Operating Procedure
PEG	Plutonium-239 Equivalent Grams
PEP	Project Execution Plan
PHS	Primary Hazard Screening
PI-1	Principal Investigator
PPE	Personal Protective Equipment
RAP	Radiological Assistance Program
RBO	Risk-Based Oversight
R&D	Research and Development
RCT	Radiological Control Technicians
RMI	Radiation Monitoring Instruction
RP	Radiation Protection
RP-1	Health Physics Operations Group
RPO	Radiation Protection Observation
RPP	Radiation Protection Program
RWP	Radiological Work Permits
SD	System Description
SAD	Safety Assessment Document
SME	Subject Matter Expert
SMP	Safety Management Program
TA	Technical Area
Tc-99	Technetium-99
UNLV	University of Nevada, Las Vegas

EXECUTIVE SUMMARY

On August 25, 2012, radioactive contamination was identified on Flight Path 04 of the Lujan Center, an experimental area that is part of the Los Alamos Neutron Science Center at the Los Alamos National Laboratory in New Mexico. Los Alamos National Laboratory is operated by Los Alamos National Security, LLC. The Operating Contractor quickly determined that the contamination had spread offsite, and response teams were immediately brought in. The Operating Contractor restricted access to the affected facilities, recalled personnel who may have been contaminated, and requested that they bring potentially affected clothing and vehicles so they could be surveyed. These responses, along with actions of the offsite response teams, stopped the spread of contamination offsite, retrieved contaminated items that could not be cleared for release, and decontaminated items where needed. The Operating Contractor preserved the onsite accident scene and initiated an internal investigation. The contamination found offsite was above DOE's release criteria in some instances, however it was at levels far below those expected to have a discernible health effect, and the safety of the workers, public, and the environment was not affected by the event.

Precise estimates of the extent of personnel contamination and maximum doses are outside the scope of this report. However, based on the amount of contamination, no dose is expected to exceed 1 millirem. Note that persons living in the United States typically receive between 300 and 600 millirem annually from routine, natural and manmade sources (such as cosmic radiation and medical procedures).

On August 29, 2012, the Administrator of the National Nuclear Security Administration appointed a Federal Accident Investigation Board (AIB) to determine how the accident occurred and prevent recurrence.

From September 4-18, 2012, the AIB interviewed witnesses and reviewed evidence. Because the area where the most significant events occurred was contaminated with radioactive material, the AIB relied heavily on the preliminary Contractor investigation (including voluminous photographic evidence), as well as information gathered in response to AIB requests. AIB members did not physically enter the rooms in the Lujan Center that were contaminated.

Accident Description, Analysis and Conclusions

The Lujan Center is a national facility for defense and civilian research in nuclear and condensed-matter sciences, hosting scientists from national laboratories, universities, industry, and international research facilities. One type of experiment conducted there is irradiation of sample materials in a neutron beam. Between 2010 and 2012, Lujan Center personnel worked with personnel from the University of Nevada, Las Vegas, to irradiate samples of powdered Praseodymium Technetate, Neodymium Technetate, and Lutetium Technetate. Each of the three samples contained Technetium-99 (Tc-99), an intrinsically radioactive isotope that emits low energy beta particles. The beta radiation from Tc-99 is of such a low energy that it will not penetrate the sample canister wall.

Thus, it is difficult to know that a sample canister contains Tc-99 if the canister is not clearly marked and/or labeled. The Lutetium Technetate sample was later determined to be the source of the contamination in the August 2012 event.

The samples were prepared at the university in 2010, put into empty sample canisters (provided by Lujan Center personnel), sealed, and shipped to the Lujan Center.

The shipping containers and packaging were clearly marked to indicate that they contained radioactive material. However, the canisters themselves were not marked to indicate they contained a hazardous or radioactive material, nor was there a process at the Lujan Center for doing so. They were only marked "Pr," "Nd," and "Lu," respectively. Element symbols from the Periodic Table, such as the letters Lu or Nd, were typically used to denote the chemical contents of a sample canister. However, most sample canisters observed by the AIB had more complete markings on them to indicate their contents than these three. Because it was only marked "Lu," someone looking at the third sample canister, separated from its paperwork, would probably have surmised that it contained Lutetium, which (if not activated) is a mostly nonradioactive element that may be harmful if inhaled but that otherwise has low toxicity. That person would have had no indication of the Technetate (i.e. radioactive) contents from the markings alone.

Lujan Center safety personnel assumed that the canisters would not be opened, but would be returned to the university. Beyond this assumption, no additional controls were established to ensure that the sample canisters were not opened. Each of the sample canisters had a cap with six screw holes that could be used to connect the cap to the canister. Screws were only threaded into three of the six available holes to secure the caps. No engineering analysis was performed to verify that the use of three screws provided an adequate seal for the expected environments that the canisters would experience.

Two of the samples were irradiated at the Lujan Center in late 2010 and returned to storage. The third, containing Lutetium Technetate, was irradiated in January 2012.

Following irradiation, positive control of the third sample was lost.

Internal management processes at the Lujan Center were not of sufficient rigor to ensure positive control and tracking of radiological or hazardous samples throughout their life cycle. Comprehensive chain of custody procedures had not been implemented, and the third canister cannot be accounted for between January and August 2012.

On August 20, 2012, an instrument operator in the Lujan Center put Tungsten powder into a sample canister and sealed it with a cap and three screws. The canister was to be used in a procedure to align an experimental apparatus.

It was later discovered that this sample canister was built using parts from the Lutetium Technetate sample canister. When retrieved during the investigation, the internal contents of the canister were found to be contaminated with Tc-99.

Based on the record of the spread of contamination, created later by the Operating Contractor, the spread of contamination began on the day of this alignment procedure, Monday, August 20, probably when the third sample canister was mistakenly opened for re-use.

Based on interviews, irradiated canisters containing powders that were thought to be non-hazardous were sometimes opened in the work area. Once opened, their contents were put into other containers, and the canisters were re-used to hold other samples. This was true even though multiple personnel agreed that this was contrary to the requirement to use a glove box (assisted by a radiological control technician) when opening a canister of irradiated powders. Management processes tolerated deviation from expectations by facility personnel, both in terms of work expectations and with respect to storage and control of materials and equipment.

Furthermore, it was not unusual for sample canisters to be separated from paperwork that would positively identify their contents. Canisters were not systematically and uniquely identified, and standard log keeping was not employed to enable positive correlations between canister markings and their precise contents.

Given these conditions (and similar conditions provided in more detail in this report), an accident of this type was inevitable and not attributable to the actions of any single individual.

Rather, the accident was the result of management conditions and routine practices – developed over years – that were incompatible with a non-routine hazard.

This accident also was (and its recurrence is) completely preventable.

Simple, common and effective management practices can ensure understanding and compliance with process and sample control requirements.

Clear, simple, and reliable engineered controls can ensure positive identification, awareness, and control of hazardous or intrinsically radioactive materials, and prevent uninformed opening of canisters that should not be opened.

Appropriate oversight focus can more systematically sample facility operations to provide a positive assurance that adequate management processes are being followed.

An aspect of the environment at the Lujan Center that deserves special focus is the high concentration of personnel from diverse and multi-cultural backgrounds. Cultural differences, including proficiency in the English language but also normative behavior when responding to authority, may have helped to create an error prone condition on Flight Path 04. Pro-active efforts are warranted to ensure that awareness of cultural differences (beyond language proficiency) are reflected in management and employee training, to ensure process development, training and implementation will be effective.

The AIB evaluated the role that Contractor and Federal oversight may have played in the accident. Federal oversight of the facility was comparable to that of facilities with similar hazards. Federal oversight of Los Alamos Neutron Science Center operations, particularly operations in the Lujan Center, has been essentially unchanged in recent years. Changes in Federal oversight practices were not a contributor to this event.

However, Federal oversight over a period of several years did not result in a familiarity with how the experimental area was being run, or the controls that were in place to preclude contamination events. Similarly, the Contractor oversight was implemented in a manner not likely to identify activity-specific shortcomings. The AIB concluded that both the Contractor and Federal oversight need to periodically sample work practices at the experimental and activity level to help ensure that appropriate and effective work practices are maintained.

1.0 BACKGROUND

The organizations related to this accident were the National Nuclear Security Administration (NNSA) Los Alamos Site Office (LASO), Los Alamos National Security, LLC (LANS), the Los Alamos Neutron Science Center (LANSCE) and the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center). LANS operates the Los Alamos National Laboratory (LANL) of which LANSCE is a part. The Lujan Center is part of LANSCE. A brief description of key organizations is provided in this section.

1.1 Los Alamos Site Office

LASO manages LANL resources for NNSA. LASO minimizes risks from LANL operations to the public, Federal, and Contractor employees; fosters quality and continuous improvement in the lab's operations; and is located in Los Alamos, New Mexico.

1.2 Los Alamos Neutron Science Center

LANSCE is a national user facility for defense and civilian research in nuclear science, condensed-matter science, and radiography, hosting scientists from universities, industry, national laboratories, and international research facilities. Operated by LANS on behalf of NNSA and the U.S. Department of Energy (DOE), the mission of LANSCE is to:

- Support the NNSA Stockpile Stewardship Program and the DOE Office of Science through leading edge research and experimentation, expertise, and modern facilities;
- Operate a national user program for neutron scattering and for basic and applied nuclear science;
- Operate an Isotope Production Facility to provide medical radioisotopes; and,
- Develop defense and civilian applications using the facility’s core competency in accelerator technology.

1.3 Manuel Lujan Jr. Neutron Scattering Center

The Lujan Center at LANSCE is a national facility for defense and civilian research in nuclear and condensed-matter sciences, hosting scientists from national laboratories, universities, industry, and international research facilities. The Lujan Center uses neutron scattering to probe the microscopic structure and dynamics of condensed matter. The mission of the Lujan Center is to support research and experimentation in materials science, engineering, condensed matter physics, chemistry, biology, and geology. Key functions of the Lujan Center are to:

- Support the NNSA Stockpile Stewardship Program and the DOE Office of Science;
- Conduct leading edge research and experimentation, supported by expertise and modern facilities;

- Operate a national user program for neutron scattering and for basic and applied nuclear science; and,
- Develop defense and civilian applications using the facility's core competencies in neutron physics and neutron scattering technology.

The Lujan Center is an integral part of LANSCE. LANSCE supplies the Lujan Center with pulses of 800 million electron volt (MeV) protons from its Proton Storage Ring. The Lujan Center generates high energy neutrons through collisions of these protons with Tungsten (W) targets, a process known as spallation. The neutrons are then reduced to lower energies by chilled water and liquid hydrogen moderators, providing a pulsed supply of neutrons to flight paths equipped with time-of-flight spectrometers for neutron scattering studies of condensed-matter. The Lujan Center is operated as a user facility offering a wide variety of neutron based research capabilities.

Flight Path 4 (FP-04) of the Lujan Center houses an instrument called the High-Pressure Preferred Orientation Neutron Diffractometer (HIPPO). This flight path and instrument are where the loss of control and confinement of radioactive material most likely occurred in this accident.

1.4 Scope and Methodology

The Accident Investigation Board (AIB) was appointed on August 29, 2012, (see Appendix A) and arrived at LASO on Tuesday, September 4, 2012, to begin the investigation. The scope of the AIB investigation was to identify all relevant facts; analyze the facts to determine the direct, contributing, and root causes of the accident; develop conclusions; and determine Judgments of Need (JONs). Appendix D provides an explanation of accident investigation terminology. The investigation was performed in accordance with DOE Order 225.1B, *Accident Investigation*, using the following methodology.

- Prior to the arrival of the AIB, LANS inspected the accident scene, conducted radiological surveys, collected physical evidence and took photographs of the scene.
- For the duration of the accident investigation, the scene was contaminated; information on the accident was provided to the AIB through interviews, reviews of documentation and photographic evidence.
- The facts were analyzed to identify the causal factors using barrier analysis, change analysis, event and causal factors analysis and root cause analysis.
- Conclusions and JONs were developed to guide the development of corrective actions that, if implemented, should prevent recurrence of similar accidents.

2.0 ACCIDENT DESCRIPTION AND ANALYSIS OF EVENTS

2.1 Accident Narrative

The accident investigated in this report is the loss of control of an intrinsically radioactive sample in LANSCE, resulting in the spread of contamination. The term 'intrinsically radioactive' is used to denote a sample that was radioactive upon arrival at LANSCE, as opposed to a material made radioactive by irradiation at LANSCE. Contamination began in the Lujan Center (an experimental facility that is a part of LANSCE) and was spread offsite. This investigation evaluated the events leading up to the spread of the contamination offsite to support corrective actions to preclude recurrence. The accident may be described as having two components: 1) the loss of control (leading to the loss of containment), and 2) the loss of containment (leading to the spread of contamination).

2.1.1 Loss of Control

In 2010, the FP-04 Instrument Scientist/Person-in-charge (referred to as IS(PIC)) made arrangements with personnel at the University of Nevada, Las Vegas (UNLV), to prepare and ship three samples for irradiation in the HIPPO: Neodymium Technetate ($Nd_2Tc_2O_7$), Praseodymium Technetate ($Pr_2Tc_2O_7$), and Lutetium Technetate ($Lu_2Tc_2O_7$). Each sample contained Technetium 99 (Tc-99), an intrinsically radioactive isotope of Technetium that emits low-energy beta radiation.

The amount of radioactive material in each sample was well below levels that had to be tracked to ensure compliance with contractual facility safety requirements, and well below levels expected to result in health hazards if released. However, the total activity in each sample – about 2 millicuries (mCi) or 4 billion disintegrations per minute (dpm) – was high enough that it would have had to be handled in an area established to control radioactive contamination if it was not in a container that could be relied upon to prevent its release.

Lujan Center personnel shipped three, empty sample canisters to UNLV, where university personnel put the samples into the canisters and attached the caps. Each canister consisted of a Vanadium tube, threaded into an Aluminum collar. An Aluminum cap was affixed using screws that pass through the cap and thread into the collar. Between the cap and collar was an Indium seal to ensure confinement. Figure 2.1.1 shows a photograph of a typical but larger canister alongside photographs of the Neodymium Technetate and Praseodymium Technetate canisters, taken after the contamination event.

The UNLV sample canisters were marked with two letter designators on the aluminum collars, using an indelible felt tip marker, indicating the distinguishing element in each sample, and were sealed with only three (of six possible) screws.

AIB Conclusion: No markings on sample canisters clearly indicate that contents are intrinsically radioactive, toxic, internally contaminated, or should be controlled for contamination. (JON 2)

Figure 2.1.2 shows a photograph of the top of the Neodymium Technetate cap showing the three screw heads used to secure the cap, and the three unused screw holes.

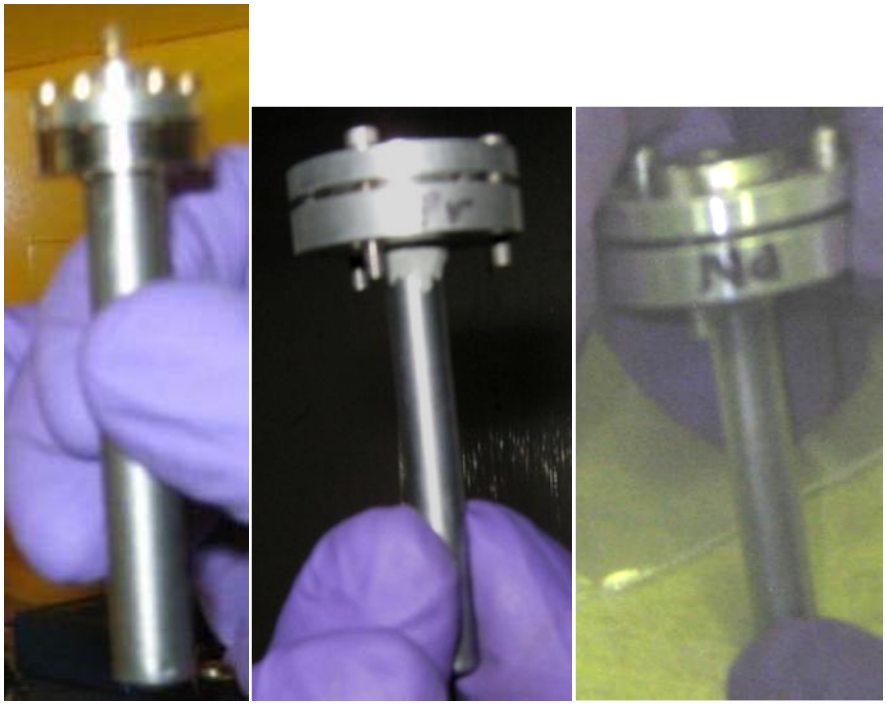

Figure 2.1.1. Typical Assembled Vanadium Sample Canister shown with Praseodymium and Neodymium Technetate Sample Canisters

Figure 2.1.2. Top of Neodymium Technetate Sample Canister

Although there was electronic mail (e-mail) traffic that discussed whether the sample collars should have epoxy applied, and that discussed the nature of the epoxy and seal material, no formal engineering specifications were provided to UNLV on how the sample canister must be assembled and sealed, such as

torque specifications for the screws, or how many screws had to be used. An engineering analysis was not performed to establish such specifications, or to ensure that the canisters, assembled per specifications, would provide confinement in the expected sample environments. No documentation was asked for by Lujan Center personnel, or provided by UNLV, on how the sample canisters were assembled and sealed.

The safety review of the proposed experiments implicitly assumed that robust seals on the canisters would provide containment while at the Lujan Center. The review explicitly assumed that the canisters would not be opened in the facility. Consequently, the hazard level was categorized as Medium. A statement that the canisters would not be opened was written into the *Comments* section of the safety review paperwork. Beyond the previously existing work controls and the statement of this assumption, no additional controls were established or required to ensure the continued validity of these assumptions. At least some of the samples were irradiated in environments that included extreme cold.

The use of only three screws, rather than six, to seal these canisters was inconsistent with the safety review assumption that the canisters were robustly sealed. Simple engineered methods, such as using all six screws and using safety wire to secure the screws in their tightened condition, were not implemented. Such methods could have both increased the confidence that the sample would remain secure while providing a visual indication that the contents were not to be disturbed unintentionally.

AIB Conclusion: Existing practices relied upon administrative controls when simple engineered measures could have protected safety review assumptions for the Technetate samples. (JON 3)

UNLV shipped the three sample canisters to the Lujan Center, where they were surveyed for removable contamination by Radiation Control Technicians (RCTs), finding no detectable activity. IS(PIC) had the cardboard box and packaging containing the three canisters stored in his locked radiological materials cabinet.

There is no indication that the RCTs, IS(PIC) or the Principal Investigator (PI-1) questioned the use of only three screws to seal these containers, which contained highly dispersible, intrinsically radioactive powders. The use of three screws provided reduced defense in depth against a contamination event.

Photographs of the radiological materials cabinet and its contents after operations were suspended at the end of August 2012 are provided in Figures 2.1.3 and 2.1.4. In Figure 2.1.3, the lock on the cabinet is shown unlocked and hanging from the hasp; however, it was unlocked after the accident to allow inspection and radiological survey. Photographs taken during the first re-entry clearly show that the cabinet was found locked. The owner name has been obscured for this report.

Figure 2.1.3. FP-04 Radioactive Material Storage Cabinet

A radioactive material posting is on the outside of the right cabinet door. The Technetate sample canisters were stored in the cardboard box that is visible in Figure 2.1.4 on the left hand side of the cabinet. A radioactive material placard is on the side of the box, facing to the right.

Figure 2.1.4. Inside of FP-04 Radioactive Materials Cabinet

The Principal Investigator (PI-1), and IS(PIC) irradiated two of the samples in FP-04 in late 2010, and returned them to the FP-04 radioactive materials cabinet. According to testimony, IS(PIC) went over the safety appraisal and discussed hazards with PI-1 prior to the experiment.

Because these samples were not being released, they were not sent to the Radiological Control Technician (RCT) station for surveying. According to testimony, survey by RCT following removal from the beam is not required by Lujan procedures, unless explicitly required by safety documentation, and items may be handled directly after removal. Historically, activity levels of irradiated sample canisters have not been sufficient to require a decay period before handling. As defense-in-depth, a few, although not all, instrument operators have been trained and equipped to use portable radiation detectors to confirm that radiation levels are low enough to permit manual handling.

Photographs of these two sample canisters in their packaging, as they appeared upon retrieval following the suspension of work in the Lujan Center, are provided in Figure 2.1.5 and 2.1.6.

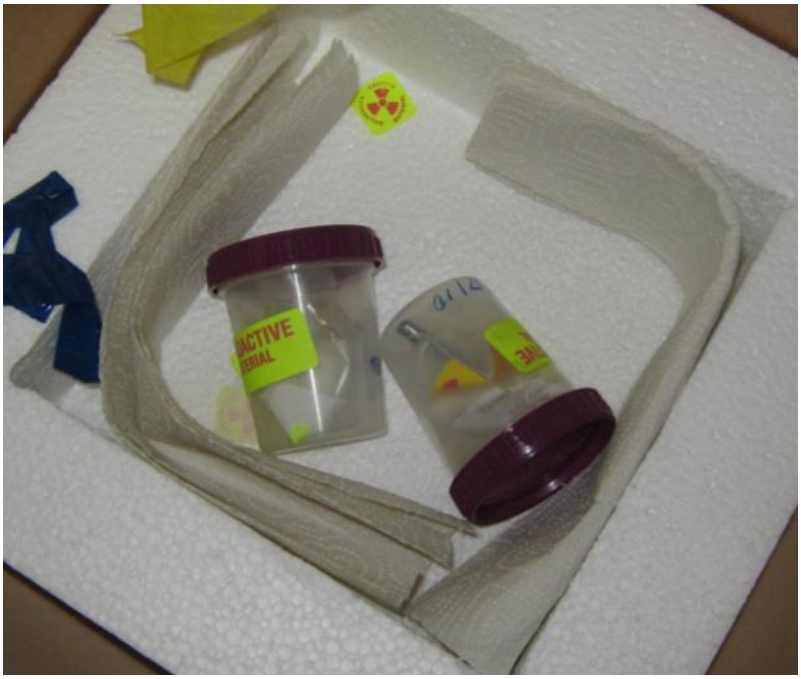

Figure 2.1.5. Pr and Nd Technetate Sample Canisters

Following the accident, the containers shown in Figure 2.1.5 were opened and the sample canisters and packaging surveyed. The sample canisters were found sealed (using three of six possible screws), and there was no detectable contamination. Figure 2.1.6 provides a photograph showing the open containers and the zip-lock plastic bags holding the sample canisters. The plastic bags are each tagged with a radioactive material label.

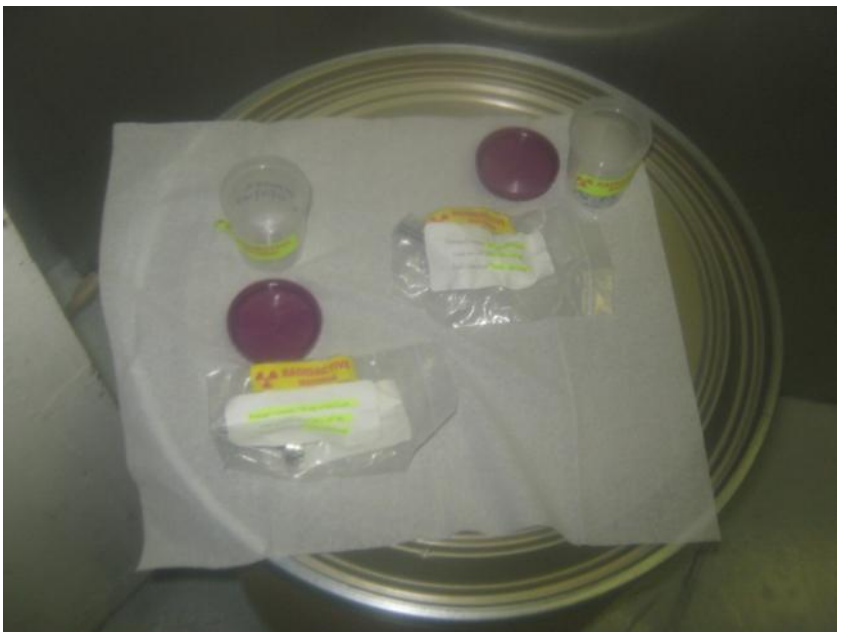

Figure 2.1.6. Contents of the Pr and Nd Technetate Containers

Because sufficient beam time was not available to run the third sample (Lutetium Technetate), it was also returned to the locked storage cabinet at the completion of irradiation of the other two samples in 2010.

In June 2011, PI-1 re-submitted the experiment proposal so that the third sample (Lutetium Technetate) could be run. The proposal was reviewed and approved; no additional controls were established, although comments about the material and the assumption that the canister would not be opened were provided.

In January 2012, FP-04 scientists, FP-04 S1 and FP-04 S2, met with PI-1 to set up the experiment. According to interviews, PI-1 directly mounted the sample canister onto the experimental apparatus – a device called a "displex" – but did not remain for the experiment to be conducted. IS(PIC) was not in the facility. The Alternate Person in Charge (APIC) was not present in the facility. The Co-Instrument Scientist was not present. There is no documentation or interview results that indicate that hazards associated with Technetium or Lutetium were discussed, or that a pre-job briefing was held. Interviews indicate that there was some confusion amongst those present as to who was responsible for ensuring that all the personnel present understood the hazards of the experiment.

FP-04 S1 and FP-04 S2 conducted the experiment on January 9-10, 2012.

At an undetermined time following the experiment, the Lutetium Technetate sample canister was removed from the displex. Interviews did not establish who removed the sample canister, when it was removed, or where it was subsequently stored.

AIB Conclusion: Control of the radioactive material was lost when the Lutetium Technetate sample canister was removed from the displex. (JON 5)

A number of conditions existed in the facility that may be related to the loss of control. These conditions and related information include:

- There were no clear roles and responsibilities established to ensure consistent handling of samples and sample canisters.
- There was no record maintained at FP-04 regarding the disposition of canisters removed from the displex.
- When a sample canister was to be sent to the RCT station, the practice was to put it into a plastic bag; a label was prepared and put in or on the bag. However, a copy of the label was not retained at the Flight Path to indicate when or if the sample went to the RCT station.
- If created, the label may have identified the originating Flight Path, user, and sample description, but in practice (according to both interviews and photographic evidence) the information was sometimes incomplete, difficult to decipher, inconsistent, or illegible.
- Sample canisters were not always sent to the RCT station following irradiation. If sent, they were placed into a common in-box. RCT hours are limited, and an RCT may not have been present to check to ensure that paperwork was properly filled out when samples were dropped off.
- Interviews and RCT logs did not show conclusively that the canister containing Lutetium Technetate was sent to the RCT station or surveyed. No such sample was recorded in the RCT logs; however, the RCT logs contain transcription mistakes regarding the contents and source of samples that were surveyed. Comparison of the RCT logs to the run logs showed inconsistencies, so it was impossible to be certain whether the sample was provided to the RCT station. The closest entry in the RCT log was a sample for a different flight path (FP-03) labeled LiTaO3. A search of all FP logs for the previous ten days did not identify a LiTaO3 sample that was exposed to the beam in that period. However, sample canisters were sometimes sent to the RCT well after irradiation; the LiTaO3 log entry could have referred to a sample irradiated earlier, or it could have been mislabeled.
- There was no log entry when samples were picked up from the RCT station, so that there was no positive exchange of responsibility for a sample canister.
- E-mail traffic documented confusion between the instrument operators and the Alternate FP-04 “Person-In-Charge,” APIC, as to whether the sample was sent to the RCT station, and if it was, by whom.
- There was no systematic naming protocol to ensure a correlation between the FP run logs and the RCT logs. In an e-mail dated October 27, 2011, IS(PIC) provided labeling and bagging guidance to preclude “irreversible loss for future processing” of samples that were similar to one another. Per the e-mail, run log titles were to include the principal investigator’s name, “otherwise we have no chance of finding a user’s runs in the run log!” FP-04 run logs from January 2012 showed that inclusion of the investigator’s name was not consistently part of the run titles.

- There was no formal tracking or logbook kept to track samples from the time they were placed into canisters until the time they were disposed of or returned to the user, to enable positive tracking.
- Inventories or sign-in/sign-out logs were not maintained for hazardous or intrinsically radioactive materials stored in radioactive material storage cabinets.
- Sample canisters did not have unambiguous features, such as serial numbers stamped into collars or caps, to enable consistent tracking. Instead, information was written on the canister tubes and/or on the cap using indelible markers. Legibility of these labels sometimes made positive identification difficult.
- Neither the UNLV nor PI-1 expressed active interest in getting the Lutetium Technetate sample returned. Consequently, there was no need to look for the sample.
- Confusion over roles and responsibilities was not limited to the Lutetium Technetate sample canister. In April 2012, PI-1 expressed a desire to recover other samples for shipment to France. His request resulted in an exchange of e-mails trying to locate the samples. According to the e-mail exchanges, the samples PI-1 was looking were found, surveyed, and declared free to release. PI-1 agreed to pick them up upon his return from a business trip. However, according to his interview, he did not do so. When this report was written, photographs of the free release box for FP-04 at the RCT Station indicated that these samples were no longer in the free release box.

AIB Conclusion: There is no systematic sample management process that positively tracks samples and sample canisters throughout their life cycle within the Lujan Center. Sample canisters do not have unambiguous features, such as serial numbers stamped into collars or caps, to enable consistent tracking. Instead, information is written on the canister tubes and/or on the cap using indelible markers. Legibility of these labels sometimes makes positive identification difficult. Existing record keeping for control of samples and canisters does not enable accountability. (JON 5)

AIB Conclusion: There are no clear roles and responsibilities established to ensure safe and positive control of samples. (JON 6)

AIB Conclusion: Inventories or sign-in/sign-out logs are not maintained for radioactive material storage cabinets. (JON 7)

AIB Conclusion: Lujan Center management did not make it clear who was the person-in-charge of conducting the experiment on the Lutetium Technetate sample in January 2012, or that the person-in-charge had competence commensurate with responsibility for performing the assigned task, or that person-in-charge responsibilities were effectively performed. A turnover of responsibility did not include a briefing or review of the Research Proposal and associated Safety Review Committee Appraisal that contained technical information regarding the radioactive and chemical characteristics of Lutetium Technetate. (JON 6)

AIB Conclusion: Written procedures did not require qualified canisters; unambiguous and documented chain of custody record; positive identification of canisters; or, protection of assumptions in the safety review for the Technetate samples. (JON 10)

2.1.2 Loss of Containment

On August 20, 2012, an FP-04 scientist, FP-04 S1, initiated work to align the FP-04 displex. The alignment process uses FP-04 while the neutron beam is off. A sample canister containing radiographically opaque material is mounted on the displex, and the assembly is inserted into the beam cavity. The beam shutter is opened and residual electromagnetic radiation from the beam cavity is used to make a radiographic image of the sample canister. For this procedure, FP-04 S1 chose to use Tungsten as the opaque material.

A photograph of the displex in its rigging fixture, with the Tungsten sample canister mounted, is shown in Figure 2.1.7, along with a close up of the sample canister. The letters 'Lu' can be seen on the collar and the letter 'W' is visible on the Vanadium tube. Lu is the chemical symbol for Lutetium, and W is the chemical symbol for Tungsten.

Subsequent analysis showed that this canister was contaminated with Lutetium Technetate, and the collar and perhaps other parts were the same used in January 2012 on the sample canister for PI-1's Lutetium Technetate sample from UNLV.

Analysis of the contamination found onsite and offsite conclusively showed that it included activated Lutetium and the intrinsically radioactive Technetium 99, consistent with a Lutetium Technetate sample that had been irradiated in a neutron beam.

Figure 2.1.7. Displex Cold Finger and Close Up of Tungsten Sample

Element symbols from the Periodic Table were usually used to denote the chemical contents of a sample canister. However, because the Lutetium Technetate sample canister was only marked with the letters 'Lu,' someone looking at the sample canister, separated from its paperwork, may have only surmised that it contained Lutetium, which (if not activated) is a mostly nonradioactive element that may be harmful if inhaled but that otherwise has low toxicity. That person would have had no indication of the Technetate contents from the markings alone.

Per an interview with FP-04 S1, he built this sample canister from parts he took from drawers in the cabinet on the sample desk in FP-04. A photograph of this cabinet is provided in Figure 2.1.8. In the photograph, note that drawers 52-54 are labeled "V Can." Per the testimony of the APIC, new canisters, caps and screws were also available from the APIC, who kept them in a box that he had recently moved to the Lujan Center, Experimental Room-2 (ER-2).

Figure 2.1.8. Supply Cabinet on FP-04 Sample Desk

FP-04 S1 said he did not open a used canister for re-use and empty the contents, or ask for a new one from the APIC. He said he probably got the parts from drawers in a supply cabinet on the sample desk. Figures 2.1.9 provides photographs of some of the drawers, removed from the supply cabinet.

Figure 2.1.9. Drawers from Sample Desk Supply Cabinet

The contents of these drawers (and others, not shown) include various components of sample canisters in various stages of assembly, consistent with testimony provided to the AIB. According to multiple interviews, the caps, collars, screws and Vanadium tubes for assembling a canister often were found in multiple drawers.

According to testimony, empty canisters staged for re-use were not usually stored assembled, with cap and collar screwed onto the Vanadium tube. However, at least one drawer, drawer 60, contains what appears to be an assembled sample canister. Figure 2.1.10 provides an enlarged image of the canister in the upper left of drawer 60. As can be seen, the cap is clearly attached; at least one screw is clearly threaded through the cap and collar, with the screw on either side not present.

Figure 2.1.10. Blow up of Drawer 60

Had the Lutetium Technetate sample canister been accidentally stored in one of these drawers, someone could have mistaken it for an empty canister, stored with its cap in place for convenience. The use of only a few screws to hold on the cap could have contributed to this impression.

According to multiple interviews, the sample canisters for each experimental device differ from one another, but adapters permit canisters assembled for one device to be connected to another. Further, the threading on the top of the Vanadium tubes allow them to be threaded into collars and caps designed for multiple devices. Thus, a sample canister used on one machine could be disassembled and its parts used to build a sample canister for a different machine.

Based on interviews with other FP-04 personnel, multiple personnel were preparing samples for other experiments and procedures at about that same time as FP-04 S1 was preparing the Tungsten sample. It was a busy time, as the flight path was being set up for an upcoming series of user experiments.

Given other workloads, the process of preparing a sample canister, putting a sample into it, and sealing it, may not all occur on a single day. For example, Figure 2.1.11 provides a photograph of a Vanadium tube mounted into a collar (but without the cap and screws), apparently empty, that was found in the FP-04 area during a re-entry following work suspension. The figure also includes a photograph of a sample vial that was found on the sample desk, apparently in the process of being prepared for an experiment. It was found in a zip-lock bag that was labeled with a chemical formula similar to that written on the side of the

Vanadium canister: $Bi_2Nd_2Ti_{x.x}Mn_{x.x}O_{12}$ (where 'x' denotes a number on the zip-lock bag that is illegible in the photograph).

Figure 2.1.11. Empty Vanadium Tube and Collar from Sample Desk with Zip-lock Bag and User Sample Staged for Processing

In his testimony, FP-04 S1 said that he could not remember for certain, but thought that the parts he used came from more than one drawer. He said that he marked on the outside of the sample canister with an indelible marker to indicate its contents. He checked to be sure there was nothing inside of the canister using a cotton swab or small screwdriver (he was unsure of which).

Because he didn't need the sample to be tightly sealed, and it was being exposed to a relatively benign environment, FP-04 S1 said he only used three screws to hold the cap to the collar.

Following the assembly of the sample holder, the Tungsten sample was mounted on the displex, placed into the beam cavity, and irradiated on Monday, August 20, and again the following morning, August 21, 2012. The canister was left on the displex, where it was found after the contamination was discovered.

When this report was written, it was not positively known how, when, where, or by whom the sample canister that contained Lutetium Technetate was opened and emptied, or whether it was opened specifically so that its parts could be used for the displex alignment procedure. In the FP-04 area is a large red tool box, which sits atop the HIPPO door (see Figure 2.1.12). Its top drawer has very few tools in it, and is at a convenient height to be used as an ad-hoc work surface. The highest contamination levels associated with the accident were found on and about this toolbox. The contractor estimated that contamination corresponding to about 0.4 billion dpm (roughly a tenth of the original Lutetium Technetate sample) was removed from the toolbox during recovery. Loss of containment probably occurred when the Lu sample canister was opened at or around the toolbox on top of the FP-04 HIPPO door.

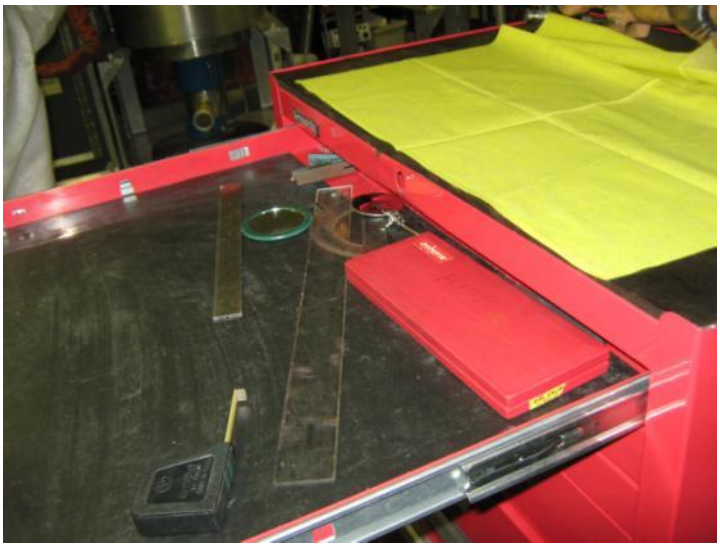

Figure 2.1.12. Top Drawer of FP-04 Tool Box

Interviews with each member of the FP-04 team indicate that none of them recall opening a sample canister in the weeks leading up to the contamination, much less putting the canister into a drawer of the cabinet on the sample desk for re-

use. More than one team member indicated that they had re-used sample canisters before, and may have opened used sample canisters for re-use during clean-ups between January and August 2012.

The use of only three screws to secure the cap to the Lutetium Technetate sample canister, combined with the absence of markings indicating the presence of Technetium, powder, or other hazardous contents, may have contributed to the accident. The un-used screw holes could have provided additional defense in depth; the fact that they were not used could have reinforced the impression that the sample canister did not present a risk if opened.

A photographic comparison of the sample canister used for the Tungsten alignment process to the Praseodymium and Neodymium Technetate sample canisters is provided in Figure 2.1.13.

Figure 2.1.13. Comparison of Pr, Nd, and Lu/W Sample Canisters

Close up photographs of the Tungsten sample canister, taken after it was removed following the suspension of operations, are presented in Figure 2.1.14. In this photograph, the screws had been loosened to permit radiation surveys of the canister contents, then the cap and screws were removed to permit further evaluation. Markings indicating Tungsten (W) powder are visible on the collar and a marking for Tungsten (W) is visible on the Vanadium tube.

Figure 2.1.14. Lutetium Technetate Canister Re-used for W (Tungsten)

Based on available evidence, no one who was in the facility before, but not after, August 20, 2012, appears to have been contaminated (except for individuals who subsequently contacted other contaminated persons). Numerous persons who were in the facility on or after August 21, 2012, were found to be contaminated. Available evidence indicates that contamination spread extremely quickly and with minimal contact. At least one contaminated item was found that had to have been contaminated no later than Tuesday, August 21, 2012. Given the speed at which the contamination spread, it is implausible that the seminal contamination event occurred any earlier than August 20, 2012.

AIB Conclusion: The loss of containment leading to widespread contamination occurred when the Lutetium Technetate sample canister was opened. Contamination evidence, the highly communicable nature of the contamination, and its rapid migration make it implausible that the Lutetium Technetate sample canister was opened earlier than August 20, 2012. (JON 3)

Conditions that existed in the facility which may have contributed to the loss of containment following loss of control of the Lutetium Technetate sample, and relevant information obtained during subsequent investigations, include the following.

- The “Lu” markings on the canister that was re-used for FP-04 S1’s Tungsten sample were consistent with the markings on the original Lutetium Technetate sample canister, which PI-1 applied. However, the Tc-99 contents were not indicated in the markings, and markings were less descriptive than those typically applied by instrument operators (i.e. the “Lu” marking only referred to a single element in the sample rather than a more complete chemical formula such as “Lu2Tc2O7”).
- No markings on the canister (prior to its use for Tungsten) clearly indicated that the contents were intrinsically radioactive or hazardous, that the canister was internally contaminated, or that it should be controlled for contamination.
- Per discussions with multiple personnel, sample canisters containing irradiated powders could only be opened for re-use in a glove-box with RCT support, and must be surveyed by an RCT before removal from the glove-box.
- The glove-box used for radiological work is also used for work with nanoparticles, and has an extensive Integrated Work Document (IWD) and set of controls. Some individuals reportedly found the controls associated with the glovebox to be overly burdensome, few were qualified to use it, and, the rules for use of the glove box were not uniformly enforced.
- Multiple persons indicated that personnel had opened sample canisters for re-use at the sample desk or elsewhere (not in the glove box) when they had no concerns regarding toxicity or intrinsic radioactivity, without RCT support. This was in spite of the fact that opening canisters containing irradiated powders required use of glove boxes and RCT support.
- There were numerous closed, used, sample canisters found on the sample desk, inside the sample desk, and in offices, with vague and often illegible markings on them to indicate their contents. There was no log or inventory control for these samples.
- There were numerous small bottles (made of glass and plastic) that contained sample material, some labeled, some not, in offices and other locations in the facility.
- If a sample had been sent to the RCT station for survey, and had intrinsically radioactive material inside of it, with low energy radiation that

would not penetrate the Vanadium can, no positive and systematic means was established to ensure the RCT or others would know that the contents were radioactive. Thus, once activation products decayed, a sample canister containing an intrinsically radioactive sample (such as Lutetium Technetate) might be mistakenly cleared for free release. Sample canisters cleared for release were not opened to ensure that their contents were not radioactive.

- There was no log kept of unique sample identifiers that would enable an individual to positively determine the contents of a sample canister if it became separated from its paperwork.
- Housekeeping, sample control, and material control procedures were informal, and deviations from expected procedures were common place, known and tolerated.
- The personnel assigned to FP-04 are multi-cultural, with diverse backgrounds, expectations, and socio-economical approaches to authority. These differences have not been systematically explored and addressed to ensure effective workplace management.
- Analysis of the contents of the Tungsten sample canister indicated that, although Tc-99 and Lu were present, they were in quantities that indicate contamination, but did not constitute a significant portion of the original sample.
- According to multiple sources, when a sample canister containing powder is opened for re-use, the contents are poured into a glass bottle, which is sealed with a screw-on cap and stored in the user's box on the sample desk. When the bottles accumulate, samples that users have not asked be returned are sent to the Chemistry Lab for characterization and disposal in an appropriate waste stream.
- When this report was written, a bottle containing Lutetium Technetate had not been found; contents of trash cans from the facility had not yielded sufficient contamination that, together with other known contamination, would account for the full Lutetium Technetate sample.

AIB Conclusion: The personnel assigned to FP-04 are multi-cultural, with diverse backgrounds, expectations, and socio-economical approaches to authority. These differences have not been systematically explored and addressed to ensure effective workplace management.

AIB Conclusion: A systematic process is not employed to ensure RCTs are aware of internal hazards that may not be externally obvious, prior to surveying sample canisters for free release. (JON 2)

AIB Conclusion: Existing processes for sample and sample canister management were not consistently enforced or followed. Known deviations were normalized. (JON 8)

AIB Conclusion: Contamination and contents of trash cans have not yielded sufficient activity to account for the full Lutetium Technetate sample; glass bottles are used to hold samples emptied from sample canisters. A glass bottle containing Lutetium Technetate has not been located. (JON 13)

AIB Conclusion: Housekeeping and material control procedures were informal. Known deviations were normalized. (JON 8)

Table 2-1. Event Chronology

Date Time	Event	Condition
03/26/2010	Research Proposal 20101117 submitted by PI-1 for conducting neutron diffraction experiments on three $Ln_2Tc_2O_7$ (Ln=Lu, Nd, Pr) samples	• Experiments to be conducted at ambient pressure and temperature. • Samples will contain about 100-200 milligram (mg) Tc-99 total. • Tc-99 is a pure beta-emitter with a maximum energy of 294 thousand electron volts (keV).
05/26/2010	LANL Safety Review Committee Appraisal approved	• Screened as a low hazard activity. • Samples to be loaded in sample canisters at UNLV. • Samples to be returned unopened to UNLV.
09/21/2010	UNLV requested information regarding sample canister configuration	• UNLV noted the seals between the Vanadium cans and aluminum collars were cracked, and requested guidance for sealing Vanadium tube to aluminum collar and for sealing the closure cap to the collar. • IS(PIC) responded that at ambient conditions epoxy is good for sealing the Vanadium tube to the aluminum collar. Something that is not brittle would be required for low temperatures. • IS(PIC) responded that UNLV could seal the closure with whatever they felt was suitable. Indium wire would be used for low temperatures. • UNLV responded that epoxy would be used for the Vanadium – aluminum joint, and Indium wire to seal the lid.
10/06/2010	Three Tc-99 samples (loaded at UNLV in LANL provided sample canisters) were received at LANSCE	• Received at LANSCE as radioactive shipment. • Receipt radiological survey conducted by a RCT. • PI-1 marked Vanadium cans with a felt tipped pen. The Lutetium Technetate sample was marked “Lu” on the aluminum collar.
10/18/2010 1302	A safety official posed questions and requested additional review	• Noted no mention of Tc-99 or how to handle samples at LANSCE.
11/16/2010 to 11/18/2010 1830 - 0900	$Pr_2Tc_2O_7$ and $Nd_2Tc_2O_7$ samples exposed in LANSCE	• Experiments were conducted at 60K and 250K rather than ambient temperature. • IS(PIC) removed samples from the displex. • PI-1 placed samples in original packaging and returned the samples to the cabinet.

Date Time	Event	Condition
02/15/2011 0623	Documented that neutron diffraction experiment of Lutetium Technetate sample was not performed in November 2010	• Not performed because of mis-understanding between PI-1 and IS(PIC).
03/05/2011	Research Proposal 20111048 submitted by PI-1 for exposure of Lutetium Technetate sample	• Continuation of Research Proposal 20101117. • Experiment to be conducted at ambient pressure and temperature.
06/06/2011	LANL Safety Review Committee Appraisal approved	• Screened as a medium hazard activity. • Noted the sample contained between 1 and 3 mCi of Tc-99. • Noted beta radiation will not penetrate Vanadium can. • Noted the sample was contained in a sample canister and the canister would not be opened. • Required the use of IWD LUJAN-FP-04-006 *General Neutron Scattering Experiments on HIPPO (FP-04).* • IWD LUJAN-FP-04-006 specified that radioactive materials require additional work controls, but no additional controls were identified. • LANSCE Run Cycle Readiness Review conducted 05/05/2011 to 06/09/2011 concluded radiation sample safety at all flight paths and experimental areas was well addressed
10/27/2011 1940	IS(PIC) directed only one sample per bag with exact description on the bag	• Noted that many samples look alike and once mixed, they are irreversibly lost.
01/09/2012 to 01/10/2012 ~1500-~1000	Lutetium Technetate sample exposed in LANSCE HIPPO displex	• PI-1 attached Lutetium Technetate sample to displex, but was not present during experiment • IS(PIC) was not present during experiment. • APIC was not present during experiment. • FP-04 S1 was placed in charge of experiment by email. • Turnover between PI-1 and FP-04 S1 did not include hazards and other information contained in the Research Proposal and associated Safety Review Committee Appraisal. • FP-04 S1 did not know the radiological hazards associated with Tc-99. • FP-04 S1 had not signed the current pre-job briefing for IWD LUJAN-FP-04-006. • The experiment was conducted at 20K

Date Time	Event	Condition
		rather than ambient temperature. • RCT coverage was not required or provided during removal of the sample from the displex. • No standardized, unambiguous sample descriptions in run logs for hazardous or intrinsically radioactive samples.
01/2012 to 08/2012	Location of sample canister with Lutetium Technetate sample was not known	• No standardized, unambiguous and durable method for distinguishing samples that contain hazardous (toxic or radiological) material from those that do not.
05/15/2012	Quarterly smear survey conducted in LANSCE Experimental area 1 at a total of 75 locations, eight of which were on FP-04.	• All smears indicated contamination was below established limits.
07/17/2012 to 08/20/2012	LANSCE Run Cycle Readiness Review conducted	• Concluded that radiation sample safety at all FPs and experimental areas was well addressed. Focused on radiation hazards of experimental sample following beam exposure; IWDs for training/authorization of flight path personnel, and flow down of controls/conditions specified in experimental safety reviews for samples to IWDs. • A prestart finding and concern was issued related to poor housekeeping, particularly for the small areas associated with flight paths. • An uncategorized comment related to HIPPO stated' "If radioactive samples are used in the experiments, Health Physics Operations Group (RP-1) is aware of this and monitors these samples", but the basis for the statement was not provided.
08/09/2012	Cleanup performed on FP-04 as directed by IS(PIC)	• Cleanup was conducted and a toolbox added. • FP-04 S1 believed that some sample containers may have been broken during the cleanup.
Unknown	Sample canister containing the Lutetium Technetate material was opened	• Highly dispersible Lutetium Technetate material was released. • The method and location of disposal of the Lutetium Technetate material has not been identified. • The person who opened the canister has not been identified.
8/20/2012	Sample canister containing Lutetium Technetate contamination was loaded	• FP-04 S1 removed an empty sample canister from plastic tray and loaded it

Date Time	Event	Condition
	with Tungsten	with Tungsten on a sample desk in FP-04. • The sample desk on FP-04 is considered radiologically “clean” and no radiological controls or containment was required. • The sample canister was later found to be marked with “Lu” on the collar and was internally contaminated with Lutetium Technetate.
08/21/2012 ~1400-1540	Last entry by CIS, who was later found to have Tc-99 contamination on shoes	• FP-04 S3 trained CIS, FP-04 S1, and FP-04 S2 in FP-04 on Sample Changer operations.
08/24/2012 ~1810	Worker alarmed PCM-2 while exiting area	• Contamination was initially thought to be naturally occurring radon.
08/25/2012 ~0200	RCTs entered accident area and began radiological survey	
08/25/2012 ~0600	RCTs determined contamination was not due to radon	• Began notifications to management,
08/25/2012 1633	Operational Emergency Declared	

2.2 Emergency Response

The AIB did not evaluate the emergency response and the following is provided to complete the record of this event. This information is from the Occurrence Reporting and Processing System report, and has not been updated; thus more current information may be available outside of this report.

At approximately 1810 on August 24, 2012, a PCM-2 whole body monitor alarmed while a worker (W1) was self-monitoring after exiting LANSCE Experimental area room 1 (ER-1) in Technical Area 53 (TA-53). W1 contacted radiation control technicians (RCTs) and they promptly responded. RCTs subsequently detected 4,000 disintegrations per minute (dpm) of beta-contamination on W1's personal clothing and 1800 dpm (beta) on his right forearm. RCTs removed the contamination from W1's forearm, confiscated his personal clothing to determine whether the contamination was due to naturally occurring radon, and provided him with modesty clothing.

At approximately 0200 on August 25, 2012, RCTs entered ER-1 and took a series of smear samples in the vicinity of Flight Path 4 (FP-04) where W1 had been working. At approximately 0600, based on sample results and readings from W1's clothing, RCTs determined that the contamination was not due to radon and took immediate action to identify the source and to control the extent of contamination. At that time, access to ER-1 was secured. The highest level of contamination found was approximately 48,000 disintegrations per minute (dpm)-beta.

At 0648, the LANSCE RCT team leader notified the Technical Area (TA)-53 on-call duty officer of the contamination event who in turn notified the LANSCE Facility Operations Director (FOD). RCTs continued surveys to determine the extent of contamination and at 0750, the FOD categorized the incident as a reportable contamination event. Subsequent surveys identified removable area contamination levels in ER-1 on experimental equipment in FP-04 of up to 4 million dpm (beta). Lower levels of removable contamination were also identified in other areas of the Lujan Center, including ER-2 and office/lab areas of TA-53-622, most notably uncontrolled office areas at TA-53-622. At that time, the LANSCE FOD directed the closure of the Lujan Center, including ER-2 and TA-53-622. An area sweep was conducted to ensure no personnel were present in the area.

At 1327, based on the extent of the contamination, the TA-53 FOD contacted Laboratory Emergency Management (EM) for assistance. At 1335, EM initiated the Radiological Assistance Program (RAP) team notification process to begin assistance with controlling and mitigating potential offsite contamination. At 1550, EM assumed incident command. At 1633, EM incident command declared an operational emergency (OE) for Health and Safety and activated the LANL Emergency Operations Center (EOC) to manage incident response. Subsequent surveys identified additional contamination in areas outside of LANL property, including in the homes and on the skin and personal clothing of LANL employees who had accessed ER-1.

Following declaration of the OE, LANL coordinated with the DOE/NNSA to make all required notifications of the incident (and potential extent of condition) to local, State, and Federal stakeholders. LANL also coordinated with DOE/NNSA on the event response and obtained assistance from RAP teams from Lawrence Livermore National

Laboratory (LLNL), Pantex Plant, Sandia National Laboratories (SNL), and the Waste Isolation Pilot Plant (WIPP).

The following is a summary of the extent of condition and response activities based on reports that were current as of August 31, 2012, at 1200.

1. Based on multiple direct measurements and all current information, this event did not pose health risks to LANL workers or the public.
2. Isotopic analysis results showed that the nuclide involved was Technetium-99, which is a low energy beta emitter. The highest levels of contamination were detected at LANSCE in ER-1 around FP-04. Further surveys identified contamination levels of up to 6 million dpm (beta) on and around an experimental piece of equipment within FP-04 that is known as the HIPPO.
3. LANL established a three-tiered approach for identifying and surveying individuals potentially involved with work activities in and around ER-1. Tier 1 included employees with unescorted access to ER-1 within the previous two weeks. There were a total of four employees identified in this Tier with skin contamination at levels up to 16,800 dpm (beta). There were several employees in this Tier with contaminated personal clothing and items with levels up to 980,000 dpm (beta). All skin contamination was removed and clothing collected. All nasal smears were negative. All Tier 1 employees were placed on special bioassay.

   Tier 2 included employees who had access to ER-2, building 622, and surrounding areas within the previous two weeks, but were not believed to have been in close proximity to the source. One Tier 2 employee had skin contamination and several had contamination on personal clothing or items. Contaminated items were collected.

   Tier 3 included employees who had been escorted into ER-1 and surrounding areas within the previous two weeks for limited time periods, but were not believed to have accessed the contaminated area. Survey results for all Tier 3 employees measured no detectable activity (NDA). LANL also performed additional personnel surveys for individuals who wanted to be surveyed but were not in the above three tiers. These surveys indicated NDA.

   In summary, five individuals were identified with skin contamination, 25 employees had contaminated personal clothing or items, and LANL performed personnel surveys of approximately 270 individuals.
4. RAP teams performed surveys in multiple areas in New Mexico, Colorado, and Arizona, including more than two dozen homes in Los Alamos, Santa Fe, Rio Arriba and Dona Ana Counties and 1 school in Los Alamos County. As of August 31, 2012, at least 9 homes in New Mexico were found with contamination at levels up to 64,000 dpm (beta). No contamination was detected in the school.
5. Because all criteria were met for termination of the Operational Emergency, on August 29, 2012, at 1614, in coordination with DOE/NNSA, LANL EM terminated

the Operational Emergency. On August 29, 2012, at 1645, LANL EM deactivated the EOC.

The offsite RAP teams were released on Friday, August 31, and Saturday, September 1, 2012. On Wednesday September 12, 2012, LANL RAP stood down and returned to normal recall mode. It should be emphasized that this information is included in this report for completeness only, and has not been updated. Providing the most current information on the extent of offsite and personnel contamination was outside the scope of the accident investigation, which focused on the accident cause and preventing recurrence.

2.3 Description of Extent of Contamination

The extent of contamination has two aspects: 1) offsite and 2) onsite. Onsite contamination includes facilities and equipment, personnel who were recalled and surveyed onsite, and clothing and vehicles brought onsite to be surveyed.

The offsite surveys were conducted by Radiological Assistance Program (RAP) teams. Offsite contamination levels, as well as onsite evaluations of personnel and their clothing, are summarized in section 2.2, and will not be repeated in this section. LANL requested that the contaminated workers provide detailed timelines of their activities to identify offsite locations with a potential for contamination. Over 30 offsite locations were surveyed by the RAP teams in accordance with their procedures. The RAP team released items that met free release criteria in accordance with DOE O 458.1, *Radiation Protection of the Public and Environment*. Contaminated items that were not able to be decontaminated to below the release criteria were bagged and collected by LANL waste management teams.

Precise estimates of the extent of personnel contamination and maximum doses are outside the scope of this report. However, based on the amount of contamination, no dose is expected to exceed 1 millirem. Note that persons living in the United States typically receive between 300 and 600 millirem annually from routine, natural and manmade sources (such as cosmic radiation and medical procedures).

Initially, the onsite surveys were performed to locate and characterize the highest levels of contamination on individuals or items. As such, count rate values were reported in terms of disintegrations per minute (dpm) and were not corrected to indicate contamination levels (normally reported in dpm/100 cm^2). Initially, the isotope in the contamination was not known and uncorrected meter readings were reported. With the identification of Tc-99 as the primary isotope in the contamination, an energy correction was applied to the meter readings to correct for calibration variances. Tc-99 is a pure low-energy beta emitter, and LANL's radiation protection instruments are calibrated to a high-energy beta emitter (Sr-90, which contains Y-90 — a pure high energy beta emitter — in secular equilibrium). Corrected count rated values are reported in this section.

The onsite surveys were conducted by LANL RCTs. Onsite surveys were used to screen potential affected workers and to establish boundaries of contaminated areas. These areas included ER-1, ER-2 and the adjoining office building (Building 622) of the Lujan Center. Contaminated areas were posted and access was controlled.

Contaminated areas were then further surveyed to help determine levels of contamination. During the initial characterization around Flight Path 4 (FP-04) within ER-1, items were found with levels of 4 to 6 million dpm. Later characterization found a glove with 17 million dpm on its palm area, and other contaminated items.

Initial surveys indicated contamination levels of 1 to 2 kilo-dpm (kdpm) in the tunnels between ER-1 and ER-2, and an area in ER-2 was identified with levels of 6 kdpm. The elevator in Building 622 was identified with levels of 17 kdpm and a hallway at 1 kdpm. Eight offices were identified with levels from 1 to 10 kdpm. More extensive surveys and decontamination activities in Building 622 are being completed.

LANS performed a comprehensive radiological survey of ER-2 on August 31, 2012. This survey consisted of both direct and smear surveys for over 1,200 locations within ER-2, roughly on a grid layout. Direct surveys provide the level of total contamination while smear surveys provide the level of removable contamination. All accessible locations were surveyed (inaccessible areas typically were tops of instruments on flight paths where personnel did not have access). Nearly all of the results were less than 5,000 dpm/100 cm^2 for direct surveys and less than 1,000 dpm/100 cm^2 for smear surveys. Only eight locations had direct survey results greater than 30,000 dpm/100 cm^2; however only one of these locations had removable contamination greater than 10,000 dpm/100 cm^2. This location is the computer workstation for reading radiographs and was expected to be contaminated based on the activities of the workers on FP-04.

A series of surveys were performed in ER-1, initially to determine the source of contamination, then to characterize the levels of contamination within ER-1, and finally to evaluate the potential scenario for the loss of confinement of the intrinsically radioactive sample. The survey results from all entries into ER-1 since August 25, 2012 are summarized in Figure 2.3.1 and Figure 2.3.2. Smear results, provided in Figure 2.3.1, report removable contamination. Direct results, provided in Figure 2.3.2, indicate total contamination, including both fixed and removable. Details of the highest count rates are provided in text boxes highlighted in red in both figures.

Smears are performed using industry standard methods and are counted in the Health Physics Analytical Laboratory. Direct surveys are performed by using a calibrated beta-gamma probe (in this case, a two-inch pancake Geiger-Mueller detector) coupled to a digital meter (in this case, an Eberline ESP-1). The nominal value is determined by the RCT from the changing digital readout and appropriate correction factors are applied. This process assumes that the contamination is basically uniform over a 10 cm x 10 cm area.

During the last entry, highly contaminated materials were taped, bagged, and extracted for further analysis. Examples of this removed material are portions of the cushioning mats within some of the tool box drawers. In some cases the contamination was entrained in the pores of the extracted material. LANS personnel estimate they extracted about 400 million dpm of contamination from the tool box that sits on top of the HIPPO door, or about 10% of the total contamination in the original Lutetium Technetate sample.

In the figures, there is a circle in the center that represents the neutron beam source for all the flight paths. A larger, concentric circle is depicted in the figures, corresponding to

a structural feature in ER-1. Small numbers (1-16) appear just outside that circle. These identify the individual flight paths. High levels of contamination were concentrated in the vicinity of FP-04 (the HIPPO instrument).

The highest contamination levels were found around and in the red tool box on the HIPPO door, and included a measured value of 53.4 million dpm/100 cm^2 (removable). Direct survey readings indicating that the count rate exceeded the range of the survey instrument (240 million dpm/100 cm^2) were observed on the top of the toolbox and in the top drawer (see Figure 2.1.12). Much of the 400 million dpm that the Contractor extracted came from the first drawer of the toolbox on top of the HIPPO door. The sixth drawer of the toolbox had more contamination than the fourth and fifth drawers, and did not have a cushioning mat. It had visible contamination which looked like a smudge, perhaps transferred from a glove. A smear of the smudge removed the visible contamination and measured 2,000,000 dpm.

The second highest contamination levels were observed on the surface of the FP-04 sample desk (referred to as “Work Station” in the figures).

The highest contamination level found on the sample desk was on its surface, near the front middle portion of the surface a few inches back of the front edge in an uncluttered area. The second hottest spot was on the purple lid of the plastic cup in which the Lutetium Technetate sample was originally received from UNLV.

In the figures, the readings labeled “Vanadium Cans in Cabinet” refer to the normally locked radioactive material storage cabinet for FP-04 (see Figure 2.1.4) where the Technetate samples had been stored.

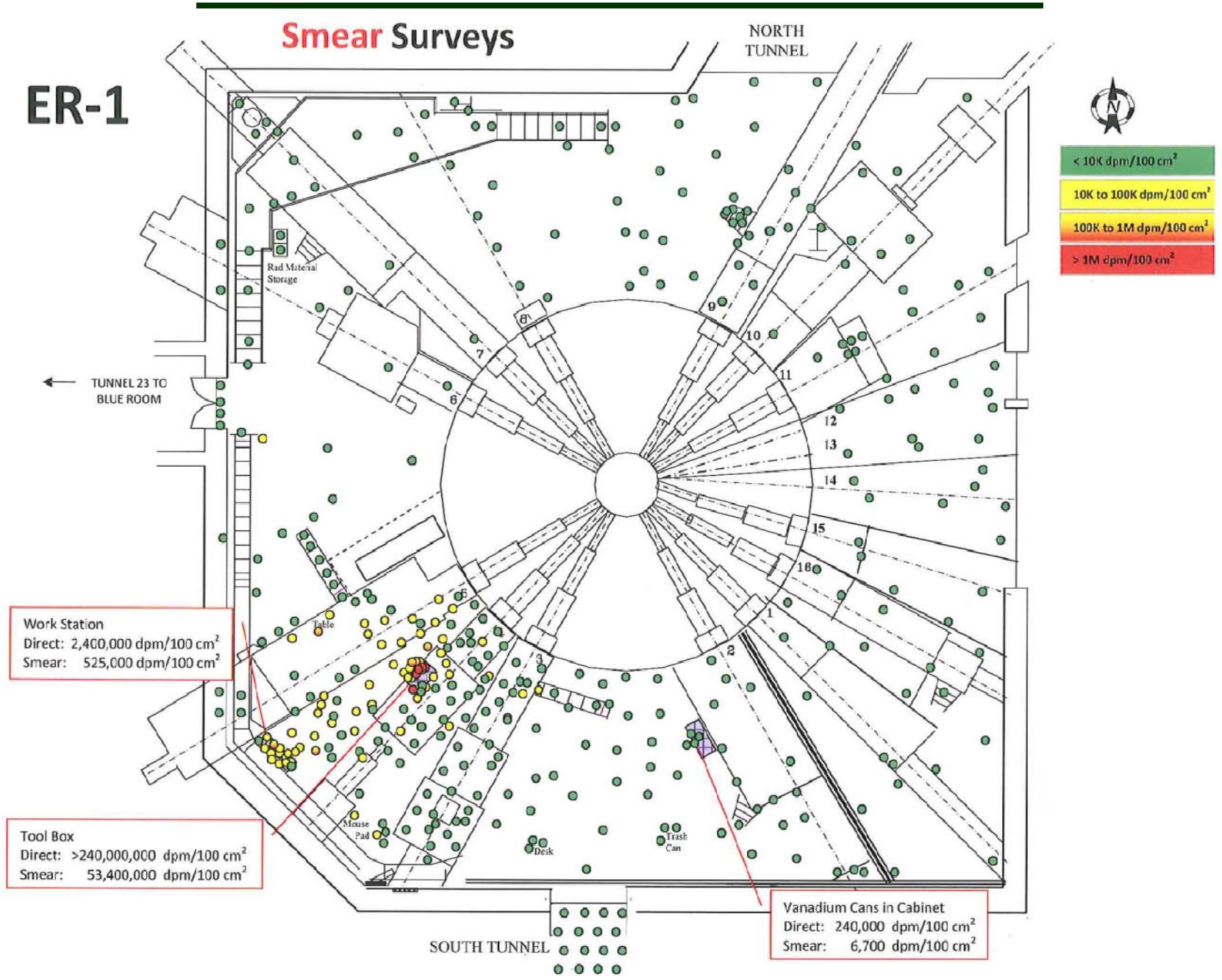

Figure 2.3.1. Results of Smear Surveys of ER-1

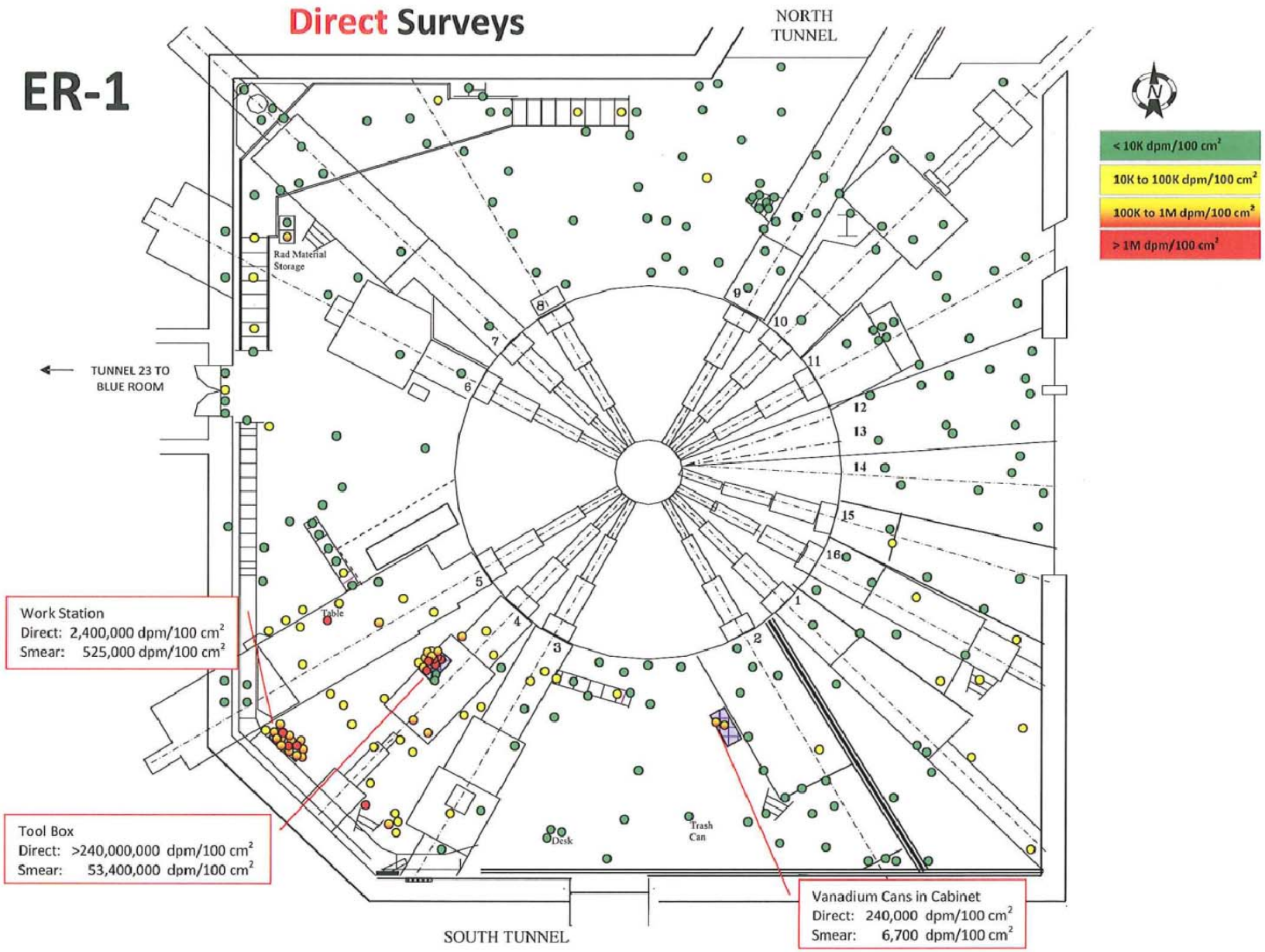

Figure 2.3.2. Results of Direct Surveys of ER-1

3.0 MANAGEMENT SYSTEMS EVALUATION

3.1 DOE Oversight

LASO performs day-to-day Federal oversight of the Contractor. NNSA Headquarters (HQ) organizations provide oversight of Site Office performance, and may influence that performance through governance initiatives or programmatic and funding decisions, as do many other Federal customers. No evidence was discovered during this investigation that indicates that Federal organizations outside of LASO played a role in this accident, or had the resources and responsibilities to have prevented it. No evidence was discovered to indicate that changes in Federal oversight played a role in the accident.

AIB Conclusion: Federal oversight of LANSCE operations, particularly operations in the Lujan Center, has been essentially unchanged in recent years. Changes in Federal oversight practices were not a contributor to this event. (JON 4)

In accordance with NNSA HQ program direction, the LASO Site Manager is responsible for on-site Federal oversight and administration of the Management and Operating (M&O) Contractors and other direct contracts. The LASO Site Manager serves as line management, site-level mission integrator, and is the authorizing official for activities at the Site on behalf of the Administrator, the Deputy Administrator for Defense Programs, the Deputy Administrator for Defense Nuclear Non-proliferation, and the Associate Administrator for Infrastructure and Operations.

The *LASO Integrated Management System Description*, including *LASO Functions, Responsibilities, and Authorities*, Plan 00.14 Revision 1, identified procedures and mechanisms associated with the day-to-day oversight of laboratory activities.

The *LASO Management Procedure* (MP) 00.08, Revision 4, defines LASO's overall approach for conducting line oversight of LANL. The determination of the depth and breadth of oversight activities conducted for various functional areas is based upon a set of common, key oversight principles:

- Use transactional level oversight for nuclear facility operations;
- Emphasize system level, not transactional level oversight for non-nuclear facility operations; and
- Increase contractor accountability.

Transactional level oversight is more detailed than process-based systems level oversight, and includes activities required to assess the contractor's system performance to determine if they meet applicable requirements and are effectively implemented. Systems level oversight involves a combination of output information from the laboratory's Contractor Assurance System (CAS) that identifies contractor performance at various levels (process, functional, activity, or facility). This information is coupled with sampling verification of program requirement implementation. Oversight methods used by LASO include

operational awareness activities such as walkthroughs, performance measures reviews, and shadowing of assessments. Operational awareness is primarily accomplished through the LASO Facility Representative (FR) Program and assigned LASO Functional Area Managers (FAMs).

For LANSCE, a non-nuclear facility operation, LASO performs system level oversight using the LANL CAS to monitor LANSCE operations, and performs a number of operational awareness activities designed to maintain cognizance of the overall facility or work activity status, major changes planned, and overall safety posture of LANSCE.

LASO has assigned one FR to conduct day-to-day operational awareness activities of LANSCE operations. In addition LASO maintains a cadre of subject matter experts (SMEs) assigned as FAMs in various areas, such as radiation protection (RP), who are expected to have general knowledge of their assigned program implementation status from the LANL CAS, and validate implementation via sampling of in-field observations of performance, shadowing of selected LANL assessment teams and oversight programs, and external reviews.

For this accident, the AIB focused on the processes and activities conducted by the LASO FR program and key LASO FAMs, in particular RP.

3.1.1 Core Function 1, Define the Scope of Work

NNSA's NA-1 Supplemental Directive 226.1A, *NNSA Line Oversight and Contractor Assurance System*, states that an assessment of each nuclear facility Safety Management Program (SMP) should occur at least once every five years. LASO implements this direction through several LASO management procedures and assignment of SMEs as FAMs responsible for each SMP, and development and implementation of a master assessment schedule. LASO oversight of LANL safety management programs, including RP, uses a risk-informed process for determining oversight of the Laboratory defined in LASO MP 00.13, Rev.1, *LASO Risk-Informed Oversight Planning*.

In addition, LANS had elected to apply DOE Order 422.1, *Conduct of Operations* to several non-nuclear high hazard facilities including LANSCE. Per LASO MP 06.04, *Facility Representative Program*, FRs are required to verify/validate implementation of the facility safety basis requirements at assigned facilities on a periodic basis. This includes assessing key elements of conduct of operations (CoO), SMPs, and verification of credited controls identified in the facility's authorization basis. LASO current staffing analysis for coverage of LANL non-nuclear high hazard facilities requires one FR to provide oversight of LANSCE. The level of FR coverage for LANSCE has been unchanged for many years.

LASO FR staffing for oversight of LANSCE is consistent with oversight resources applied to DOE Hazard Category 3 nuclear facilities.

LASO has one subject matter expert who serves as the RP FAM to provide systems level oversight for LANL RP program. The RP FAM is qualified as a health physicist under the Federal Technical Capabilities Program. The RP FAM programmatic responsibilities extend across the entire LANL. The LASO RP

FAM is also is assigned responsibility to provide oversight of LANL packaging and transportation functional area.

Although the span of programmatic responsibilities and additional duties assigned to the LASO RP FAM presents challenges, the AIB could not identify any concerns on the availability of the RP FAM that directly contributed to the event under investigation.

3.1.2 Core Function 2, Analyze the Hazards

LASO oversight of LANL SMPs, including RP safety, uses a risk-informed process for determining oversight of the Laboratory, as defined in LASO MP 00.13, Rev.1, *LASO Risk-Informed Oversight Planning*. The LASO RP FAM's evaluation considered the risk or vulnerability of various elements and activities of the contractor's RP program, which includes contamination control, work planning, and material release. Risks associated with these RP elements were judged to be most significant in nuclear facilities.

The LASO Management System Effectiveness Summary Analysis for RP rated LANL as having a mature RP program for the review period of 10/1/2010 to 2011. LASO MP 00.13, *LASO Annual Assessment Planning* defines mature as: the elements of CAS are in place and being used by LANL.

Discussions with the LASO RP FAM indicated the effectiveness of implementation and transparency of LANL CAS for RP is very mature. As a result, the LASO RP FAM did not identify a need for any additional LASO RP oversight assessments beyond those already planned by the contractor. Review of LASO assessment planning documents identify shadowing of the LANL Triennial Assessments of 10 Code of Federal Regulations (CFR) 835, *Occupational Radiation Protection* and LANL CAS activities at other LANL nuclear facilities that identify the RP program as a credited SMP within the facility's documented safety analysis.

LASO procedures require day-to-day FR operational oversight of LANSCE to include CoO, SMP, and credited equipment and controls for the LANSCE Safety Assessment Document (SAD). The LANSCE FR, in his testimony, stated that his focus for oversight activities was on the accelerator, due to the high electrical and radiation hazards presented in accelerator beam-line operations.

Although focus of FR operational awareness activities was on high hazard operations of the accelerator, it was not evident that sufficient consideration was given to the unique challenges presented in programmatic work at the Lujan Center, in particular, where many short term experiments are typically scheduled to be conducted in a run cycle, such as with HIPPO operations.

3.1.3 Core Function 3, Develop/Implement Controls

Per LASO MP06.04, *LASO Facility Representative Program*, FRs are required to report to their assigned facility each morning, where they review operator and/or control room logs, attend plan-of-the-day and plan-of-the-week meetings, conduct facility walkthroughs, discuss topics of concern with facility management

and staff and review abnormal occurrence information. Key activities of each LASO FR along with the status of key facility work activities are summarized in an "FR Daily Report" on a daily basis. Review of FR Daily Reports from 1/1/2011 through 8/24/2012 show evidence of FR activities being performed on a routine day-to-day basis at LANSCE, however, most FR activities did not involve the Lujan Center.

LASO work instructions require LASO Field Operations personnel, including FRs, to formally document and communicate findings, observations, or strengths to LANL and the responsible LASO supervisor or FR Team Leader. LASO work instructions also require LASO Field Operations Personnel to formally document their results of surveillances and walkthroughs in an "Attachment A" form. Interviews with LASO FR Team Leader and the Assistant Manager for Field Operations stated LASO FRs are required to conduct and formally document a minimum of three walkthroughs per month. From 11/20/2009 to 8/27/2012, 95 FR Attachment A's have been documented for LANSCE, however, only a few Attachment A's involved the Lujan Center.

The FR assigned to LANSCE was performing day-to-day operational oversight of LANSCE, in accordance with LASO procedures and work instructions. However, most documented operational oversight did not involve the Lujan Center.

As a result of the last two annual risk-based assessment planning cycles, the LASO RP FAM did not identify a need for any LASO RP oversight assessments. However, LASO did shadow the last three LANL Triennial Management Assessments of 10 CFR 835, *Occupational Radiation Protection*, including the LANL Management Assessment for 10 CFR 835, *Radiation Program Triennial Assessment*, Part 2 of 3, relevant to the event under investigation. The LASO RP FAM also shadowed LANL Facility Centered Assessments at other LANL nuclear facilities that identify the RP program as a credited SMP within the facility's safety analysis document.

In an interview, the LASO RP FAM said that other oversight and operational awareness performed included, but was not limited to: follow up on LANL event critiques to RP safety events; attendance at LANL Institutional Radiation Safety Committee meetings; attendance at weekly LANL RP managers' technical meetings; and other LANL self-assessments related to his assigned responsibilities. With regards to operational awareness and oversight activities specific to the Lujan Center; the RP FAM recalls conducting a walkthrough accompanied by an FR assigned from another LANL nuclear facility at LANSCE, but could not recall the last time being in ER-1 at the Lujan Center on a walkthrough. The RP FAM Indicated he had never looked at experimental sample management work practices at LANSCE user facilities, including the Lujan Center, and that he does not always maintain formal documentation for all of his oversight activities conducted.

Review of limited records available found: (1) emails that demonstrated involvement in several event critiques at the Lujan Center involving issues with dosimetry, (2) the only documented evidence of a walkthrough at LANSCE

occurred on 9/8/2010, and (3) no evidence, such as an Attachment A, that identified issues requiring transmittal of a LASO contracting officer representative (COR) letter to LANL for corrective action.

RP systems-level oversight was focused on high-hazard nuclear facilities and activities, consistent with the results of the LASO risk-formed oversight planning evaluation used by the LASO RP FAM.

Although LASO oversight processes and procedures are in place, mechanisms to implement LASO RP oversight of the contractor were not sufficiently defined, and formal records demonstrating implementation did not always exist.

3.1.4 Core Function 4, Perform Work Safely

LASO procedures and mechanisms require FRs to maintain operation awareness and understanding of their assigned facilities. Testimony of the FR assigned to LANSCE stated that he: (1) had been assigned as the LANSCE FR for three years, and held several prior FR positions at other LANL nuclear facilities; (2) was unfamiliar with experimental handling at the Lujan Center, and does not get involved with the day-to-day experimental operations at the LANSCE user facilities; (3) had reviewed the users program at the Lujan Center, focusing on training and documents; and (4) had never looked at sample management practices at LANSCE user facilities, but had looked inside radioactive storage cabinets at the Lujan Center and observed LANSCE run cycle readiness reviews.

In addition, the FR further stated he never attended any pre-job meetings or weekly meetings at the Lujan Center. The FR also stated that his main focus of operational awareness activities was accelerator beam-line operations, and critical equipment that supports implementation of the accelerator safety assessment document (SAD), including systems and equipment surveillances, and stated he had not identified any findings in SAD implementation. Other oversight activities cited included vehicle safety, life safety and fire safety occasionally, and had identified some radiation posting deficiencies.

Review of LASO FR Daily Reports reviewed from 1/1/2011 through 8/24/2012 show evidence of FR activities being performed primarily on CoO, accelerator beam-line operations, and critiques of events at LANSCE.

Evidence of shadow observations was provided showing oversight activities performed by the LANSCE FR and another LASO site person for the past two LANSCE Run Cycle Readiness Reviews. No findings, observations or concerns were identified by LASO regarding the depth and breadth of these reviews.

As a result of minimal FR presence at Lujan Center and the LASO focus on nuclear facilities, there has been no significant LASO presence at the Lujan Center or LASO awareness of work conditions and work practices for the last three years.

LASO personnel did not effectively sample workplaces and work practices, and did not identify and ensure correction of less than adequate control of radioactive

samples. The level of LASO presence at the Lujan Center and inattention to experimental work practices at HIPPO resulted in a lost opportunity to help ensure that LANL established and maintained an adequate and effective formality of operations at the facility.

AIB Conclusion: LASO oversight roles and responsibilities as defined by the Line Oversight/Contractor Assurance System (LO/CAS) and Facility Representative programs were so broad that LASO did not identify activity-specific deviations from established LANL safety and health programs and procedures by the High-Pressure Preferred Orientation Neutron Diffractometer (HIPPO) team. (JON 4)

3.1.5 Core Function 5, Feedback and Improvement

During this investigation the AIB reviewed the results of recent NNSA HQ Biennial Review of Site Nuclear Safety Performance for LASO, conducted in June 2012 to determine if issues were found that had similar characteristics to this event under investigation. The review identified that LASO did not have a formal, documented process for reviewing and approving the LANL RP program required by 10 CFR 835, nor a formal documented process for oversight of the RP SMP. In response, LASO developed a corrective action plan to formally address all of the weaknesses identified in the review report, including weaknesses identified in LASO oversight of LANL RP program.

The NNSA Biennial Review was effective in identifying weaknesses in the transparency of LASO oversight of LANL RP program, and corrective actions to establish a formal process were adequately identified and appropriate actions were being taken by LASO.

Because LANSCE is not a nuclear facility and thus, not subject to the requirements of 10 CFR, Part 830, *Nuclear Safety Management*, evaluation of FR program oversight of LANSCE was not in the scope of the Biennial Review.

During this investigation, the AIB reviewed the Type B Investigation of the Americium 241 Contamination Event at the Sigma Facility to determine if any issues were found that had similar characteristics to this event under investigation. The following findings and concerns are relevant to this accident.

- "given the limited SME availability, the lack of a FR assigned to Sigma, and the LASO focus on nuclear facilities, there has been no significant LASO presence in Sigma, or LASO awareness of the status of radiological operations in the facility, for the past few years"
- "since neither LANL's institutional assessment processes nor LASO's oversight efforts have focused on Sigma, there has been no viable external oversight of the facility for multiple years; the absence of LASO oversight and field presence in Sigma resulted in a lost opportunity for the NNSA to observe and assess the contractor's implementation and effectiveness of the IWM processes including the IWDs"
- "the lack of LANL and LASO oversight of Sigma likely contributed to the failure to identify and correct accepted practices and assumed requirements

that had developed in the facility in conflict with the formally established requirements of LANL and DOE"

AIB Conclusion: Lessons learned from the 2005 Americium contamination event at the Sigma facility were not effectively implemented at Lujan Center. (JON 1)

3.2 Implementation of LANL Radiation Protection Program

The responsibility for the LANL Radiation Protection Program resides with the Radiation Protection (RP) Division. The LANL RP Division Leader is responsible for establishing the institutional program and providing guidance for its implementation. The Health Physics Operations Group (RP-1) is responsible for supporting the implementation of the operational aspects of the program. Radiological Control Technicians (RCTs) and operational health physicists are members of the RP-1 group and are assigned to support programmatic and facility organizations conducting radiological activities. Other RP Division groups provide support such as analytical services, calibration services, dosimetry, radiological engineering, and support for radiation generating device and radioactive sealed source programs.

The Radiation Protection Program (RPP), approved by LASO, is implemented through an institutional procedure: P121, *Radiation Protection*. Additional requirements are developed on a facility basis through a Facility Radiation Protection Requirements (FRPR) document or for specific activities through radiological work permits (RWPs). The RP Division has implemented comprehensive procedures for performance of work, including RCT activities. Essential to the LANL RPP and P121 is field implementation of the requirements by all workers; in this sense, programmatic and facility organizations and all radiation workers are key members of the RPP.

The RP-1 LANSCE team consists of one team leader, one health physicist and 12 RCTs. In addition to supporting daily operations within LANSCE, these personnel are also responsible for conducting routine surveillance activities to monitor the radiological conditions within the buildings and to support line management responsibility to maintain the facility's compliance with LANL's RPP and P121 requirements and compliance with 10 CFR 835.

As an accelerator facility, LANSCE is not subject to 10 CFR 830, but instead DOE O 420.2C, *Safety of Accelerator Facilities*. To ensure that sample activities do not entail sufficient quantities of radioactive material to cause the facility to exceed the DOE-STD-1027 thresholds, LANSCE has implemented a screening process on the amount of plutonium-239 equivalent grams (PEG) that is proposed to be used in an experiment.

3.2.1 Control of Radioactive Samples

Samples containing radioactive materials are surveyed upon receipt at the Lujan Center to ensure the dose rates and contamination levels are assessed in accordance with Department of Transportation and DOE requirements. The samples must be labeled or packed in a container that is labeled to communicate

the presence of the radioactive material. Information included on the label includes the radiological trefoil indicating the presence of radioactive materials at a minimum. Shipping papers include isotopic information, the activity of the sample, and associated dose rates and contamination levels when applicable. Figure 3.1 provides a photograph of the shipping containers for the Praseodymium and Neodymium Technetate samples shipped from UNLV.

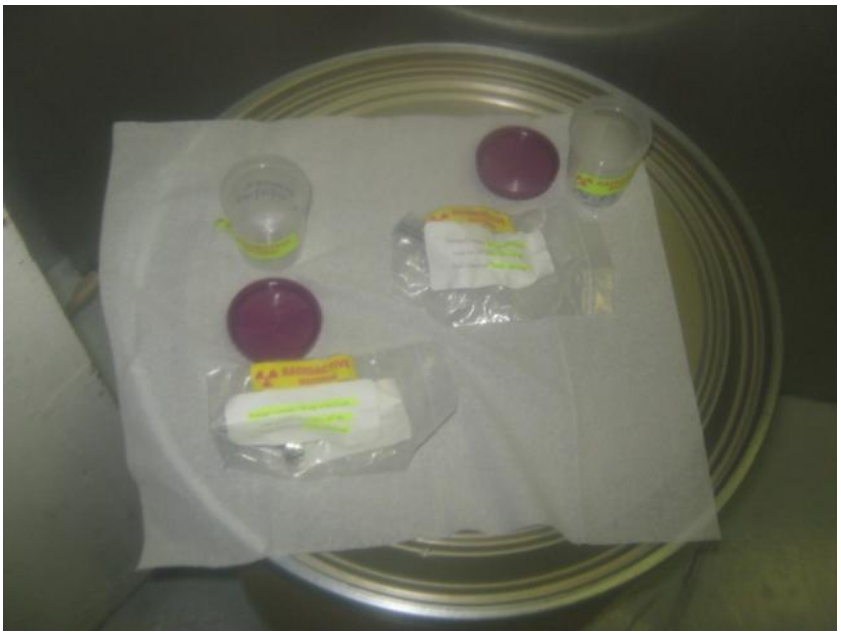

Figure 3.1. Packaging and Labeling used for Tc-99 Samples Shipped from UNLV

When opening the shipping container, an RCT is required to check for potential dose rates and contamination to ensure the sample hazards are known and appropriately controlled. After verification of the shipment's integrity, the samples are stored in locked radioactive material storage lockers in ER-1 or ER-2.

Samples typically remain in the locked storage cabinets until they are scheduled for irradiation. The *TA-53 Facility Radiation Protection Requirements* procedure indicates that it is important to maintain knowledge of process in the handling, movement, and storage of potentially radioactive and contaminated items by the use of labeling, marking, and storage in appropriate containers and radiological areas. The sample canisters do not include formal marking or labeling to indicate that they contain hazardous materials or that can be used in the identification and tracking of all samples. The sample canisters are typically marked using an indelible marker to indicate the user and the material being irradiated.

Following irradiation, sample canisters containing samples that are to be released or returned to their user are placed in a plastic zip lock bag with a label on it indicating that a radiological survey is required. The bag is placed in a common RCT in-box pending survey of its contents. Figure 3.2. is a photograph of a typical label used to indicate an item is to be surveyed by an RCT (the name

of the user and their email address has been intentionally obscured for use in this figure). Note that the label does not include any indicator to communicate whether the contents are intrinsically radioactive. Such information would have to be entered into the sample description box to alert the RCT to the presence of internal, intrinsically radioactive materials.

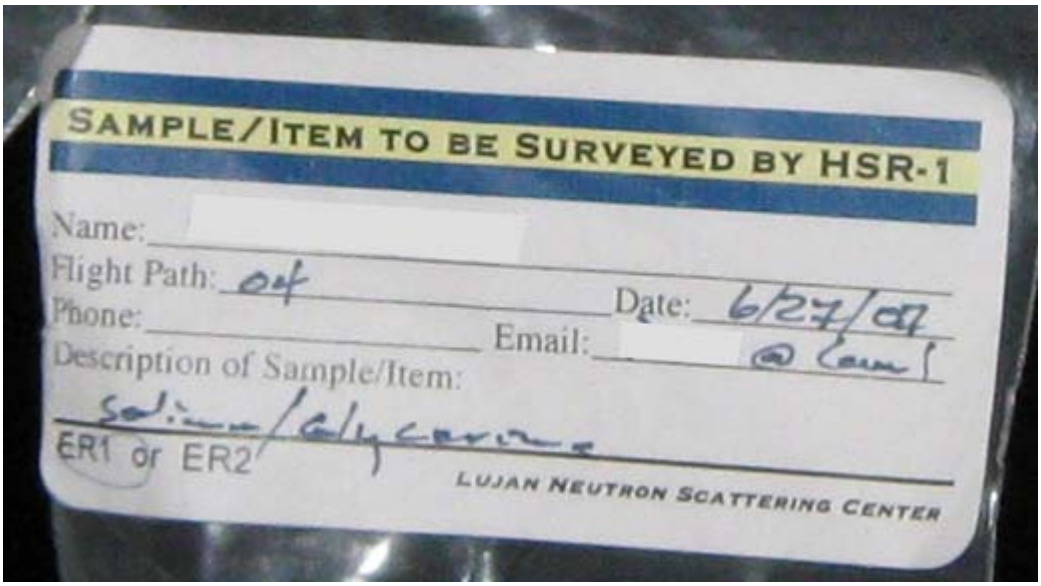

Figure 3.2. Sample to be Surveyed Label

Information provided in several interviews indicated that irradiated sample canisters could be held in ER-1 without being submitted to the RCTs for survey, and that surveys were only required if canisters were being removed from the controlled area. Procedures allowing for this option have not been provided to the AIB.

Following RCT survey, sample canisters are either tagged as radioactive and retained for activation decay, or cleared for release. If they are radioactive, the RCT puts them in a Plexiglas box for radioactive samples at the RCT station (each flight path has its own set of Plexiglas boxes at the RCT station, one box for radioactive items that have been surveyed, and one for items cleared for release). If a sample canister is determined to be non-radioactive and uncontaminated, the RCT attaches a free release sticker and puts the sample canister into the Plexiglas box for cleared items. Flight path personnel can take radioactive items out of their boxes at the RCT station and store them at their flight path if desired. This is sometimes necessary if the Plexiglas boxes at the RCT station become full.

The TA-53 Facility Radiation Protection Requirements procedure does not include a specific process for handling and labeling of inherently radioactive samples, with activity less than one tenth of the 10 CFR 835 Appendix E values. The procedure introduces a "knowledge of process" (KOP) concept that may be intended to ensure proper handling by maintaining appropriate information and labeling with inherently hazardous samples.

Once the experiment is completed, and either the sample is to be returned to the user or the sample canister is needed for a different experiment, the samples are transferred from the reusable canisters into glass vials. Samples that the user does not want returned are sent to the Chemistry Laboratory for characterization and disposal in the appropriate waste stream. Transfer of irradiated powders or inherently hazardous samples from sample canisters into different containers must be performed in a glove box, with RCT coverage. Following transfer, an RCT survey would determine whether the contents of the sample canister retained residual activity. It was not clear from documentation provided that RCT survey was required prior to disposal of non-powdered samples removed from their sample canisters. Samples that are not returned to users are typically stored in ER-1 to allow the activated samples to decay to near background levels. Samples are then surveyed by the RCTs prior to their movement to the Chemical Laboratory for characterization and disposal. However, RCTs do not open sample canisters unless evidence of contamination exists.

Samples are disposed of based on their radiological and chemical properties and do not enter the non-radioactive waste stream.

Information obtained during this investigation indicates that the Technetate samples likely followed the required process through receipt inspection and survey, initial storage, and sample irradiation. However, after irradiation the facts are uncertain but indicate departures from the typical process. The evidence indicates that the Lutetium Technetate sample was not placed back into the original labeled zip lock bag to maintain knowledge of process, and may have been placed in a new zip lock bag with a Lujan label indicating the sample was to be surveyed by a RCT. This new label may not have conveyed information indicating that the sample was intrinsically radioactive, unless the individual completing the label included this information in the sample description. According to testimony, the individual most likely to have put the sample canister into a bag for RCT survey was not aware that its contents were intrinsically radioactive.

While the TA-53 Facility Radiation Protection Requirements procedure indicates that following irradiation samples are submitted to the RCT for survey, interviews indicate that this step was considered optional and that samples could be retained in the work area pending final survey prior to removal of the sample from the Radiological Control Area. It is not clear whether the Lutetium Technetate sample was submitted to the RCT for survey or retained in ER-1. It is also not clear whether the sample was placed in a zip lock bag and labeled to indicate a RCT survey was required or whether it was stored in one of the locked radioactive storage lockers.

The evidence indicates that the knowledge of the intrinsic radioactivity of the sample was lost at the time of irradiation and the sample was treated as a non-hazardous sample activated by exposure to the neutron beam. This resulted in the sample being handled in manner which would not ensure control of the Tc-99. The evidence indicates that the sample was opened without the use of a glovebox, resulting in the contamination of the HIPPO work area and the spread

or contamination to other LANL facilities and offsite locations. The balance of the sample may have been placed in a glass vial pending disposal in an approved waste stream, retained in storage in ER-1 or ER-2, or could have been disposed of in the clean trash (with or without a vial).

One item noted is that the RCTs do not typically open glass vials to survey the contents when preparing to send them to the Chemical Laboratory for final characterization prior to disposal. The sample control process must inform the RCT of internal hazards to ensure awareness. Without such awareness, the presence of intrinsically radioactive materials with radiation emissions that can't be detected through the vial walls could be missed. It is likely that a vial mistakenly containing an intrinsically radioactive powder would have external contamination that the RCT would detect (either from cross contamination or because of minute spillage during transfer). A vial containing a solid, however, may not be externally contaminated.

The Lujan Center has not effectively implemented the KOP requirements for maintaining labeling and marking information with intrinsically hazardous materials nor has it ensured that sample handling and storage requirements are effectively implemented.

AIB Conclusion: The Lujan Center has not effectively implemented the requirements of the FRPR. (JON 1)

AIB Conclusion: The current process of only surveying the exterior of the sample vial prior to preparing the sample for disposition, coupled with the lack of an effective sample control process does not ensure that radioactive samples are controlled. (JON 1)

3.2.2 Control of Radioactive Contamination

Since no contamination is expected at ER-1, specific contamination controls identified are limited in scope. Examples of implemented controls include the use of approved containers for radioactive materials with contamination levels in excess of pre-identified levels, restrictions on opening containers with radioactive materials inside, proscriptions on considering glass containers as a barrier to a spill or leak, receipt surveys of incoming radioactive materials, operational surveys for glove box and hood operations, material release surveys, and quarterly Radiological Monitoring Instruction (RMI) surveys to verify that contamination has not spread into the work environment. There is no requirement for personnel leaving ER-1 to exit through a personnel contamination monitor or to be surveyed for contamination.

Implementation of the FRPR requirements resulted in ineffective practices including the use of unapproved containers for storage and handling of samples with internal surface contamination levels in excess of the proscribed limits; reliance on glass vials for handling, storage, and disposal of radioactive samples;

and ineffective knowledge of process practices for samples with intrinsically hazardous materials.

However, the fundamental failure leading to the release of irradiated Lutetium Technetate was the failure to fully evaluate the hazards in handling intrinsically radioactive samples in a readily dispersible form, resulting in a consequent failure to define and implement controls for the identified hazards. Procedures lack clarity and have internal inconsistencies that may create confusion for personnel responsible for their implementation. The FRPR requires labeling for radioactive materials in quantities greater than one tenth of 10 CFR 835, Table E, values and indicates that knowledge of process for potentially radioactive materials shall be maintained by labeling or marking. However, labeling and marking processes identified in the procedure focus on labeling to identify activated materials and do not identify a unique process for ensuring intrinsically radioactive materials are labeled to differentiate between intrinsically radioactive samples and activated samples. Lacking marking and labeling to identify the inherent radioactive properties of the samples, the RCT may simply survey the sample for activation and contamination and not realize that it contains intrinsically radioactive materials, potentially resulting in the release of radioactive samples into uncontrolled areas.

While the radiological hazards of the sample, including its readily dispersible nature were known, the sample was stored in an unapproved container that did not have specific design requirements, such as torque for screws and number of screws to be used, to ensure the sample integrity was maintained.

AIB Conclusion: Controls identified to address the radiological hazards presented by the Technetate samples did not adequately ensure containment was maintained to prevent the spread of contamination; effective Quality Assurance requirements for sample canister preparation and sealing were not specified. (JON 10)

AIB Conclusion: The Lujan Center has not implemented engineering and administrative controls to ensure intrinsically radioactive samples are identified and controlled in a manner consistent with10 CFR 835 "Occupational Radiation Protection," including ALARA (As Low as Reasonably Achievable) requirements identified in Sections 101(c) and 1001 (a) and (b). See also DOE G 441.1-1C "Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection" Section 12.2 General Requirements for Posting and Labeling for Radiological Control. (JON 3)

3.3 LANL Implementation of Integrated Safety Management

LANL System Description (SD) 100, *Integrated Safety Management System Description Document* with embedded *10 CFR 851 Worker Safety and Health Program (SD100)* dated February 1, 2012, describes LANL implementation of the Department of Energy Acquisition Regulations (DEAR) 970.5223-1, *Integration of Environment Safety, and Health into Work Planning and Execution* (Dec.

2000) (see Appendix D, DEAR 970.5223-1, Clause 1.074). LANL Integrated Work Procedure (P300), *Integrated Work Management*, dated March 30, 2012, establishes the Laboratory Integrated Work Management (IWM) expectations for doing work in a manner that protects the people, the environment, property, and the security of the nation. P300 outlines the IWM process to ensure all work is governed by the five steps of the Integrated Safety Management (ISM) core functions.

On December 2, 2009, the Defense Nuclear Facilities Safety Board issued a letter to the NNSA Administrator reporting the staff's evaluation of work planning and control processes at LANL. In response to one of the issues identified, LANL committed to conduct a Lab-wide Independent Assessment, using the NNSA guidance *Attributes of Activity Level Work Planning*, tailored to the institution.

On January 20, 2010, LASO issued the Laboratory a memorandum, expressing concerns about recent safety incidents that had a programmatic or conduct-of-research nexus. Of specific concern to LASO was "the commonalities between recent and earlier events indicate that the organizational learning and the sustained focus on improvement necessary for a proactive safety culture have not been embraced across the site." LASO requested that LANL provide its evaluation of recent incidents having a programmatic or conduct-of-research nexus, and describe the actions that LANL would take to improve institutional safety in programmatic and research environments.

On February 5, 2010, the three Principle Associate Directorates with line responsibilities for moderate hazard research and development (R&D) work at LANL, in coordination with the Principle Associate Director for Operations, provided a response to LASO, stating that they believed that the LANL policy, P300, *Integrated Work Management*, which covered work control, was a good process. However, there were clear gaps in the implementation of P300 in the R&D environment.

On April 15, 2010, a team of the Deputy Associate Directors issued a *Project Execution Plan (PEP) for Moderate Hazard Research and Development (R&D) Safety Improvements*, which outlined the systematic actions that LANL took to improve institutional safety in programmatic and research environments. The PEP defined the approach that LANL pursued to achieve a uniform approach for moderate hazard identification and evaluation throughout the Laboratory. The approach was designed to appropriately engage workers with all levels of management, operate within defined safety envelopes with well-understood risks for each experiment, and provide for the dynamic nature of R&D by accommodating real-time modifications of conditions.

In September 2010, the LANL Contractor Assurance Office conducted a *Moderate Hazard R&D Safety Improvements Management Assessment Evaluation*. The primary object of this assessment was to assess the status of PEP implementation in directorates having responsibility for programmatic or R&D activities – its focus was on verifying that the actions outlined in the PEP for

execution by programmatic and R&D line organizations were successfully completed.

While the report did provide information on how the various Directorates were progressing, it did not reach a conclusion. Many of the improvements had not been in place for more than a few months, so the assessment did not provide feedback regarding the progress or sustainability of improvements. Further, the assessment focus on completion of actions provided only limited insight into whether the issues that the PEP was intended to resolve were actually resolved.

In January, 2011, LANL conducted an *Independent Effectiveness Evaluation (EE): Moderate Hazard Research & Development Safety Improvements at Los Alamos National Laboratory.* This EE was conduct by the Contractor Assurance Office under the direction of the Institutional Management Review Board, to address the question of whether implementation of the PEP for Moderate Hazard Research & Development Safety Improvements resulted in improved institutional safety in programmatic and research environments.

The EE concluded that the goals for the moderate hazard R&D safety initiative have largely been met. Further optimization of the initiative's effectiveness would likely be achieved through increased maturation of supporting processes (e.g., training curriculum upgrade based on needs analysis and associated roll-out, IWM toolbox refinement, improved utility of institutional IWM metric) coupled with ongoing improvements in IWM process implementation. The EE resulted in 18 recommendations that were evaluated and dispositioned by the Institutional Management Review Board. The Effectiveness Evaluation Review Rating that resulted from the EE was 'Effective.'

In August 2011, LANL conducted an Independent Integrated Safety Management/Integrated Work Management Assessment of R&D and Programmatic Work to assess the status of implementation for ISM and IWM, again using the NNSA guidance *Attributes of Activity Level Work Planning*, tailored for LANL.

This assessment included selected LANL Directorates and focused on moderate hazard R&D and Programmatic work, including the Lujan Center. The number of IWDs and work activities evaluated was based on the total number of IWDs in the organizations. This assessment looked at a 5% sample, and included work observations, document review, interviews and data review. The assessment provided a number of conclusions, including:

- Work was being performed in a safe manner;
- Responsible line managers, PICs, workers, and facility operations director representatives demonstrated knowledge of the work processes and were willing to pause or stop work;
- LANL organizations had adapted their approach to implementation of P300 based on their operations; they had implemented work process reviews, hazard analysis, and feedback learning processes most effective for their respective work teams and organizations;

- There had been significant improvement in R&D and programmatic IWM implementation due to focused efforts based on the senior management completion of the PEP and the addition of peer and SME reviews (this conclusion was based on the results of assessments and effectiveness evaluations);
- The IWM program had achieved a higher level of maturity as demonstrated by the reduction in the number and severity of reportable events, the consistency of requirements being met based on the assessment results, and the fact that the Findings and Opportunities for Improvement were primarily at the local level; and,
- Areas of improvement for a few organizations involved attention to detail in implementing requirements; while the Conduct of Operations at TA-55 needed to be strengthened, the review of documents and activities by the team demonstrated that hazards were identified and controls were in place.

LASO and LANL have placed significant management attention and resources to improve implementation of ISM/IWM. LASO was aware of the poor performance with regard to ISM/IWM implementation by LANL for R&D and programmatic work, and took appropriate actions in accordance with the contract requirements.

3.3.1 Core Function 1, Define the Scope of Work

Research Proposals submitted in 2010 and in 2011 for examining Tc-99 compounds in LANSCE indicated the samples would be examined at ambient temperature and pressure. The three Tc-99 compounds were each examined in the displex and were actually subjected to temperatures as low as 20 Kelvin.

In January 2012, PI-1 assigned FP-04 S1 to be in charge for conducting the experiment on the Lutetium Technetate sample. FP-04 S1 was not aware of the radiological and chemical hazards associated with Lutetium Technetate.

P 300, Integrated Work Management, requires experiments categorized as "new work" to include a walk down and pre-job briefing. In January 2012 Lujan Center personnel did not consider the Lutetium Technetate experiment as "new work" and therefore did not conduct a walk down and pre-job briefing.

AIB Conclusion: The scope of work was significantly changed without formal review and approval, and the experiments were conducted differently than proposed. The three sample canisters containing Technetate compounds were assembled based on the understanding that the samples would be examined at ambient temperature and pressure, but were subjected to temperatures as low as 20 Kelvin. While the affect of extremely low temperatures on the sample canisters was not evaluated during this investigation, the significant change in the experimental conditions without a formal change control process demonstrated a weakness in implementation of ISMS for Lujan Center operations. (JON 11)

Lujan Center management did not ensure that FP-04 S1, who was placed in charge of conducting the experiment on the Lutetium Technetate sample in

January 2012, maintained competence commensurate with responsibility for performing the assigned task. The turnover of responsibility from PI-1 to FP-04 S1 occurred by email, and did not include a briefing or review of the Research Proposal and associated Safety Review Committee Appraisal that contained technical information regarding the radioactive and chemical characteristics of Lutetium Technetate.

3.3.2 Core Function 2, Analyze the Hazards

Neither of the two Safety Review Committee Appraisals associated with experiments involving the three sample canisters containing Tc-99 compounds required additional controls to address the radiological hazard associated with the release of 1 to 3 mCi of Tc-99 in a highly dispersible powder form.

The experiment plan on which the safety review was based called for beam exposures at ambient temperature and pressure, but the sample canisters were actually subjected to temperatures as low as 20 Kelvin.

No engineering review was conducted to ensure that the design of the sample canister was appropriate for containment of radioactive material throughout the intended experimental environments, or that three screws were sufficient to seal the sample canisters in the experimental environments.

The requirements of 10 CFR 835 are implemented at the Lujan Center through *Los Alamos National Laboratory Radiation Protection Program,* P121, and *TA-53 Facility Radiation Protection Requirements,* LANCE-ST-121-003.R31. Reviews conducted to confirm implementation of 10 CFR 835 did not identify requirements for controlling samples containing radioactive material below 10 CFR 835 Appendix E values that could exceed surface contamination level values in 10 CFR 835 Appendix D.

As a result, the sample canisters containing Tc-99 compounds were not controlled or marked as containing radioactive material.

The safety reviews assumed that the sample canisters would not be opened in the Lujan Center; however, the sample canisters were not designed to provide a highly visible, uniform, tamper resistant, positive indication that they contained intrinsically radioactive or hazardous material. Markings applied to the canisters did not indicate their intrinsically radioactive contents.

Both Safety Review Committee Appraisals identified the sample canisters would contain Tc-99 compounds, but did not adequately address the possibility of an uncontrolled release of the material without ensuring design and assembly specifications of the sample canister were adequate for the intended experiment conditions.

Health Physics was included in the review of both Safety Review Committee Appraisals associated with the sample canisters which would contain Tc-99 compounds, but did not recognize the possibility of an uncontrolled release of the material, and consequently did not implement measures to detect a release and prevent contamination from escaping from the controlled area.

AIB Conclusion: Equipment or instrumentation capable of effectively detecting contamination (such as a hand monitor) was not present in the area where the Tc-99 samples were stored and handled because it was not believed that a contamination event was credible, but rigorous controls were not in place to preclude the contamination event. (JON 1)

3.3.3 Core Function 3, Develop/Implement Controls

The Safety Review Committee Appraisal for Proposal 20111048, completed in June 2011, identified conditions/comments important for safe performance of the experiment, including:

1) The sample canister containing Lutetium Technetate would not be opened;
2) The sample canister would contain up to 3 mCi of Tc-99;
3) The beta radiation would not penetrate the sample canister (i.e. would not be directly measurable from outside the canister); and,
4) The sample canister would contain a chemical hazard that was toxic as well as a carcinogen.

However, the safety review did not identify controls necessary to ensure the critical assumptions would be protected.

Note: During the investigation, it was anecdotally reported to the AIB that when surveying the two Technetate sample canisters (Praseodymium and Neodymium), the RCTs were able to detect the bremsstrahlung x-rays that result from the impact of the beta radiation on the interior walls of the canisters. This was not confirmed as of the date of this report, but was contrary to comments and an assumption documented on the safety review forms.

IWD LUJAN-FP-04-006, *General Neutron Scattering Experiments on HIPPO (FP-04),* specified that radioactive materials required additional work controls. A separate work control document (IWD or RWP) was not prepared for handling the radioactive and hazardous Lutetium Technetate sample.

AIB Conclusion: Additional work controls for working with radioactive or hazardous chemical materials were not developed as required by IWD LUJAN-FP-04-006 General Neutron Scattering Experiments on HIPPO (FP-04). (JON 12)

A Lujan Center PIC did not ensure the personnel involved in the work were familiar with the hazards and hazard controls for the work, and did not lead a pre-job briefing with participating workers.

For the purpose of developing and implementing controls, the person responsible for conducting the experiment on the Lutetium Technetate sample in January 2012 was not aware of the radiological and chemical hazards associated with the Lutetium Technetate sample.

Effective verbal and written communication of hazards, controls, processes and performance expectations between management and employees were not tailored to reflect the multi-cultural environment; cross-cultural normal's; and cultural differences in responding to and communicating with authority figures.

AIB Conclusion: The personnel assigned to FP-04 are multi-cultural, with diverse backgrounds, expectations, and socio-economical approaches to authority. These differences have not been systematically explored and addressed to ensure effective workplace management. (JON 9)

Implementation of the Los Alamos National Laboratory *Radiation Protection,* P121, did not require the sample canister containing the Lutetium Technetate sample to be labeled or marked as radioactive material after an RCT surveyed the outside of the sample canister for radiation, if that survey found no detectable activity.

Implementation of the Los Alamos National Laboratory *Radiation Protection,* P121, did not require sample canisters containing dispersible radioactive material (such as the Technetate samples) to be subject to any specific radiological controls, except the general control that canisters containing irradiated powders were not to be opened outside of the glovebox.

The Lutetium Technetate sample containing radioactive and chemically hazardous (toxic and carcinogenic) was not required to be controlled or tracked.

The *LANL Quality Assurance Program*, SD 330, required that work was to be conducted in accordance with written procedures, plans, and other work documents. However, specific plans for ensuring the quality of the sample canister containing intrinsically radioactive powders were not documented.

Following exposure of the Lutetium Technetate sample in January 2012, the sample was not returned to the original radioactive material packaging.

The Lutetium Technetate sample canister containing radioactive and chemically hazardous material was marked "Lu" with a felt tipped pen, but markings did not indicate the intrinsically radioactive contents.

3.3.4 Core Function 4, Perform Work Safely

Readiness Run Cycle Reviews

LANSCE conducts a comprehensive "Run Cycle Readiness Review" every year prior to the resumption of instrument operations to determine if the experimental areas at the LANSCE User Facility are ready to receive "beam" from the LANSCE Linear Accelerator at the start of each run cycle. Various focus/functional areas are chosen for the review and detailed walk downs of flight paths and experimental areas at the Lujan Center and other LANSCE user facilities are conducted. These reviews are typically "shadowed" by LASO personnel.

The AIB reviewed the results of the last three run cycle readiness reviews from 2010 to 2012 and found that all three reviews assessed the same functional

areas, which included IWM implementation, radiation safety (with emphasis on sample handling), and human performance improvement (HPI). Lines of inquiry used to guide the run cycle reviews for HPI and radiation safety remained unchanged. Lines of inquiry for radiation safety focused on expected conditions of a sample after being exposed in the beam, and did not address atypical conditions of intrinsically radioactive material samples prior to beam exposure. With the exception of the most recent 2012 readiness run cycle review, lines of inquiry for IWM did not address flowdown of experimental safety reviews into work.

All three run cycle readiness reviews concluded radiation (sample) safety at the flight paths and experimental areas was well addressed, including FP-04. Concerns with radiation, chemical and equipment cabinet housekeeping were identified in the 2012 run cycle readiness review, particularly for small areas associated with ER-1 flight paths, including FP-04. Housekeeping concerns were also mentioned for radiation storage cabinets with samples and activated user equipment. All three run cycle readiness reviews concluded that the IWDs reviewed were well written and informative, including those for FP-04. Prior issues identified with IWDs focused on document clarity and updating.

The reviews did not place sufficient attention to flowdown of experimental safety controls into IWDs, nor atypical conditions of intrinsically radioactive, toxic, or internally contaminated samples prior to being placed into the beam.

Readiness run cycle review runs did not identify problems with radioactive material identification and control. Less than adequate control of radioactive samples was not identified and corrected through the run cycle readiness review process.

AIB Conclusion: Housekeeping and material control procedures were informal. Known deviations were normalized. (JON 8)

3.3.5 Core Function 5, Feedback and Improvement

The core function of feedback and improvement is implemented at multiple levels in a large complex organization, such as LANL. As described in LANL System Description (SD) 100, *Integrated Safety Management System Description Document* with embedded *10 CFR 851 Worker Safety and Health Program (SD100)* dated February 1, 2012, feedback and improvement occur continuously at all stages of work through three principle mechanisms: (1) issues management; (2) assessments; and (3) performance measurement. For evaluating performance in Core Function 5, the AIB considered relevant LANL independent assessments, Radiation Protection Observations (RPOs), management assessments, and Management Observation and Verifications (MOVs), which are also used by LANL managers to evaluate work as it is being done.

The AIB reviewed the results of Lujan Center MOV reports to determine if any issues were found that were similar to issues found during the event under

investigation. The AIB placed emphasis on radiation safety and work place practices observed by Lujan Center managers at the flight paths and experimental areas, especially FP-04. Eighty-three documented MOVs were conducted at the Lujan Center by LANSCE management from 6/25/2010 through 8/20/2012. Twelve MOVs were identified that were relevant to the event under investigation. The AIB's review of the MOVs of FP-04 found that management's focus was placed on housekeeping, user knowledge and understanding of operations and IWD/IWM implementation; and identification of human performance concerns. The MOVs did not identify any findings in IWM/IWD or radiation sample safety implementation. One MOV did identified two electrical safety issues, which were included as pre-start findings in the 2012 run cycle readiness review assessment.

Management did not place sufficient attention to flowdown of experimental safety controls into IWDs, nor atypical conditions of intrinsically radioactive, toxic, or internally contaminated samples prior to being placed into the beam.

One MOV was identified by the AIB that was similar to issues found with the event under investigation. The MOV conducted on February 9, 2012, covered ALARA practices at ER-2. It specifically addressed the handling of radioactive samples in the context of where they should be stored before and after beam irradiation, and how ALARA should be achieved. The MOV made the following observation and recommendations.

> For samples that start radioactive and whose activity appreciably exceeds that which is induced during a typical neutron beam irradiation, the following best practices were recommended: Draw specific attention to all involved concerning the atypical sample activity during pre-job briefings. Assign responsibility for samples that might increase ALARA concerns to a single person – especially if experiments involve handoff across several researchers and may last several days. Pay attention to real-time housekeeping and limit the use of radioactive sample cabinets to samples that have been in the beam or start radioactive. Move the sample to a location away from the computer to satisfy ALARA.

No findings or actions were cited in the MOV associated with the recommendations. The AIB requested and did not receive any additional evidence on formal management actions the related to this MOV.

Although management recognized some of the weaknesses and vulnerabilities in Lujan Center sample management practices, management did not take sufficient actions to fully address the concerns raised in this MOV.

The AIB reviewed RPOs from January 1, 2010 to present and found three instances where personnel had been identified as either loading or unloading radioactive samples without RCT coverage. In one case the transfer was completed in the glovebox while the remaining two RPOs indicate the samples were transferred in the work area without the use of the required glovebox. Information about specific corrective actions implemented following the incidents

have been requested, however, as of the time this report is being drafted specific information has only been provided for two of the RPOs.

RCT coverage had not been requested for the glovebox transfer prior to the time the RCT observed the work being conducted. The RCT took positive steps to ensure coverage was provided. A formal review of the incident identified a number of corrective actions to ensure RCT coverage would be requested for any work being conducted in the glovebox.

Corrective actions included revising the IWD and orientation checklist (to include the requirement for the RCT and provide greater clarity); performing worker orientations using the revised IWD (personnel were re-authorized upon completion); and posting a formal notice on the glovebox requiring an orientation prior to use (replacing a hand written notice). Additional recommendations included ensuring that communication and training methods addressed cultural and language barriers, that the PIC/supervisor consider observing the first time a worker uses the glovebox, and that the PIC/supervisor ensure the glovebox is only used for radioactive materials such as activated or potentially activated samples.

The evaluation of the glovebox incident and the corrective actions were appropriate and thorough in nature. Two items worth noting in the context of this investigation is the recognition of the issues associated with cultural and language barriers and the almost total focus on activated materials as compared to intrinsically radioactive samples.

Information about the two transfers completed outside the glovebox indicate that one involved the loading of a radioactive sample into a sample canister and the second involved the clean out of a Gas Cell containing uranium powder. Specific information on corrective actions implemented for the sample loading activity has not been provided at the time this report is being drafted. In the case of the uranium powder, the RPO indicates that no corrective actions were required since no contamination was released.

The determination that no corrective actions were required because there was no release of contamination reflected an inadequate evaluation of the issues involved in the incident. The opening of the sample outside the glovebox was a violation of requirements that needed to be addressed. Even though significant contamination was not released during the work activity, it could have been. The RPO provided an opportunity to identify weaknesses and implement corrective actions to ensure more serious incidents did not occur in the future.

Lessons learned and corrective actions for RPOs reviewed were not fully identified and implemented.

The AIB reviewed the results of the last three management assessments on 10 CFR 835 (referred to as *Radiation Assessment Program Triennial Assessments)*, and identified the triennial assessment conducted on November 15-19, 2010 as being relevant to the event under investigation. The *Management Assessment for 10 CFR 835 Program Triennial Assessment, Part 2 of 3*, dated January 28,

2011 assessed radiation program elements in the areas of: monitoring of individual and areas; radioactive contamination control, including control of material and equipment; and labeling, storing and receiving radioactive materials/items. Facilities and areas evaluated included Technical Areas 3-29, 3-66, 21, 48, 54 and TA-53, including the Lujan Center. The assessment was conducted over a three day period, and included LASO personnel as shadow assessors. The assessment identified three findings related to currency of radiation protection documents, survey performance of radioactive material tags and survey form documentation deficiencies. The assessment also identified six opportunities for improvement, one related to improper handling of a bag with potential radioactive waste.

However, the report did not identify any specific work observations observed, identify any IWDs of programmatic work activities reviewed, or specific work practices observed at the Lujan Center.

The scope of the assessment was broad; not sufficiently focused on observations of programmatic work; and not conducted at a sufficient depth to likely identify performance concerns at the Lujan Center similar to the event under this investigation.

The AIB also reviewed the results of the management assessments and independent assessments conducted in 2011 on LANLs implementation of IWM discussed in Section 3.3 of this report. The AIB's review of the results of the *Associate Director Experimental Physical Sciences PEP Verification Management Assessment Report*, dated 9/15/2010 found the review: (1) sampled IWDs, including Lujan FP-04-006 *General Neutron Scattering Experiments on HIPPO IWD*, (2) conducted several interviews of Lujan Center personnel not related to HIPPO; and (3) conducted two work observations unrelated to the personnel interviewed and IWDs reviewed. The review did not identify any experimental safety reviews reviewed as part of work observations, and did not identify any findings requiring corrective action. It identified 75 opportunities for improvements, none related to control of experimental samples, and concluded that the directorate is meeting the requirements of IWM process.

Because the assessment was not conducted in a performance-based manner, it resulted in a missed opportunity to identify performance concerns at FP-04 similar to the event under this investigation.

The AIB also reviewed of the results of the *Independent Effectiveness Evaluation Report: Moderate Hazard R&D Safety Improvements at LANL*, conducted on January 10-21, 2011. The review included independent assessments of directorates having responsibility for programmatic or R&D activities, including of the Lujan Center; a sample of IWDs; personnel interviews; and several work observations. None of the work observations involved ER-1 or ER-2. The evaluation report did not identify any experimental safety reviews reviewed as part of work observations, and did not identify any findings on IWM implementation.

Although the assessment included more performance-based elements, the scope of this review was not sufficiently broad to identify performance concerns at the Lujan Center similar to the event under this investigation.

Finally, the AIB reviewed the results of the *Independent ISM/ISM Assessment of R&D and Programmatic Work*, conducted July 21 to August 22, 2011. The review included a representative sample of LANSCE programmatic activities, including the Lujan Center. The review also included a sample of work activities, review of associated IWDs and safety reviews, interviews of Lujan personnel and observation of the work activity related to the IWDs. The review focused on flight paths 5, 14, & 9, and radiation/nanomaterial glovebox operations. This assessment also included LASO personnel as shadow assessors, and did not identify any findings.

Although this assessment included appropriate performance-based elements, such as evaluation of flowdown of experimental safety reviews into IWDs, the scope of this review was not sufficiently broad and resulted in a missed opportunity to identify performance concerns at the Lujan Center similar to the event under this investigation.

LANL's institutional oversight processes were not conducted at a sufficient depth and breadth to detect weaknesses with radioactive material identification and control.

AIB Conclusion: LANS oversight roles and responsibilities were not implemented in a manner that was likely to identify and correct activity-specific deviations from established LANL safety and health programs and procedures by the HIPPO team. (JON 14)

During this investigation the AIB reviewed the Type B Investigation of the Americium 241 contamination at the Sigma Facility to determine if any issues were found that had similar characteristics to this event under investigation. The AIB believes the following two findings and concerns are relevant to this accident.

- "NMT's feedback and improvement processes were not effective in identifying or correcting the failure to adhere to procedures and requirements for surveying and labeling packages being prepared for shipment;"
- "that the one MOV identified above was a direct indication of the existence of conditions identified in this accident investigation"

Corrective actions from similar events were not implemented at Lujan Center. Positive control of radioactive materials was not established.

AIB Conclusion: Lessons learned from the 2005 Americium contamination event at the Sigma facility were not effectively implemented at Lujan Center. (JON 1)

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4.0 Human Performance Improvement Analysis

4.1 Error Prone Conditions

The goal of Human Performance Improvement (HPI) is to facilitate the development of a facility structure that recognizes human attributes and develops defenses that proactively manage human error and optimize the performance of individuals, leaders, and the organization**.**

Although the Board was not looking at HPI from the perspective of program implementation, the Board evaluated HPI considerations to the extent that they played a part in this accident.

One tool employed in HPI evaluations is to identify those situations and environments that result in error prone conditions. Error prone conditions are those in which errors are likely to be made which could result in an accident or near miss. Error prone conditions may involve latent organizational weaknesses that, when combined with a specific worker incident or action, degrade the barriers to accidents, making accidents more likely.

The AIB identified numerous error prone conditions that made this type of accident so likely as to be inevitable. These conditions are captured in the Contributing Causes and represented in the Judgments of Need for this report. Specifically, Contributing Causes numbered 1, 2, 3, 4, 6, 7, 8, 9, 11, 13, 14, 16a, 18, 19, 20, 23, and 24 represent particularly error prone situations, although some of the causes and conclusions not represented in this list could also be argued to represent error prone conditions. Eleven of the fourteen Judgments of Need (JONs 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, and 12) are intended to eliminate or mitigate the existing error prone conditions at the Lujan Center.

An aspect of the environment at the Lujan Center that deserves special focus is the high concentration of personnel from diverse and multi-cultural backgrounds. Cultural differences, including proficiency in the English language but (perhaps more importantly) differences in normative behavior when responding to authority, may have helped to create an error prone condition. For example, expectations on what is expected when answering a seemingly simple question such as “Do you understand?” vary between cultures. There were indications that such cultural differences complicated the operations of FP-04, were not fully understood by those involved, and may have played a role in the accident.

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5.0 CAUSAL FACTORS

5.1 Direct Cause

An individual opened an uncontrolled sample canister containing hazardous Lutetium Technetate powder, resulting in widespread contamination.

5.2 Root Cause

Lujan Center management did not ensure development and implementation of sufficiently rigorous formality of operations and quality assurance programs for the handling of radioactive and toxic samples.

5.3 Contributing Causes

1. The amount of radioactive material in each sample was below levels that had to be tracked to ensure compliance with contractual facility safety requirements. It was also below the levels specified in 10 CFR 835 specifically requiring tracking and labeling, and below levels expected to result in health hazards if released.
2. The Lujan Center has not implemented engineering and administrative controls that ensure intrinsically radioactive samples are identified and controlled in a manner consistent with ALARA (As Low as Reasonably Achievable) requirements.
3. Both Safety Review Committee Appraisals noted that the sample canisters would contain Tc-99 compounds, but failed to positively address the possibility of an uncontrolled release of the material. They explicitly assumed that the canisters would not be opened in the facility, and implicitly assumed that robust seals on the canisters would provide containment while at the Lujan Center. Beyond previously existing work controls, no additional controls were established or required to protect these assumptions.
4. Existing practices relied upon administrative controls when simple engineered measures could have protected safety review assumptions for the Technetate samples.
5. Requirements found in IWD LUJAN-FP-04-006, *General Neutron Scattering Experiments* for additional work controls when working with radioactive or hazardous chemical materials were not met.
6. Sample canisters assembled at UNLV were not marked to indicate that they contained Technetium. No markings or features on the Lutetium Technetate canister (prior to its use for Tungsten) indicated that the contents were intrinsically radioactive or hazardous, that the canister was internally contaminated, or that it should be controlled for contamination.
7. The sample canisters were not designed to provide a highly visible, uniform, tamper resistant, positive indication that they contained intrinsically radioactive or hazardous material and were not to be opened.

8. The UNLV sample canisters were sealed using only three (of six possible) screws.
9. No formal engineering specifications were provided to UNLV on how the sample canister must be assembled, marked and sealed.
10. No engineering review was conducted to ensure that the design of the sample canister was appropriate for containment of radioactive material throughout the intended experimental environments, particularly with only three screws used to attach the cap.
11. Written procedures did not require qualified canisters; unambiguous and documented chain of custody record; positive identification of canisters; or protection of assumptions in the safety review for the Technetate samples.
12. Neither the RCTs who surveyed the shipment of sample canisters from UNLV upon receipt, IS(PIC), or PI-1 questioned the use of only three screws to seal the sample canisters, which contained highly dispersible, intrinsically radioactive powders.
13. Clear roles and responsibilities were not established to ensure consistent handling of samples.
14. A formal tracking system was not implemented to document handling of samples and sample canisters throughout their lifetime, and that would enable positive accountability.
    a. Sample canisters do not have unambiguous features, such as serial numbers stamped into collars or caps, to enable consistent tracking. Instead, information is written on the canister tubes and/or on the cap using indelible markers. Legibility of these labels sometimes makes positive identification difficult.
    b. There is no systematic naming protocol to ensure a correlation between the FP run logs and the RCT logs.
    c. Inventories or sign-in/sign-out logs are not maintained for hazardous or intrinsically radioactive materials stored in radioactive material storage cabinets.
    d. When a sample canister is to be sent to the RCT station, the practice is to put it into a plastic bag; a label is prepared and put in or on the bag. However, a copy of the label is not retained at the Flight Path to indicate when (or if) the sample went to the RCT station.
    e. If created, the RCT label may identify the originating Flight Path, user, and sample description, but in practice the information is sometimes incomplete, difficult to decipher, inconsistent, or illegible.
    f. Sample canisters are not always sent to the RCT station following irradiation. If sent, they are placed into a common in-box. RCT hours are limited, and an RCT may not be present to check to ensure that paperwork is properly filled out when samples are dropped off.

g. If a sample had been sent to the RCT station for survey, and had intrinsically radioactive material inside of it, with low energy radiation that would not penetrate the Vanadium can, no positive and systematic means was established to ensure the RCT or others would know that the contents were radioactive.

h. There is no log entry made when samples are picked up from the RCT station, so that there is no positive exchange of responsibility for a sample canister.

i. There was no method employed that would enable an individual to positively determine the contents of a sample canister, short of chemical analysis, if it became separated from its paperwork.

15. Sample canisters are re-used; a sample canister used on one machine could be disassembled and its parts used to build a sample canister for a different machine.

16. FP-04 personnel sometimes opened sample canisters for re-use at locations other than the glove box when they had no concerns regarding toxicity or intrinsic radioactivity, without RCT support.

    a. Existing processes for sample and sample canister management were not consistently enforced or followed.

    b. According to Radiation Protection Observations, there have been at least three instances in the last two years that noted workers were loading or unloading radioactive samples from sample canisters without requesting RCT coverage; testimony confirmed that sample canisters are inappropriately opened outside of glove boxes.

    c. Lessons learned and corrective actions were not effectively identified and implemented; known deviations were normalized.

17. Although the plan was for the samples to be returned to UNLV, neither the UNLV nor PI-1 expressed active interest in getting the Lutetium Technetate sample returned. Consequently, no one looked for the sample until the week of the contamination event.

18. There were numerous closed, used sample canisters found on the sample desk, inside the sample desk, and in offices, with vague and often illegible markings on them to indicate their contents, increasing the chances of mishandling.

19. Lujan Center management did not ensure an effective person-in-charge was responsible for conducting the experiment on the Lutetium Technetate sample in January 2012.

    a. It was unclear who was serving as person-in-charge for the experiment.

    b. Management did not ensure competence commensurate with responsibility for performing the person-in-charge task.

c. A turnover of responsibility did not include hazards and other information contained in the Research Proposal and associated Safety Review Committee Appraisal. FP-04 S1, who ran the experiment, did not know the radiological hazards associated with Tc-99.

20. The Lutetium Technetate sample canister was not placed back into the original labeled zip lock bag and container to maintain knowledge of process; may have been placed in a new zip lock bag with a Lujan label indicating the sample was to be surveyed by a RCT.
21. Equipment or instrumentation capable of effectively detecting Tc-99 in the workplace (such as a hand monitor), to prevent an uncontrolled spread of contamination, was not present in ER-1, where the TC-99 samples were stored and handled.
22. There is no requirement for personnel leaving the ER-1 to exit through a personnel contamination monitor or to be surveyed for contamination.
23. Housekeeping, sample control, and material control procedures were informal; deviations were normalized.
24. The personnel assigned to FP-04 are multi-cultural, with diverse backgrounds, expectations, and socio-economical approaches to authority. These differences have not been systematically explored and addressed to ensure effective workplace management.
25. Lessons learned from the 2005 Americium contamination event at the Sigma facility were not effectively implemented at Lujan Center.
26. Reviews conducted to confirm implementation of 10 CFR 835.1102 did not identify requirements for controlling samples containing radioactive material below 10 CFR 835 Appendix E values that could exceed surface contamination level values in 10 CFR 835 Appendix D.
27. LASO oversight roles and responsibilities were so broad that LASO did not identify activity-specific deviations from established LANL safety and health programs and procedures by the HIPPO team.
28. LANS oversight roles and responsibilities were not implemented in a manner that was likely to identify and correct activity-specific deviations from established LANL safety and health programs and procedures by the FP-04 team.
29. RCT and Radiation Protection coverage is limited; effective implementation of radiation protection requirements relies heavily on the workers.

6.0 CONCLUSIONS AND JUDGMENTS OF NEED

JONs are the managerial controls and safety measures determined by the AIB to be necessary to prevent or minimize the probability or severity of a recurrence. These JONs are linked directly to the causal factors, which are derived from facts and analyses and form the basis for corrective action plans and which are the responsibility of line management. Table 6-1, contains the AIB's conclusions and the JONs.

Table 6-1. Conclusions and Judgments of Need

CONCLUSIONS	JUDGMENTS OF NEED
1. Lessons learned from the 2005 Americium contamination event at the Sigma facility were not effectively implemented at Lujan Center. (JON 1) 2. The Lujan Center has not effectively implemented the requirements of the FRPR. (JON 1) 3. The current process of only surveying the exterior of the sample vial prior to preparing the sample for disposition coupled with the lack of an effective sample control process does not ensure that radioactive samples are controlled. (JON 1) 4. Equipment or instrumentation capable of effectively detecting contamination (such as a hand monitor)was not present in the area where the Tc-99 samples were stored and handled because it was not believed that a contamination event was credible, but rigorous controls were not in place to preclude the contamination event. (JON 1)	JON 1. Revise Lujan Center policies and procedures to ensure risks associated with samples containing intrinsically radioactive and hazardous materials are fully identified, evaluated, documented and controlled. (1,2,3,4)
5. No markings on sample canisters clearly indicate if contents are intrinsically radioactive, toxic, internally contaminated, or should be controlled for contamination. (JON 2) 6. A systematic process is not employed to ensure RCTs are aware of internal hazards that may not be externally obvious prior to surveying for free release. (JON 2)	JON 2. Establish processes by which risks are effectively communicated to workers by readily identifiable features on the sample canisters and in routine pre-job and safety briefings. (5,6)

7. The loss of containment leading to widespread contamination occurred when the Lutetium Technetate sample canister was opened. Contamination evidence, the highly communicable nature of the contamination, and its rapid migration make it implausible that the Lutetium Technetate sample canister was opened earlier than August 20, 2012. (JON 3) 8. Existing practices relied upon administrative controls when simple engineered measures could have protected safety review assumptions for the Technetate samples. (JON 3) 9. The Lujan Center has not implemented engineering and administrative controls to ensure intrinsically radioactive samples are identified and controlled in a manner consistent with10 CFR 835 “Occupational Radiation Protection,” including ALARA (As Low as Reasonably Achievable) requirements identified in Sections 101(c) and 1001 (a) and (b). See also DOE G 441.1-1C “Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection” Section 12.2 General Requirements for Posting and Labeling for Radiological Control. (JON 3)	JON 3. Establish effective engineering and administrative controls to ensure intrinsically radioactive samples are identified and controlled. (7,8,9)

10. LASO oversight roles and responsibilities as defined by the Line Oversight/Contractor Assurance System (LO/CAS) and Facility Representative programs were so broad that LASO did not identify activity-specific deviations from established LANL safety and health programs and procedures by the High-Pressure Preferred Orientation Neutron Diffractometer (HIPPO) team. (JON 4) 11. Federal oversight of LANSCE operations, particularly operations in the Lujan Center, has been essentially unchanged in recent years. Changes in Federal oversight practices were not a contributor to this event. (JON 4)	JON 4. LASO oversight activities need to periodically sample work practices at the experimental and activity level. (10)(11)
12. Control of the radioactive material was lost when the Lutetium Technetate sample canister was removed from the displex. (JON 5) 13. There is no systematic sample management process that positively tracks samples and sample canisters throughout their life cycle within the Lujan Center. sample canisters do not have unambiguous features, such as serial numbers stamped into collars or caps, to enable consistent tracking. Instead, information is written on the canister tubes and/or on the cap using indelible markers. Legibility of these labels sometimes makes positive identification difficult. Existing record keeping for control of samples and canisters does not enable accountability. (JON 5)	JON 5. Implement a systematic sample management process that positively tracks samples and sample canisters throughout their life cycle within the Lujan Center.(12.13)

14. There are no clear roles and responsibilities established to ensure safe and positive control of samples. (JON 6) 15. Lujan Center management did not make it clear who was the person-in-charge of conducting the experiment on the Lutetium Technetate sample in January 2012, or that the person-in-charge had competence commensurate with responsibility for performing the assigned task, or that person-in-charge responsibilities were effectively performed. A turnover of responsibility did not include a briefing or review of the Research Proposal and associated Safety Review Committee Appraisal that contained technical information regarding the radioactive and chemical characteristics of Lutetium Technetate. (JON 6)	JON 6. Establish clear roles and responsibilities for controlling samples and participating in experiments. (14, 15)
16. Inventories or sign-in/sign-out logs are not maintained for radioactive material storage cabinets. (JON 7)	JON 7. Establish formal processes for managing material in radiological material storage cabinets. (16)
17. Existing processes for sample and sample canister management were not consistently enforced or followed. Known deviations were normalized. (JON 8) 18. Housekeeping and material control procedures were informal. Known deviations were normalized. (JON 8)	JON 8. Ensure personnel understand and comply with management processes. (17, 18)
19. The personnel assigned to FP-04 are multi-cultural, with diverse backgrounds, expectations, and socio-economical approaches to authority. These differences have not been systematically explored and addressed to ensure effective workplace management. (JON 9)	JON 9. Implement policy and practices to address the multi-cultural environment to ensure effective work place management. (19)

20. Written procedures did not require qualified canisters; unambiguous and documented chain of custody record; positive identification of canisters; or, protection of assumptions in the safety review for the Technetate samples. (JON 10) 21. Controls identified to address the radiological hazards presented by the Technetate samples did not adequately ensure containment was maintained to prevent the spread of contamination; effective Quality Assurance requirements for sample canister preparation and sealing were not specified. (JON 10)	JON 10. Establish quality control requirements that ensure containment of intrinsically radioactive material and enable chain of custody management. (20, 21)
22. The scope of work was significantly changed without formal review and approval, and the experiments were conducted differently than proposed. The three sample canisters containing Technetate compounds were assembled based on the understanding that the samples would be examined at ambient temperature and pressure, but were subjected to temperatures as low as 20 Kelvin. While the affect of extremely low temperatures on the sample canisters was not evaluated during this investigation, the significant change in the experimental conditions without a formal change control process demonstrated a weakness in implementation of ISMS for Lujan Center operations. (JON 11)	JON 11. Revise work control process to ensure that work scope remains consistent with reviewed and approved proposals. (22)
23. Additional work controls for working with radioactive or hazardous chemical materials were not developed as required by IWD LUJAN-FP-04-006 General Neutron Scattering Experiments on HIPPO (FP-04). (JON 12)	JON 12. Ensure that personnel understand that assumptions and preconditions must be explicitly protected with controls and cannot be used to dismiss hazards from safety reviews. (23)

24. Contamination and contents of trash cans have not yielded sufficient activity to account for the full Lutetium Technetate sample; glass bottles are used to hold samples emptied from sample canisters. A glass bottle containing Lutetium Technetate has not been located. (JON 13)	JON 13. Conduct a thorough investigation of material in ER-1, ER-2, offices and the Chemistry Lab to ensure containers do not contain the remnants of the Lutetium Technetate sample. (24)
25. LANS oversight roles and responsibilities were not implemented in a manner that was likely to identify and correct activity-specific deviations from established LANL safety and health programs and procedures by the HIPPO team. (JON 14)	JON 14. LANS oversight activities at the Area Manager level and above need to periodically sample work practices at the experimental and activity level. (25)

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7.0 LIST OF AIB MEMBERS, ADVISORS AND STAFF

AIB Members

Chairperson	Don Nichols, Associate Administrator for Safety & Health (NA-SH-1), National Nuclear Security Administration
Vice Chairperson	Marcus Hayes, Occupational Safety and Health Manager, NA-SH-40, National Nuclear Security Administration,
Member	Milton Chilton, Health Physicist, NA-SH-70 National Nuclear Security Administration,
Member	Robert Freeman, Nuclear Engineer, HS-45
Member	Robert Murphy, Health Physicist, Los Alamos Site Office
Advisor	Robert Seal, Contractor, MAS Consultants
LANS Point of Contact	Kurt F. Schoenberg Los Alamos National Security, LLC
Office of Science Observer	John Blaikie, Health Physicist, SC-31.1
Administrative Support	LaLisha Mcknight, Contractor, DRA

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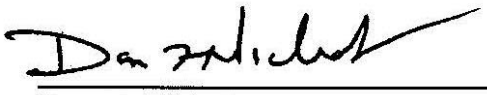
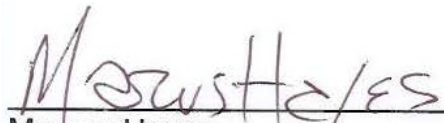
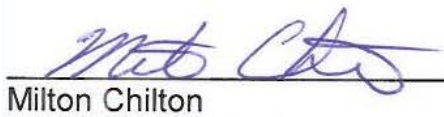
8.0 SIGNATURES



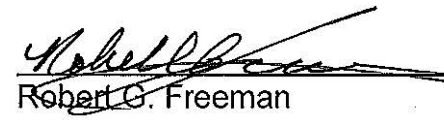
Don F. Nichols
NNSA Board Chairperson
Associate Administrator for Safety and Health



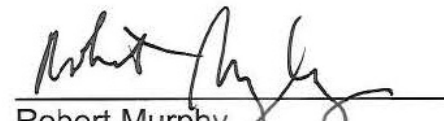
Marcus Hayes
NNSA Board Vice Chairperson
NA-SH-40



Milton Chilton
NNSA Board Member
NA-SH-70



Robert G. Freeman
NNSA Board Member
HS-40



Robert Murphy
NNSA Board Member
Los Alamos Site Office

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APPENDIX A - APPOINTMENT OF FEDERAL ACCIDENT INVESIGATION BOARD

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Department of Energy
National Nuclear Security Administration
Washington DC 20585

August 29, 2012

OFFICE OF THE ADMINISTRATOR

MEMORANDUM FOR DON F. NICHOLS
ASSOCIATE ADMINISTRATOR FOR SAFETY AND HEALTH

FROM: THOMAS P. D'AGOSTINO
ADMINISTRATOR

SUBJECT: Accident Investigation into Contamination at the Los Alamos Neutron Science Center on or about August 21, 2012

In accordance with the requirements of Department of Energy (DOE) Order 225.12B, *Accident Investigations*, I am authorizing you to chair and establish an Accident Investigation Board (AIB) to investigate the contamination at the Los Alamos Neutron Science Center (LANSCE), on or about August 21, 2012. Based on your training in accident investigations and extensive review experience as Chief of Defense Nuclear Safety, you are appointed as the AIB Chairperson. Your Vice Chairperson will be Mr. Marcus Hayes, who has significant experience in leading accident investigations. You are authorized to compose the AIB with membership at your discretion. All members of the AIB, in accordance with the requirements of DOE Order 225.1B, are released from their normal regular duty assignment to serve on the AIB during the period the AIB is convened.

The scope of the AIB's investigation is to include, but not be limited to, identifying all relevant facts, determining direct, contributing, and root causes of the event, developing conclusions, and determining the judgments of need to prevent recurrence. Also, the scope of the investigation is to include the Department of Energy's (DOE) programs and oversight activities.

The Board is expected to provide my office with periodic reports on the status of the investigation. Please submit draft copies of the factual portion of the investigation report to Michael K. Lempke (NA-00), the contractor, and me for factual accuracy review prior to finalization. The final report should be provided to me no later than 30 days from the date of this memorandum. Discussion of the investigation and copies of the draft report will be controlled until I authorize release of the final report.

cc: N. Miller, NA-2
M. Lempke, NA-00
K. Smith, Manager, Los Alamos Site Office
G. Podonsky, HSS

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

AUGUST 29, 2012

MEMORANDUM FOR DISTRIBUTION

FROM: DON F. NICHOLS
ASSOCIATE ADMINISTRATOR FOR SAFETY AND HEALTH

REFERENCE: MEMORANDUM FROM THOMAS P. D'AGOSTINO AUTHORIZING CONVENTION OF AN ACCIDENT INVESTIGATION BOARD, DATED AUGUST 29, 2012

SUBJECT: Accident Investigation into Contamination at the Los Alamos Neutron Science Center on/about August 21, 2012

In accordance with the requirements of Department of Energy (DOE) Order 225.12B, Accident Investigations, and the referenced memorandum, attached, I am establishing an Accident Investigation Board (AIB) to investigate the contamination at the at the Los Alamos Neutron Science Center (LANSCE), on/about August 21, 2012. Membership on the Board is as listed below.

- Don Nichols – Chairperson, Associate Administrator for Safety and Health (NA-SH)
- Marcus Hayes – Vice Chairperson (NA-SH-40)
- Robert Murphy – Board Member (NA-00/Los Alamos Site Office)
- Milton Chilton – Board Member (NA-SH-70)
- Robert G. Freeman – Board Member (HS-45)
- Kurt F. Schoenberg – Los Alamos National Security, LLC (LANS Point of Contact)
- Robert Seal – Consultant Advisor/Coordinator (Contractor, MAS Consultants)
- LaLissa Mcknight – Administrative Support (Contractor, DRA)

All members of the AIB, in accordance with the requirements of DOE Order 225.1B, are released from their normal regular duty assignment to serve on the AIB during the period the AIB is convened.

The scope of the AIB's investigation is to include, but not be limited to, identifying all relevant facts, determining direct, contributing, and root causes of the event, developing conclusions, and determining the judgments of need to prevent recurrence. Also, the scope of the investigation is to include DOE's programs and oversight activities.

The Board is expected to provide the Administrator with periodic reports on the status of the investigation. Draft copies of the factual portion of the investigation report are to be submitted

to NA-1, NA-00, and the contractor for factual accuracy review prior to finalization. The final report should be completed no later than 30 days from the date of this memorandum. Discussion of the investigation and copies of the draft report will be controlled until NA-1 authorizes release of the final report.

The onsite portion of the review will be September 4-18, 2012. Review team members should plan to work Saturdays. Plan to work 10 hour weekdays, with 8 hour days on Saturday. We will begin at 1:00pm on September 4, 2012, meeting in Guaje room at the LASO Building, TA-3, Bldg 1410. We may conclude the on-site portion early if we complete our work, but plan to stay for the duration.

ATTACHMENT

APPENDIX B - BARRIER ANALYSIS

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Table B-1. Barrier Analysis

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
Performance of Principle Investigator (PI-1) responsibilities during preparation of Research Proposal 201111048 for examination of Lutetium Technetate sample.	Failed	PI-1 did not prepare the work control document (IWD or RWP) required to be used in addition to IWD LUJAN-FP-04-006 for handling the radioactive and hazardous Lutetium Technetate sample. PI-1 did not ensure the hazards associated with the Lutetium Technetate sample were communicated to the PIC. The Research Proposal did not indicate the Lutetium Technetate sample would be examined in the displex and did not specify a minimum temperature in Kelvin. This was a change from the original proposal which specified the samples would be examined at ambient temperature and pressure.	The Lutetium Technetate sample was not identified and controlled as a hazardous sample during exposure, and became indistinguishable after being comingled with other samples following exposure. The sample was assembled and loaded assuming it would be examined at ambient temperature and pressure, and it is not known if exposure of the sample under a	CF3 CF4 GP2 GP6 CF1 CF2 GP6

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
			vacuum at 20 degrees Kelvin affected structural or containment integrity.	
Safety Review Committee Appraisal for Proposal 20111048	Failed	Did not identify controls to ensure two key assumptions were protected. (assumption 1: Sample canisters will not be opened; assumption 2: confinement function of the canisters must be assured)	Opening the sample canisters was the direct cause of the accident. The sample canisters did not remain unopened and was not controlled as a carcinogenic and radioactive material in accordance with the requirements in the appraisal.	CF2 CF3
IWD LUJAN-FP-04-006 *General Neutron Scattering Experiments on HIPPO (FP-04)*	Implementation failed	Specified that radioactive materials required additional work controls.	Lujan personnel did not follow the IWD; controls did not reflect the intrinsic nature of the radioactive material, resulting in loss of containment and subsequent contamination.	CF3

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
Integrated Work Management, P 300	Implementation failed	Lujan personnel did not consider the Lutetium Technetate sample "new work" and therefore did not require a walk down and pre-job briefing.	The sample was not controlled as being radioactive material.	CF1
LANSCE Chemical Hygiene Plan Lujan Center TA 53	Failed	CHP relied on the "user" to identify that the material was toxic and carcinogenic, but since the sample was not to be opened, identification was not considered necessary.	The sample was not controlled as being toxic and carcinogenic material.	CF2
Implementing Formality of Operations, P 315-2	Failed	Lujan Center Log keeping (including run logs and RCT logs) • did not result in a positive tracking or chain of custody for hazardous samples; and, • did not provide an accurate history of key facility events. Lujan Center Operations Organization and Administration did not establish and enforce clear operations policies for hazardous or intrinsically	Inadequate log keeping aggravated loss of control. Rather than ensuring accurate tracking of the sample, the record keeping system obscured the loss and made recreating the movement of the sample through the facility impossible. Inadequate identification of the sample as a	GP2 GP3 GP7 CF4

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
		radioactive samples; responsibilities were not clearly documented and understood.	hazardous material likely contributed to the loss of control. Although removal of samples from canisters was required to be performed in a glove box with RCT coverage, practice was to not use the glove box or RCT support if the technician believed no hazard existed. This practice directly resulted in the opening of the sample canisters, resulting in contamination. Lack of clear roles and responsibilities and processes led to confusion over who should take the Tc99	

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
			sample to the RCT station after irradiation, contributing to loss of control.	
Performance of Person in Charge (PIC) responsibilities during January 2012 Exposure of the Lutetium Technetate sample.	Failed	The PIC was not aware of the radiological and chemical hazards associated with the Lutetium Technetate sample, and did not ensure the personnel involved in the work were familiar with the hazards and hazard controls for the work, and did not lead a pre-job briefing with participating workers.	The Lutetium Technetate sample was not identified and controlled as a hazardous sample during exposure, and became indistinguishable after being comingled with other samples following exposure.	CF1 CF2 CF3 CF4 GP1 GP2 GP3 GP6
10 CFR 835.1102 (a and b)	Implementation failed	Safety Reviews implementing the CFR did not require the sample to be controlled as radioactive material. Effective detection equipment or instrumentation was not present to detect and prevent spread of contamination.	Allowed the radioactive material to be present in the facility with no radiological markings or control in a container with no known pedigree. Once material was spilled, it was not controlled and	CF2 CF3 CF4 CF5 GP6

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
			contamination spread. Lujan did not fully implement feedback from Sigma event.	
Los Alamos National Laboratory Radiation Protection Program P121	Failed	Did not require the canisters to be controlled as radioactive material once the RCT surveyed the canisters and cleared it for release. AND Did not require the canisters with internal contamination to be physically and visible identifiable.	Allowed dispersible radioactive material to be present in the facility with no radiological markings or control.	CF3 GP6
TA-53 Facility Radiation Protection Requirements LANCE-ST-121-003.R31	Failed	Did not require the canisters to be controlled as radioactive material once the RCT surveyed the canisters and cleared it for release. AND Did not require the canisters with internal contamination to be physically and visible identifiable.	Allowed dispersible radioactive material to be present in the facility with no radiological markings or control.	CF3 GP6

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
Marking of Irradiated Sample Canisters as Radioactive Material	Failed	Did not exist	The person who opened the Vanadium container was not alerted that radioactive material was involved	CF3 GP6
Radiological Controls Surveys (Periodic general area surveys)	Ineffective **(This is not a barrier for this accident)**	Accident occurred after the last periodic (quarterly) survey was completed	No effect	
Material Storage / Tracking	Failed	Tracking the sample was not required	Resulted in loss of control of sample.	CF3 GP2 GP3 GP6
LANL Quality Assurance Program, SD 330	Failed	Work was not conducted in accordance with written procedures, plans, and other work documents. Written procedures did not require: • qualified canisters for confinement of hazardous or intrinsically radioactive materials; • an unambiguous, documented chain of custody record for hazardous or intrinsically radioactive	The Vanadium container was opened rather than returned unopened to UNLV; did not confine its contents.	CF3 CF5 GP1 GP5 GP6

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
		materials; • positive identification of canisters having hazardous or intrinsically radioactive contents; • assumptions in the safety review to be protected with controls; or, • a hierarchy of controls that would implement simple engineered controls over administrative controls to protect those assumptions.		
Effective verbal and written communication of hazards, controls, processes and performance expectations between management and employees	Failed	Communication approaches and training were not tailored to reflect the multi-cultural environment; cross-cultural norms; and cultural differences in responding to and communicating with authority figures.	Understanding and acceptance of hazards and controls, processes and performance expectations, was not assured.	GP2 GP3 GP6
DOE Oversight	Ineffective	LASO personnel did not effectively sample workplaces and work practices.	Did not identify and ensure correction of less than adequate control of radioactive samples.	CF3 CF4 GP2 GP4 GP7

Hazard: Radioactive Contamination		Target: Employees and Building Areas		
What were the barriers?	**How did barrier perform?**	**Why did barrier fail?**	**How did the barrier affect the accident?**	**Context: HPI/ISM**
LANL Oversight Including Contractor Assurance System and Readiness Reviews	Ineffective	Numerous assessments did not identify problem with radioactive material identification and control	Less than adequate control of radioactive samples was not identified and corrected.	CF4 CF5 GP1 GP7
Feedback and Improvement Process	Failed	Corrective actions from similar events were not implemented at LANSCE	Positive control of radioactive materials not established.	CF5
Sample Canister (Physical barrier)	Failed	No Engineering review to ensure that the design was appropriate for the purpose and intended environments. Was not designed to provide a highly visible, uniform, tamper resistant, positive indication that it contained intrinsically radioactive or hazardous materials.	Radioactive material was released to the work area when the container was opened without the individual knowing that it was not to be opened.	CF2 CF3 CF4 GP6

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APPENDIX C - CHANGE ANALYSIS

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Table C-1. Change Analysis

Accident Situation	Prior, Ideal or Accident-Free Situation	Difference	Evaluation of Effect
Safety Review Committee only identified an assumption that the sample canisters containing Lutetium Technetate was not to be opened.	Safety Review Committee should have identified a requirement that the sample canisters containing Lutetium Technetate was not to be opened and required positive controls to prevent opening.	Positive measures to preclude opening were not established.	The sample canisters containing Lutetium Technetate was opened and containment was lost.
Comment included in the Safety Review Committee Appraisal that the Technetium -99 (Tc-99) radiation will not penetrate the sample canisters wall was not incorporated into the work control process. (Most radioactive samples on FP-04 canisters be detected by RCT surveys.)	Comment included in the Safety Review Committee Appraisal that the Tc-99 radiation will not penetrate the sample canisters wall should have been incorporated into the work control process.	An opportunity was missed to establish precautions for handling radioactive material that could not be measured with standard survey instruments. Researchers who handled the sample were unaware of the internal intrinsically radioactive material.	Loss of knowledge may have contributed to loss of control.

Accident Situation	Prior, Ideal or Accident-Free Situation	Difference	Evaluation of Effect
Chemical hazard included in the Safety Review Committee Appraisal that the sample was carcinogenic and toxic was not recognized and was not incorporated into the work control process.	Chemical hazard included in the Safety Review Committee Appraisal that the sample was carcinogenic and toxic, should have been recognized and incorporated into the work control process.	Opportunity was lost to establish precautions for handling hazardous material. Researchers who handled the sample were unaware of the hazard.	Loss of knowledge may have contributed to loss of control.
PI1 loaded sample onto displex then left and was not present for the run, neither the IS (PIC) nor the APIC were present for the run. FP-04 S1 & FP-04 S2 coordinated exposure of the Lutetium Technetate sample; did not have knowledge of the sample material, and were not involved in developing work control documents.	PI1 and IS (PIC) coordinated exposure of the $Pr_2Tc_2O_7$ and $Nd_2Tc_2O_7$ samples with expert knowledge of the sample material hazards and assumptions and were involved in developing work control documents.	FP-04 S1 & FP-04 S2 were not aware of specific safety documentation associated with the Lutetium Technetate sample.	Loss of process knowledge.
RCT coverage was not requested for the Lutetium Technetate sample.	RCT coverage was requested and provided.	Opportunity was lost to control as intrinsically radioactive material.	RCT coverage would have reduced likelihood of loss of control.

Accident Situation	Prior, Ideal or Accident-Free Situation	Difference	Evaluation of Effect
PI1 with knowledge of the sample material was not available to coordinate and be personally involved in exposure of the Lutetium Technetate sample.	PI1 with knowledge of the sample material coordinated and was personally involved in exposure of all three Tc_2O_7 samples.	The persons conducting the experiment were not aware of the characteristics of the sample material and the safety assumptions associated with it.	Following exposure to the beam the Lutetium Technetate sample, control of the sample as intrinsically radioactive was lost.
Following exposure of Lutetium Technetate sample in January 2012, the sample was not returned to original radioactive material packaging.	Following exposure of the $Pr_2Tc_2O_7$ and $Nd_2Tc_2O_7$ samples in November 2010, the samples were returned to original radioactive material packaging.	Following exposure the Lutetium Technetate sample was not identified or controlled as intrinsically radioactive material.	Following exposure to the beam the Lutetium Technetate sample, control of the sample as intrinsically radioactive was lost.
The Lutetium Technetate sample canisters contained radioactive and chemically hazardous material was only marked “Lu” with a felt tipped pen on the collar.	Each sample canisters containing radioactive or hazardous material would be clearly marked to indicate the hazard, contents, and user.	The “Lu” marking did not provide sufficient information to allow employees to effectively track and recognize the hazards associated with the Lutetium Technetate sample.	Following exposure to the beam the Lutetium Technetate sample, control of the sample as intrinsically radioactive was lost.
No formal process in place for unambiguously identifying assembled sample canisters.	A formal process would be in place to ensure a unique identifier was assigned and affixed to each assembled sample canisters to allow identification and characterization of the sample material.	If had they done that, each assembled canisters would have an identifier to allow identification of the sample material. Personnel handling the Lutetium Technetate sample canisters could have knowledge of the contents.	Workers were unable to identify the contents and any special precautions prior to opening an assembled canisters.

Accident Situation	Prior, Ideal or Accident-Free Situation	Difference	Evaluation of Effect
Sample canister was labeled by PI1.	Sample canisters were labeled by Instrument Scientists.	PI1 markings were less descriptive of contents and user than typical FP-04 Scientist markings.	Increased likelihood of loss of control.
Two samples were run and the third sample was run over a year later.	All three samples were to be run together.	Different personnel involved; inconsistent treatment of samples; unclear roles and responsibilities; loss of process knowledge.	Increased likelihood of loss of control.
Lujan Center management did not ensure workers were aware of hazard material involved.	Lujan Center management would ensure workers were aware of hazard material involved.	Workers were not aware of hazards.	Increase of likelihood of loss of control.
The sample was intrinsically radioactive.	Most samples are not intrinsically radioactive.	Special precautions were necessary.	Sample was handled as though it were not intrinsically radioactive.

APPENDIX D - ACCIDENT INVESTIGATION TERMINOLOGY

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Accident Investigation Terminology

A **causal factor** is an event or condition in the accident sequence that contributed to the unwanted result. There are three types of causal factors: direct cause(s), which is the immediate event(s) or condition(s) that caused the accident; root causes(s), which is the causal factor that, if corrected, would prevent recurrence of the accident; and the contributing causal factors, which are the causal factors that collectively with the other causes increase the likelihood of an accident, but that did not cause the accident.

The **direct cause** of an accident is the immediate event(s) or condition(s) that caused the accident.

Root causes are the causal factors that, if corrected, would prevent recurrence of the same or similar accidents. Root causes may be derived from or encompass several contributing causes. They are higher-order, fundamental causal factors that address classes of deficiencies, rather than single problems or faults.

Contributing causes are events or conditions that collectively with other causes increased the likelihood of an accident but that individually did not cause the accident. Contributing causes may be longstanding conditions or a series of prior events that, alone, were not sufficient to cause the accident, but were necessary for it to occur. Contributing causes are the events and conditions that "set the stage" for the event and, if allowed to persist or recur, increase the probability of future events or accidents.

Event and causal factors analysis includes charting, which depicts the logical sequence of events and conditions (causal factors that allowed the accident to occur), and the use of deductive reasoning to determine the events or conditions that contributed to the accident.

Barrier analysis reviews the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative.

Change analysis is a systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the accident.

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