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LANL Investigation Report: Investigation of Two Separate Worker Injuries and Resultant Internal Contamination

Authors:
Chris Cantwell, Harold Conner, Sharon Cook, Matt Hardy,
Gary Hoovler, William Lloyd, Robert McQuinn, and David Wannigman

Department of Energy Observer:
Dave Styers

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Los Alamos
NATIONAL LABORATORY
EST. 1943

Acknowledgments

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The Accident Investigation Team would also like to thank and acknowledge the contributions of Gary Mansfield (LLNL) for consulting with and advising us regarding internal dose assessments, Belinda Martinez for her assistance with editing and publishing, and Jackie Valdez for her logistical support.

Report Acceptance

On January 22, 2007, I appointed an Accident Investigation Team to simultaneously investigate two separate events involving workers with injuries that were found to be internally contaminated. The first event occurred on January 8, 2007 at the CMR Facility. The second event occurred on January 17, 2007 at TA-55.

The Accident Investigation Team's responsibilities have been completed. I accept the Team's report and acknowledge the Team's belief that LANL could more effectively use FODs and their functional support staff to ensure programmatic work is conducted safely. I will ensure that the Corrective Action Plan development team considers methods to more effectively use FODs and their organizations as they develop a corrective action plan that addresses the JONs identified in this report.

Signature on File Date: March 28, 2007
Michael R. Anastasio
Director, Los Alamos National Laboratory

This report is a product of an Accident Investigation Team appointed by Michael R. Anastasio, Director of Los Alamos National Laboratory. The Team was appointed to perform a Type B-like investigation of these two accidents and to prepare an investigation report in accordance with PS7-PRO-TI01, R0, *Conduct a Team Investigation*.

The discussion of facts, as determined by the Team, and the views expressed in the 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.

Accident Investigation Team Signatures:

Signature on File James C. Cantwell, LANL	February 23, 2007 Date
Signature on File Harold T. Conner, Jr., WSRC	February 23, 2007 Date
Signature on File Sharon K. Cook, BWXT	February 23, 2007 Date
Signature on File Matthew W. Hardy, LANL	February 23, 2007 Date
Signature on File Gary S. Hoovler, BWXT	February 23, 2007 Date
Signature on File William E. Lloyd, Jr., WGI	February 23, 2007 Date
Signature on File David L. Wannigman, LANL	February 23, 2007 Date
Signature on File Robert L. McQuinn, LANL Chair	February 23, 2007 Date

Acronyms

Acronym	Definition
ADCLES	Associate Director Chemistry, Life, and Earth Sciences
ADEPS	Associate Director Experimental Physical Sciences Directorate
ADI&SS	Associate Director Infrastructure & Site Services
ADNHHO	Associate Director Nuclear and High Hazard Operations
ADSMS	Associate Director Stockpile Manufacturing and Support
AIT	Accident Investigation Team
AWC	Area Wing Controller
BSL	Biosafety-Level
Ca-DTPA	Calcium-Diethylenetriamine Pentacetic Acid
CEDE	Committed Effective Dose Equivalent
CMR	Chemistry and Metallurgy Research
COB	Close-of-Business
DAC	Derived Air Concentration
DGL	Deputy Group Leader
DOE	Department of Energy
DR	Doctor
DTPA	Diethylenetriamine Pentacetic Acid
EM	Environmental Management
EMS	Environmental Management System
ES&H	Environment, Safety, and Health
ESH&Q	Environment, Safety, Health, and Quality
FDA	Food and Drug Administration
FOD	Facility Operation Director
GB	Glovebox
GBW	Glovebox Worker
GGIP	Glovebox Glove Integrity Program
HCP	Hazard Control Plan
HFM	Hand and Foot Monitor
HPAL	Health Physics Analysis Laboratory
ICAM	Issues and Corrective Action Management
ICRP	International Commission on Radiological Protection
IMP	Implementation Procedure
ISD	Implementation Support Document
ISMS	Integrated Safety Management System
ISSM	Integrated Safeguards and Security Management System
ISSO	Information Systems Security Officer
IWD	Integrated Work Document
IWM	Integrated Work Management
LAMC	Los Alamos Medical Clinic
LANL	Los Alamos National Laboratory
LANS	Los Alamos National Security, LLC
LAS	Large Area Swipe
LASO	Los Alamos Site Office, NNSA
LIMTS	LANL Issue Management Tracking System
M1	Machinist 1 (injured at TA-55)

MD	Medical Director
mrem	milli Roentgen Equivalent Man
MST	Materials Science & Technology
NaI	Sodium Iodide
NASA	National Aeronautics and Space Administration
nCi	nano Curie
NDA	No Detectable Activity
NMT	Nuclear Materials Technology
OCD	Operations Center Dispatcher
ORPS	Occurrence Reporting, and Processing System
PA	Physician Assistant
PF	Plutonium Facility
PIC	Person-in-Charge
PPE	Personal Protective Equipment
PrHA	Process Hazard Analysis
QC	Quality Control
R&D	Research and Development
R2A2	Roles, Responsibilities, Authorities and Accountabilities
RAD	Responsible Associate Director
RBA	Radiological Buffer Area
RC	Root Cause
RCA	Radiological Controlled Area
RCS	Radiological Control Supervisor
RCT	Radiological Control Technician
RD	Requirements Document
REAC/TS	Radiation Emergency Assistance Center/Training Site
RLM	Responsible Line Manager
RP	Radiation Protection
RPP	Radiation Protection Program
RWP	Radiation Work Permit
SM	Staff Member (injured at CMR)
SME	Subject Matter Expert
SMS	Stockpile Manufacturing and Support
TA	Technical Area
TEDE	Total Effective Dose Equivalent
TL	Team Leader
USQ	Unreviewed Safety Question
WCM	Weapons Component Manufacturing
WCRR	Waste Compaction, Reduction, and Repackaging
WCT	Wound Count Technician
WETF	Weapons Engineering Test Facility
WI	Work Instruction
WR	War Reserve
Zn-DTPA	Zinc- Diethylenetriamine Pentacetic Acid

Executive Summary

The Events

Two serious glovebox incidents occurred in January 2007 at the Los Alamos National Laboratory (LANL) involving the use of sharp tools inside a glovebox. The first occurred on January 8th at the Chemistry and Metallurgy Research Facility (CMR). The second occurred on January 17th at Technical Area 55 (TA-55). Each event resulted in an internal plutonium exposure. On January 8th, an MST-16 employee performing a routine operation inside a glovebox used a screwdriver to remove a piece of material from a metallographic sample he was preparing. The material suddenly gave way, and the screwdriver punctured a glovebox glove injuring his left index finger. On January 17th, a WCM-1 machinist machining a component on a lathe inside a glovebox cut his wrist when one of his arms struck a machine tool while donning cotton gloves. In the January 8th CMR incident, the direct cause was using a sharp screwdriver to scrape the samples without using the required personal protective equipment (e.g. leather gloves). The screwdriver slipped, punctured the unprotected left index finger of the worker, and contaminated his wound with Pu-239. In the TA-55 event, the direct cause of the injury was the difficulty of donning cotton gloves over glovebox gloves. The machinist's arm slipped while performing the ergonomically complex task of donning cotton gloves over rough glovebox gloves, a task that he had successfully completed many times before.

On January 22nd, the Director of LANL appointed a Type B-like accident investigation team (AIT) to investigate both events. The Associate Director for Nuclear and High Hazard Operations was named to lead the investigation. Both events were investigated for causal factors, root causes, and judgments of need (JONs) to prevent recurrence. The AIT was comprised of line managers, safety professionals, and technical experts selected from LANL and LANS' parent companies. The Los Alamos Site Office (LASO) assigned an observer to monitor the investigation process and activities of the AIT. The investigation team began its investigation on January 29, 2007 and completed it on February 23, 2007.

Background

LANL is located in Los Alamos, New Mexico and has been operated by LANS since June 1, 2006, for the National Nuclear Security Administration. The CMR Facility, a Hazard Category 2 Nuclear Facility, was built in 1952 to house research and experimental facilities for plutonium and uranium metallurgy research and analytical chemistry. Working within CMR, the MST-16 group is charged with the characterization of new and aged pit construction materials, the development of technologies for advanced actinide materials analysis, and the performance of actinide materials science investigations. TA-55 is a multidisciplinary facility consisting of organizations responsible for the science, engineering, and technology of plutonium and other actinides. This work is in support of the nation's nuclear weapons stockpile, nuclear materials disposition, and nuclear energy programs. Working within TA-55, WCM-1 provides scientific and technical expertise for recapturing the nation's capability to manufacture replacement pits.

Analysis and Judgments of Need

The AIT conducted numerous interviews, reviewed relevant documents, and conducted a cold glovebox reconstruction of one event to derive causal factors, root causes, and judgments of need. Both events were considered in the root cause analysis. The AIT identified the following root causes that, if corrected, should prevent recurrence and/or mitigate the consequences of any future event. (Additional discussion of each root cause and judgment of need can be found in the associated section of this report.)

Cross Reference of Root Causal (RC) Factors to Judgments of Need	
Root Cause	Judgments of Need
RC1: LANL personnel did not follow formal procedures.	JON 1: LANL needs to ensure all workers comply with existing processes and procedures.
RC2: Management expectations were less than adequate, especially with regard to supervising and overseeing workers, work, and work space.	JON 2: LANL needs to provide supervision that exerts positive control and surveillance over all workers, work activities, and work space. JON 3: LANL needs to ensure sufficient oversight of all workers, work activities, and work space to ensure all activities (*programmatic and non-programmatic*) are performed in a safe and compliant manner. JON 4: LANL needs to implement a human performance process to proactively prevent errors that cause significant events.
RC3: Management did not effectively respond to precursor events.	JON 5: LANL needs to ensure the effectiveness of their response to (precursor) events and conditions. JON 6: LANL needs to establish an aggressive glovebox glove program to reduce glove failures to as low as reasonably achievable.

Cross Reference of Root Causal (RC) Factors to Judgments of Need	
Root Cause	Judgments of Need
RC4: Not all LANL programmatic managers are equipped with the operational experience required to be able to fulfill their assigned responsibility for ensuring work is performed safely. FODs and others who do have the operational experience are not effectively used to ensure the safe conduct of daily programmatic work.	JON 7: LANL needs to establish clear standards, expectations, and mentoring to equip supervisors to fulfill their assigned responsibility for ensuring work is conducted safely. JON 3: (see RC2 above)
RC5: Management did not eliminate or remove the hazard. (At TA-55, the cutting tool could have been repositioned away from the worker or a tool guard used.)	JON 5: (See RC3 above)

Summary

The AIT concluded that both accidents were preventable.

Several of the JONs are similar to past Type B and Type B-like investigations, especially with regard to supervision and to ensuring work is completed in a safe and secure manner. This indicates ineffective and/or incomplete corrective actions. LANS needs to intensify their efforts and commitment to ensuring all the core principles of Integrated Safety Management and the Integrated Work Management Process are institutionalized.

Introduction & Methodology

This report documents two event investigations. The AIT investigated and analyzed each event separately. A description of each event is provided as is a general causal analysis. After analyzing both events independently, the AIT combined the two analyses and developed root causes and JONs.

In January 2007, two events occurred at LANL involving workers who received puncture wound injuries and internal plutonium exposures. One of the events is expected to result in a significant dose to the worker from an internal exposure to Pu-239. Following the first event on January 8, 2007, the Director of Los Alamos National Laboratory appointed the Deputy Associate Director for Stockpile Manufacturing and Support (SMS) to lead an investigation of the event and its causes. Following the second event on January 17, 2007, the Director rescinded that appointment, and on January 22, 2007, appointed the Associate Director for Nuclear and High Hazard Operations (ADNHHO) to investigate both events concurrently. The ADNHHO preserved both accident scenes and assembled a team of line managers, safety professionals, and technical experts. Team members were selected from both LANL and LANS' parent companies. An observer from DOE's Los Alamos Site Office was also assigned.

The scope of the investigation was defined in the appointment memorandum (see Appendix A) and included identifying facts, analyzing those facts to determine the direct, root, and contributing causes that led to the accident, and developing JONs for preventing similar accidents in the future. The AIT conducted the investigation in accordance with LANL's internal procedure (PS7-PRO-TI01, R0) *Conduct a Team Investigation*.

The Investigation Team began its investigation on January 29, 2007. The following methods were used:

- Interviewing eye witnesses and others involved in the two events
- Inspecting and photographing both accident scenes
- Reviewing documents and other physical evidence
- Conducting a cold glovebox reconstruction of one event

On February 23, 2007, the AIT completed its investigation.

Accident Analysis Terminology and Techniques

A *causal factor* is an event or condition in a sequence of events and existing conditions that combine to trigger an accident. This report references three types of causal factors:

- **direct cause**, is the event or condition that immediately precede and directly results in the accident,
- **root cause**(s), are those causal factors that if corrected would prevent or significantly reduce the probability of recurrence of the accident, and
- **contributing cause**(s), are those causal factors that increase the likelihood of an accident but which individually did not cause the accident.

Event and Causal Factor Analysis is an analytical technique, which organizes events and conditions into a chronological timeline and facilitates the use of deductive reasoning to determine those events and conditions that combined to cause the accident. This analysis also allows the AIT to compare actual events to the sequence that should have happened and then evaluate any deviations.

Barrier Analysis is an analytical technique, which reviews the hazards present at the time of the accident and the barriers that are in place (or should be in place) to mitigate the hazard.

Change Analysis is a systematic approach to examining both planned and unplanned changes that occurred and determining those changes that contributed to or caused the accident.

The AIT also used commercially available **software tools** to analyze the event.

CMR Event Description

CMR and MST-16

The CMR Facility, a Hazard Category 2 Nuclear facility, was built in 1952 to house research and experimental facilities for analytical chemistry as well as plutonium and uranium chemistry and metallurgy research. The facility is divided into six wings and contains an administration area. Wings 2, 3, 4, 5, and 7 contain laboratories and office space. Wing 9 houses hot cells and supports remote handling operations. MST-16 resides in Wing 2.

Material Science and Technology Division's Nuclear Materials Science Group (MST-16) is charged with the characterization of new and aged pit construction materials, the development of technologies for advanced actinide materials analysis, and the performance of actinide materials science investigations.

Activities encompass the evaluation of site-returned pits and the preparation, testing, and examination of various nuclear weapons materials using a comprehensive suite of materials science techniques. The group's multidisciplinary expertise comprises the core actinide materials science and metallurgical capability within the nuclear weapons production and surveillance communities. Destructive and nondestructive analysis of weapon materials is performed by six MST-16 materials science teams: metallography, mechanical and dynamic testing, interfacial science, physical metallurgy and thermodynamics, materials physics and metallurgy, and corrosion and gas reaction studies. The MST-16 staff member (SM) injured in the CMR event was a member of the metallography team. He has over 35 years of metallographic experience, is considered a leading expert in his field, and was performing a task he had performed many times before.

The evaluations performed by MST-16 are essential for the nuclear weapons program as well as nuclear materials storage, forensics, and actinide fundamental science.

Work Control Documents

The work described below is covered under six work control documents (three sets of two):

1. NMT-16-IWD-W1-637, R0, "Using Hand Tools and Small Power Tools in CMR Labs and Offices"
2. NMT-16-WI-637, R0.1, Ibid.
3. NMT-16-IWD-W1-642, R0.1, "Working in Open Front Hoods, Slot Boxes, & Gloveboxes in CMR Wing 2 and Associated NMT-16 Operations"
4. NMT-16-W1-642, R0.1, Ibid.
5. NMT-16-IWD-W1-005A, R0.1, "Actinide Metallography"
6. NMT-16-WI-005, R2, "CMR Actinide Metallography"

Description of Event

In **December 2006**, an MST-16 worker cast two plutonium metal samples in epoxy to prepare them for metallographic analysis. Before he could complete the final preparation of the sample (cutting, grinding, and polishing) the individual was transferred to TA-55.

The glovebox (2136-01) where work was performed

On **January 3, 2007** an MST-16 staff member, who planned to use the samples, requested a glovebox worker (GBW) from MST-16 to prepare the two samples for metallographic analysis. At approximately 12:30, GBW asked SM for help, because SM had more experience preparing samples. SM agreed to provide assistance while still continuing his own programmatic work. SM spoke with the requesting staff member to better understand the history of the samples, because that would determine how SM could handle and prepare the samples. SM informed the requesting staff member that SM needed to begin soon in order to meet both personal and work-related time constraints and complete the sample preparation before leaving at noon the following day. He knew he would not return until January 8th, and he wanted to provide finished samples to the other staff member before he left. All MST-16 staff at CMR needed to complete their work and meet an April 1st deadline for moving from CMR to TA-55; wing 2 was being closed. SM examined the samples and observed bubbles in the epoxy. He was concerned the bubbles might interfere with final sample preparation (CMR metallographic samples must often be re-mounted because of unsatisfactory conditions that develop as the epoxy cures). At 13:00, SM informed the other staff member of the problem with bubbles in the epoxy, and they jointly decided that SM would attempt to polish the better of the two samples for analysis. GBW was to observe SM as part of his training to learn how to prepare samples of this type.

On the morning of **January 4, 2007**, SM finished polishing the one sample and provided it to the requesting staff member who determined that both samples would require remounting. Later that morning, SM observed GBW breaking the two samples out of the epoxy. GBW advised SM that he would re-mount the samples so they would be ready for final preparation on Monday, January 8th. SM left the Laboratory shortly before noon.

GBW re-mounted the samples twice, once on Thursday January 4th and again on Friday, January 5th. On Monday, **January 8, 2007**, at approximately 13:00, SM determined that the epoxy was too soft to properly prepare the samples. He considered heating the samples to accelerate curing of the epoxy, but this was not a viable option because it could possibly damage the metal samples. SM consulted with the other staff member to see if the fragments remaining from the original sample stock could be used. They could not be used; they were needed for other experiments. Once again, the two mounted samples needed to be broken out of the epoxy

and re-mounted. Shortly after 15:00, SM returned to a glovebox in room 2136 (glovebox-2136-01) to begin breaking out the samples. This glovebox was used because it has thicker gloves (30 mils) than gloves installed in other boxes in the same line.

SM removed both samples from their epoxy mounts by placing the mounts in a machinist's vise inside the glovebox, striking them with a small ball peen hammer to loosen the samples and break the epoxy, and then prying the samples out with a screwdriver (shown below).

Handtools used by SM. Screwdriver is visible.

Using vise grip pliers to grasp a sample and bracing the sample against the small machinist's vise, SM used the screwdriver to scrape adherent clumps of epoxy from the first sample and placed the sample in an acetone bath to soften the remaining epoxy residue. He did not don cut- or puncture-resistant gloves before performing this operation (NMT-16-WI-637-R01, p.8) nor did he regard the screwdriver as a "sharp" tool. Using the same small tools and repeating the process, SM began scraping epoxy clumps from the second sample. He was exerting an extra amount of force (generally directed away from his body) to remove a tightly adherent clump when the material suddenly gave way. The screwdriver ricocheted off the vise, and the tip of the screwdriver struck his left index finger tip. He knocked the dangling piece of epoxy from the metal sample and then dropped the sample in the acetone bath. He inspected the left-hand glove and was at first unsure whether it had been punctured. He began to experience pain at the location struck by the screwdriver. In accordance with standard practice at CMR, there was not a second person in the room to render or summon assistance (in contrast with requirements contained in CMR-NOTICE-017). SM removed his right hand from the glovebox glove and surveyed it; no contamination was detected. Peering down the left glovebox glove, he saw a spot of blood. SM slowly removed his left hand from the glovebox glove, doffing his outer surgeon's glove and leaving it inside the glovebox glove. SM clenched his left hand into a fist, completely withdrew it from the glovebox, and surveyed it; no contamination was detected. At about 15:35, SM went to the phone in the adjourning room (2134) to summon assistance. He tried to call an RCT, the Area Wing Controller (AWC), and an MST-16 Team Leader (MST16 TL) from another team. Unable to reach any of these people, he then called the other staff member (for whom he had been preparing the samples) and notified him of the punctured glove and finger. SM did not call the CMR Operations Center, whose number was posted beside the phone, but called the RCT because of the close daily working relationship that had been established.

The AIT concluded that

- *SM's actions (removing hand from glovebox glove) were consistent with CMR-RD-555-R1, p. 48.*

- *SM should have called the CMR Operations Center (CMR-AP-002, R3).*
- *SM should have donned secondary protective gloves (e.g., Kevlar or leather) over his glovebox gloves (NMT16-WI-637,R0)*
- *The CMR RAD should have ensured the two person rule was in effect throughout the facility (CMR-NOTICE-017)*

Response

Facility Response

The other staff member contacted the CMR Operations Center (OCD1), MST-16 Group Office, and the Radiation Protection (RP-1) Supervisor's Office (RCS1). RCS1 notified RCS2, who attempted unsuccessfully to dispatch a radiological control technician (RCT). RCS2 then left the office and went to room 2136.

In the Operations Center, OCD1 informed OCD2 and then left the Operations Center to advise the CMR Operations Manager and the Facility Operations Director. Shortly afterward, MST16 TL contacted OCD2 in the Operations Center and advised they needed an RCT at the location of the incident in Wing 2, but there was no skin puncture. OCD2 made a facility-wide announcement requesting anyone with knowledge of the Wing 2 incident to call the Operations Center.

Meanwhile, SM, aware that no continuous air monitor (CAM) alarms were sounding, returned to room 2136 and surveyed his left sleeve and left hand; the instrument indicated "a couple hundred" disintegrations per minute (dpm) of alpha contamination. He doffed his Tyvek® sleeve and right-hand surgeon glove into the radiological trash can, then doffed his left-hand glove and placed it on a Kimwipe® on the countertop. At about 15:40, the AWC, who was making security rounds, arrived. He called the Operations Center and spoke with OCD1, who informed him they had already been notified of the event.

Location of glove puncture

The AWC called the Operations Center again after the announcement and clarified there was a skin puncture, but that the facility's Emergency Response Team was not required. Later, MST16 TL contacted the Operations Center again to correct his earlier report, and to make sure they knew there had, in fact, been a skin puncture.

At about 15:45, RCS2 arrived at room 2134. On his way, he had met both the MST16 TL and the AWC, and had seen the puncture wound through the window looking into room 2136 from the uncontrolled side of the room. RCS2 contacted RCS1 and advised him to make preparations for a wound count. On his way into 2134, RCS2 checked the radiological conditions in the room. He performed a large area swipe (LAS) through 2134 to the doorway of 2136; result was no

detectable activity (NDA). RCS2 noted no CAM alarms were sounding. He surveyed SM's left hand and detected 1500 dpm of alpha contamination (one minute scaler count). He placed a surgeon's glove over SM's left hand to contain the contamination and then completed a whole body frisk of SM. No other contamination was detected.

RCT1 arrived at room 2136 and began additional room surveys. RCS2 directed RCT1 to complete a room survey, to survey the glove port and then remove it from service (leaving the abandoned outer surgeon's glove inside the glovebox glove), and to retrieve and retain the punctured left-hand glove from the counter.

After being notified by RCS2, RCS1 contacted the Health Physics Measurement Group (RP-2) to request that preparations be made for a wound count. RCS1 then paged the RP-1 Team Leader (RP1 TL) to notify her of the skin contamination event. RP-2 dispatched a wound count technician (WCT) to the Occupational Medicine Facility; WCT arrived before SM. Occupational Medicine personnel learned of the pending case from WCT. WCT made the necessary preparations to perform wound counts on SM's injured left index finger and waited for his arrival.

At about 15:50 and after properly monitoring for contamination, RCS2 escorted SM out of the radiological buffer area to a CMR decontamination room. In the decontamination room, RCS2 removed the left-hand glove from SM's hand and surveyed the puncture wound again; results still indicated about 1500 dpm alpha. RCT2 arrived at the decontamination room and verified the survey result. RCS2 did not have a key to the decontamination supply cabinet, so he commenced decontamination efforts using tape compressions and rinsing with warm water. Shortly thereafter, the key to the supply cabinet arrived, and RCS2 was able to access additional decontamination supplies. He began a sponge scrub for 30-45 seconds. He dried the area and surveyed the exterior surface of the wound: result was NDA. RCS2 then squeezed SM's finger until a small drop of blood appeared in an effort to expel embedded contamination. He dabbed the area dry and surveyed again; result remained NDA.

RCT2, SM, and AWC exited the controlled area after monitoring for contamination using both a hand and foot monitor (HFM-7) and a whole body monitor (PCM-2); all results were NDA. SM's left hand was not covered with a sterile dressing. Nasal smears were collected from SM and left in an RCT's office. RCT2 and AWC accompanied SM to the Occupational Medicine Facility around 16:15.

RCT1 completed a survey of room 2136; results were NDA. He returned to 2136 and retrieved the left-hand glove from the countertop. RCS2 and RCT1 surveyed the glove and detected alpha contamination. They collected a smear from the puncture site, which measured 300-400 dpm on the smear counter. Nasal smears and the index finger from the left-hand surgeon's glove were later analyzed at the Health Physics Analytical Laboratory (HPAL). Nasal smears were negative. Spectral analysis of the glove finger indicated high-purity Pu-239.

OCD2 was advised by RCS1 at around 18:00 to post room 2136 as a "Hot Job Exclusion Area". The room was so posted, and the posting was visually confirmed by RCS1 and RP1 TL. The glovebox port was covered. All area surveys in room 2134 and 2136 were negative.

The AIT concluded that the wound on SM's left hand should have been covered with a sterile dressing; HSR-1-09-02, R1.1 & HSR-1-09-05.4).

Medical Response

SM, RCT2, and AWC arrived at the Occupational Medicine Facility and entered through the front door. By 16:20, WCT had completed the initial wound count; result was 17 nCi. Following this initial count, WCT informed his Team Leader (HPAL TL) of the result. HPAL TL decided his assistance was needed at Occupational Medicine. He arrived at the facility at approximately 16:35, and he was present for all successive wound counts that evening.

The AIT concluded that SM, RCT2, and AWC should have entered the Occupational Medicine Facility through the emergency entrance rather than through the front door.

Around 17:00, RCS1 informed RP1 TL of the initial wound count results. RP1 TL notified the RP-1 Deputy Group Leader (RP1 DGL), who was in the RP-1 Group Office at the time, that the initial wound count result was 17 nCi. RP1 DGL, with assistance from his Group Leader, began to muster dose assessment/bioassay resources, and confirmed that the incident area at CMR was being radiologically evaluated and controlled. RP1 DGL called the after-hours dose assessment number; no one answered. He then tried to call the RP-2 Group Leader at his work number (no answer); he tried to reach the RP-2 Team Leader (RP2 TL) at home and spoke with RP2 TL's wife who agreed to have him call back shortly. RP2 TL, an internal dosimetrist, called RP1 DGL (who was still at the Group Office), and was advised of the 17 nCi wound count. RP2 TL said he would develop a potential dose estimate and call back.

LANL's Medical Director (MD) arrived at the Occupational Medicine Facility at about 17:00. During the course of treatment described below, at least 14 LANS personnel other than the medical staff were present at various times. At least 2 of these people voiced concerns regarding the merit, efficacy, and side-effects of administrating a chelating agent.

At the Occupational Medicine Facility, a physician's assistant (PA1) and a nurse, under the guidance and direction of a physician (DR1), attempted to decontaminate the wound. They assessed progress by repeated wound counts. PA1 and the nurse were wearing appropriate protective clothing and equipment and were both in the treatment room; DR1 remained outside the room. Initial decontamination attempts were not successful. Sometime between 17:06 and 17:23, PA1 used a scalpel to scrape the wound area in an attempt to remove contamination; the subsequent wound count remained about 17 nCi. Wound count data indicated little or no decontamination was being achieved. At about 17:30, the medical staff packed SM's wound with chelating paste, bandaged it, and covered it in preparation for releasing SM with direction to return the following morning for evaluation and further treatment. At this point, MD left his office and went to the treatment area to obtain additional information.

Around 17:35, RP1 DGL arrived at Occupational Medicine and overheard a conversation between MD, the MST-16 Group Leader, and the MST-16 Deputy Group Leader. They were referring to the contamination level as 3,700 dpm. RP1 DGL inserted himself into the discussion and clarified that 17 nCi corresponds to about 37,000 dpm, not 3,700 dpm. He expressed

concern about the wound count results, the potential committed effective dose equivalent (CEDE) consequences, and about the decision to release SM without excision or chelation treatments.

At 17:45, with his wound packed and bandaged, SM signed his discharge instructions and was preparing to leave Occupational Medicine. Before SM departed, MD decided to proceed with additional medical intervention based on the information and clarification he had just received.

At 17:50, RP2 TL called RP1 DGL and informed him that the potential CEDE for a 17 nCi internal exposure could be up to 50 rem based on worst case assumptions. RP1 DGL gave his phone to MD and RP2 TL provided the same information directly to MD. At this point, MD decided on a treatment plan of excision and chelation. RP2 TL informed both RP1 DGL and MD of the desire to obtain a pre-chelation urine sample for *in vitro* bioassay. Bioassay kits are not stored at the Occupational Medicine Facility. Taking the bioassay sample was delayed while a kit was obtained from TA-55.

Around 17:55, PA1 conducted a punch biopsy on SM's left index finger in another attempt to remove the contamination; the ensuing wound count was 9 nCi. MD completed another excision; a subsequent wound count indicated 17 nCi. The variability in wound count results is not unusual because the measurements from the NaI detector are highly dependent on the geometry. After a total of ten excisions by MD, the wound count at 19:26 was reduced to 12 nCi**.**

At 19:30, MD suspended excision and ordered medical personnel to administer a zinc-based chelation treatment. A baseline *in vitro* bioassay (urine) sample was collected prior to starting chelation per earlier instructions from RP2 TL. At 20:00, Occupational Medicine personnel contacted REAC/TS for a consultation. At 20:15 the drip chelation treatment commenced**.** The total elapsed time from injury to chelation was about five hours. MD then resumed his attempts to excise the contamination. Shortly after chelation started and after MD had reviewed SM's medical history, the chelating agent was changed from zinc to calcium. This change was based on MD's review of SM's medical records and on information received from REAC/TS during the earlier consultation; REAC/TS recommended starting with calcium and then changing to zinc. SM received about 250cc of the zinc-based chelating agent before the switch was made to the calcium-based agent. Chelation treatment continued until about 20:55, during which time continued excisions and wound counts took place. Medical personnel sutured the wound closed at 22:15. The final wound count (taken at 22:05) was 11 nCi. SM was released from Occupational Medicine at about 22:30.

> *Note 1:* The wound counter at Occupational Medicine Facility does not measure an attenuation correction factor, so none was applied. Subsequent wound counts conducted on January 9th at HPAL with a high-resolution spectrometer indicated a correction factor of 2.7. This correction factor would produce an attenuation-corrected activity of 46 nCi for the initial wound count taken on January 8th.
>
> *Note 2: Treatment Guidelines for Radiation and Biologic Exposures* (PED119-7B-160.0, August 2004, Attachment 5.2) Guideline 3 states that chelation treatment is best begun within one or two hours of exposure. Guideline 5 states

excision should be considered at a threshold of 1 nCi. Guideline 6 states that if any of the chelation/excision criteria are present, chelation should be recommended and administered before any attempt at excision is made.

Post-Event Medical Care

January 9, 2007: SM returned to the Occupational Medicine Facility the following morning where medical personnel administered a calcium-based chelation treatment beginning at 10:15. Two wound counts (using a NaI scintillator) were completed during the treatment; each count indicated approximately 9 nCi. At around 11:00, the wound was counted with a high-resolution germanium detector (Ortec instrument model LO-AX); results indicated significant tissue attenuation. The correction factor was initially (and incorrectly) estimated as unity (1). This error was discovered about one week later and the actual attenuation correction factor was determined to be 2.7. Retroactively applying this correction factor to the January 9th measurements yields a corrected value of 24 nCi.

Note 1: Retrospective application of 2.7 attenuation correction factor from the January 9th HPAL wound count to January 8th results may be non-conservative (i.e., low) because of the amount of tissue excised on January 8th.

Five wound counts (using a NaI scintillator) were conducted from 13:12 through 16:03 with (uncorrected) results ranging from 6 to 8 nCi. Four counts of tissues excised by physician 2 (DR2) were NDA.

RCTs performed a detailed survey of rooms 2134 and 2136, collecting 26 LASs and 50 small-area (100 cm^2) smears in each room. All results were NDA. Fixed-head air sample filters were collected and analyzed; results were NDA with the exception of one low-level (3 DAC-hour) filter count from room 2134.

January 10-12, 2007: Additional wound counts (using a NaI scintillator) were obtained each day with all (uncorrected) results falling between 7 and 9 nCi. (Applying the tissue attenuation correction factor obtained by the LO-AX measurement on 1/9/07, would indicate the activity remaining at the wound site was approximately 22 nCi). Additional (superficial) debridement was performed on 1/12/07 by DR2. A zinc-based chelation treatment was administered each day.

January 13-14, 2007: A zinc-based chelation treatment was administered each day.

January 16, 2007: A zinc-based chelation treatment was administered. DR2 performed numerous excisions. Ten wound counts (using a NaI scintillator) were taken with results ranging from 5 to 12 nCi (uncorrected for tissue attenuation). Thirty measurements were taken of excised tissue or related medical samples (bandages, sutures, cloths, swabs, etc.) with results ranging from NDA to approximately 2 nCi. Nine of these measurements show activity that is statistically above background, and they indicate 6 nCi (uncorrected) or more may have been removed from the wound site.

January 17, 2007: A zinc-based chelation treatment was administered. Another LO-AX wound count was obtained resulting in a new correction factor of 1.67 (consistent with removal of tissue) and a corrected wound activity measurement of 15 nCi.

January 18, 2007: A zinc-based chelation treatment was administered. Three wound counts (using a NaI scintillator) were taken; (uncorrected) results ranged from 6 to 9 nCi.

January 19, 2007: Nine wound counts (using a NaI scintillator) were taken; (uncorrected) results ranged from 6 nCi to 11 nCi. A single count of tissue (scab) excised by DR2 was obtained; result was NDA.

January 22, 2007: Nine wound counts (using a NaI scintillator) were taken; (uncorrected) results ranged from 4 to 10 nCi.

January 23, 2007: A zinc-based chelation treatment was administered. A single wound count (using a NaI scintillator) was taken; the (uncorrected) result was 9 nCi. A count of the dressing that was removed prior to this count showed NDA. A subsequent LO-AX count produced a new correction factor of 1.4 and a corrected activity at the wound site of 13 nCi.

January 24, 2007: LANL Occupational Medicine personnel consulted with an off-site board certified surgeon (DR3) regarding the treatment of the injured worker. This additional expertise was requested in an attempt to remove contamination still present in the wound. DR3 conducted debridement at the Occupational Medicine facility, and a single count (using a NaI scintillator) of 4 pieces of excised tissue was obtained showing approximately 0.5 nCi. A subsequent wound count showed an uncorrected result of 10 nCi.

January 25 – February 6, 2007: Eight wound counts (NaI) were obtained during this time period with uncorrected activities ranging from 7 to 10 nCi. A single count of gauze was obtained on 1/25/2007 which showed NDA. Zinc-based chelation treatments were administered on 1/25/07, 1/30/07, 2/1/07, and 2/6/07.

February 8, 2007: A LO-AX wound count was obtained that verified the 1.4 correction factor (from 1/23/07) and resulted in a corrected activity at the wound site of 11 nCi.
Following this, DR2, in concert with MD and a REAC/TS physician, met with SM and reviewed his bioassay results to date. They jointly decided that the bi-weekly chelation treatments would be suspended because of the decreased effectiveness of continued treatment. RP2 TL was consulted and concurred with this determination. It was agreed that a similar review would be conducted in 2-4 weeks and all pertinent information would be evaluated to determine if additional chelation treatments would be warranted.

February 21, 2007: A LO-AX wound count was obtained resulting in a corrected activity at the wound site of 12 nCi. SM met with DR2 and requested an additional chelation treatment. Based on her previous consultations with MD and REAC/TS, DR2 granted this request and administered a zinc-based treatment.

Management Response

As a result of the CMR incident, the MST-16 Group Leader issued an all-employees memo on January 11th requiring her team leaders to review with their teams, procedures and operations that involve working with sharps in gloveboxes. This memo explicitly defined sharps, and it specified requirements for their use and storage. Before any MST-16 employee could use a sharp tool, a Team Leader or delegate was required to review:

- the use of the sharp tool as the appropriate tool for the job,
- its use is authorized by approved work authorization documents, and
- the sharp tool is used as intended and in a safe manner.

This memo directed that by COB on January 16th, MST-16 team leaders were to have walked-down every MST-16 glovebox and confirmed that all sharps in MST-16 gloveboxes are necessary, are the appropriate tool for the job, and are safely stored. This memo also suspended program operations in rooms 2134 and 2136, and reaffirmed the strict two-person rule for work in potentially contaminated gloveboxes or equivalent enclosures.

On January 20th, the Associate Director for Chemistry, Life, and Earth Sciences (ADCLES), who is the CMR responsible AD (RAD), sent an all-employee e-mail ordering a pause in all CMR glovebox work pending completion of a line manager review. The review and corrective actions required mirrored the ADSMS guidance promulgated following the TA-55 event. The e-mail attached a description of the TA-55 corrective actions for the PF-4 event (discussed later), and directed that, for those who work in groups split between TA-55 and CMR:

- when working at TA-55, follow all guidance and best practices for work there;
- when working at CMR, follow all guidance and best practices for work there; and
- if the work and the amount of hazardous material in the glovebox is the same for work at both sites, then follow the TA-55 guidance.

The January 20th ADCLES e-mail stated that for all work involving sharps, the default inner glove must offer exposure protection comparable to that provided by a Nitrile® glove; when handling or working near sharps, default outer gloves should be those that, "offer the cut/puncture protection." Kevlar or leather gloves should be used when they would mitigate cut/penetration hazards and not introduce new hazards. On January 22nd, ADCLES expanded these activities to all CLES glovebox operations outside of CMR.

Analysis

Causal Analysis

The AIT determined the direct cause of the CMR event was using a screwdriver to scrape the samples without using appropriate personal protective equipment (e.g. leather gloves) as required by the work control document. The screwdriver slipped and punctured the unprotected left index finger of the worker and contaminated the wound with Pu-239.

The AIT determined that two factors allowed this event to occur. The first cause of this event was a lack of adequate involvement by MST management and a corresponding lack of direct

supervision of the worker. This resulted in a worker being able to perform work in a manner that was unsafe and contrary to the work control document.

MST management places a high degree of trust in a worker to perform work safely and does not acknowledge the element of human error. A worker's decision to forego the use of PPE had consequences far beyond that which was accepted when approving and authorizing the work. By not providing proper oversight and supervision of work, MST management abdicates its responsibility (for ensuring work is performed safely and in accordance with defined procedures) to the worker. Workers are allowed to choose unsafe methods and set aside prescribed controls resulting in an unacceptable risk. Setting aside controls increases the risk back to an unmitigated level, a level above the mitigated risk-level achieved and accepted through the application of a formal work control process.

The second (and related) factor is LANL's management structure. LANL assigns the responsibility for adequately supervising the worker to a line organization, in this case MST-16, MST Division, and the Experimental Physics Sciences Directorate (ADEPS). At the same time, LANL assigns the overall responsibility for operating the CMR facility (the facility in which the work was performed) to a second line management organization, the Chemistry, Life and Earth Sciences Directorate (ADCLES). Finally, LANL involves a third organization, the Nuclear and High Hazard Operations Directorate (ADNHHO), who supports ADCLE in ensuring the CMR facility is operated within its safety basis envelope.

Neither of the two programmatic management chains (ADEPS and ADCLES) provided the necessary supervision to promote formality and ensure workers are implementing controls and complying with requirements. The MST team leader was located at another site and visited CMR infrequently. ADNHHO has assigned a Facility Operations Director (FOD) to CMR, but the FOD does not have direct line management authority over how daily programmatic work is performed by workers in the facility. A tour of the accident scene revealed evidence that vulnerability to an accident of this type was high, and that rigorous compliance with required controls was essential. Many sharp hand tools were inside the glovebox, but no leather gloves were present. MST-16 was relying solely on the skill of the worker to prevent this kind of event.

The AIT determined that medical personnel deviated from their formal written treatment guidelines. First, medical personnel had planned to discharge SM prior to excising the wound. Second, medical personnel attempted to excise the contamination without first beginning chelation. Third, the chelation treatment did not begin until 4 hours and 45 minutes after the event. The impact of these deviations on the final dose to the worker is an unknown. (See Appendix F)

There was not a clear command and control structure established at the Occupational Medicine Facility, and the conditions on the evening of January 8, 2007 hampered both the decision-making process regarding chelation and the communication of wound count information. At least 14 LANS employees (not counting Occupational Medicine staff) were present for some of that time, at least two of whom expressed concerns about the merit, efficacy, or side-effects of chelation. Although he provided telephone consultation, the LANS dosimetrist (RP2 TL) was not physically present. The MD reports hearing a wide range of wound count results (including

some as low as 2 nCi; the AIT found no wound count reports lower than 9 nCi). There did not appear to be an understanding by MD or other medical staff that the ***highest*** wound count reported could, in fact, be the bounding ***lower*** limit of contamination because of geometric and attenuation effects. Although the wound counter provides its results in nCi and PED119-7B-160.0 also uses nCi as the unit of radioactivity, conversions were being made to dpm, which were an order of magnitude low because of an apparent conversion error. PED119-7B-160.0 does not stipulate formal guidelines for how wound count results should be reviewed, evaluated, qualified, and presented to the responsible medical authority (in this case, MD). MD and others believed, based on information provided, that the form of plutonium in the wound was insoluble.

Note 1: The significance of a high wound count measurement combined with no detectable surface contamination is that the contamination could potentially be embedded resulting in an under-measurement of the actual activity present in the wound.

Note 2: PED119-7B-160.0, August 2004, Attachment 5.2, Guideline 5 states excision should be considered at threshold of 1 nCi. An initial wound count of 17 nCi was made at 16:20; except for some scraping, no excision occurred until more than 1-1/2 hours later when a punch biopsy was performed at 17:55**.**

Note 3: PED119-7B-160.0, August 2004, Attachment 5.2, Guideline 6 states that if any of the chelation/excision criteria are present, chelation should be recommended and administered before any attempt at excision is made because of the potential for excision to release contamination into the bloodstream. Guideline 3 of Att 5.2 states that chelation treatment is best begun within one or two hours of exposure. Chelation did not commence until nearly 2-1/2 hours after excision, four hours after arrival at Occupational Medicine, and nearly five hours after the skin puncture occurred.

ISMS Analysis

The AIT's analysis concluded that the ISM system failure occurred in Step 4: Perform the Work. While the hazard had been identified and controls developed, the worker did not implement those controls. More importantly, managers and supervisors did not provide sufficient oversight and supervision to cause the worker to comply with requirements.

TA-55 Event

Descriptions of TA-55 and WCM-1

TA-55 is a multidisciplinary facility made of organizations responsible for the science, engineering, and technology of plutonium and other actinides in support of the nation's nuclear weapons stockpile, nuclear materials disposition, and nuclear energy programs. TA-55 supports the programs of the National Nuclear Security Administration (NNSA) and provides products to the Department of Energy (DOE) Offices of Environmental Management (EM) and Nuclear Energy, Science and Technology (NE), and the National Aeronautics and Space Administration (NASA).

WCM-1 provides scientific and technical expertise for recapturing the nation's capability to manufacture replacement pits for the enduring stockpile in a safe and secure operating environment.

WCM-1 provides the technical expertise and supporting infrastructure to ensure an interim pit manufacturing capability for WR-quality pits. The technical focus area consists of five teams: Casting, Machining, Assembly Chemical & Mechanical Operations, Assembly Gas Operations, and Equipment Maintenance. These teams are responsible for reliably producing and maintaining over 100 pit manufacturing processes to the satisfaction of the Nuclear Weapons Program Design Agency.

Description of Event

Background: In **July 2002**, Los Alamos National Laboratory's Nuclear Materials Technology (NMT) Division planned and implemented a process for machining mechanical parts in support of their national security mission. The planning included the development of a process hazard analysis (PrHA), a hazard control plan (HCP), and a work instruction for a specific activity performed on a lathe inside a radiological glovebox. The HCP identified many hazards associated with general machine shop activities and defined controls to mitigate those hazards; this included the potential for puncturing a glovebox glove and internally contaminating the worker.

The Weapons Component Manufacturing-Pit Manufacturing Group (WCM-1) currently has three machinists qualified and certified to machine parts on the lathe. All three are trained on the hazards and controls, the process, and the techniques necessary to machine a quality part. They have all machined quality parts in the past. The machinist injured in this event (M1), who has 6 years of direct experience using this lathe, was performing a task he had performed many times before.

The WCM-1 team leader (TL1) scheduled lathe operations and placed the activity on the plan of the day for **January 17, 2007**. On the morning of the **17th**, TL1 assigned M1 to machine a part on the lathe.

M1 arrived at work, donned radiological and other personal protective equipment (PPE) including: one pair of coveralls, one pair of latex gloves taped to the coverall sleeves with masking tape, one pair of booties, and a pair of safety glasses. M1 entered the work area (TA-55-4-319).

View inside lathe glovebox

The work area is a machine shop located inside a radiological buffer area (RBA). The RBA is established to control both external radiation and potential contamination hazards that could be present inside the room. Specific radiological hazards within the room are posted in accordance with 10CFR835.

M1 went to work machining a part on the lathe contained inside glovebox 385. Glovebox 385 is a large glovebox and workers must access the lathe by using rows of glove ports installed along the length and breadth of the glovebox. The glovebox is maintained at a slightly negative pressure with respect to room 319. The ports have 30 mil leaded Hypalon® gloves installed to protect the worker from radiological hazards inside the glovebox. The glovebox gloves used by M1 were fitted gloves, one for a left hand and another for a right.

M1 followed the work instruction and completed machining one surface of the part. The machining process is computer controlled and the lathe's cutting bit had been automatically positioned to the left of and towards M1 (near his left hip). M1 was about to reposition the part and continue the machining process. The cotton gloves over the glovebox gloves had worn through and needed to be replaced. This required M1 to don a new pair of cotton gloves (see picture) over the glovebox gloves. The cotton gloves are used to protect the part from chemical contamination and not to protect the worker.

Donning cotton gloves

To reposition the part, M1 needed to have his right hand in a glove located at shoulder level and his left hand in a glove located just above his waist. M1 donned his right cotton glove without incident. Next, M1 began donning his left cotton glove. As M1 was tugging on the left cotton glove, his grip on the glove failed and his right hand slipped free. M1's right hand moved forcefully upward and toward the lathe's machining tool. M1's right wrist struck the machining bit with sufficient force to puncture the glovebox glove and penetrate through to M1's skin. M1 did not immediately know that his skin had also been punctured, but did recognize that the glovebox glove had been breached.

Response

Facility Response

M1 notified TL1, who was working nearby, of the breached glove. In accordance with facility procedures, M1 kept his hands inside the glovebox gloves and waited for personnel to respond. TL1 made an announcement to clear the room of personnel and then left the room; he returned with two respirators. Hearing the announcement, a radiological control technician (RCT-1) responded to the scene. RCT-1 verified the room's continuous air monitor (CAM) readings as he went. When he arrived at the glovebox, he observed the damaged glovebox glove. RCT-1 donned a full face respirator and assisted M1 in doing the same. RCT-1 assisted M1 in slowly removing his hands from the glovebox glove. During the process, RCT-1 monitored M1's arm for contamination and detected approximately 1000 disintegrations per minute (dpm) of alpha contamination on the right forearm of M1's coveralls/glove, near the wrist. RCT-1 instructed M1 to reinsert his arm back into the glovebox glove. M1 had been sweating profusely and his coveralls were damp. The moisture was likely attenuating the alpha emission and resulted in a low alpha contamination level measurement. RCT-1 assisted M1 in removing his right arm from the glovebox glove and simultaneously doffing the contaminated glove. RCT-1 immediately covered the contaminated area by assisting M1 in donning a clean latex glove. RCT-1's supervisor (RCT-S), who was standing outside of room 319, was notified of the event.

RCT-1 escorted M1 to the decontamination room where he assisted M1 in removing the clean glove. RCT-1 noted a small spot of blood on the sleeve's cuff and recognized that M1 had been slightly injured by the lathe's cutting bit. RCT-1 resurveyed the area (now dry) and detected 10,000 dpm of alpha contamination. RCT-S arrived and worked with RCT-1 to cut off the contaminated sleeve from the coveralls and removed it from M1. RCT-1 monitored the 3/16th inch-long cut on M1's wrist and detected 10,000 dpm. RCT-S consulted with the TA-55 RP-1 team leader (RPTL) and decided to continue decontamination efforts at TA-55. RCT-1 and RCTS worked together using both tape and warm water to decontaminated M1's wrist. They could only reduce the contamination level to approximately 500 dpm. Using paper to shield the alpha emission, he isolated the contamination to the small wound. RCT-S then decided that M1 needed to be transported to Occupational Medicine, via a government vehicle, for further decontamination, evaluation and treatment. A third RCT transported M1 accordingly.

While M1 was being tended to in the decontamination room and at the Occupational Medicine Facility, other RCTs continued to respond inside room 319 and the immediate area. They took nasal smears for those who had been inside room 319 at the time of the event; results were NDA. They monitored CAM readings and retrieved filters from fixed-head air samplers; all indications and results were NDA. They performed radiological surveys of the area; no additional contamination was found. The breached glovebox glove was replaced and work inside the glovebox was stopped.

- *The AIT concluded that the response by the RCTs and other facility personnel for both the CMR and TA-55 events was commendable.*

Medical Response

M1 (the injured machinist) arrived at the Occupational Medicine Facility for a wound count at 15:30. A physician's assistant PA1 and two nurses donned personal protective equipment in preparation for decontaminating the wound. A medical doctor (DR1) and dosimetrist (RP2 TL) were present outside the treatment room. PA1, assisted by the nurses, decontaminated the wound; final monitoring results using a hand held instrument were NDA.

A wound count technician (WCT1) completed a wound count at 16:10; results indicated that 1.31 nCi (+/- 0.29) of contamination was present in the wound. DR1 and RP2 TL considered the result to be approximately 1 nCi.

DR1 contacted LANL's Medical Director (MD) by telephone and discussed the injury, contamination, and treatment options. DR1, MD, and the dosimetrist agreed to sending the patient home for the night and continuing treatment the next day.

At 16:40**,** DR1 released M1. M1 returned to work at TA-55.

DR1 contacted REAC/TS and consulted with them regarding the case. REAC/TS told DR1 that 1 nCi is the threshold for recommending and offering chelation treatment to a patient.

DR1 contacted MD and discussed the information and recommendation received from REACTS. DR1 subsequently recalled M1 back from TA-55. M1 arrived at the Occupational Medicine Facility at 17:20. DR1 explained that 1 nCi was the threshold for administering a chelating agent to remove any soluble metal that could have potentially reached his bloodstream. After describing the risks and benefits of the treatment option, DR1 recommended chelation; M1 consented to receiving the treatment. DR1 administered a single treatment using a calcium-based chelating agent; treatment began at 18:30. M1 was subsequently released and asked to return to the Occupational Medicine Facility the following morning.

M1 returned the next morning. WCT1 performed a wound count; result was 1.6 nCi. DR1 administered a second chelation treatment and then excised a small flap of skin from the wound. The flap of skin was counted; result was 1.24 nCi. DR1 directed a final wound count; result was NDA. DR1 sutured the wound closed and released M1 back to work with restrictions.

On **January 24, 2007**, M1 returned to the Occupational Medicine Facility where his sutures were removed.

On **January 30, 2007**, M1 was released back to work without restrictions.

Management Response

The Director commissioned an investigation team led by the Associate Director of Nuclear and High Hazard Operations. The investigation team consisted of LANL personnel, LANS' parent representatives, and an observer from LASO. The Laboratory paused similar glovebox operations pending line management review and investigation team findings.

As a result of both glovebox incidents, the WCM Division Leader at Technical Area 55 paused all glovebox operations effective 4:00 pm on January 17th pending a review of sharps, PPE, and operations. Weapons Component Manufacturing in conjunction with the subject matter experts and support from the Facility Operations Director scheduled a walk down of all operations prior to release. The Moore T-Base 1 lathe was scheduled to undergo a Job Hazards Analysis as well as an evaluation of operations and PPE. A checklist was prepared to document the results of the walk downs and to evaluate the need for corrective actions.

Two days after the event (January 19th), the ADSMS gave formal guidance and direction regarding corrective actions to enhance the safety of glovebox operations. This guidance consisted of three activities: SMS management would brief all glovebox workers on the two recent incidents; the default glovebox glove for all glovebox work would become either the Nitrile® or Kevlar type and the outer glove would be evaluated by the group leaders as to potential hazards; and SMS management would conduct formal walk downs of all potentially harmful operations at Technical Area 55 concentrating on gloveboxes. Briefing of glovebox workers was conducted by the ADSMS or his deputy and by the WCM-1 group leader. New inner gloves are still being evaluated or on order. The Trionic gloves will continue to be used. The walk downs resulted in several identifications of sharps that were not needed for operations and were removed. Proper storage of required sharps was a concern and corrective actions were taken or entered into the corrective action tracking system LIMTS. Maintenance activities are captured on the IWD and the proper controls implemented. Each process in Technical Area 55 was evaluated for other hazards (e.g. radiological, ergonomic, crushing, pinching, and chemical hazards). Of the forty-one processes walked down, all but five were released.

Generally, corrective actions focused on glovebox conditions, procedures, PPE and briefing of personnel. In the CMR event and TA-55 event, clear procedures related to the definition of and protection against sharps were already in applicable IWDs and work instructions, and workers had already been briefed on these procedures and requirements. Actions to limit the number and storage of sharps had previously been taken. In the progression of both events, these procedures and training were violated. While focusing on conditions, procedures, and training are necessary, they are insufficient to assure that a similar event will not occur. For example, the management response for both events does not include measures to provide ongoing management surveillance of worker practice and behavior, nor does it control/restrict the introduction of new sharps at some later time. Workers should constantly look for hazards and potential problems each time they enter glovebox operations and insist on any corrective actions needed. Timeliness and scope of the management response to both events could be improved.

Analysis

Causal Analysis

The AIT determined the direct cause of the TA-55 injury and internal contamination was the difficult nature of donning cotton gloves over the glovebox gloves. M1's right hand unintentionally slipped while performing the ergonomically complex task of donning cotton gloves over dirty glovebox gloves, a task he had successfully completed many times before.

At least four factors played a role in allowing the TA-55 injury and internal contamination to occur. The first and most significant cause is that management did not follow through and complete corrective actions resulting from previous and similar events. The need to place guards over machine cutting tools had been previously identified, but neither guards nor interim measures were put in place to protect workers from accidental contact with those tools.

A second cause is that management did not adequately respond to feedback. Workers reported that the cotton gloves were difficult to don and that they did not provide an adequate grip when handling machined parts inside the glovebox. Workers believed the cotton gloves were too small. Management provided the largest size commercially available, but these were still reported to be too small and difficult to don over the glovebox gloves. Using a local training facility at TA-55, AIT members donned cotton gloves (both medium and extra large) over glovebox gloves inside a clean glovebox; they found that the cotton gloves slipped on easily. While significantly smaller than the glovebox gloves, the cotton gloves could be stretched as they were slipped over the larger glovebox gloves. Larger cotton gloves would make donning even easier. Management did not pursue acquiring custom-made cotton gloves sized to fit over the glovebox gloves nor did they attempt to understand what was causing the difficulty in donning cotton gloves inside the radiologically contaminated glovebox used to machine parts. AIT team members concluded that the surface of the glovebox gloves likely becomes rough (like sandpaper) during use. Fine metal oxide becomes embedded in the glove. This increases the difficultly of donning the cotton gloves. Without fully understanding the problem and the danger, management concluded the difficulty was a “reasonable inconvenience” and took no additional action.

The AIT learned that another machinist (the machine owner) routinely moved the cutting tool out and away from him while donning the cotton gloves; this effectively prevented him from inadvertently striking the cutting tool while struggling to slip the cotton gloves over the glovebox gloves. This control was never communicated to the other machinists performing the same work, but would have been a reasonable action for management to consider; it could have been included in the work instruction and would have prevented this event.

A third cause of the event was that neither managers nor workers stopped work and resolved the problem. Management did not provide a sufficient level of supervision such that they could observe and stop the use of excessive force by workers struggling to don cotton gloves inside the contaminated glovebox. Similarly, workers did not stop work when the unsafe condition was identified. Previously, the need to use excessive force to don cotton gloves had resulted in workers striking glovebox windows and the boring bar which holds the lathe’s cutting tool. An ample number of precursor events occurred to have caused personnel to stop work and take action.

A fourth cause of the event is an inadequate work instruction. Hazards and controls did not flow down from the hazard control plan. The hazard control plan did identify the potential for a glovebox glove puncture and listed the associated controls, but the hazards and controls did not flow down to specific steps in the work instruction where the hazard was present and the control should be implemented. The work instruction did not contain a step to don or use cotton gloves nor did it contain a warning regarding the difficulty associated this task and the need to use

caution or (had they known) to move the cutting tool out of the way. The requirement to use cotton gloves originated approximately four years ago to address anomalies detected on machined parts. The requirement was not formally added to the work instruction, and the hazards introduced by the new requirement were not adequately evaluated or mitigated. The observations made by the AIT showed that the change had not been walked down in the PF-39 training facility.

The AIT team learned that using cotton gloves may not be necessary. After the event occurred, management looked into the actual requirement and the basis for using cotton gloves. It is likely that the requirement to use cotton gloves for this particular process will be rescinded. While not having to don cotton gloves would have caused M1 to not have performed the task and therefore to have not injured his wrist in the process, the other latent conditions (position of the cutting tool, etc.) were still present and available to cause an injury.

Adequacy of IWM Implementation in PF-4

The initial decision to vary from the requirements of IMP 300 by the issuance of NMT-AP-045, R0, and "Integrated Work Management for Work Activities" does not appear to have been authorized at the institutional level. The specific result was the continued use of the existing HCP's instead of IWD's.

The hazards and controls regarding sharps and glove penetration/contamination hazards identified in the PrHA and HCP related to the PF-4 event are not integrated into the operating procedure. This, combined with the lack of procedure steps for the donning and doffing of the cotton gloves, resulted in a failure to identify specific hazard or control notes in the operating procedure that address the possibility of slipping and striking the sharp point of the cutting tool.

Although there is formal involvement of workers in the development of the operating procedure for this process, there is no indication that concerns voiced by the workers over difficulty donning the gloves was recognized and acted on in a timely fashion by responsible line management as a glove puncture hazard.

In the case of the PF-4 event, the AIT concluded that the TA-55 implementation of the requirements of IMP 300 were inadequate.

ISMS Analysis

The AIT's analysis concluded that the ISM system failed in two respects. The first failure occurred in Step 2: *Analyze the Hazards*. The hazard associated with the cutting tool position while donning the cotton gloves had not been explicitly identified in the work planning process. Therefore, controls were not developed to protect workers from the cutting tool on the lathe. The second failure occurred in step 5: *Ensure Performance*. The hazard was explicitly identified by precursor events, but the response was not timely and corrective actions were not implemented before this event occurred. Likewise, workers communicated problems to their line manager, but the problems were determined to be a reasonable inconvenience. Finally, one machinist actually repositioned the tool out of the way while donning the cotton gloves, but this improvement was not fed back into the work instruction.

Subject Areas

Institutional Work Management and Control

Los Alamos National laboratory manages the conduct of work through its Integrated Work Management (IWM) process. This process is described in Implementation Procedure (IMP) 300.4 *Integrated Work Management for Work Activities*. This process was initially instituted as an improvement effort on June 28, 2004 in response to prior concerns about work management and control at LANL. The document is on its fourth revision. The latest revision aligned the roles and responsibilities in the procedure with those established in the Laboratory's Conduct of Operations Manual. The scope of IMP 300.4 applies to all work activities performed at LANL except for some subcontract activities. The procedure emphasizes work control at the activity level and complements facility and institutional controls that mitigate safety, security, and environmental risks. Additional laboratory work-management requirements exist, such as the Unreviewed Safety Question (USQ) process used in nuclear facilities and those for project management, construction activities, or work for others.

IWM defines the requirements for implementing the five-step process defined by the LANL Integrated Safety Management System (ISMS) and integrates the Integrated Safeguards and Security Management (ISSM) system and Environmental Management System (EMS) into the work planning process. The expectations outlined in the LANL IWM include the following:

- Management and worker accountability;
- Applying the worker's knowledge and experience;
- Providing integrated, worker-friendly documentation that includes defined work tasks/steps linked to specific hazards and unambiguous controls;
- Identifying a single Person-in-Charge (PIC) for each work activity;
- Providing independent oversight and facility coordination;
- Formally validating, releasing, and closing out work activities; and
- Feedback and continuous improvement.

The IMP 300.4 process specifically requires responsible managers to:

- Establish processes to implement the requirements of IWM;
- Determine the adequacy of controls to mitigate risks;
- Determine the competence and commitment of workers to perform work in a safe, secure, environmentally responsible manner; and
- Assess operations to identify needed improvements.
- In certain cases the adequacy of controls must be evaluated and approved by institutional support organizations: for example, Biosafety Committee, Pressure Safety Committee, Industrial Hygiene and Safety, Radiation Protection Division for Radiation Work Permits, Risk Reduction and Environmental Stewardship Division for environmental permits, and Security and Safeguards (S) Division for vaults, classified computing, alarms, access control systems, etc.

The general steps in the process are:

1. Definition of the scope of the activity or task.
2. Identification of the hazards involved in the activity. For activities rated as high or moderate risk an Integrated Work Document is generated that captures the identified hazards and associated controls. The process does allow for tools other than the Institutional Job Hazard Analysis tool to be used as long as an equivalent level of analysis is performed.
3. Development of emergency or contingency actions as appropriate to the risk of the activity.
4. Validation of the work controls by the person in charge of the work, the workers, and appropriate Subject Matter Experts to ensure the identified hazards and controls are appropriate, adequate and workable.
5. Performance of the work, including pre-job briefs for Moderate Hazard and High Hazard/Complex activities within the bounds established by the work control documentation.
6. Post activity reviews to determine improvement opportunities or lessons learned for future activities. This step is required for Moderate Hazard and High Hazard/Complex activities.

When IMP 300 was initially issued on June 28, 2004 an implementation schedule was included that provided expectations for the implementation of the new process by January 3, 2005.

Flow Down of Work Control Procedures

Work control requirements for both TA-55 and CMR are governed by an administrative procedure, NMT-AP-045, R0, "Integrated Work Management for Work Activities". The procedure was issued on May 31, 2005 and refers to the institutional work control procedure, IMP 300. However, NMT-AP-045, R0 allowed for the continued use of existing Hazard Control Plans (HCPs) beyond the implementation schedule established in IMP 300. It is not clear that this deviation from the institutional procedure was formally authorized. NMT-AP-045, R0 is in a format that reflects the pre-June 1, 2006 organization where TA-55 and CMR operations were under one division, Nuclear Materials Technology (NMT). TA-55 and CMR became part of different organizations after the June 1, 2006 transition. TA-55 and CMR have reviewed and identified those documents that are pertinent to their respective organizations.

Work Control related to the PF-4 glove penetration event.

The manufacturing process being conducted during the January 17, 2007 glove penetration and internal contamination event is governed by a specific procedure development process that starts with the development of Process Hazard Analysis (PrHA) Component Machining Operations at TA-55 (LA-CP-01-95). This document outlines the activities to be conducted and identifies a general set of hazards that are determined to be credible risks during the execution of the activities. The PrHA was developed and approved. A Hazard Control Plan (NMT5-HCP-004, R2 Hot Machining) was subsequently developed that provided additional hazards and risk analysis for the activity and established a control set for each of the identified hazards. The first revision of this HCP was effective on July 19, 2002. The second revision was effective on

February 7, 2005. An extension was issued on January 24, 2007 with the next review date set for May 7, 2007. The process for generating the HCP includes an independent peer review, input from ES&H and Criticality Subject Matter Experts (SMEs), and approvals from line management up through the Group Leader. A review of the HCP indicated that the hazard of penetrating glove containment with a sharp object or instrument with subsequent wound contamination was recognized as a hazard and both specific and administrative controls were established. For example:

- Removal/exclusion of extraneous sharp objects
- Substitution of tools/objects with rounded edges
- Use of forceps to handle turnings
- Puncture resistant gloves

The initial risk level of this type of hazard was determined in the PrHA to be "Low Risk" (Moderate Consequence and Occasional Frequency).

The HCP also identified and addressed risk and controls for the following additional hazards:

- External Ionizing Radiation
- Internal Ionizing Radiation: Inhalation of Airborne Radioactive Material
- Nuclear criticality concerns
- Chemicals/Hazardous Materials
- Compressed Gas/Pressure/Pressurized Systems/Hydraulic Systems/Vacuum Systems
- Energized Electrical Work
- Mechanical Hazards (rotating equipment, pinch points, etc.)
- Thermal Hazards
- Non-ionizing Radiation (Class 2 Laser)
- Ergonomic/Physical Hazards

Specific work instructions are established in Operating Procedures that are developed by a team which included the SME for that particular operation. SME's are qualified operators or machinists that have knowledge, skills and experience in the particular operation covered by the procedure. All workers who will be using a procedure are required to review and sign it prior to being authorized to start operations. The procedures for Hot Machining Operations are designed to be used as reference procedures with each step executed as indicated in the specific procedure. While the procedures delineate the steps necessary to produce the expected product, they do not include hazard cautions or specific steps to implement the controls identified in the HCP.

Work control processes within TA-55 differ between programmatic and non-programmatic work. Non-programmatic work is more closely aligned with the requirements in IMP 300 and an IWD is generated as a part of each work package. Safety and Health professionals are included in the development of these non-programmatic packages. This allows them to help identify industrial hazards in the early stages of work and ensure the proper hazards controls are included. The development of programmatic work practices or procedures does not require Safety and Health SME participation.

Work Control related to the CMR incident

The sample breakout and remounting activities that were being conducted during the CMR event were in support of the general work process Actinide Metallography. Work Instruction (WI) NMT16-WI-005, R0.1, "CMR Actinide Metallography" governs these general work activities at the CMR, and it identifies specific hazards and controls. While the steps for making the epoxy preparations are identified in the work instruction, the sample breakout process where the injury occurred is not included. There are two IWDs that correspond to this WI. NMT-16-IWD-WI-005A, R0.1, "Actinide Metallography" covers all parts of the WI, and NMT-16-IWD-WI-005B, R0.1, "Actinide Metallography Sample Preparation" which excludes those activities that would require R&D Electrical Training. These IWDs only address the removal of the epoxy puck from the mold. The activity being conducted by SM when the event occurred (breaking partially cured epoxy off of a sample) was not addressed in either the work instructions or the IWDs and no specific controls for this activity were identified.

Instead, there are two general WIs for the activity associated with this event:
Glovebox Work: NMT16-WI-642, R0.1, "Working in Open-Front Hoods, Slot Boxes and Gloveboxes in the CMR Wing 2 and Associated NMT-16 Operation" generically identifies the industrial and radiological hazards presented by routine glovebox work. Glovebox glove failures, punctures, and contaminated wounds are addressed in Section 2.0 of this work instruction, specifically, under the hazards Sharp Objects and Mechanical Hazards. This WI does not define what a sharp object is nor does it identify what types of objects could create the mechanical hazard. The relevant controls for these hazards are storing tools when not in use to avoid inadvertent punctures, wrapping sharp objects for disposal, and using "puncture proof gloves where appropriate." (e.g. leather, Kevlar which are puncture resistant, not puncture proof) The corresponding IWD refers to the WI hazards and controls description, and as such, doesn't add any additional information.

Using Hand Tools: NMT16-WI-637, R0.1, "Using Hand Tools and Small Power Tools in CMR Laboratories and Offices" identifies the industrial and radiological hazards presented when using hand tools in a glovebox. This is the single work document that most directly governs the work activity SM was performing when his injury occurred. Glovebox glove failures, punctures, and contaminated wounds are addressed in Section 2.0 of this work instruction, specifically, under the hazard Sharps, as excerpted below:

Hazard	Control
Sharps: Using hand tools, e.g. scissors, knives, razor blades, saws, chisels, screw drivers, etc. to assemble and disassemble equipment, to prepare samples, and to break out samples from metallographic mounts could results in cuts, punctures, contamination of personnel and/or glovebox gloves (emphasis added).	Secondary protective gloves (e.g. Kevlar or leather) are worn over glovebox gloves or hands (in cold operations) when handling large, heavy pieces of sharp metal, equipment or glass and when using hand tools with sharp edges, blades, or points (emphasis added).

The AIT viewed the CMR gloveboxes in room 2136 and found that neither Kevlar nor leather gloves were present anywhere in the glovebox line.

It is not evident that the CMR procedures supporting the work in question are adequate and meet the intent of IMP 300. While IWD documents do exist, they simply refer to the applicable work instruction. The work instructions do address the use of sharps and appropriate controls and review indicates they are clear enough to have been applied to the task of removing epoxy from the sample. In this case, the worker involved did not apply those controls to this work. If the screwdriver had been identified as a sharp (it is identified as such in the WI) and over gloves of leather or Kevlar used, the chance of the injury occurring would have been greatly reduced. The IWM process was not implemented in several areas. The complete scope of the activity was not addressed in the WI. The identification of the sharps hazards from the screwdriver was not clearly linked to this task The worker did not recognize the use of the screwdriver as a tool to clean epoxy off the sample as a sharp even though it was specifically called out in the IWD. The lack of management or peer oversight contributed to the worker's acceptance of the risk posed by the use of the screwdriver as a chisel or cleaning tool. This practice existed without an incident, and over time, the worker accepted the risk.

It is interesting to note that MST-16 personnel working at TA-55 perform the same work that SM was doing when his injury occurred. They break out metallographic samples in room 115 of PF-4 following NMT16-WI-602, R2.1, "Preparing Samples for Materials Characterization in a Radiological Area." Step 3 of Section 5.10, *Breaking Out Samples* states, "Using a brass hammer, carefully crack the epoxy mounts to remove the samples. Other hand tools may be used to further remove residual epoxy from the samples." The following CAUTION, in blue text, is included in this WI just prior to this step:

CAUTION

Hazard: Sharp hand tools may nick, puncture, or tear glovebox gloves.

Control: Don Kevlar or other protective gloves over glovebox gloves prior to working with hand tools with sharp edges, blades or points. Periodically and carefully inspect your glovebox gloves for damage while working with sharp hand tools.

As in the PF-4 event, the implementation of the requirements in IMP300 was inadequate. Although the hazard was recognized and a proper control was identified, the controls were not implemented by the worker. While there is accountability on the part of the worker, there were latent organizational weaknesses in the area of procedure development and clarity, management oversight, and lack of clarity in organizational R2A2

Organizational Structure

Stockpile Manufacturing and Support in the TA-55 Building

The organizational design of Stockpile Manufacturing and Support (SMS) shown in figure 1 consists of the Associate Director (ADSMS) and Deputy Associate Director. The ADSMS is supported by a Chief of Staff and Principal Administrator, Continuous Improvement Director, Seaborg Institute Center Leader, and a Support Services Office consisting of Business Operations, Capital Project Interfaces, Contractor Assurance, and Human Resources. The SMS directorate contains seven functional organizations that perform work for mission accomplishment: Program Management; Manufacturing Capability; Pit Manufacturing and Technology; Weapons Component Manufacturing; Manufacturing Quality; and TA-55 Facility Operations.

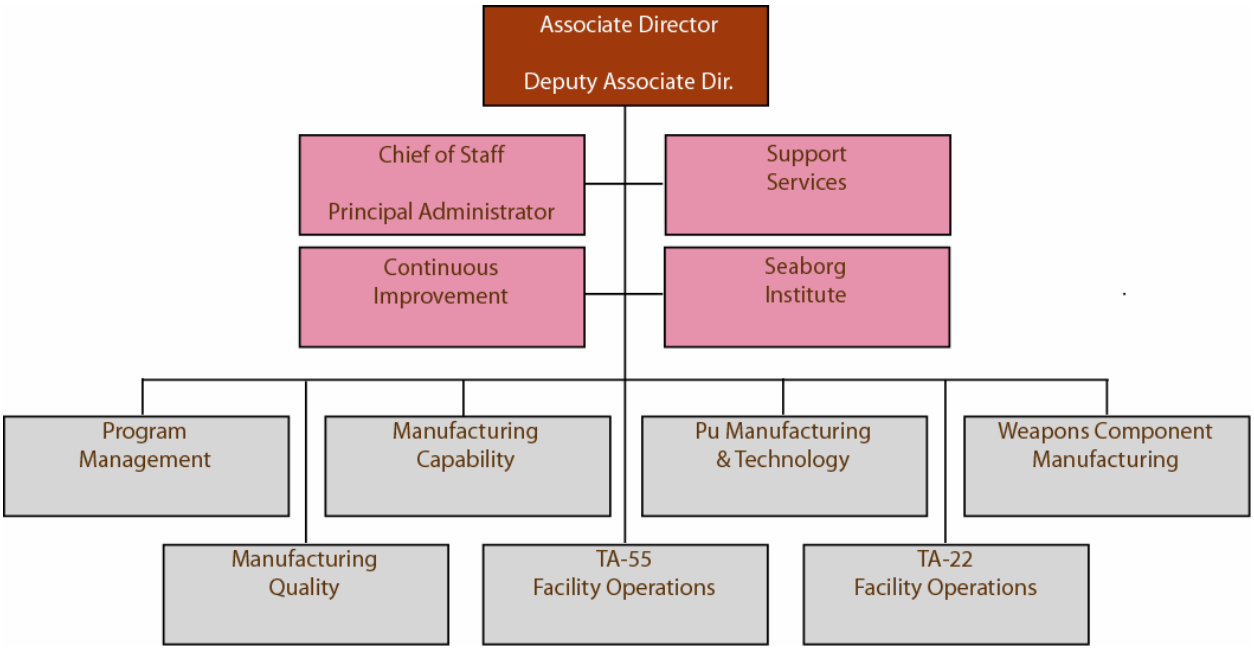

Figure 1: SMS Organization Chart

The TA-55 Facility Operations Director (TA-55FOD) is matrixed into the ADSMS from the Associate Director of Nuclear and High Hazards Facility Operations (ADNHHO) organization shown in figure 2.

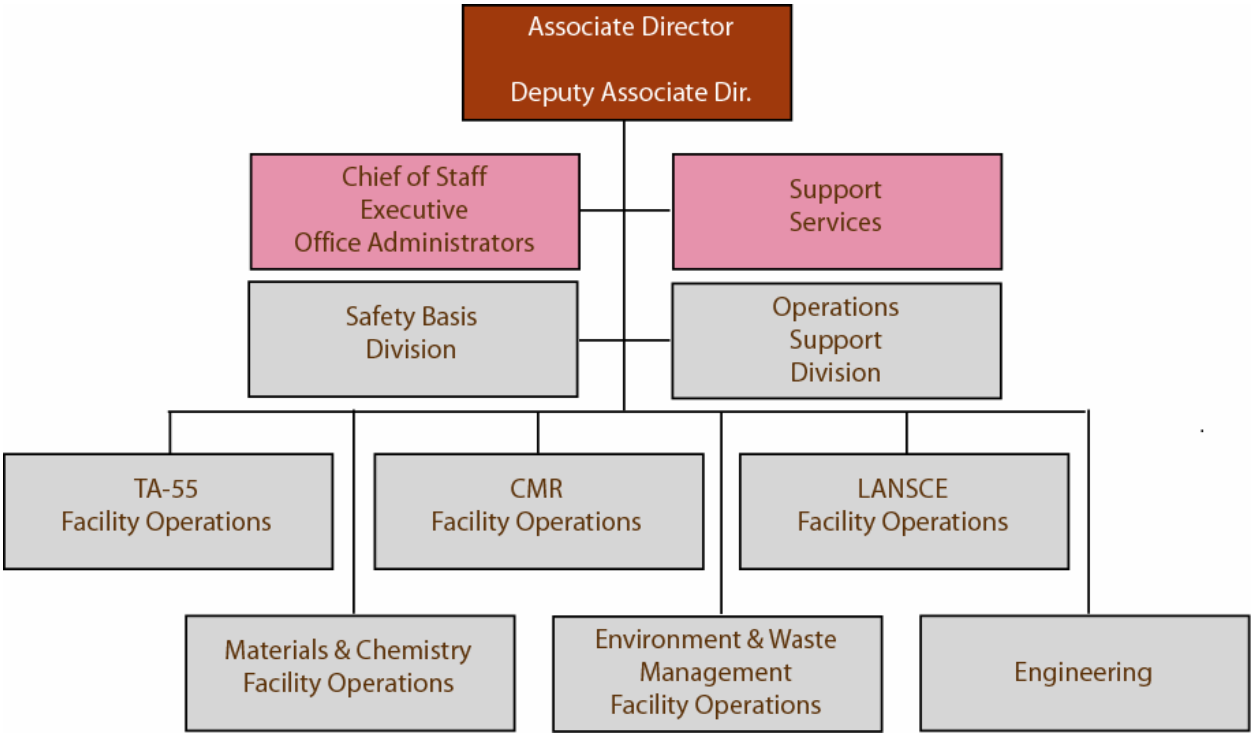

Figure 2: NHHO Organization Chart

Chemistry, Life, and Earth Sciences in the Chemical and Metallurgy Research Building

The organizational design of the Chemistry, Life, and Earth Sciences Directorate is shown in figure 3. ADCLES is supported by a Chief of Staff, Administrative Personnel, ISSO, Senior Advisor, Interface Manager, and deployed personnel. The ADCLES has three functional organizations that support accomplishment of mission objectives: Chemistry; Biosciences; and Earth and Environmental Sciences. ADCLES was the AD responsible for the CMR Facility.

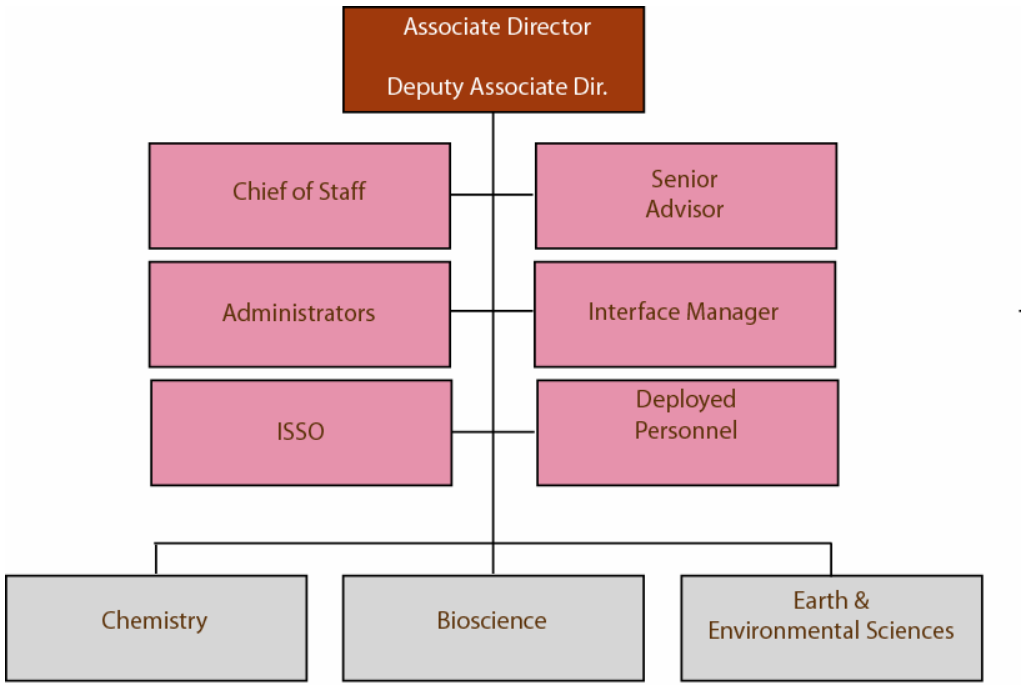

Figure 3: CLES Organization Chart

Experimental and Physical Sciences Directorate

The organizational design of the Experimental and Physical Sciences Directorate is shown in figure 4. ADEPS is supported by a support staff and has four functional organizations that support accomplishment of mission objectives: Los Alamos Neutron Science Center (LANSCE), Material Science and Technology Division, Materials Physics and Applications Division, and Physics Division. The worker injured at CMR was an employee of MST Division. ADEPS has a facility – tenant agreement with ADCLES that allows some MST employees to work inside the CMR Facility.

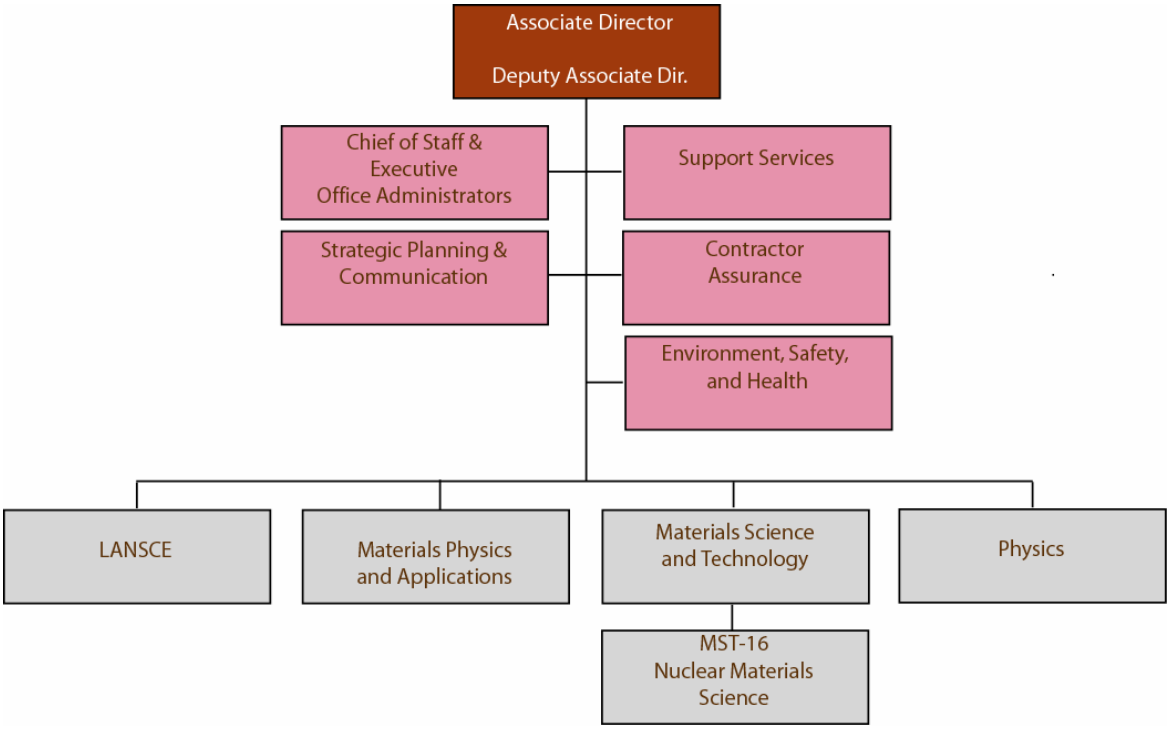

Figure 4: EPS Organization Chart

The CMR Facility Operations Director shown in figure 5 is matrixed into the ADCLES to perform work. The CMR Facility Operations Director (CMRFOD) is assigned from the ADNHHO shown in figure 2. The CMR FOD has seven functional areas that support the mission accomplishment including: Maintenance; Operations; Environment, Safety, Health, and Quality Assurance; Waste Services; Engineering; Support; Security, and Radiological Control.

Implementation procedure IMP 313.0 is the defining document that governs the Roles, Responsibilities, Authorities and Accountabilities for all ADs and FOD staff. Issuing authority comes from the Principal Associate Director for Operations and the Responsible Manager is the Associate Director for Nuclear and High Hazards Operations. A worker's *Role* is the function that he or she performs. A worker may have one or more *Roles*. *Responsibilities* are formally assigned specific actions that a worker is expected to perform. *Authority* is the power or influence to make decisions and *Accountability* represents assurance that actions taken under an employee span of controls are within expectations.

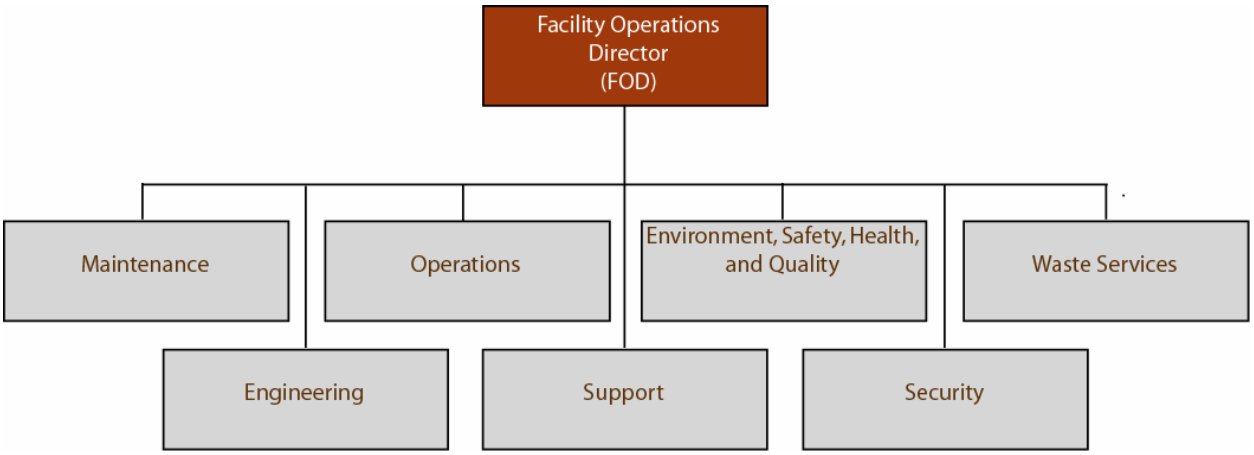

Figure 5: General FOD Organization Chart

LANL's organizational structure consists of Principal Associate Directors and Associate Directors under the leadership of the Laboratory Director as shown in figure 6. For Facility Operations the Director has chosen a Facility Responsible Associate Director (RAD) Model. Under this model the Facility Responsible Associate Director has overall *responsibility* and *accountability* to the Director for the safe, secure, and environmentally compliant performance of all work within an assigned set of faculties.

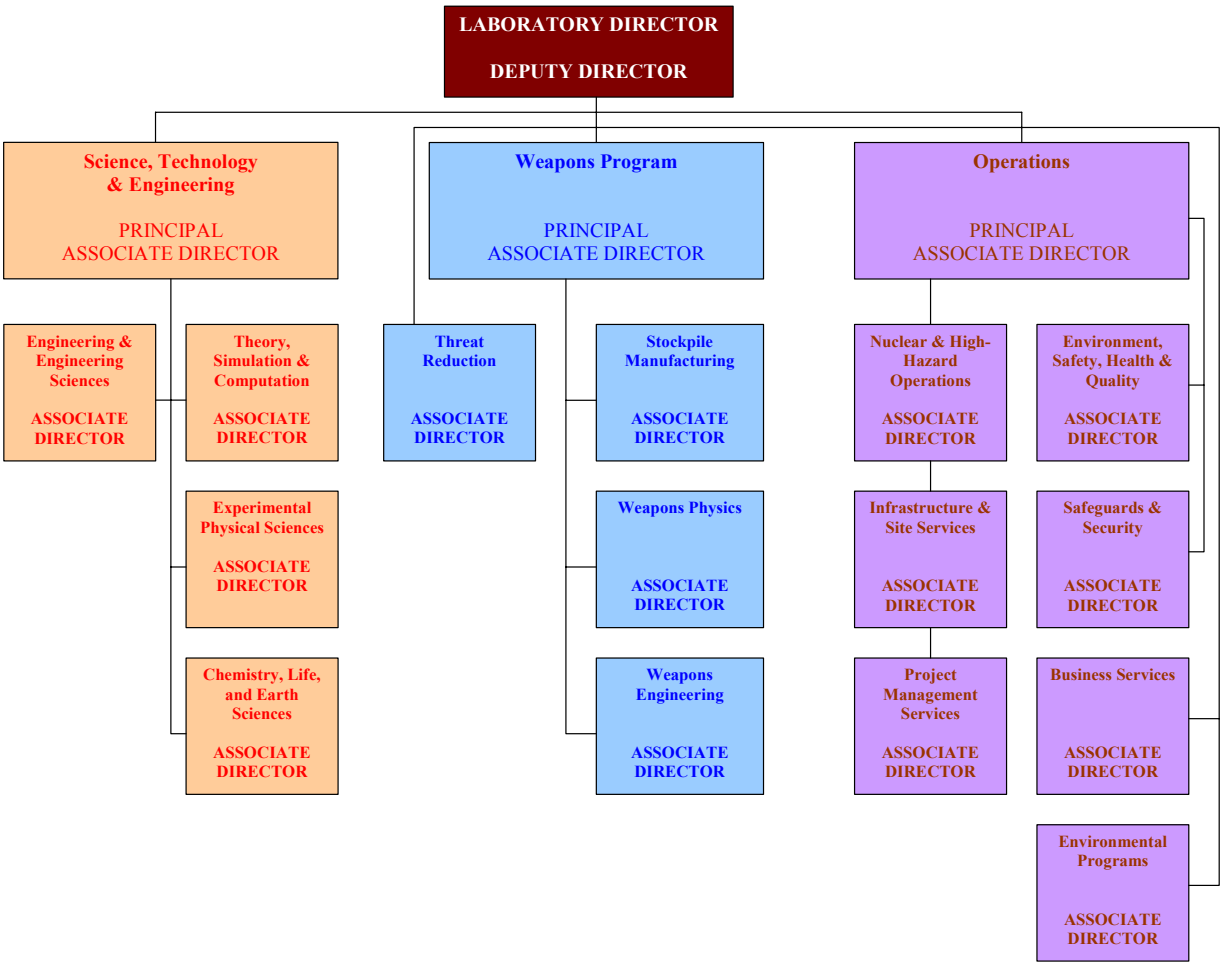

Figure 6: LANL's Organizational Structure

Under this model some key responsibilities of the RAD include: define the mission need and use of the facility; own the facility safety, security and compliance envelope; ensure effective implementation of applicable regulatory contractual and institutional programs and requirements; set and communicate expectations for the safe, secure, and compliant operation of the facility; establish the operating budget for the facility; and establish mission and programmatic objectives and milestones. Additionally, the RAD establishes the interface agreements as required for other tenants working inside their assigned facility. The RAD has the authority to establish strategy and priorities for assigned facilities, and to set budgets. A key responsibility of the RAD is to suspend operations in assigned facilities when appropriate and to resume work after an interruption in operation per procedure.

The Responsible Line Manager (RLM) is the line manager (e.g. division leader and group level manager or equivalent subcontractor) having the responsibility, authority, and accountability to plan, validate, coordinate, approve, execute, and close out work activities in accordance with IWM. Responsibilities of the RLM include defining the work in sufficient detail to assess the risks, identifying and analyzing work hazards and grading these hazards, ensuring all workers are trained and certified, ensuring work is released by the Facility Operations Director (FOD), monitoring work to ensure it is executed in a safe, secure manner, and ensuring appropriate feedback on and improvement of the process. The RLM has the authority to control and manage activities in order to execute the responsibilities outlined in the programmatic requirements of the Mission. The RLM is also accountable to the FOD and RAD to ensure activities are conducted within the safety envelope of the facility and do not place the public or co-located workers at risk.

The FOD takes direction from the RAD and is the senior line manager who provides overall facility operations. The FOD provides organizational leadership for facility Maintenance, Operations, Environment, Safety, Health, and Quality Assurance, Waste Services, Engineering, and Radiological Control. The FOD coordinates all these functional areas to ensure that all activities are performed in a safe and compliant manner. The FOD uses deployed personnel from other base operations at LANL. Key responsibilities of the FOD include establishing the facility safety bases and compliance envelope, ensuring appropriate training, implementing Conduct of Engineering, Conduct of Maintenance, and Conduct of Operations, and *performing field operations to ensure activities are being performed safely and compliantly*. The FOD has the authority to restart activities on the approval of the RAD, authority to control facility access requirements, authority to set performance objectives for and provide input to the performance appraisals of assigned and deployed personnel. The FOD is accountable to the RAD for managing the facility, maximizing the availability of the facility for mission programs, and conforming to the facility's operating budget. The FOD is accountable to the RAD and ADNHHO or ADI&SS for effective implementation of Conduct of Operations, Conduct of Engineering, and the Conduct of Maintenance.

IMP313.1 assigns, to the FOD, the role of "coordinating the efforts of [support] managers to ensure that all facility and programmatic activities are performed in a safe and compliant manner", the responsibility for "performing field observations and assessments to ensure activities are safely and correctly conducted" and for "implementing institutional programs (i.e. Conduct of Engineering, Conduct of Maintenance, Conduct of Operations, etc.)", and the authority to "control and manage activities and work within their facilities in order to execute the responsibilities." In practice, these definitions apply to facility activities and support functions, and do not apply directly to programmatic work. FODs do not have the R2A2s to enable them to ensure programmatic work performed inside their facilities is conducted in a safe and compliant manner. These R2A2s reside with RADs and RLMs, who in these events, did not achieve the expected level of performance to ensure safety.

Radiation Protection

LANL's Radiation Protection Program (RPP)

The responsibility for LANL's RPP resides with the Radiation Protection (RP) Division. The RP Division Leader serves as the LANL RPP Manager and is responsible for establishing the institutional program and providing guidance for its implementation. The RP Division Leader reports to the Associate Director for Environment, Safety, Health, & Quality (ADESHQ) who in turn reports to the Director.

Implementation Support Document (ISD) 121-1.0, *Radiation Protection*, documents the various elements of the RPP. The ISD details the policies and requirements for implementing 10 CFR 835 *Occupational Radiation Protection* at LANL. It identifies the roles, responsibilities accountabilities and authorities (R2A2) for key personnel, including requirements to ensure worker safety and compliance with applicable regulations. The ISD provides specific requirements for implementing IWM where radiological hazards are involved.

Within the RP Division, the Health Physics Operations Group (RP-1) is responsible for supporting the line implementation of the operational aspects of the program. All radiological control technicians (RCTs) and operational health physicists (HPs) at LANL are members of this group. They are deployed through a matrix concept to line organizations conducting radiological activities.

The Health Physics Measurements Group (RP-2) is also a part of the RP Division. They provide support functions such as analytical services, calibration activities, bioassay monitoring, and internal dosimetry.

LANL's RPP is implemented into the workplace through the development of facility-specific radiation protection requirement documents (RDs). These RDs identify the requirements for most radiological work in radiological control areas (RCAs) and radiological buffer areas (RBAs) including routine work in gloveboxes. Radiation work permits (RWPs) are used at LANL only for unique tasks or for unique radiological hazards.

RP Implementation of Integrated Safety Management (ISM)

IMP 300, *Integrated Work Management for Work Activities,* establishes the comprehensive LANL program for conducting work safely. IMP 300 requires the development of IWDs to document the work activity hazards and establish controls. The radiological protection operations and emergency response activities performed by RCTs are covered by *Surveys, Inspections, and Radiological Protection Activities in Radiological Areas* (IWD-HPO-06-01). The single control established for this work is current LANL RCT qualification (i.e., Qualified Worker).

Response to Radiological Injuries

ISD 121-1.0 provides general guidance for dealing with minor injuries and potentially contaminated wounds. This information is supplemented by radiological protection procedures. These documents prescribe the following actions:

- Monitor the wound area and the object causing the wound (if practicable) to determine the extent of contamination
- Remove anti-C clothing or other coverings from the contaminated area of the person's body
- Perform simple, noninvasive decontamination by using tape compressions followed by washing with mild soap and lukewarm water
- Cover the wound with sterile dressings
- Transport the worker to Occupational Medicine or LAMC for medical evaluation
- Monitor the wound, excised tissues and/or bandages for contamination using specialized wound counting instrumentation
- Provide radiological data to medical personnel as it's acquired
- Evaluate the need for medical intervention such as wound debridement or the use of blocking/chelating agents
- Determine the need for bioassay monitoring
- Establish radiological work restrictions for the injured person, as necessary

Chelation Therapy and DPTA (excerpted from the USFDA website)

When a person is internally contaminated with plutonium or other transuranic elements, chelation therapy can be used to increase the rate of excretion of these materials from the body. This is accomplished by chemically binding a specialized molecule (the chelating agent) to the plutonium so that it can be passed out of the body in the urine before it is incorporated into tissues or bone.

The standard chelating agent for the treatment of plutonium internal contaminations is diethylenetriaminepentaacedic acid or DTPA. The FDA-approved method for administering DTPA is through calcium pentetate or zinc trisodium injections (Ca-DTPA or Zn-DTPA). These drugs have been used investigationally for over 40 years for the treatment of industrial accidents involving plutonium, americium, and curium exposures.

The FDA recommends that when both Ca-DTPA and Zn-DTPA are available, Ca-DTPA should be given initially, followed by Zn-DTPA if needed. This specific treatment sequence is recommended because Ca-DTPA is roughly 10 times more effective than Zn-DTPA during the first 24 hours after the event. After the initial 24 hours, Zn-DTPA and Ca-DTPA are similarly effective, but Ca-DTPA causes more loss of essential metals from the body. Therefore, Zn-DTPA is preferred for maintenance therapy.

Other than the physical discomfort involved with the transvenous administration, and the possibility of a few minor side effects, the risks associated with the administration of DTPA are minimal. The main side effects of DTPA chelation therapy is the loss of certain essential nutritional metals from the body. These side effects can be countered by taking mineral supplements. Other side effects may include nausea, vomiting, diarrhea, fever, or muscle cramps. Ca-DTPA and Zn-DTPA are not recommended for use in minors, pregnant women, and in patients with pre-existing kidney disease; Ca-DPTA is contra-indicated for patients having a history of kidney problems.

Bioassay Monitoring and Dose Assessment (excerpted from HSR-12-03-TB-01.0)

In every contamination event with the potential for an internal exposure, LANL's Internal Dosimetry team plays a role in evaluating the risks associated with the exposure. The involvement of Internal Dosimetry is usually limited to initiating appropriate bioassay and assessing doses as data become available. In some cases, the team also consults with medical personnel about the advisability of medical treatment such as chelation therapy.

Following their initial notification of a radiological incident, Internal Dosimetry identifies the need for special bioassay monitoring. Special bioassay is designated as either *diagnostic,* which refers to a single sample, or *prompt action*, which refers to a series of successive samples. The team uses a variety of field indicators (air filter results, nasal swipes, wound count data, etc.) to determine the appropriate strategy. In general, diagnostic monitoring is indicated for potential doses between 100 mrem and 500 mrem. Prompt action monitoring is indicated for potential doses of 500 mrem or greater.

For both events described in this report, the initial wound counts were greater than 0.2 nCi indicating the need for prompt action bioassay monitoring. Additionally, the Internal Dosimetry Team Leader consulted with and advised medical personnel with regard to wound debridement and chelation therapy.

Internal dose assessment is performed by the Internal Dosimetry team using current recommendation of the ICRP regarding biokinetic models and default parameters. The administration of chelating agents directly impacts these models. Thus, a reliable dose assessment cannot be recorded for an extended period of time following the cessation of chelation therapy.

Units of Radiation Dose

Since 1992, radiation dose limits and annual dose reports to workers have been expressed in terms of the total effective dose equivalent (TEDE). The TEDE is the sum of the deep dose received from radiation sources outside the body (e.g., from exposure to x-rays) and the committed effective dose equivalent (CEDE), which is the dose received from taking radioactive material into the body.

The CEDE is the calculated dose an individual will receive during the 50 years after radioactive material is taken into the body. Some radioactive chemicals, such as plutonium oxide, remain in the body for very long periods of time and continue to deliver dose to the individual at a fairly constant rate over an extended time.

REAC/TS

Since 1976, the Oak Ridge Institute for Science and Education has managed the Radiation Emergency Assistance Center/Training Site (REAC/TS). The REAC/TS mission for DOE is two-fold:

- Provide over-the-phone advice and consultation on radiation emergency medicine
- Provide 24/7 availability to deploy and provide on-scene emergency medical services

In addition to these services, REAC/TS teaches accredited continuing education courses in radiation emergency medicine for physicians, physicians' assistants, nurses, emergency medical technicians, health physicists, and first responders. These courses involve lectures, discussions, and hands-on exercises that expose attendees to their roles in the medical management of a radiation incident.

Glovebox Glove Integrity Program (GGIP)

GGIP Program for TA-55 and CMR:

TA-55 has a Glovebox Glove Integrity Program (GGIP). Programmatic operations at TA-55 require the use of many different types of gloveboxes. These operations include the processing of various actinides. The primary actinide is plutonium (Pu-239 / Pu-238). Other actinides are used as well and present similar toxic and radiological hazards. Gloveboxes are used to confine the radiological hazard and glovebox gloves present the weakest hazard barrier in the confinement system. Currently, no glovebox glove manufacturer produces a puncture / breach proof glovebox glove.

The program is documented in procedure TA-55-AP-039, R1. The program requires that the facility install each glove and mark each glove with the install date. This date is used to calculate the expiration date of the glove. The procedure provides a set frequency for change out. Gloves used in a Pu-239 operation have a 2 year service life and gloves used in a Pu-238 operation have a 1 year service life.

Glovebox gloves are required to be inspected daily, prior to use. These inspections are performed by the workers who check for normal wear as well as any obvious damage that would make the glove unusable. An annual inspection is also required and is documented by the procedure. During the investigation, the team witnessed glove usage in the facility. Inspection adherence and radiological monitoring should be emphasized to all workers and compliance must be reinforced by supervision and management. The GGIP allows the facility to extend the service life of the glovebox gloves. This is accomplished by a team of personnel.

The composition of the team is as follows:

- One RCT
- A Glovebox Subject Matter Expert (SME)

These personnel are trained to inspect the glovebox gloves. The extension period is 1 year, and the gloves can be extended a maximum of 4 intervals. Thus, a 1 year glove could be used for 5 years. The GGIP also tracks and trends glove failures. When the facility changes a glovebox glove for any reason, the procedure uses a form to collect information that can be tracked and analyzed. The facility tracks and trends this data which dates from 1993 to the present time.

The TA-55 facility has approximately 8000 glovebox gloves. Of the 8000, approximately 2500 gloves are in active use. On an annual basis, the facility experiences approximately 50 glove breaches or failures. The following definitions are used in the TA-55 procedure:

- A **glove breach** is defined as mechanical damage during operations (e.g., penetration with a sharp object, rotating equipment, pinch points, thermal sources, etc.).

- A **glove failure** is defined as degradation of the mechanical properties over time (e.g., exposure to chemicals and nuclear materials).

The primary means of minimizing glove failures is through controlling the service life and formal inspection frequencies for the glovebox gloves. Of these 50 breaches / failures, 10 are failures and the remaining 40 are acute glove breaches. Acute breaches are generally some type of puncture or tear. These are due to sharp objects in the glovebox or contact with rotating equipment in the glovebox.

The CMR facility GGIP was managed by TA-55 personnel until the October 2006 timeframe. Beginning in November, the CMR facility began to manage an informal GGIP. The GGIP procedure is in draft form and is awaiting review by an internal CMR committee. Approval of the CMR GGIP is expected in March 2007.

CMR's draft procedure is modeled after the TA-55 GGIP and has been revised to account for the unique operations at the CMR facility, but it has not been formally implemented. Implementing a formal GGIP would assist the facility in gathering data that could be used to strengthen the program.

Other glovebox glove programs in place at LANL are generally informal and immature. The following is a table of facilities with glovebox gloves.

Facility	Hazard	Formal GGIP
TA-55	Actinides and other Radionuclides	Yes
CMR	Actinides and other Radionuclides	Draft Procedure
WCRR	TRU Wastes	None
BSL-3	Biological Agents / Materials	Planned for use at Startup
WETF	Tritium	None
RC-1	Actinides and other Radionuclides	None

Since the glovebox gloves are not a robust barrier to prevent actinide or other uptakes, additional care must be exercised whenever a worker is using them. For example, facilities could inspect gloves regularly and control glovebox glove service life.

WR Cotton Glove Usage

The TA-55 facility produces Weapons Components for National Security Missions. These missions are required to follow the requirements of QC-1. QC-1 provides very stringent controls of materials that come in contact with the components. In the June 2002 timeframe the facility instituted the use of cotton gloves. The cotton gloves provide a contamination barrier between the component and the glovebox glove environment. The cotton gloves are worn over the glovebox glove. See figure 7 below.

Figure 7

The gloves are procured to War Reserve (WR) requirements and are used multiple times in the process. The gloves are not difficult to don onto clean glovebox gloves. Members of the investigation team were able to easily don and doff the cotton gloves over the cold glovebox gloves in the PF-39 cold training lab. The investigation team witnessed two TA-55 machinists donning and doffing cotton gloves with ease in the glovebox gloves in

PF-39. As the glovebox gloves wear and / or become engrained with oxides, the cotton gloves become very difficult to don. The glovebox glove is essentially as rough as fine-grit sandpaper. Significant effort is required to don the cotton glove, including a strong pulling motion on the cuff of the cotton gloves. This is the type of pulling motion that is the direct cause of the incident. The approximate configuration of the machinist and the tooling is shown in figure 8 below.

Figure 8

The machinist was tugging on the cuff of the left cotton glove when the injury occurred. The right interior wrist is the site of the wound. The force necessary to don the cotton gloves made the strike on the machining bit penetrate through the glovebox glove and the latex gloves worn by the machinist. The wound is the result of the right wrist striking the machining bit in the boring bar shown in figure 9 below.

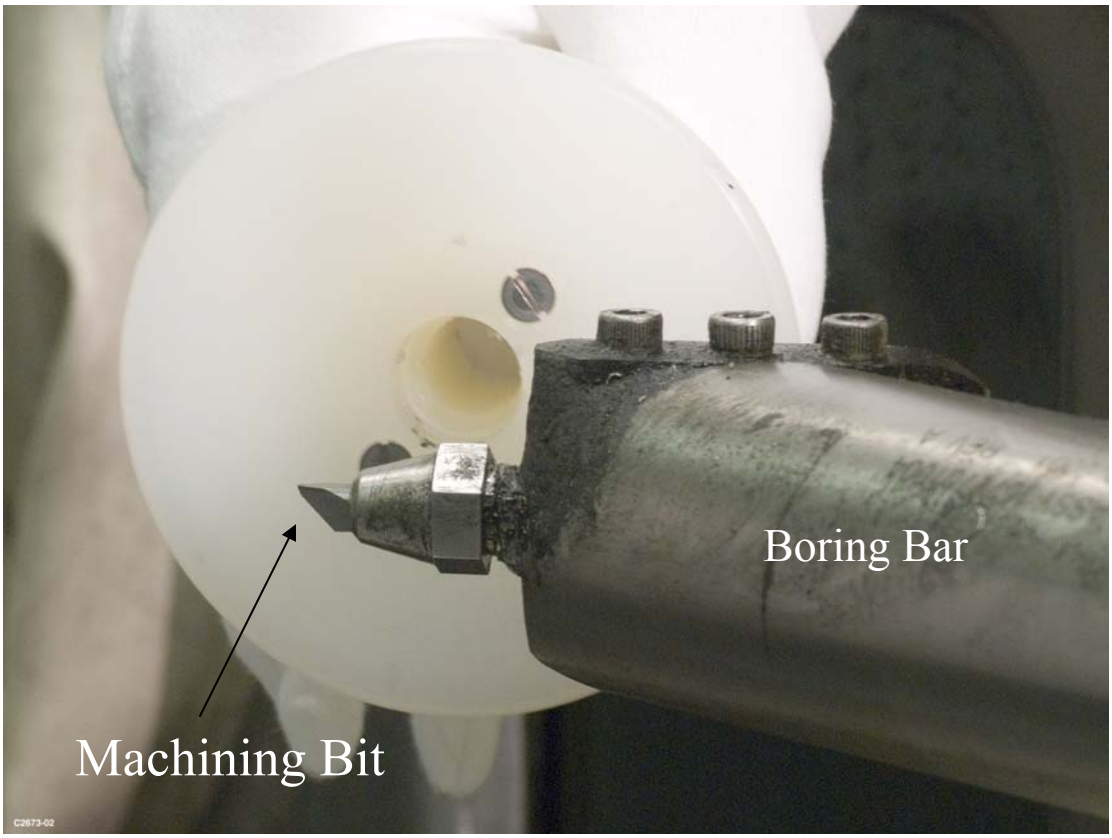

Figure 9

Weapons Component Manufacturing (WCM) is pursuing a removal of the cotton gloves from the process. This action is expected to be complete in the near term and will enhance the safety of the operation. In addition, WCM has designed and built several tool covers. These will be used to shield sharp tools from the glovebox gloves. These actions are planned. but have not been formally implemented.

The work instruction that is used to machine the component does not include steps that direct the use of the cotton gloves. The procedure does not include any notes or warnings. A typical nuclear facility work instruction or procedure would give specific direction as to when and how the gloves must be used. The TA-55 work instruction did not provide any direction in this regard. Interviews with the personnel involved revealed that the cotton gloves are donned at approximately the same step in the machining process. The interviews also indicated that the position of the boring bar relative to the glovebox gloves was different for different machinists. At least one of the machinists moved the boring bar away from the glovebox gloves prior to donning the cotton gloves. This "Good Practice" was not included as a step in the work instruction nor was it communicated to all personnel. The management team was not aware of this practice. The position of the boring bar in the distant position is shown in figure 10 below.

Figure 10

Compare figure 8 with figure 10. The change in distance is approximately 15 inches. This change in distance from the glovebox gloves would have prevented this incident.

The machining process is complex, involves plutonium and other actinides, and requires that workers pay a high degree of attention to details. Management's effort did not result in controlling or removing hazards posed by sharp tools in the glovebox environment. Not all sharp tools were removed or repositioned nor were they guarded or otherwise rendered harmless when not in use.

Interviews indicate that management does not elicit feedback from workers involved in the work, and that there is a clear emphasis on producing the required number of components without a corresponding emphasis on doing the work safely.

Previous Similar Events:

At TA-55, the average number of glovebox glove breaches/ failures is approximately 50 per year. This number is excessive. Since most other facilities do not track glove breaches or failures, the average number of failures across LANL facilities is an unknown.

Facilities in the Weapons Complex with a large number of glovebox gloves and manual handling of actinides do not exhibit comparable breaches / failures rates. There is no clear evidence that LANL has taken action to reduce the failure rate; therefore, the AIT believes this indicates that LANL has accepted the rate (and the associated risk of an uptake) as a "cost of doing business".

The TA-55 facility experienced two breaches that are of particular interest. On November 21, 2006, a machinist using a horizontal lathe was machining a part to specification. During this operation, the machinist experienced a glovebox glove breach. The breach occurred when reaching across the tool rest to make an adjustment. Fortunately, the inner latex glove was not breached. The facility was within 0.021 inches of a contaminated wound and potential uptake, the thickness of the latex glove. A critique was held and corrective actions planned.

On December 11, 2006, the exact same incident occurred with the same machinist. Based on data gathered from the interviews, none of the corrective actions from the previous incident had been implemented. No formal occurrence declaration was made. The management team allowed the machining operation to continue without putting compensatory measures in place until all corrective actions were implemented. After the second incident, the machinist was removed from the process for additional training.

Members of the team were able to visually inspect the glovebox where the November and December events took place. The glovebox gloves are not placed appropriately for the work activities. The machinist is forced to reach across the tool rest to manipulate the part. Following the events, the management team did not take timely actions to prevent reoccurrence.

A review of recent type "B" investigations and significant events was performed. These included:

- LANL Investigation of a Laser Eye Injury (9/01/2004)
- Type "B" Investigation of the Americium Contamination Accident at the Sigma Facility (07/14/2005)
- Investigation Report of the CMR Fire Event (06/16/2006)
- Type "B" Accident Investigation of Hoisting and Rigging Accident (06/06)

The Judgments of Need in each report are strikingly similar to one another. This indicates that prior corrective actions were not effective. This could be a result of:

- Ineffective corrective actions
- Corrective actions not implemented
- Corrective actions not enforced

This investigation team has derived another set of Judgments of Need and they are similar to the previous reports as well. Senior Laboratory management needs to ensure effective implementation of actionable and enforceable corrective actions to prevent recurrence.

Collective Analysis of Both Events

Root Cause Analysis

The AIT considered both events in determining root causes. In each event, actions, inactions, and conditions were present that allowed two separate workers to injure themselves. Both wounds were contaminated and, in the CMR event, a significant CEDE could result. The causes of each event are different, but they indicate potentially broader problems that allow accidents to occur. Those root causes are described below.

1. LANL personnel did not follow formal procedures.
    a. At CMR, the worker did not comply with the work instruction and implement the appropriate controls. The work instruction required the worker to don leather (or other protective) gloves over the glovebox gloves; this was not done.
    b. Occupational Medicine personnel did not follow their formally defined guidelines. Several of the doctors were not aware the guidelines existed.
    c. The CMR work instruction did not cover the process of removing a sample from the epoxy mold. The work simply defaulted to a work instruction for using hand tools inside a glovebox. A more rigorous work definition could have been developed, including when controls are required. This would have resulted in a consistent and safe procedure for conducting this work.
2. Management expectations were less than adequate, especially with regard to supervising and overseeing workers, work, and work space.
    a. Over time, expert-based systems can allow too much freedom and discourage co-workers from questioning the expert. Supervisors and managers develop a trust in the expert's abilities and fail to verify the worker's performance in general areas such as industrial or radiological safety. Expert-based systems also make it difficult to stop work or otherwise question the work being performed because the expert is making the determination. Experts can underestimate the risk associated with routine tasks such as using hand-tools or donning cotton gloves over glovebox gloves.
    b. MST-16 supervision lacked a sufficient presence to ensure work was being performed safely. SM's team leader only visited CMR on a monthly basis. Infrequent management presence led to an inconsistent implementation of safe work practices, methods, and behaviors. Without frequent supervision, standards of performance cannot be established and reinforced. Workers were allowed to take unacceptable risks; their unsafe actions were either not detected or were tolerated.
    c. The AIT believes that supervisors and managers could easily have watched both events occur and that they would not have stopped work to make the necessary corrections to prevent these events.

   d. Without appropriate supervisions, workers lose an appreciation for the potential consequences of an error, not only to themselves, but to the institution. Workers become "self-supervised," and this becomes an expectation.
   e. Management advocates and accepts behavior that emphasizes "production over safety." Programmatic work is not subject to rigorous formality of control that is appropriate for nuclear and other high hazard work, even when the "programmatic" work is of a routine facility or laboratory operation nature.
   f. Management assigns team leaders and expects them to be supervisors, without clearly defining their roles, responsibilities, authorities, and accountabilities (R2A2).
   g. R2A2s are also not clearly defined and aligned with respect to Associate Directors, facility tenants, and FODs.
3. Management did not effectively respond to precursor events.
   a. At TA-55, events occurred in June, November, and December 2006. While some actions were taken, they were administrative in nature.
   b. The management of CMR failed to learn from the events at TA-55. The management of CMR did not respond with a sense of urgency to their January 2007 event until after the January event at TA-55. The corrective actions that were taken (training, upgrade procedures, identify "sharps") had all been taken before, yet had not prevented an occurrence. There is no reason to believe they will, by themselves, prevent recurrence in the future.
4. Not all LANL programmatic managers are equipped with the operational experience required to be able to fulfill their assigned responsibility for ensuring work is performed safely. This is especially evident at Nuclear and High Hazard Facilities. FODs and others who do have the operational experience are not effectively used to ensure the safe conduct of daily programmatic work.
5. Management did not eliminate or remove the hazard.
   a. At TA-55, the cutting tool could have been repositioned away from the worker. This practice was done by at least one of the machinists.
   b. At TA-55, a tool guard was not utilized. Prior events had identified the need to install tool guards, but the action had not been implemented. Interim compensatory actions were not implemented until such time as the guards could be developed and put into use. At the time of the event a prototype was available
   c. At TA-55, managers listened to worker feedback, but did not respond. The concern over the difficulty in donning and using the cotton gloves was accepted as a reasonable inconvenience. The cotton gloves may actually be an unnecessary requirement.

Analysis of Medical Response

The Occupational Medicine Facility has a set of guidelines entitled, *Occupational Medicine Program Treatment Guidelines for Radiation and Biologic Exposures* (PED119-7B-160.0). Occupational Medicine personnel were not fully aware of the written guidelines and, therefore, these guidelines were not completely followed. They state that chelation should start as soon as possible, is best begun within one or two hours of exposure, and should precede excision. This early administration allows the maximum time for the chelating agent to act. However, such a time frame leaves little time for decision-making.

The overall environment at the Occupational Medicine Facility lacked formality, command, and control. Communications were not effective in transferring wound count information to the medical doctor(s) so that informed decisions could be made regarding treatment. A dosimetrist was not present to advise medical doctors.

In both cases, the worker was released prematurely. In the CMR event, the worker had signed the release paperwork and was preparing to leave, but was retained before he actually left the facility. Similarly in the TA-55 event, the worker was released and returned to TA-55 for a short period of time before being recalled by the doctor.

Accordingly, to the extent practical, medical personnel need to prepare in advance and be ready to respond to an acute event involving a potential internal exposure. Such preparations need to include:

- Strengthening the training and information regarding merit, efficacy, and side-effects of chelation for workers and management.
- Setting clear expectations for Occupational Medicine staff that treatment guidelines will be followed absent medical contraindications.
- Conducting drills of the medical response to contaminated wounds and other intakes in emergency exercises.
- Designating that a senior dosimetrist (or senior health physicist with internal dosimetry experience) be present at Occupational Medicine to assist medical staff with interpreting radiological measurements and information used for medical decisions.

The medical treatment provided for both injuries significantly reduced the potential CEDE to each affected worker. In the case of TA-55, excision averted over 95% of the potential CEDE. In the CMR event, significant CEDE was also averted. However similar lapses in the future could potentially result in more unfavorable outcomes. Even though the efficacy of medical intervention is often influenced by factors beyond the control of the care provider, the AIT believes correcting the noted deficiencies is critical.

The AIT has entered this issue into the institutional issues management system in accordance with ISD 322.4, Issues and Corrective Action Management Process.

Human Performance Analysis

These two events were evaluated utilizing human performance tools. The purpose of the human performance analysis is to identify the error precursors and latent organizational weaknesses that contributed to the human error present in these events. Error precursors are existing conditions that are known to increase human error rates. These conditions are predicable and can be eliminated or mitigated. Latent organizational weaknesses are undetected deficiencies in organizational processes or values that create workplace conditions that provoke error or weaken defenses. This investigation found both error precursors and latent organizational weaknesses that were contributing factors to this event.

Two of the major issues that appear to be prevalent at LANL are: 1) A belief that competent and/or expert employees are infallible and that they don't need supervision. All humans are fallible and even the best make mistakes; 2) People can either focus on the task at hand or on situational awareness. They are not capable of doing both at the same time. This makes peer checks, independent verifications, and hands-on supervision critical to eliminating errors that can cause significant events. Both issues are fundamental human performance tenants.

Human Performance Improvement Analysis – Error Precursors

Task Demands

Time Pressure (in a hurry)

- The CMR SM had professional time pressure to get the samples to the requester as well as complete his own work. He also had personal time-demands that caused him to be away from work creating additional time pressure.
- PF-4 production demands require near constant operation of machine tooling.

Irrecoverable act

- The chelation treatment of SM was delayed when compared to the Occupational Medicine guidelines. (The impact of this delay on the CEDE is an unknown.)

Unclear goals, roles, and responsibilities

- Supervision does not have clear standards and expectations necessary to fulfill its responsibility for ensuring work is performed safely.

Work Environment

Distractions/interruptions

- There was not a process for controlling the crowd at the occupational medical facility. This created a confusing and error-likely environment.

Changes/departures from routine

- Cotton gloves become required at PF 4

Individual Capabilities

Unfamiliarity with the task/first time

- Several of the doctors were relatively new and had never previously treated this type of contaminated wound.

Lack of knowledge (mental model)

- Several of the doctors did not understand radiation units of measure.

New techniques not used before

- Several of the doctors were not familiar with the guidance for treating a contaminated puncture wound.

Imprecise communication habits

- The communication between the radiological personnel and the occupational medicine personnel on the subjects of wound counting and dose calculations was not effective.
- SM did not communicate (as directed by procedure) with the CMR Operations Center to initiate an emergency response.
- TA-55 machinists did not share the good practice of moving boring bar out of the way.

Lack of proficiency/inexperience

- Several doctors were inexperienced and lacked proficiency in treating contaminated wounds.

Unsafe attitude for critical task

- The Occupational Medicine doctors did not consult their guidelines
- PF-4 workers continued the machining process despite the hazardous work condition (i.e. the difficulty in donning cotton gloves).

Human Nature

Stress

- SM was under personal and professional stress
- Schedule pressures at PF-4 were evident to the workers

Assumptions

- Assumption was made by SM that he was not dealing with a sharp.
- Assumption was made that the contamination in the wound was insoluble.

Complacency/Overconfidence

- The laboratory in general tends toward complacency and overconfidence when dealing with competent and experienced personnel.

Mindset ("tuned" to see)

- LANL tends to believe that competent personnel or experts are infallible.
- LANL tends to believe that competent personnel or experts don't need supervision.
- LANL tends to believe that conduct of operations and work control are not necessary for science.

Inaccurate risk perception

- SM did not perceive the screwdriver as a sharp.
- Management did not accurately perceive the risk associated with not supervising SM.

Judgments of Need (JONs)

Judgments of Need	Supporting Discussion
JON 1: LANL needs to ensure all workers comply with existing processes and procedures.	IWM documents and work instructions are only effective in so far as the workers comply with the requirements. In the CMR event, the controls contained in the work instruction were sufficient to have protected the worker.
JON 2: LANL needs to provide supervision that exerts positive control and surveillance over all workers, work activities, and work space.	Supervision is critical with regard to developing safe habits and behaviors in the work force. Behaviors such as following a procedure and implementing established controls or stopping work are vital in mitigating the impact of human error.
JON 3: LANL needs to ensure sufficient oversight of all workers, work activities, and work space to ensure all activities (*programmatic and non-programmatic*) are performed in a safe and compliant manner.	IMP 313 assigns FODs the responsibility to ensure all activities are performed in a safe and compliant manner. FODs presently have authority to release work, but are not expected to oversee programmatic work performed in their facility to ensure accepted Nuclear Standards such as Conduct of Operations, Conduct of Maintenance, and Conduct of Engineering are implemented.
JON 4: LANL needs to implement a human performance process to proactively prevent errors that cause significant events.	All humans are fallible and commit errors. A human performance initiative will reduce human error and identify organizational weaknesses that contribute to human error. This is especially critical for expert-based systems.

Judgments of Need	Supporting Discussion
JON 5: LANL needs to ensure the effectiveness of their response to (precursor) events and conditions.	The AIT believes there are opportunities for improvement in the areas of developing and completing corrective actions; assessing the potential nature of an event as a precursor event; and considering the extent to which the nature of the event and lessons learned apply to other organizations and/or facilities within the institution. Multiple precursor events preceded these two injuries. Prompt and effective response to these precursor events would have prevented both events from occurring. In the case of TA-55, a corrective action was planned, but had not been implemented. In the case of CMR, prior actions had still not mitigated the "sharps" hazard posed by certain hand tools.
JON 6: LANL needs to establish an aggressive glovebox glove program to reduce glove failures to as low as reasonably achievable.	TA-55 has a mature Glovebox Glove Integrity Program (GGIP). The program is not completely effective in preventing glove failure and breaches; there are nominally 50 failures and breaches per year at TA-55. Other glovebox facilities do not have a working GGIP. The failure and breach rate must be reduced to a point where uptake / injury are unlikely.
JON 7: LANL needs to establish clear standards, expectations, and mentoring to equip supervisors to fulfill their assigned responsibility for ensuring work is conducted safely.	These two events indicate that management has a tendency to accept habits, work behaviors, and conditions in the working environment that are not consistent with performing work safely. Production can easily take precedence over safety if managers do not remain vigilant. Using a screwdriver inside a glovebox without the appropriate PPE was an accepted practice. The difficulty associated with donning cotton gloves over glovebox gloves was considered a reasonable inconvenience.

Appendix A: Appointment Memorandum

Los Alamos NATIONAL LABORATORY EST. 1943

memorandum

Office of the Director

To/MS: Robert L. McQuinn, ADNHHO, E517
From/MS: Michael R. Anastasio, A100
Phone/Fax: 7-5101/Fax 7-2997
Symbol: DIR-07-025L
Date: January 22, 2007

Subject: Appointment of LANL Investigation Team for Two Recent Internal Contamination Events at CMR and TA-55

On January 8, 2007, a Los Alamos National Laboratory (LANL) worker was injured while performing work at the Chemistry and Metallurgy Research (CMR) Facility. On January 17th, a second LANL worker was injured at the Plutonium Facility (TA-55). In both cases, work was being performed inside a radiological glovebox. Both injuries resulted in internal contamination.

On January 12, 2007, I appointed Carl Beard as the team chair to lead a team in investigating the incident at the CMR Facility (DIR-07-018L). In light of the most recent event at TA-55, I have rescinded that appointment (DIR-07-024L).

I hereby establish a new LANL investigation team to investigate both events and appoint Robert L. McQuinn, Associate Director for Nuclear and High Hazard Operations, as the team chair. As team chair, you are authorized to appoint core team members to complete the investigation. You should, in consultation with the LANS Board of Governors Operations and Business Subcommittee, choose one or more members of your team from a parent company. The team should also include an observer from the Los Alamos Site Office. You may also identify and utilize advisors, consultants, and other resources as necessary to complete the investigation. Please work with the Quality Assurance-Operational Assurance Group in assembling the team and completing the investigation. The team should include an observer from the Los Alamos Site Office.

The team will conduct the investigation and analysis of these two incidents and will provide an investigation report to me for my approval by February 23, 2007. The scope of the team's investigation must include, but is not limited to:

- identifying and establishing all relevant facts regarding both incidents;
- determining the causes of both incidents;
- evaluating similar previous events for common causes and corrective action effectiveness;
- evaluating the extent of condition related to the incidents;
- evaluating LANL's immediate response to each incident;
- determining conclusions; and
- developing judgments of need that address the causes and that should prevent recurrence.

Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. Factual accuracy reviews are allowed. Please provide my office with weekly reports on the status of the investigation.

Appendix A: Appointment Memorandum

Cy: Mike Anastasio, DIR, A100
Jan Van Prooyen, DD, A100
Ed Wilmot, Manager, LASO, A316
Vann Bynum, PADOPS, A102
Terry Wallace, PADSTE, A127
Glenn Mara, PADWP, A107
Carl Beard, ADSMS, E585
Doug Beason, ADTR, A135
Jerry Ethridge, ADISS, K774
Scott Gibbs, ADE, C921
Doris Heim, ADBS, A108
Asa Kelley, ADPMGT, M984
Bret Knapp, ADWE, A109
Mike Mallory, ADSMS, E585
Charlie McMillan, ADWP, A113
Alan Bishop, ADTSC, B210
Sue Seestrom, ADEPS, A106
Mary Neu, ADCLES, F629
Paul Sowa, ADSS, G729
Dick Watkins, ADESHQ, K491
IRM-RMMSO, A150
DIR-07-025L

Appendix B: CMR Event Chronology

Date & Time	Facts
12/06	Two plutonium metal samples are cast in epoxy to prepare them for metallographic analysis • individual performing this casting is transferred to TA-55 (from CMR) before final sample preparation (cutting, grinding, polishing, etc.) could be performed
01/03/07 12:30 p.m.	MST-16 staff member requests GBW prepare the metallographic samples for analysis • GBW asks SM for help because SM has more experience and GBW has other (escorting) duties to perform • SM agrees to help while continuing his own work • SM speaks with MST-16 staff member to obtain history of samples which will determine how SM can handle and prepare them • SM has personal and work-related time constraints so he must leave by 12:00 p.m. on 1/4/07 and won't be back until 1/8/07
01/03/07 12:45 p.m.	SM discovers bubbles in epoxy of two metallographic mounts and is concerned that bubbles will interfere with final sample preparation • Epoxy mounts frequently fail to cure properly requiring samples to be pried from their original mounts and be re-mounted
01/03/07 1:00 p.m.	SM informs the other MST-16 staff member of the problem with bubbles in the epoxy and they jointly decide on a plan of action: • SM will attempt to polish the better of the two samples • GBW will observe SM's work to better learn metallographic sample preparation
01/04/07 9:30 a.m.	SM finishes polishing one of the samples and provides it to the requesting staff member • the requesting staff member determines that both samples will need to be remounted
01/04/07 11:00 a.m.	SM observes GBW breaking out samples to remount them • GBW intends to remount both samples so they would be ready for final preparation by SM when he (SM) returns to work on 1/8/07 • SM leaves Laboratory shortly afterwards
01/04/07 to 01/05/07	GBW has to remount the samples twice • once on the afternoon of 1/4/07, and • once on 1/5/07
01/08/07 1:00 p.m. to 3:00 p.m.	SM determines that epoxy of the GBW's final mount was too soft for use • SM determines that heating sample to cure the epoxy would likely damage the samples • SM consults with the requesting MST-16 staff member and concludes that remaining fragments of the original sample, which had not been mounted, could not be used because they were needed for other experiments • SM concludes that samples has to be re-mounted once again • This would be the fourth mounting required which is not normal

Appendix B: CMR Event Chronology

Date & Time	Facts
01/08/07 3:00 p.m.	SM begins breaking out the re-mounted samples in GB-2136-01 that has 30 mil gloves • NMT16-IWD-WI-637,R0, *Using Hand Tools & Small Power Tools in CMR Labs and Offices* • NMT16-WI-637,R0.1, *Ibid* • NMT16-IWD-WI-642,R0.1, *Working in Open Front Hoods, Slot Boxes, & Gloveboxes in CMR Wing 2 and Associated NMT-16 Operations* • NMT-16-WI-642,R0.1, *Ibid* • NMT-16-IWD-WI-005A,R0.1, *Actinide Metallography* • NMT-16-WI-005,R2, *CMR Actinide Metallography*
01/08/07 3:15 p.m.	SM pries samples loose from epoxy mount by placing mounts in machinist's vise, striking them w/ small ball peen hammer to loosen the samples and break the epoxy, and prying the samples out with the screwdriver • Using small hand tools (vise grip pliers to grasp the sample and screwdriver to scrape), SM removes adherent clumps of epoxy from the 1st sample and places it in an acetone bath to soften remaining epoxy residue • SM does not don protective gloves over glovebox gloves when using screwdriver as a chisel (NMT16-WI-637, R0.1, page 8) • SM stated later that he did not regard the screwdriver as a "sharp"
01/08/07 3:25 p.m.	Using same small hand tools (vise grips and screwdriver), SM begins scraping epoxy clumps from second sample. As he exerts extra effort (generally directed away from his body) to loosen a tightly adherent clump, the material suddenly gives way • Screwdriver tip strikes SM's left index finger • Screwdriver may have deflected off the machinist's vice that was being used to support the sample
01/08/07 3:26 p.m.	SM knocks off the dangling piece of epoxy from the second sample and drops it in a second acetone bath • He inspects left glove and is at first unsure whether it has been punctured
01/08/07 3:30 p.m.	SM begins to feel pain at the location struck by screwdriver • There is no second person within hailing distance (CMR-NOTICE-017) • SM removes right hand from glovebox and surveys it finding no contamination • Peering down left glovebox glove, SM sees spot of blood on his finger • Leaving outer left surgeon's glove inside glovebox glove, he slowly retracts his left hand clenching it into a fist • SM surveys his left, fisted hand and finds no contamination • SM actions are all consistent with CMR-RD-555, R1, page 48

Appendix B: CMR Event Chronology

Date & Time	Facts
01/08/07 3:35 p.m.	SM goes to phone in 2134 to summon aid • SM places 4 phone calls before reaching anyone: Wing RCT's office; no answer Area Wing Controller; no answer Team Leader from another MST-16 team (MST16 TL); no answer Finally reaches the requesting MST-16 staff member • SM did not attempt to contact CMR Ops Center (CMR-AP-002,R3) even though Ops Center number is posted by phone, instead calling RCT because of close daily working relationship
01/08/07 3:36 p.m.	SM advises the MST-16 staff member that he has a punctured glove and finger and requests the other staff member to summon an RCT and notify group office • Other staff member contacts OCD1 • Other staff member contacts MST-16 Group Office • Other staff member contacts RCS1 and advises him of accident
01/08/07 3:37 p.m.	RCS1 relays message to RSC2 • RCS2 attempts to locate and dispatch an RCT to Wing 2 without success • RCS2 departs office for room 2136
01/08/07 3:38 p.m.	SM, aware that there are no CAMs alarming, returns to room 2136 and surveys left sleeve and hand (couple hundred dpm) • SM doffs right outer surgeon's glove • SM doffs left Tyvek® sleeve • SM doffs left-hand inner glove and places it on Kimwipe® on counter
01/08/07 3:39 p.m.	AWC, who was making security rounds, arrives and learns of glove puncture and wound • AWC calls Ops Center and OCD1 states that they have already been informed
01/08/07 3:40 p.m.	OCD1 advises OCD2 of incident and leaves Ops Center to advise Ops Manager and Facility Ops Director.
01/08/07 3:41 p.m.	MST16 TL learns of incident from the other MST-16 staff member • MST 16 TL contacts OCD2 requesting RCT to report to scene • MST16 TL incorrectly reports that there is no skin puncture, just a glovebox glove breach
01/08/07 3:42 p.m.	OCD2, confused by the conflicting reports, makes PA announcement requesting anyone with knowledge of Wing 2 incident to call Ops Center
01/08/07 3:43 p.m.	RCS2 arrived at Wing 2 and proceeds down uncontrolled corridor meeting up with MST16 TL • RCS2 looks through window in door and sees puncture wound on SM's finger • RCS2 is member of CMR ERT and advises AWC that no

Appendix B: CMR Event Chronology

Date & Time	Facts
	additional ERT response is required • RCS2 contacts RCS1 and advises him of need for wound count • RCS1 contacts RP-2 and informs them to prepare for a wound count at Occ Med
01/08/07 3:45 p.m.	AWC calls Ops Center in response to PA announcement and clarifies there was a skin puncture, but additional ERT is not required • Later, MST16 TL re-contacts Ops Center and corrects his earlier report, now stating that there had, in fact, been a skin puncture
01/08/07 3:47 p.m.	RCS2 enters Wing 2 controlled area and proceeds to room 2134 • RCS2 checks room radiological conditions and performs LAS through 2134 doorway into 2136 finding no detectable activity (NDA) • Hearing no CAM alarms, RCS2 proceeds into Room 2136 and surveys SM's wound area finding 1500 dpm alpha via a one minute scaler count • RCS2 places a latex glove over SM's left hand to contain contamination • RCS2 performs whole body frisk of SM finding no contamination anywhere else on SM • RCT1 arrives and RCS2 directs him to continue room surveys specifically to survey glove port (leaving SM's abandoned outer, left-hand surgeon's glove inside), remove glovebox from service, and survey and secure SM's inner, left-hand surgeon glove from counter top
01/08/07 3:48 p.m.	RCS2 contacts RCS1 and informs him of skin contamination result and the need for additional RCT assistance • RCS1 pages RCT2 and directs him to assist RCS2 • RCS1 advised RP1 TL of skin contamination via alphanumeric page
01/08/07 3:49 p.m.	RP-2 dispatches WCT to Occ Med to perform wound count • WCT arrives at Occ Med prior to SM's arrival • Occ Med first learns of event via WCT's arrival • WCT prepares for wound count and awaits SM's arrival
01/08/07 3:50 p.m.	RCS2 escorts SM to CMR decon room after surveying out of Room 2134 • RCT2 meets up with RCS2 and SM at decon room and verifies skin contamination survey results • RCS2, without a key to the decon supply cabinet, commences efforts to decontaminate wound using tape compressions and rinsing with warm water • AWC retrieves key to decon cabinet from RCT1 and delivers it to RCS2 in decon room • Now able to access additional decon supplies, RCS2 begins sponge scrub of wound for 30-45 seconds • RCS2 dries wound area and resurveys it finding NDA

Appendix B: CMR Event Chronology

Date & Time	Facts
	• RCS2 squeezes SM's finger until a small drop of blood appears in an attempt to expel embedded contamination • RCS2 dabs the area dry and resurveys finding NDA
01/08/07 4:00 p.m. to 4:10 p.m.	RCT2 and AWC escort SM to Occ Med office for wound count and treatment • They all process through the HFM-7 and PCM-2 contamination monitors • SM's wound was not covered with sterile dressing per HSR-1-09-02, R1.1 and HSR-1-09-05.4 • Prior to leaving Wing 2, RCT2 has SM submit nasal smears and leaves them in RCT office • RCT1 completes room surveys and finds NDA • RCS2 and RCT1 survey left hand surgeon glove that had been punctured finding 1500 dpm direct alpha contamination on left index finger near site of perforation • RCS2 and RCT1 perform smear survey of glove finding 300 to 400 dpm removable alpha contamination • Nasal smears and index finger from left hand surgeon's glove later analyzed at HPAL; nasal smears NDA; spectral analysis of glove finger indicates high purity Pu-239
01/08/07 4:15 p.m.	RCT2, AWC and SM arrive at Occ Med through front door rather than through emergency entrance
01/08/07 4:20 p.m.	WCT completes initial wound count at Occupational Medicine finding 17 nCi; WCT notifies the HPAL TL of elevated result • Wound counter (NaI) at Occupational Medicine does not provide attenuation correction factor • Medical treatment guidelines say to consider excision at 1 nCi • Medical guidelines say to chelate before excision • Medical guidelines say to chelate ASAP, preferably within 1-2 hrs • Despite high (17 nCi) wound count, direct survey is NDA indicating the possibility of embedded contamination and under-measurement of activity in wound
01/08/07 4:35 p.m.	HPAL TL arrives at Occupational Medicine to assist WCT
01/08/07 4:40 p.m. to 5:00 p.m.	RCT2 informs RCS1 of wound count result • RCS1 advises CMR RP Team Lead (RP1 TL) of 17 nCi result
01/08/07 5:00 p.m.	MD arrives at Occ Med
01/08/07 5:00 p.m. to 5:30 p.m.	RP1 TL notifies RP1 DGL (who is at Group Office attending the same meeting that she was) of 17 nCi wound count result • RP1 DGL, with help from his Group Leader: --calls Dose Assessment's Emergency (after hours) phone number (231-5187); no answer --calls RP2 Group Leader at work; no answer --calls Internal Dosimetrist (RP2 TL) at home for consultation; leaves message with RP2 TL's wife

Appendix B: CMR Event Chronology

Date & Time	Facts
	--musters bioassay resources via TA-55 emergency supplies --confirms CMR is being radiologically evaluated and controlled • RP2 TL calls RP1 DGL at RP-1 Group Office and is advised of 17 nCi wound count; RP2 TL provides info on potential CEDE (based on worst case assumptions); RP2 TL explains that he will investigate dose consequences further and will call RP1 DGL back
01/08/07 5:01 p.m.	Occ Med attendants (PA1 and a nurse), under guidance of physician 1 (DR1), attempt to decon wound; initial attempts are unsuccessful • PA1 and nurse are suited up in treatment room; DR1 is outside treatment room observing and recording results
01/08/07 5:06 p.m. to 5:23 p.m.	PA1 uses scalpel to scrape the wound area in an attempt to remove contamination; wound counts remain at 17-18 nCi
01/08/07 5:25 p.m. to 5:30 p.m.	Medical staff packs SM's wound with chelating paste, bandages it, and covers it in preparation for releasing SM with direction to return the following morning for evaluation and further treatment • MD leaves his office and goes back to the treatment area to obtain additional information
01/08/07 5:30 p.m.	SM signs his discharge instructions and prepares to leave the clinic
01/08/07 5:35 p.m.	RP1 DGL arrives at Occ Med and overhears MD discussion (with MST16 GL and MST16 DGL) referring to contamination level as 3,700 dpm • RP1 DGL inserts himself at this point, pointing out that 17 nCi = 37,000 dpm not 3,700 dpm • RP1 DGL expresses concerns about potentially high CEDE consequences and decision to send SM home without excision or chelation
01/08/07 5:45 p.m.	MD decides to proceed with additional medical intervention based on information and clarifications he has just received from RP1 DGL • There was apparently confusion about contamination units, variability in wound counts, solubility of Pu, as they were being heard by MD • At least 14 LANS staff were present throughout portions of the treatment activities at Occ Med • Two of these people expressed concerns about the merit, efficacy, or side-effects of chelation • RP2 TL was never physically present at Occ Med • Highest wound count reported could be the bounding lower limit of contamination because of geometric and attenuation effects
01/08/07 5:50 p.m.	RP2 TL reaches RP1 DGL at Occ Med and advises that unmitigated CEDE for 17 nCi could be up to 50 rem • RP1 DGL hands phone to MD and RP2 TL advises MD of dose consequences • MD orders treatment plan of excision and chelation

Appendix B: CMR Event Chronology

Date & Time	Facts
	• RP2 TL informs both RP1 DGL and MD of the desire to collect a pre-chelation urine sample for *in vitro* bioassay
01/08/07 5:55 p.m. to 6:28 p.m.	Punch biopsy performed by PA1; subsequent wound count at 6:06 p.m. shows 9 nCi, but subsequent wound count at 6:28 p.m. after another excision indicates 17 nCi • wound count variability is not unusual; technique highly dependent on measurement geometry
01/08/07 6:00 p.m.	RP1 TL advises RCS1 back at CMR to post rooms as "Hot Job Exclusion Area" • RCS1 visually confirms room posting and sees that glovebox port has been covered/secured • RCS1 informs OCD2 that room posting as HJEA has occurred • All area surveys in rooms 2134 and 2136 show NDA
01/08/07 7:26 p.m.	After a total of ten excisions, wound count has been reduced to 12 nCi
01/08/07 7:30 p.m.	Attempts at excision are temporarily suspended so chelation can be initiated; baseline in vitro bioassay sample (urine) is collected
01/08/07 8:00 p.m.	Occ Med Group Leader (also a physician) contacts REAC/TS for consultation
01/08/07 8:15 p.m.	Drip chelation commences • DR1 reports some difficulty is experienced inserting IV • chelation started with zinc; REAC/TS advises start with calcium then follow up with zinc • after reviewing SM's medical records, MD orders chelation changed to calcium • 250 cc of zinc DTPA administered before change, so chelation completed with 250 cc of calcium DTPA
01/08/07 8:15 p.m. to 8:55 p.m.	Excision resumes by DR2 under direction of MD and continues during chelation
01/08/07 8:55 p.m.	Chelation is completed
01/08/07 8:55 p.m. to 10:15 p.m.	Excision and wound debridement continues • final wound count (NaI) is 11 nCi (uncorrected)
01/08/07 10:15 p.m.	SM's wound is sutured
01/08/07 10:30 p.m.	SM is released from Occ Med with instructions to return the next morning
01/09/07 10:15 a.m. to 10:45 a.m.	SM is chelated at Occ Med with calcium DTPA • two wound counts (NaI), conducted during chelation, indicate about 9 nCi
01/09/07 11:00 a.m.	SM goes to HPAL to get a wound count conducted with a high resolution spectrometer (LO-AX) to develop attenuation correction factor • HPAL TL initially (and incorrectly) reports attenuation correction factor as unity • HPAL TL discovers his error about one week later; he derives a correction factor of 2.7 from this Jan 9th LO-AX measurement and retrospectively applies it to all previous wound counts • This yields a corrected wound activity of 24 nCi

Appendix B: CMR Event Chronology

Date & Time	Facts
01/09/07 11:30 a.m.	RCTs perform detailed surveys of rooms 2134 and 2136, collecting 26 LASs and 50 small area (100 cm^2) smears in each room • all results are NDA • air filters are collected and analyzed; all results are negative with the exception of one low-level (3 DAC-h) filter result from room 2134
01/09/07 1:12 p.m. to 4:03 p.m.	DR2 excises tissue from SM's finger • five wound counts (NaI) are conducted during excision • results range from 6 to 8 nCi (uncorrected) • four counts of excised tissue are all NDA
01/10/07 to 01/12/07	Zinc chelation is administrated each day, with DR2 performing additional (superficial) debridement on 1/12/07 • wound counts (NaI) obtained during this time range from 7 to 9 nCi (uncorrected) • applying the 2.7 attenuation correction factor indicates activity remaining at the wound site is approximately 22 nCi
01/13/07 to 01/14/07	Zinc chelation is performed each day
01/16/07 10:23 a.m. to 3:04 p.m.	Zinc chelation is performed, followed with additional tissue debridement and wound counting • Ten wound counts (NaI) are obtained and results range from 5 to 12 nCi (uncorrected) • Thirty measurements of excised tissue and related medical samples (bandages, sutures, cloths, swabs, etc) are obtained with results ranging from NDA to 2 nCi • Nine of these measurements show measurable activity indicating 6 nCi or more may have been excised
01/17/07	Zinc chelation is administered and another LO-AX wound count is obtained • A new correction factor of 1.67 (consistent with removal of tissue) is obtained • This gives a corrected wound activity measurement of 15 nCi
01/18/07	Zinc chelation is performed and three wound counts (NaI) are taken at around 11:00 • Results range from 6 to 9 nCi (uncorrected)
01/19/07	Nine wound counts (NaI) are obtained with results ranging from 6 to 11 nCi (uncorrected) • A single count of excised tissue (scab) is obtained; results are NDA
01/22/07	Nine wound counts (NaI) are obtained with results ranging from 4 to 10 nCi (uncorrected)
01/23/07	Zinc chelation is performed • A wound count (NaI) is taken indicating 9 nCi (uncorrected) • A LO-AX wound count is taken and it provides a new attenuation correction factor of 1.4

Appendix B: CMR Event Chronology

Date & Time	Facts
	• This results in a wound activity measurement of 13 nCi (corrected)
01/24/07	Assistance is requested from an (off-site) board-certified surgeon (DR3); DR3 conducts additional debridement • Excised tissue counts (NaI) indicate 0.5 nCi (uncorrected), but with large relative uncertainty • A subsequent wound count (NaI) indicates 10 nCi (uncorrected)
01/25/07 to 02/06/07	Eight wound counts (NaI) are obtained with results ranging from 7 to 10 nCi (uncorrected) • A single count of gauze is obtained on 1/25/07; results are NDA • Zinc chelation is administered on 1/25/07, 1/30/07, 2/1/07, and 2/6/07
2/8/07	DR2, in concert with MD and a REAC/TS physician, meet with SM and review his bioassay results to date • They jointly decide that the bi-weekly chelation treatments will be suspended for 2-4 weeks because of their decreased effectiveness • RP2 TL is consulted and he agrees with this determination • A LO-AX wound count is obtained that verifies the 1.4 correction factor • This results in a corrected activity at the wound site of 11 nCi
2/21/07	SM meets with DR2 and requests an additional chelation treatment • Based on her previous consultations with MD and REAC/TS, DR2 grants this request and administers a zinc-based chelation • A LO-AX wound count is obtained resulting in a corrected activity at the wound site of 12 nCi

Appendix C: TA-55 Event Chronology

Date & Time	Facts
2001	TA-55/CMR began the Glovebox Glove Integrity Program
07/01/02	NMT authorization basis group develops the Process Hazard Analysis for lathing operations in GB 385 • Originally approved in 1998 for a similar process
07/03/02	Hazard control plan is developed • WCM-1 Group Leader approved the HCP (NMT5-HCP-004, R2, EXT 1) • Puncture and internal contamination hazard was identified • Generically addresses "sharps"
07/05/02	M1 develops the work instruction • Lead machinist reviews, provides input, and signs the work instruction • Controls from the HCP did not flow down to the work instruction
08/02	Machinists were trained, qualified, and certified on the lathing operations • Training process is currently governed by TA-55-AP-047, R0, effective on 12/19/2006
09/02	Machinists perform lathing operations from 2002 to present • Events on June 7 & 20, 2006 • Delays in notifying the operations center • Glove puncture in PF-4 rooms 114 and 105 • List other precursor events
2003	Product Engineer sets the requirement to use cotton gloves when handling the machined part • Anomalies were noted on the machined components • Believed to be caused by handling with glovebox gloves • No indication that the requirement was walked down, hazards evaluated, and controls put in place
01/03/05	M1 was last qualified on the lathe process
11/05	WCM-1 GL implements the requirement to use cotton gloves for the lathe operation • 2003 requirement had been implemented for other processes, but not the lathe process
Early 2006	RCT stops work because machinists are not wearing leather gloves over glovebox gloves • Was not the lathe operation
06/01/06	LANS takes over the contract • New organizational structure is introduced • Began emphasizing the seriousness of glovebox glove failures at TA-55; events are critiqued

Appendix C: TA-55 Event Chronology

Date & Time	Facts
07/01/06	Machinists provide feedback to their manager = the cotton gloves are difficult to use • They are too small and require excessive force to don • Machinist's hands have slipped and hit the glovebox window and boring bar • They have poor gripping properties; parts slip when handled • At least one machinists dislikes the Nitrile® gloves more than the cotton • AIT subsequently determined the difficulty is likely associated with the oxide becoming engrained in the glovebox gloves and creating a sandpaper-like surface
07/03/06	WCM-1 group leader orders the largest size (i.e. XL) of cotton gloves available • No other action taken • Gloves are still difficult to use • Considers the problem to be a "reasonable inconvenience"
10/06	CMR stops using the GGIP SME and begins developing their own GGIP • Still in draft form in Feb 2007
11/21/06	A precursor event occurs in room 319 on the waist-banding machine • Glovebox glove sliced and breached by a machine tool • No injury or contamination • A near-miss type event
12/11/06	A second, identical precursor event occurred in room 319 • Glovebox glove sliced and breached by a machine tool • No injury or contamination • A near-miss type event • No compensatory or corrective actions from previous event • Worker removed, retrained, and returned to work after two weeks • RP-1 provided additional self-monitoring instruments
01/03/07	Another precursor event occurred in room 319 • Glovebox glove punctured with blunt tweezers
01/04/07	No effective actions are implemented in response to the precursor events • WCM-1 planned to implement a guard to cover cutting bits when they were not in use. (not yet implemented) • Division Leader visits work area a few times per week, usually for a specific purpose; not unusual for him to miss a week • Group Leader visits more frequently • Deputy Group Leader is present in the work area about 50% of the time • Managers tend to focus on production
01/17/07 8:00 a.m.	M1 begins his workday • TL1 assigns M1 to machine a part on the lathe inside GB 385
01/17/07 8:05 a.m.	M1 dons his personal protective equipment including:

Appendix C: TA-55 Event Chronology

Date & Time	Facts
	• Coveralls • Latex gloves taped to coveralls • Booties • Safety glasses • Glovebox gloves are 30 mil, leaded Hypalon® leaded gloves
01/17/07 8:10 a.m.	M1 enters room 319 • 18 other people are working inside the room • Room 319 is an RBA
01/17/07 9:00 a.m.	DOE facility representative visits room 319 • Observes a person chewing gum • Hears a radio playing loudly • DOE rep is new to the job (arrived April 2006)
01/17/07 1:00 p.m.	M1 completes machining one surface • The machine is programmed to automatically position the cutting bit away from the component • The new position is towards and to the left of where M1 stands (near his left hip) • At least one other machinist manually positions the cutting tool out of the way at this point in the procedure
01/17/07 2:00 p.m.	M1 begins changing cotton gloves • Division Leader has never seen this task performed • This is not a specific step in the work instruction
01/17/07 2:01 p.m.	M1 dons a cotton glove over his right glovebox glove
01/17/07 2:02 p.m.	M1 attempts to don a cotton glove over his left glovebox glove
01/17/07 2:03 p.m.	M1's right hand slips, and he strikes his right forearm/wrist against the lathe's cutting bit
01/17/07 2:04 p.m.	The cutting bit punctures through the glovebox glove, the latex glove worn by M1, and the cloth of the coveralls • Cutting bit is contaminated with Pu-239
01/17/07 2:05 p.m.	M1's injury is contaminated with a radionuclide from the bit
01/17/07 2:06 p.m.	M1 sees that the glovebox glove has been breached • M1 does not realize he has been injured • M1 keeps his hands/arms inside the glovebox gloves
01/17/07 2:07 p.m.	M1 notifies TL1 that he has breached a glove • TL1 was standing nearby
01/17/07 2:08 p.m.	TL1 makes a PA announcement inside room 319 • All personnel evacuated room 319 (except M1) • RCT-1 hears the announcement and responds to the scene • RCT-1 visually confirms the damaged glovebox glove (he does not know whether the glove has been breached) • RCT-1 monitors radiological conditions in the room; no indication of an airborne problem
01/17/07 2:10 p.m. to	RCT-1 surveys M1 and surrounding area while waiting for TL1 to return

Appendix C: TA-55 Event Chronology

Date & Time	Facts
2:35 p.m.	with respirators • TL1 returned to the room with two respirators • RCT-1 dons a respirator and assists M1 in donning his • RCT-1 assists M1 in slowly removing his right arm from the glovebox glove and detects 1000 dpm of alpha contamination on right forearm of M1's coveralls/glove, near the wrist • M1 reinserts his arm into the glovebox glove • M1 was sweating profusely, his coveralls were damp, and this moisture was likely attenuating the alpha emission • RCT-1 removes the contaminated latex glove from M1's hand as M1 removes his arm from the glovebox glove • RCT-1 assists M1 in immediately donning a clean latex glove over the contaminated area • Contamination monitoring still indicated 1000 dpm • CAMs did not alarm
01/17/07 2:15 p.m. to 2:35 p.m.	RCT supervisor (RCT-S) is notified and responds to room 319 • RCT-1 escorts M1 to the decon room • Room 319 is "red lit" • Other RCTs take nasal smears from worker who were inside room 319; results were NDA • Contamination surveys are performed; results were NDA • Glovebox glove port is plugged • Breached glove is promptly replaced
01/17/07 2:40 p.m. to 2:55 p.m.	Now in the decon room, RCT-1 removes the clean glove from M1's right hand and monitors the skin for contamination detects 10,000 dpm alpha • RCT-1 observes a small red dot on the right cuff • RCT-S arrives and observes a small abrasion on the right wrist • RCT -1 covers the wound with loose tape • RCT-1 / RCT-S work together to cut of the right coverall sleeve at the shoulder • RCT-1 bags the sleeve for subsequent isotopic analysis • RCT-1/RCT-S assist M1 in removing his coveralls • RCT-1 attempts to remove the skin contamination by removing the tape; not successful; level remains at 10,000 dpm • RCT-S and RCT-1 consult with their team leader and jointly decide to continue decon at TA-55 • RCT-1 / RCT-S wash M1's wound with warm water and soap; repeated 2 times; a foaming agent was also used • Contamination reduced to 500 dpm
01/17/07 2:55 p.m.	RP-1 Team Leader arrives at the decon room • decon efforts (3 attempts) at TA-55 could not reduce the contamination level below 500 dpm • RCT-S consults with team leader and they jointly decide to

Appendix C: TA-55 Event Chronology

Date & Time	Facts
	transport M1 to occupational medicine for continuing decon and treatment
01/17/07 3:05 p.m.	RCT-3 transports M1 to Occ Med • M1 is transported in a government vehicle
01/17/07 3:30 p.m. to 4:10 p.m.	M1 arrives at Occ Med • Medical staff decons M1's wound and contamination levels are reduced to NDA • Wound count is obtained indicating 1.31 (+/- 0.29) nCi
01/17/07 4:40 p.m.	Occ Med doctor releases M1 to return to TA-55 • No chelation • No excision
01/17/07 4:45 p.m.	Occ Med doctor consults with the LANL Medical Director, calls REAC/TS, then calls the Medical Director a second time.
01/17/07 4:50 p.m.	Occ Med doctor contacts M1 at TA-55 and instructs M1 to return to Occ Med.
01/17/07 5:20 p.m.	M1 arrives back at Occ Med
01/17/07 6:30 p.m.	Occ Med doctor administers the first chelation treatment and then releases M1 • Pre-chelation bioassay sample is collected • Calcium-based chelating agent is used • Subsequent to chelation treatment, M1 is released from Occ Med with instructions to return the following morning
01/18/07 8:00 a.m.	M1 returns to Occ Med • Wound count indicates 1.6 nCi
01/18/07 9:00 a.m.	Occ Med doctor administers a second chelation treatment
01/18/07 10:00 a.m.	Occ Med doctor excises a small amount of tissue from the wound site • Tissue counted; results indicated 1.24 nCi • Wound counted; results were NDA • Wound site stitched and bandaged
01/18/07 12:00 p.m.	Occ Med doctor releases M1 to return to TA-55 • Work restricted to non-radiological (cold) areas • Additional bioassay kits were issued
01/24/07	Occ Med Doctor removes M1's stitches.
01/30/07	Occ Med Doctor releases M1 to return to work without restriction.

Appendix D: CMR Barrier Analysis

Barrier	Discussion	Causal
Procedural implementation	Gloves were required with screwdrivers; sterile dressings were required over wound	Yes
Time pressure (pride)	Self-imposed (by worker on himself) and externally/programmatically imposed;	Yes
Distraction	Broken water pipes at home	Yes
Stress	See time pressure, distraction, being moved from CMR to TA-55, work important/high value sample; budgetary uncertainties	Yes
Supervisor oversight	Supervisor remote location (at TA-55) resulted in a lack of direct line supervision at CMR	Yes
Two-person rule response	Poor implementation; procedure written too loose; procedures and notices are not consistent; considered impractical.	Yes
Consistency of work practices	CMR rules vs. TA-55 rules in work control, work process, and formality; use of PPE; oversight; Difference in work instructions.	Yes
Fear	Error can lead to closing the Lab, retaliation due to making mistake	No
Critique, event reporting	Painful process post-reporting; number of people in attendance	No
Communication – response	In Wing 2; at Occupational Medicine; to doctor regarding material characteristics	Yes
Risk Perception	Inaccurate due to worker's expertise; belief that no supervision is needed; inaccurate due to efficiency of wounds in delivering dose	Yes
Complacency	Sharps (tool selection); expectation of negative wound count	Yes
Occupational Medical staff's knowledge of radiological measurements	Unfamiliar, confusing units and instruments	Yes
Epoxy mounting process	Is an art; hard to achieve a good result	Yes
High value/unique sample	Affects ways to process it during mounting and preparation.	Yes
Hazard recognition	Screwdriver not perceived as a sharp	Yes
PPE	Leather gloves not used.	Yes
Personnel staffing	Relocating one employee to TA-55	No
Stop work	Not asking for help; pushing past the work stoppage point	Yes
Customer priority	Unique work vs. safety	Yes
Facility response notification	Worker did not notify the Operations Center	No
Sharps	Guarding, tool selection	Yes
Conduct of Operations	In regards to calling Ops Center (sometimes	No

	they don't evacuate work area during drills)	
Peer review	Lack of use; HPAL depth attenuation error	Yes
Questioning attitude	Lack of use	Yes
Organizational interfaces	Occupational Medicine with Radiation Protection	Yes
Pre-job briefings	Infrequently performed	Yes
Chelation	Knowledge and experience; understanding risks/benefits; understanding proper administration	Unknown
Training	With regards to chelation and medical staff.	Yes
Lack of understanding by medical staff of the material they're working on	Insoluble Pu and excision decisions	Yes
Mindset	Infallibility of competent workers	Yes
Mindset	Non-questioning attitude	Yes
Ergonomic issues	Now-heavier, Nitrile® gloves; 30 mil gloves and tendonitis	No
Inadequate procedures	Breaking sample out epoxy mount	Yes
Command and control	Situational control at Occupational Medicine	Yes
Lack of experience/proficiency	Occupational Medicine staff with regards to contaminated wounds.	Yes
Formality of work control	Programmatic work and medical response	Yes
Sharing of authority	With regards to CMR AD and tenants	No
Supervision	Of glovebox worker; Medical Director to staff	Yes
Assumptions	Inaccurate at Occupational Medicine	Unknown
Bioassay kits	Availability after hours	No
After hours response	An order of magnitude increase in difficulty	Yes
IWDs	Need them to be work specific	No
Human Performance Improvement	Implementation; understanding	Yes
IWM Feedback step/lessons learned	No appreciation of past events; inability to understand past events and use that understanding to preclude future events	Yes
Non-routine work	Boundary of when current work is not covered by work processes	Yes
Management directives	When mid-manager makes change, scientists go around them to senior managers and then implementing manager gets in trouble	No
LANL culture	Preoccupied by perceived potential for RIFs	No
Management expectations	Acceptance is the standard	Yes
Interface: Occupational Medicine and RP-2	Interface not clearly defined	Yes

Appendix E: TA-55 Barrier Analysis

Barrier	Discussion	Causal
Sharp covers/guards	One was manufactured, not used	Yes
Training	Did train of WI revisions	No
Work instruction	No caution statements	Yes
Hazard Control Plan	Sharp/Puncture hazard was recognized	No
Process Hazard Analysis	Sharp/Puncture hazard was recognized	No
Supervisor oversight	Workers worked quickly, Human performance – donning cotton gloves was difficult, Supervisors did not stop work and address problem, considered a reasonable inconvenience	Yes
Proper gloves	Cotton glove size was too small	Yes
Communication	Peer to peer was poor One machinist repositions the tool, was not communicated to others	Yes
Leather gloves	Listed in HCP, not used	No
Cotton gloves required	Might not have necessary	Yes
Management response to employee concerns	Workers provided feedback to supervisors and managers. No action taken.	Yes
Removal of hazard	Reposition of machine tool, removing other sharps	Yes
Work control	IMP 300, No controls in Work Instruction	Yes
Corrective action process	Actions were planned, not executed Timeliness and completeness were less than adequate.	Yes
Response to prior events	Critiqued, collective significance not fully evaluated, ignored indicators	Yes
Management oversight	Focused on production first	Yes
Worker qualification/certification	Workers were qualified/certified	No
Two man rule	Second person was present	No
Glovebox gloves	Are not “puncture proof”	No
Trionics gloves	Nitrile® gloves are more puncture resistant (but neither are puncture proof)	Yes
Coveralls	Provided added layer of protection	No
Organization	R2A2s of FOD do not support safe programmatic work.	Yes
GGIP	Tracked and Trended GB Glove failures and breaches	No
Lessons learned	Not used effectively.	Yes
Continuing training	Maintain skill level	No
Breached glove response process	Was followed properly.	No
Radiological Monitoring	Was performed properly	No
Nitrile® gloves	Not used	Yes

Management expectations	Management accepted 50 GB glove failures / breaches per year.	Yes
Stop work	Work was not stopped by workers or managers because donning cotton gloves presented a hazard.	Yes
Ergonomics of Glovebox	Arm positions and characteristics of GB gloves made the task of donning difficult.	Yes
Work authorization process	Work was authorized.	No
Procedure walkdown	Walkdown of donning cotton glove was not performed. (Would have been found to be easy based on reconstruction by AIT)	No
Production schedule pressures	Were present and accepted. Shifted focus to production	Yes
RCT response	No problems noted.	No
Medical response	Guidelines followed, but worker had to be recalled.	Unknown
QA requirements	Cotton gloves may not actually be necessary.	Yes
Guarding program	Did not exist	Yes
Lathe programming changes	Not implemented to move the machine tool to a safer location for donning cotton gloves	Yes
Sharp protection program	Sharps were still present in gloveboxes.	Yes
Engineered controls program	Engineered control (tool guard) was not used	Yes
PBIs	Schedule pressure to produce more that planned	Yes
Human performance initiatives	Schedule pressure, poor communication between workers, acceptance of unsafe work activities as necessary inconvenience	Yes
Medical Guidelines	Guidelines were not well understood by doctors	No
Drill/exercise program	Not implement at Occupational Medicine	Yes
Respirators	Have handy	No
Speed of work	Workers were skilled and worked quickly	Yes

Appendix F: External Review of LANL Response

Provided by Gary Mansfield, LLNL

Introductory Comments:

The following is my review of the health physics, medical, and internal dosimetry response to the "CMR" and "PF-4" contaminated wound incidents which occurred at Los Alamos National Laboratory in January of 2007. These observations, comments, and recommendations are based on a site visit with the "Type B like" Investigation Team on February 6th, 7th, and 8th, 2007, which included interviews with some of the workers and staff involved in the response. My observations and comments are based on information collected at LANL by members of the Investigation Committee prior to and during my visit (e.g., the incident "timelines"), as well as information made available through interviews I took part in during my visit. Some of the timeline events had not been fully resolved at the time of this writing.

Much of the following discussion focuses on issues regarding the medical response to and intervention methods (i.e., chelation and excision) used in this event. However, it is important that attention not be shifted from *prevention* of such incidents. For reasons stated below, the major emphasis on corrective actions should be on prevention of such incidents in the first place.

In events such as the CMR or PF-4 contaminated wound incidents, the dose ultimately received by the worker is often simply a matter of chance. The injected mass of plutonium (or similar transuranic radionuclides) required to produce serious radiation doses is only a fraction of a microgram. (For example, the potential dose per microgram of material absorbed into the bloodstream is about 200 rem for Pu-239, and about 50,000 rem for Pu-238). What fraction or multiple of a microgram of material might be deposited in the wound during a contaminated wound event depends upon so many factors that it is impossible to predict. It is also difficult to predict what fraction of the initially deposited activity will be eventually absorbed to the bloodstream (where it will contribute to dose).

Once a contaminated wound occurs, the only reasonable* medical interventions available are chelation and/or excision (including debridement). It is important to realize that no matter how quickly or expertly chelation and/or excision are used, the efficacy of those interventions is often a matter of chance. Accordingly, neither of these methods should be relied upon as effective dose mitigating factors in such events.

Accordingly, while efforts should be made to assure that appropriate and prompt medical intervention methods are available and employed, *every effort must be made to avoid placing the workers at significant risk of such contaminated wounds.*

*Amputation has been mentioned in some cases, but this would only be considered in extraordinary circumstances, and only as a last resort.

Appendix F: External Review of LANL Response

Provided by Gary Mansfield, LLNL

Executive Summary:

Although a number of aspects of the response went well, there appear to be several important areas in which the response was inconsistent with LANL procedures and standard guidelines. Although several criteria for medical intervention (chelation and excision) were clearly satisfied (e.g., wound contaminated with plutonium, wound count result of 17 nCi) the patient was almost released without either chelation or significant excision. The decision to provide further treatment appears to have been made when an error in conversion of radiological units was pointed out to the Occupational Medicine staff by a Sr. Radiological Protection staff member who happened to be present.

Once the decision to provide further treatment was made, attention was focused on efforts to excise contaminated tissue from the wound. Contrary to Occupational Medicine's existing guidelines, DTPA was not administered before excision efforts began and, in fact, was not administered until about 5 hours after the incident occurred. Contrary to guidelines provided by REAC/TS, treatment was initially begun with Zn-DTPA, rather than Ca-DTPA.

Finally, more than a week after the event, it was realized that a significant error had been made in the calculations used to estimate the depth of the plutonium deposited in the wound. This depth information may have been used to guide decisions about continued excision efforts.

Significant contaminated wound events are rare – perhaps occurring once every few years. It is therefore important that response guidelines be in place and that responders be adequately trained and/or experienced. The guidelines and procedures must be clear, understood and agreed upon by all principal responders (i.e., Occupational Medicine, Internal Dosimetry, and Radiological Protection) available for ready reference, and used during such events.

Occupational Medicine had a conservative and fairly detailed set of guidelines for use of chelation and excision for plutonium-contaminated wounds. Key guidelines in this procedure related to chelation were:

- specific chelation "trigger" levels, such as a wound caused by plutonium-contaminated objects and/or wound counts greater than 1 nanocurie,
- chelate as soon as practicable (ideally within an hour or so) after the wound occurs, and
- administer the chelating agent *before* performing excision.

These key guidelines do not appear to have been followed in the response to the CMR event.

Appendix F: External Review of LANL Response

Provided by Gary Mansfield, LLNL

It appears that the inexperience of some of the Occupational Medicine staff resulted in confusion about radiological units, a lack of appreciation of the significance of the early wound count results, and possible incorrect assumptions about the usefulness of DTPA for what was believed to be "insoluble" plutonium in the wound. All of these factors appear to have contributed to the problems mentioned above and detailed below.

At several DOE facilities (e.g., Hanford, LLNL) the response team at the medical facility typically includes the equivalent of a Sr. Internal Dosimetry Staff member. This person not only provides early dose estimates to the medical staff, but also assists in interpretation of the exposure potential and early measurements such as wound count results, and can provide a much-needed link between the "field information" and the physician.

Measurement systems (like the wound counters) and associated calculations used for treatment decisions must be verified to be correct before use, and should be peer-reviewed during use in an actual response.

Detailed below are my specific observations, comments, and recommendations in the areas of:

1. Planning and Preparation
2. Facility Response
3. Response at Occupational Medicine
4. Wound Counting and,
5. Dose Assessment

A timeline (derived from the written timeline supplied by the Investigation Committee) is presented in Figure 1. Excerpts from various guideline documents are included in Appendix A. Unless otherwise stated, these observations and comments refer to the CMR event.

Appendix F: External Review of LANL Response

Provided by Gary Mansfield, LLNL

1. Planning and Preparation

Observations and Comments

- During my visit, I became aware of the fact that the LANL Occupational Medicine procedure (Appendix 5.2) for response to internal contamination incidents (e.g., wounds, inhalation) was apparently taken essentially verbatim from LLNL guidelines and procedures. Since I am the author of those LLNL procedures, I cannot provide independent comment on the adequacy of those procedures. However, I can state that these guidelines are intentionally conservative, and represent a consensus of standard practices.

- The Internal Dosimetry Team Leader (RP2-TL) was not familiar with the LANL Occupational Medicine procedures (App 5.2) and in fact, had not been given the opportunity to review them (even though he is a recognized expert in this area).

- During the CMR incident, there appears to have been a wide range of opinions and beliefs among various LANL staff and management regarding the medical intervention actions that would be considered to be appropriate in these sorts of incidents.

- There is an arrangement with the Los Alamos Medical Center (LAMC) to treat contaminated/injured workers during off-hours.

- Two minor procedural observations:

    - Procedure HSR-12-03-PR-005.0 states that, "if the potential dose [from an uptake] is 5 rem or more, assign 24-hour fecal samples for three consecutive days." Although fecal sampling is sometimes useful in wound uptake events, it is likely that this statement was intended to apply only to inhalation events.

    - Procedure HSR-12-03-PR-005.0 states that, "if the nuclides involved are Am-241 or Pu-239 and the potential dose is 1 rem or more, assign *in vivo* lung counts …" It is likely that this statement also was intended to apply only to inhalation events.

Recommendations:

- LANL procedures pertaining to response and treatment of suspected intakes of radioactive material should, ideally, be developed jointly by experienced Sr. staff in both Occupational Medicine and the Internal Dosimetry Team. At the very least, the Occupational Medicine response procedures should be reviewed and approved by or concurred with Sr. Internal Dosimetry staff. (It is my understanding that the Internal Dosimetry Team Leader is now reviewing this procedure).

- In reviewing and developing these procedures – particular attention should be paid to critical issues such as the criteria and time frames for administration of DTPA and excision. Guidelines and procedures should be based on the best current information and models. Significant inconsistencies with practices at other major DOE facilities should be justified.

- Procedures, equipment, and assets necessary for response to LAMC during off and on-shift hours should be reviewed and assured to be in place. Joint training and drills with LAMC staff should be conducted on a periodic basis. Such response should include a member of the Internal Dosimetry Team as recommended above.

- Clarify the "fecal sample" and "*in vivo* lung count" statements in HSR-12-03-PR-005.0) to make it clear that these particular recommendations apply to inhalation intakes and not to wound intakes.

2. Response in Facility (Radiation Protection)

Observations and Comments:

- The response by RCTs and RCT supervisors appears to be good. They focused on protection of the workers and facility, with all the correct priorities (e.g., checking for CAM alarms).

- It appears that the first notice that Occupational Medicine had of this case was the appearance of the wound counting technician (who informed them that a patient was being transported).

- The issue of "squeezing" the wound site (to encourage bleeding and perhaps assist in removing activity from the wound site) was mentioned by one of the RCTs. The possible benefit of this practice would be to remove some activity from the wound. However, a possible consequence of such an action would be to break up or help disperse particulate contamination – thus making it more likely to be absorbed from the wound site into the body. It is difficult to predict what would happen in any specific case – however, it is noted that the Internal Dosimetry Team Leader, when questioned about this practice, stated that he "doesn't think it is a good idea."

- A sample of contaminating material was preserved, and material was rapidly ID'ed – this is important for wound counting and response decisions.

- After making initial notifications, the Radiation Protection Deputy Group Leader (RP1-DGL) went to Occupational Medicine (presumably to assist in the response). His presence at Occupational Medicine appears to have been instrumental in the decision to proceed with excision and (eventually) chelation.

Recommendations:

- Procedures for notification of Occupational Medicine should assure that sufficient information (name of patient, nature of injury, nature and extent of contamination, material involved, etc). is transmitted as soon as possible. This notification would allow Occupational Medicine to review the health history of the patient prior to their arrival, and prepare for patient treatment.

- LANL Internal Dosimetry, Occupational Medicine, and Radiological Protection should jointly establish policy regarding wound "squeezing" actions and incorporate those recommendations (or contraindications) into appropriate procedures and training.

3. Response at Occupational Medicine

Observations and Comments:

- It appears that several of the attending Occupational Medicine staff were relatively inexperienced in dealing with contaminated wounds. (They did appear to have experience with decontamination of intact skin, but not with contaminated wounds). This inexperience may have affected treatment decisions.

- The initial several wound counts were all about 17 nCi – clearly well above the "1 nCi" guideline level. It is not clear that Occupational Medicine Staff understood that because these results were not corrected for depth attenuation, they were likely to be *minimum* values.

- Early wound count results were conveyed to the Medical Director through at least one intermediate Occupational Medicine Staff member.

- In the CMR incident, it is not clear that Occupational Medicine Staff appreciated the significance of the level of contamination that was clearly present in the wound. According to the patient's chart, *the worker was almost released without either chelation or significant excision.*

- It appears that questions raised by RP1-DGL about the potential seriousness of the wound caused the Occupational Medicine Staff to reconsider their decision to release the patient without chelation or significant excision.

- In the subsequent PF-4 incident the initial wound count results were only slightly above the "reference" level of 1 nCi. Initially, the decision was made not to chelate, and the patient was released without treatment (other than minor first aid). Subsequently, after discussions with REAC/TS, Occupational Medicine decided to recall the patient and chelate. The next day, the wound was excised with apparent success.

- The multiple units (e.g., nCi, dpm, rem) used in radiological incidents appear to have been a source of confusion with the Occupational Medicine Staff. One of the Occupational Medicine Staff stated something like: "we don't understand rad [radiological] units."

- The Medical Director had heard [source unclear] that the material involved was expected to be an insoluble metal. It appears that this information may have led the Medical Director to believe that chelation would not be very effective in this case, and may have influenced his decision about whether and when to chelate.

- LANL Occupational Medicine Guidelines (App 5.2) recommend chelating as soon as practicable if certain criteria are met. These criteria include wounds caused by plutonium or plutonium-contaminated objects, and/or wound count results greater than 1 nanocurie. Multiple criteria were clearly met in this (the CMR) case.

- Contrary to existing Occupational Medicine guidelines [App 5.2] DTPA was not administered prior to excision efforts.

- A great deal of effort was focused on attempts to excise contaminated tissue from the wound site. Since excision can be almost 100% effective in removing activity - these attempts at excision appear to be appropriate. It appears that in this case, excision has been moderately successful in removing some contamination from the wound.

  (In the PF-4 incident, excision was performed the next day. It appears that this excision removed most, if not all, of the activity at the wound site).

- Application of a local DTPA solution/paste to the wound was used.

- One or more x-ray exams of the wound site were made to attempt to localize any particulate contamination. This is a good practice.

- The initial treatment with DTPA was not administered until almost 5 hours after the incident. This is within the "< 6 hour" time recommendation in the REAC/TS DTPA package insert. However, it appears that sufficient information upon which to base the decision to chelate (i.e., incident circumstances, coupled with several wound count results) was available within about 1 hour after the incident.

  (In the PF-4 incident, the DTPA was not administered until about 4 1/2 hours after the wound occurred).

  A review of DTPA treatment guidelines (including LANL's Occupational Medicine procedure and procedures for other DOE facilities) and in the literature (e.g., DOE/CEC 1992 recommendations) indicates that administering the first dose of DTPA as soon as practicable (e.g., with an hour or so) is a common theme. See Attachment A.

- It is not clear (and is probably impossible to determine) whether the delay in administration of the DTPA had any effect on the efficacy of the chelation treatment in this case.

- After the decision to chelate was made, the Medical Director (who was the attending physician) initially specifically ordered that **Zn**-DTPA be administered. REAC/TS (and other) procedures/guidelines recommend that (barring any contraindications, of which there were none in this case) **Ca**-DTPA be used for the initial administration because it is expected to be up to 10 times more effective than Zn-DTPA.

- After the Zn-DTPA administration was started, one of the other physicians informed REAC/TS staff of their actions, and REAC/TS recommended switching to Ca-DTPA. The staff physician relayed this recommendation to the Medical Director, who ordered the switch to Ca-DTPA. (About 250 ml of the Zn-DTPA solution had already been delivered, leaving 250 ml of the
Ca-DTPA solution to be delivered).

- It appears that Occupational Medicine Staff is paying appropriate attention to the psychological/social (e.g., family) issues that may be expected in incidents of this sort. This is a good practice.

- During one interview, the Medical Director expressed concern about the number of people "maybe 30 people" who were present near the treatment area during the response.

Recommendations:

- Since events that warrant chelation therapy are relatively infrequent, use of and reference to established procedures during such events become very important. Such procedures should be quickly reviewed as part of the response to suspected significant intakes, and the existing guidelines should be used unless compelling circumstances dictate otherwise. LLNL has found "decision flowcharts" to be helpful in such response situations.

- During the response to potentially serious internal contamination events, a Sr. Internal Dosimetrist and/or Sr. Health Physicist with internal dosimetry experience should be present as part of the response team at Occupational Medicine. As part of that team, he or she can assist the Occupational Medicine Staff in interpreting radiological measurements and information used for treatment decisions, and consult with the Occupational Medicine Staff regarding treatment options.

- Critical information (i.e., information that may be used to direct treatment) should either be directly conveyed to the decision maker (e.g., the attending physician) or should be conveyed by a person who is experienced and knowledgeable in the field (i.e., an internal dosimetrist or Sr. level Health Physicist with experience in responding to internal contamination incidents).

- The need for conversion of radiological units in such response situations should be minimized. Thus, for example, action levels for wound count results should be expressed in the same units as generated by the wound counter (i.e., nanocuries).

- In the case of plutonium-contaminated wounds, if appropriate chelation criteria are met, chelation should always be considered regardless of the suspected chemical or physical form of the material. Oftentimes the true nature of the material is not known with any certainty, and even oxides of plutonium can have some fraction that will be absorbed from the wound site into the bloodstream. In the CMR case, early bioassay data indicate that the DTPA treatments have been quite effective in reducing dose.

- Periodic focused training for all medical staff responders (perhaps including “mini” drills or walk-through exercises) may be useful in assuring that the medical staff remains familiar with key response recommendations.

- Occupational Medicine may wish to consider some sort of “crowd” or access-control procedures for such events.

- The RP1-DGL should be commended and recognized for intervening at Occupational Medicine and questioning why the patient was being released without chelation.

4. Wound Counting

Observations and Comments:

- The wound counting staff quickly responded to Occupational Medicine, and promptly provided wound counting services using the NaI wound counter. This is a good practice.

- This wound counter does not provide information about the depth of deposited activity, and the 'raw' results from these counts are not corrected for attenuation. Thus, these results represent "minimum" amounts of activity.

- After the first wound count result (~17 nCi) the wound counting technician immediately notified his supervisor (the HPAL Team Leader). This is a good practice.

- The early wound count results (first several wound counts) were relayed to the MD through one or several Occupational Medicine Staff members (e.g., PA, or staff physician).

- Wound count results were consistently reported in units of nanocuries.

- It appears that the results of the wound counts (on the NaI system) are relatively consistent – indicating a good degree of positioning reproducibility from count-to-count.

- On January 9th, the HPAL high-resolution germanium detector system (Ortec instrument model LO-AX) was used to attempt to determine the depth of deposited activity. It was initially reported that the activity appeared to be relatively shallow (i.e., a few millimeters deep).

- On January 16th the HPAL Team Leader realized that an error had been made in calculating estimated depth values (based on energy region count ratios) from the LO-AX high-resolution wound counter. These calculations are performed essentially manually, with no independent checking/review before use. The corrected values were quickly (same day) transmitted to Internal Dosimetry and Occupational Medicine.

- The initial (incorrect) estimate of relatively shallow deposition was being taken into consideration with respect to continuing excision efforts. The correct values led to an estimate of deeper deposition (on the order of 1 cm). It is not clear whether the revised depth estimate had any effect on treatment decisions.

Recommendations:

- Calculational procedures, methods, and assumptions used in deriving wound count results from measurements should receive independent review and verification prior to approval for use. As appropriate, Software Quality Assurance practices should be applied to any spreadsheets or programs that are used to generate results that may be used to guide medical decisions.

- During the response and follow-up to such events, results of these calculations should be peer reviewed before those results are released to be used in treatment decisions.

- To the extent practicable, calculations performed to provide results used in treatment decisions should be automated to minimize the likelihood of calculational errors. Human factors and error-trapping (e.g., bounds checking on input) should be used to minimize the likelihood of errors.

5. Dose Assessment

Observations and Comments:

- There was some difficulty in contacting a representative of the Internal Dosimetry Team – however the Internal Dosimetry Team Leader (RP2-TL) was eventually reached.

- During the initial response (January 8th) to the CMR incident, the Internal Dosimetry Team Leader was contacted by phone (he was offsite). Initially, he did not speak directly to Occupational Medicine Staff, he was not requested to provide direct assistance to Occupational Medicine and he did not go to Occupational Medicine to offer assistance. The Internal Dosimetry Team Leader did speak directly to the Medical Director when he (RP2-TL) returned a call to the RP-1 Deputy Group Leader (RP1-DGL) who was present at Occupational Medicine at the time.

- In light of some of the miscommunication and/or misunderstanding that occurred at Occupational Medicine it appears that it would be very valuable to have a Sr. Internal Dosimetry staff member present to assist with treatment decisions and interpretation of information for significant events (such as the CMR case). It has been our experience at LLNL that the presence of a Sr. Internal Dosimetrist at Occupational Medicine has been welcome and helpful.

- Effective use is being made of rapid processing of early bioassay (urine) samples to make estimates of the efficacy of the DTPA treatments.

- The Internal Dosimetry Team Leader is an internationally recognized expert in wound dosimetry. He is applying the latest wound/biokinetic model (which he helped develop for the NCRP) to this case. It appears that the dose follow-up (bioassay schedule, estimation of dose averted, dose estimation) are all appropriate. This information is being "fed back" to the Occupational Medicine to assist in making decisions about continued chelation treatment.

- In the early phases of intake and dose estimation, there is always an enormous amount of uncertainty regarding the final dose values. The Internal Dosimetry Team Leader has stated that it is premature (at this time) to give any dose estimates. I agree with this statement.

Recommendations:

- During the medical response to significant internal contamination incidents (the criteria for "significant" will have to be determined) a senior member of the Internal Dosimetry Team should be present at Occupational Medicine as a member of the response team.

- The Internal Dosimetry Team may wish to consider requesting an in-vivo count of the axillary lymph region. (They may already be planning this).

Attachment A

Excerpts from Pertinent Documents

Decision Making

CEC/DOE Guidebook for the Treatment of Accidental Internal Radionuclide Contamination of Workers, Radiation Protection Dosimetry, Vol 41, No 1, 1992:

> "The decisions about treatment after intake of radioactive material rests with the physician."

LLNL Internal Dosimetry Program Manual, June 2000

> "The decision to use medical intervention shall be a joint decision between the patient and the Health Services physician. Internal Dosimetry is responsible for providing guidance to both the patient and to the Health Services physician to assist them in making this decision."

Intervention Levels

CEC/DOE Guidebook for the Treatment of Accidental Internal Radionuclide Contamination of Workers, Radiation Protection Dosimetry, Vol 41, No 1, 1992:

> "Treatment is not a consideration when the estimated [doses from] intakes are below [2 rem]." "When the [dose from] intake is likely to be between [2 rem and 20 rem] treatment should be considered." "When the estimated [dose from] intake exceeds [20 rem] then extended or protracted treatment . . . should be implemented."
>
> "Most deposits of non-transportable radionuclides can be removed by surgical excision. Under these conditions . . . many physicians would wish, provided there was little risk of functional impairment, to remove the radioactivity until it is no longer detectable."

LLNL Internal Dosimetry Program Manual, June 2000

> "Medical intervention shall be considered if, based on early information, it appears that the committed effective dose equivalent from the intake may exceed 5 rem."

> "Administration of chelating agents shall be considered if, based on early information, it appears that the committed effective dose equivalent from the intake may exceed 5 rem."

LLNL Technical Basis Manual for Internal Dosimetry, December 2000

> "Excision should be considered if the plutonium activity in the wound is estimated to be greater than 1 nCi."

The Savannah River Site Internal Dosimetry Technical Basis Manual (U), Revision 9, December 2004

> "Chelation is considered by the physician if a suspected intake could result in a CEDE in excess of 2 rem. [reference to CEC/DOE Handbook 1992] This means that chelation is strongly considered if . . . any activity is detected in a wound."

Time Frame for Administration of DTPA

REAC/TS package insert for Ca-DTPA:

> "The chelating efficiency is greatest within one hour of exposure when the radionuclide is circulating in or available to tissue fluids and plasma. However, a post-exposure interval > 1 hour does not preclude the administration and effective action of Ca-DTPA." "Because the efficiency of chelation decreases with time, DTPA should be given within 6 hours of exposure, if possible."

CEC/DOE Guidebook for the Treatment of Accidental Internal Radionuclide Contamination of Workers, Radiation Protection Dosimetry, Vol 41, No 1, 1992:

> "Internal contamination . . . by actinides, especially plutonium, that may have exceeded one ALI [2 rem] should be treated as rapidly as possible by a direct intravenous injection . . . of CaDTPA . . ."

"Medical Management of Radiological Casualties: Current Concepts", Annals of Emergency Medicine, Vol 46, No. 6, June 2005

> "The FDA recommends that therapy be initiated with a single 1.0-g loading dose of Ca-DTPA . . . administered intravenously as soon as possible after exposure."

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LLNL Technical Basis Manual for Internal Dosimetry, December 2000

> "In order to be effective, the initial administration of DTPA should be given as soon as possible, preferably within an hour after the uptake occurs."
>
> "Note that if any of the "chelation/excision" criteria wound caused by contact with plutonium . . . , wound caused by transuranic contaminated needle or sharp, detectable transuranic contamination in or around wound] are present, consideration should be given to administering a first dose of DTPA before the wound count is performed." This recommendation is based on the possibility that some fraction of the deposited plutonium may be rapidly translocated from the wound site into the bloodstream. Since both the initial quantity of plutonium in the wound is unknown, and some time will have already passed since the wound occurred, administering DTPA as quickly as possible is a conservative approach."
>
> "The first dose of DTPA should be administered before any attempts at wound excision. The reason for this recommendation is that the excision process can result in further rapid transfer of activity from the wound site to the bloodstream. It is therefore important to assure that the bloodstream is "loaded" with DTPA before excision begins."

Use of Ca-DTPA for Initial Administration:

REAC/TS package insert for Ca-DTPA.

> "Ca-DTPA is approximately 10 times more effective than Zn-DTPA for initial chelation of transuranics; therefore, Ca-DTPA should be used whenever larger body burdens of transuranics are involved. Ca-DTPA is the form of choice for initial patient management unless contraindicated. Approximately 24 hours after exposure, Zn-DTPA is, for all practical purposes, as effective as Ca-DTPA. This comparable efficacy, coupled with its lesser toxicity, makes Zn-DTPA the preferred agent for protracted therapy."

CEC/DOE Guidebook for the Treatment of Accidental Internal Radionuclide Contamination of Workers, Radiation Protection Dosimetry, Vol 41, No 1, 1992:

> "Treatment would normally be started with calcium DTPA, which is more efficient and should continue, after a few days or so, with zinc DTPA, which is potentially less toxic for prolonged administration."

"Medical Management of Radiological Casualties: Current Concepts", Annals of Emergency Medicine, Vol 46, No. 6, June 2005

> "The FDA recommends that therapy be initiated with a single 1.0-g loading dose of Ca-DTPA . . . administered intravenously as soon as possible after exposure."

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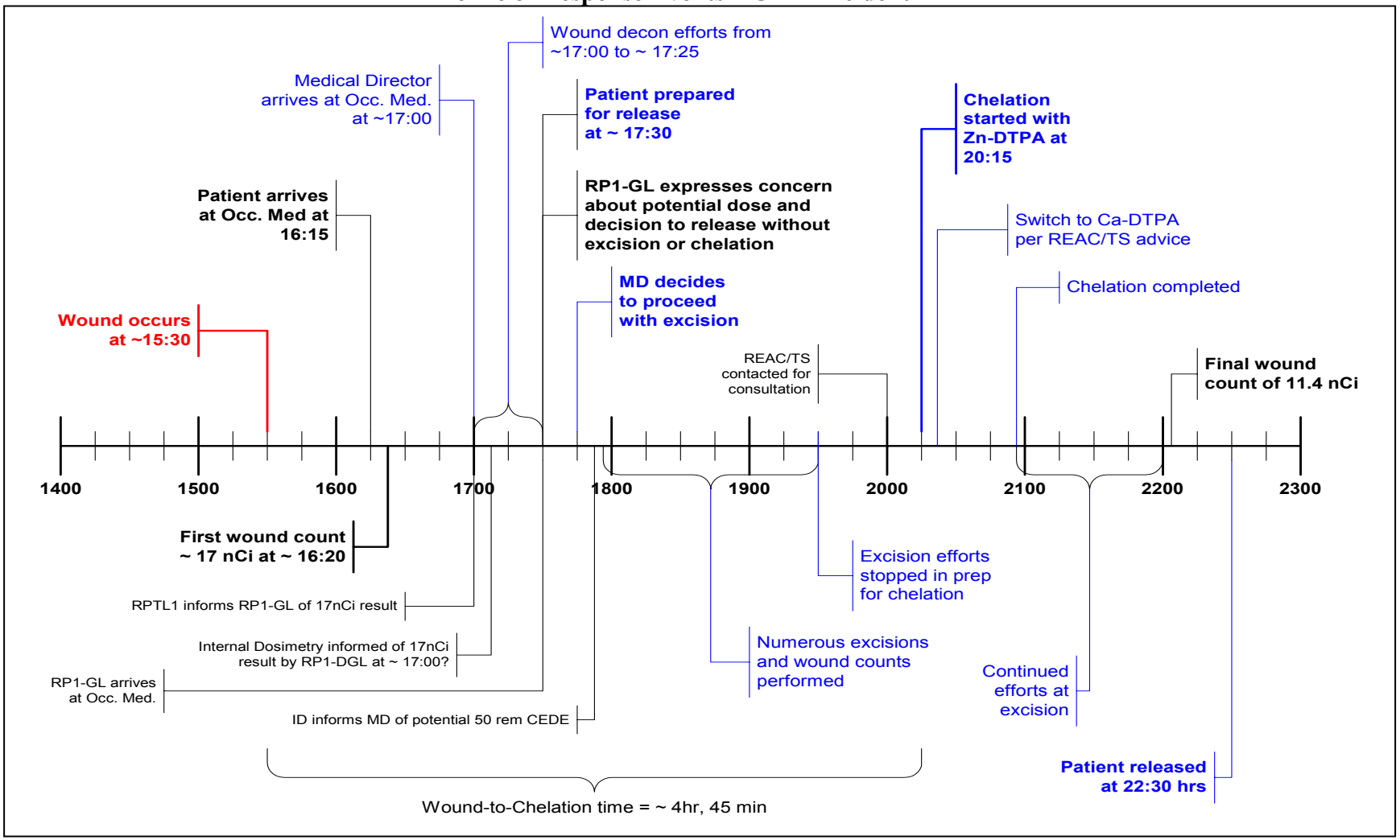
Figure 1

Timeline of Response Events – CMR Incident



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